Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Connect America Fund	)	WC Docket No. 10-90
	)	
A National Broadband Plan for Our Future	)	GN Docket No. 09-51
	)	
High-Cost Universal Service Support	)	WC Docket No. 05-337

NOTICE OF INQUIRY AND NOTICE OF PROPOSED RULEMAKING

Adopted: April 21, 2010 **Released: April 21, 2010**

Comment Date: (60 days from publication in the Federal Register)
Reply Comment Date: (90 days from publication in the Federal Register)

By the Commission: Chairman Genachowski and Commissioners Copps, McDowell, Clyburn and Baker issuing separate statements.

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Heading Paragraph #

By the Commission:

I. INTRODUCTION

1. On March 16, 2010, the Commission released a Joint Statement on Broadband stating that "[t]he nearly $9 billion Universal Service Fund (USF) and the intercarrier compensation (ICC) system should be comprehensively reformed to increase accountability and efficiency, encourage targeted investment in broadband infrastructure, and emphasize the importance of broadband to the future of these programs."[1] On the same day, the Commission delivered to Congress a National Broadband Plan recommending that the Commission adopt cost-cutting measures for existing voice support and create a Connect America Fund (CAF), without increasing the overall size of the Fund, to support the provision of broadband communications in areas that would be unserved without such support or that depend on universal service support for the maintenance of existing broadband service.[2]

2. Today's notice of inquiry (NOI) and notice of proposed rulemaking (NPRM) is the first in a series of proceedings to implement that vision. This proceeding will develop the detailed analytic foundation necessary for the Commission to distribute funds in an efficient, targeted manner that avoids waste and minimizes burdens on American consumers. The NOI seeks comment on whether the Commission should use a model to help determine universal service support levels in areas where there is no private sector business case to provide broadband and voice services. The NOI also seeks comment on the best way to create an accelerated process to target funding toward new deployment of broadband networks in unserved areas, while we are considering final rules to implement fully a new CAF funding mechanism that efficiently ensures universal access to broadband and voice services. Finally, the accompanying NPRM seeks comment on specific common-sense reforms to cap growth and cut inefficient funding in the legacy high-cost support mechanisms and to shift the savings toward broadband communications.

II. NOTICE OF INQUIRY

A. Background

1. Current High-Cost Support Programs

3. The purpose of high-cost universal service support always has been to help ensure that consumers have access to telecommunications services in areas where the cost of providing such services would otherwise be prohibitively high. The current system of high-cost support has achieved

[1] *Joint Statement on Broadband*, GN Docket No. 10-66, Joint Statement on Broadband, FCC 10-42, 2 (rel. Mar.16, 2010).

[2] Federal Communications Commission, *Connecting America: The National Broadband Plan*, 144-45, 149-50 (rel. Mar. 16, 2010) (National Broadband Plan).

considerable success, helping ensure access to affordable voice services in all regions of the nation.[3] However, it was not designed to universalize broadband.[4] Today, federal high-cost support is provided through a complicated patchwork of programs, developed over decades, in which the types of support a carrier receives depends on the size and regulatory classification of the carrier, not the characteristics of the area to which support is directed.[5] Because only voice is a supported service, there is no requirement to provide broadband service to consumers, nor is there any mechanism to ensure that support is targeted toward extending broadband service to unserved areas.[6] Moreover, some of the current high-cost programs do not provide support in an economically efficient manner. For example, eligibility for certain types or levels of support is based on company size or regulatory classification, rather than the cost of serving the area.[7] In addition, several programs provide support based on an incumbent carrier's embedded costs, whether or not a competitor provides, or could provide, service at a lower cost.

4. In the *Universal Service First Report and Order*, the Commission found that "the proper measure of cost for determining the level of universal service support is the forward-looking economic cost of constructing and operating the network facilities and functions used to provide the supported services."[8] Prior to the Telecommunications Act of 1996,[9] explicit federal universal service support was based on embedded costs. In setting forth the framework for implementing the 1996 Act, the Commission found that "the use of embedded cost to calculate universal service support would lead to subsidization of inefficient carriers at the expense of efficient carriers and could create disincentives for

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[3] The Commission's most recent report on telephone subscribership, released in February 2010, found that the telephone subscribership penetration rate in the United States in 2009 had increased to 95.7 percent – the highest reported penetration rate since the Census Bureau began collecting such data in November 1983. Industry Analysis and Technology Division, Wireline Competition Bureau, *Telephone Subscribership in the United States*, 3 (February 2010) (Telephone Subscribership Report).

[4] *See* National Broadband Plan at 135.

[5] The federal high-cost support mechanism includes five major components. High-cost loop support provides support for intrastate network costs to rural incumbent local exchange carriers (LECs) in service areas where the cost to provide service exceeds 115 percent of the national average. *See* 47 C.F.R. § 36.631. Rural incumbent LECs may also receive support under two additional sub-mechanisms in limited circumstances. Carriers may qualify for additional support, i.e., safety net additive support, if they demonstrate significant investment in infrastructure. *See* 47 C.F.R. § 36.605. Carriers may be eligible for additional support, i.e., safety value support, in instances where they acquire exchanges and invest in that infrastructure. *See* 47 C.F.R. § 54.305(d). Local switching support provides intrastate support for switching costs for companies that serve 50,000 or fewer access lines. *See* 47 C.F.R. § 54.301. High-cost model support provides support for intrastate network costs to non-rural incumbent LECs in states where the cost to provide service in non-rural areas exceeds two standard deviations above the national average cost per line. *See* 47 C.F.R. § 54.309. Interstate access support (IAS) provides support for price cap carriers to offset certain reductions in interstate access charges. *See* 47 C.F.R. § 54.800-809. Interstate common line support (ICLS) provides support to rate-of-return carriers, to the extent that subscriber line charge (SLC) caps do not permit such carriers to recover their interstate common line revenue requirements. *See* 47 C.F.R. § 54.901-904.

[6] *See* National Broadband Plan at 141.

[7] Small carriers typically receive considerably more per-line support than larger carriers serving high-cost geographic areas.

[8] *See Federal-State Joint Board on Universal Service*, CC Docket No. 96-45, Report and Order, 12 FCC Rcd 8776, 8899, para. 224 (1997) (*Universal Service First Report and Order*) (subsequent history omitted).

[9] Telecommunications Act of 1996, Pub. L. No. 104-104, 110 Stat. 56 (1996 Act). The 1996 Act amended the Communications Act of 1934. 47 U.S.C. § 151, *et seq*. (Communications Act or Act).

carriers to operate efficiently."[10] In 1997, the Commission determined that, initially, the larger, i.e., "non-rural," carriers, such as the Regional Bell Operating Companies, would transition to receiving support based on forward-looking economic cost, and that the smaller, i.e., "rural," carriers, would gradually shift to a support system based on forward-looking economic cost after further review.[11] Subsequently, in 2001, the Commission adopted modified embedded cost support rules for rural carriers pending more comprehensive reform.[12] As a consequence, only non-rural high-cost support is based on forward-looking economic cost, as determined by the Commission's voice telephony cost model.[13]

2. The Commission's Hybrid Cost Proxy Model

5. In 1997, the Commission adopted ten criteria to be used in estimating the forward-looking economic cost of providing universal service in high-cost areas and thereby ensure economically efficient levels of support.[14] For example, the "technology assumed in the . . . model must be the least-cost, most-efficient, and reasonable technology for providing the supported services that is currently being deployed."[15] Because existing incumbent local exchange carrier plant in a particular area may not reflect forward-looking technology or design choices, the costs estimated by the model "must not be the embedded cost of the facilities, functions, or elements."[16] Instead, the model "must be based upon an examination of the current cost of purchasing facilities and equipment."[17] To reflect the economies of scale associated with the provision of multi-line business, special access, and private lines, the model "must estimate the cost of providing service for all businesses and households within a geographic

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[10] *Universal Service First Report and Order*, at 8901, para. 228.

[11] *Id*. at 8889, paras. 203-204.

[12] *See Federal-State Joint Board on Universal Service*, *Multi-Association Group (MAG) Plan for Regulation of Interstate Services of Non-Price Cap Incumbent Local Exchange Carriers and Interexchange Carriers* , CC Docket Nos. 96-45, 00-256 Fourteenth Report and Order and Twenty-Second Order on Reconsideration, Report and Order, 16 FCC Rcd 11244, 11248, para. 8 (2001) (*Rural Task Force Order*). Based on the Rural Task Force proposals, the Commission adopted modified embedded cost rules to provide support to rural carriers for a five-year period. Over the next few years, the Commission had planned to develop a "long-term universal service plan for rural carriers that is better coordinated with the non-rural mechanism," and "that better targets support to carriers serving high-cost areas." *Id*. The Commission stated that "in developing a long-term universal service plan that better targets support to the highest cost rural areas, we intend to consider all options, including the use of forward-looking costs, to determine appropriate support levels for both rural and non-rural carriers." *Id.* at 11310, para. 170. The Commission further indicated that, although it believed that distinct rural and non-rural mechanisms were appropriate at that time, two distinct mechanisms might not be viable in the long term. *Id*. In 2004, the Commission asked the Joint Board to review the Commission's rules regarding high-cost support for rural carriers and to determine the appropriate rural mechanism to succeed the five-year plan adopted in the *Rural Task Force Order*. *See Federal-State Joint Board on Universal Service*, CC Docket No. 96-45, Order, 19 FCC Rcd 11538 (2004) (*Rural Referral Order*). Although the Commission originally intended that the rules adopted in the *Rural Task Force Order* would remain in place for five years, the Joint Board had not completed its review and recommendations by 2006. The Commission extended those rules until such time that it "adopts new high-cost support rules for rural carriers." *Federal-State Joint Board on Universal Service; High-Cost Universal Service Support*, CC Docket No. 96-45, WC Docket No. 05-337, Order, 21 FCC Rcd 5514, 5515, para. 2 (2006).

[13] *See infra* para. 6.

[14] *See Universal Service First Report and Order*, 12 FCC Rcd at 8912-16, para. 250.

[15] *Id.* at 8913, para. 250 (criterion one).

[16] *Id*. (criterion three).

[17] *Id.*

region."[18] To enable all interested parties to review and comment on the model and its inputs, "all underlying data, formulae, computations, and software must be available," and all underlying data should be verifiable.[19] To provide transparency and flexibility, the cost model "must include the capability to examine and modify the critical assumptions and engineering principles."[20]

6. Using the ten criteria to provide guidance for selecting a cost model and its input values, the Commission, between 1997 and 1999, developed its current forward-looking economic cost model, called the Hybrid Cost Proxy Model (HCPM), in an open, deliberative process in which industry experts, state commissions, staff of the Federal-State Joint Board on Universal Service, and other interested parties provided valuable assistance.[21] First, the Commission looked at the network design, engineering, and technology issues relevant to constructing a network to provide the supported services and adopted the model "platform," i.e., assumptions about the design of the network and network engineering, and fixed characteristics such as soil and terrain.[22] Second, the Commission looked at the costs of the components of the network, such as cable and switch costs, plant maintenance expenses, and various capital cost parameters, and adopted the model input values.[23] The Commission developed an extensive record

[18] *Id*. at 8915, para. 250 (criterion six).

[19] *Id*. (criterion eight).

[20] *Id.* (criterion nine).

[21] *See, e.g., Common Carrier Bureau to Post on the Internet Modifications to the Forward-Looking Economic Cost Model for Universal Service Support*, Public Notice, CC Docket Nos. 96-45, 97-160, 14 FCC Rcd 1893 (1998); *Common Carrier Bureau Releases Preliminary Common Input Values to Facilitate Selection of Final Input Values for the Forward-Looking Cost Model for Universal Service,* Public Notice, CC Docket Nos. 96-45, 97-160,14 FCC Rcd 2372 (1999); *Common Carrier Bureau Releases Preliminary Results Using Proposed Input Values in the Forward-Looking Cost Model for Universal Service,* Public Notice, CC Docket Nos. 96-45, 97-160, 14 FCC Rcd 9648 (1999); *Common Carrier Bureau Releases Revised Spreadsheet for Estimating Universal Service Support Using Proposed Input Values in the Forward-Looking Cost Model*, Public Notice, CC Docket Nos. 96-45, 97-160, 14 FCC Rcd 11313(1999). The Wireline Competition Bureau was previously named the Common Carrier Bureau. HCPM is available for downloading on the Commission's Web site at http://www.fcc.gov/wcb/tapd/hcpm/welcome.html.

[22] *Federal-State Joint Board on Universal Service*, *Forward-Looking Mechanism for High-Cost Support for Non-Rural LECs*, Fifth Report and Order, CC Docket Nos. 96-45, 97-160, 13 FCC Rcd 21323, 21330 (1998) (*Fifth Report and Order*). The model platform adopted by the Commission combined elements from each of the three models considered in that proceeding: (1) the BCPM, Version 3.0 (BCPM); (2) the HAI Model, Version 5.0a (HAI); and (3) the Hybrid Cost Proxy Model, Version 2.5 (HCPM). BCPM was submitted by BellSouth, US WEST, Inc., and Sprint. HAI was submitted by AT&T and MCI. HCPM was developed by Commission staff.

[23] *Federal-State Joint Board on Universal Service, Forward-Looking Mechanism for High Cost Support for Non-Rural LECs*, Tenth Report and Order, CC Docket Nos. 96-45, 97-160, 14 FCC Rcd 20156 (1999) (*Tenth Report and Order*), *affirmed*, *Qwest Corp. v. FCC*, 258 F.3d 1191 (10th Cir. 2001) (*Qwest I*). In the companion *Ninth Report and Order,* the Commission also adopted the methodology for determining high-cost support for non-rural carriers. *Federal-State Joint Board on Universal* Service, Ninth Report and Order and Eighteenth Order on Reconsideration, CC Docket 96-45, 14 FCC Rcd 20432 (1999) (*Ninth Report and Order*), *remanded, Qwest I*, 258 F.3d 1191; *Federal-State Joint Board on Universal* Service, Order on Remand, Further Notice of Proposed Rulemaking, and Memorandum Opinion and Order, CC Docket 96-45, 18 FCC Rcd 22559 (2003), *remanded, Qwest Communications Int'l, Inc. v. FCC*, 398 F.3d 1222 (10th Cir. 2005) (*Qwest II*); *High-Cost Universal Service Support; Federal-State Joint Board on Universal Service*, WC Docket No. 05-337 and CC Docket No. 96-45, Order on Remand and Memorandum Opinion and Order, FCC 10-56 (rel. April 16, 2010) (*Qwest II Remand Order*). The forward-looking cost mechanism takes the costs generated by the cost model, compares statewide average costs to a national benchmark, and provides support to non-rural carriers in those states where the costs exceed that benchmark. This mechanism became effective January 1, 2000. On July 31, 2001, the United States Court of Appeals for the Tenth (continued….)

before adopting its high-cost universal service model, including issuing two further notices of proposed rulemaking,[24] providing additional guidance to parties submitting cost models,[25] and conducting several series of workshops on model platform and inputs issues and numerous *ex parte* meetings.[26]

7. The Commission recognized that "the task of establishing a model to estimate forward-looking costs is a dynamic process that will need to be reviewed and adjusted periodically,"[27] and that "the model must evolve as technology and other conditions change."[28] Although the Commission's forward-looking economic cost model used to determine non-rural support was adopted more than a decade ago, it has not been comprehensively updated. It estimates the costs of a narrowband, circuit-switched network that provides "plain old telephone service," whereas today's most efficient providers are constructing fixed or mobile networks that are capable of providing broadband as well as voice services. Not only are the model inputs out-of-date, but the technology assumed by the model no longer reflects "the least-cost, most-efficient, and reasonable technology for providing the supported services that is currently being deployed."[29]

8. Today, a significant portion of current high-cost support is provided to both incumbent telephone companies and competitive telephone companies based on an incumbent carrier's embedded costs, regardless of whether a competitor could provide service at a lower cost. In 2009, the Commission

(Continued from previous page)
Circuit affirmed the Commission's use of the cost model and deferred to the Commission's expertise in establishing the cost model's technical specifications. *See Qwest I*, 258 F.3d at 1205-06.

[24] *See Federal-State Joint Board on Universal Service*, *Forward-Looking Mechanism for High-Cost Support for Non-Rural LECs*, Further Notice of Proposed Rulemaking, CC Docket Nos. 96-45, 97-160, 12 FCC Rcd 18514 (1997) (*1997 Further Notice*); *Federal-State Joint Board on Universal Service*, CC Docket No. 96-45, *Forward-Looking Mechanism for High-Cost Support for Non-Rural LECs*, Further Notice of Proposed Rulemaking, CC Docket No. 97-160, FCC 99-120 (rel. May 28, 1999), 64 Fed. Reg. 31,780 (June 14, 1999) (*1999 Further Notice*).

[25] *See, e.g., Guidance to Proponents of Cost Models in Universal Service Proceeding: Customer Location and Outside Plant*, Public Notice, CC Docket Nos. 96-45, 97-160, 12 FCC Rcd 18340 (1997); *Guidance to Proponents of Cost Models in Universal Service Proceeding: Switching, Interoffice Trunking, Signaling, and Local Tandem Investment*, Public Notice, CC Docket Nos. 66-45, 97-160, 13 FCC Rcd 5884 (1998); *Common Carrier Bureau Requests Further Comment on Selected Issues Regarding the Forward-Looking Economic Cost Mechanism for Universal Service*, Public Notice, CC Docket Nos. 96-45, 97-160, 13 FCC Rcd 9346 (1998); *Common Carrier Bureau Seeks Comment on Model Platform Development,* Public Notice, CC Docket Nos. 97-160, 13 FCC Rcd 21680 (1998).

[26] *See, e.g., Weekly Meetings on Forward-Looking Cost Mechanism for Universal Service Support,* Public Notice, CC Docket Nos. 96-45 and 97-160, 12 FCC Rcd 22481 (1997); *Workshops on Forward-Looking Cost Mechanisms for Universal Service Support for Non-Rural Carriers, September 3 and September 11, 1997,* Public Notice, CC Docket Nos. 96-45 and 97-160, 13 FCC Rcd 4276 (1998); *Common Carrier Bureau to Hold Three Workshops on Input Values to be Used to Estimate Forward-Looking Economic Costs for Purposes of Universal Service Support*, Public Notice, CC Docket Nos. 96-45, 97-160, 13 FCC Rcd 23728 (1998).

[27] *Fifth Report and Order*, 13 FCC Rcd at 21330, para. 13.

[28] *Tenth Report and Order*, 14 FCC Rcd at 20170, para. 28. When the Commission adopted the model platform, it delegated to then Common Carrier Bureau (now the Wireline Competition Bureau) (Bureau) the authority to make technical changes "as necessary and appropriate" on an ongoing basis to ensure that the model operates as the Commission intended. *See Fifth Report and Order*, 13 FCC Rcd at 21330, para. 13. Pursuant to this delegated authority, the Bureau has made technical changes to the model platform and limited changes to the input values, such as updating annual line counts. The Bureau last updated the lines used in the model to estimate costs in 2003 (using year-end 2002 lines), and non-rural high-cost support has been based on these cost estimates since 2004.

[29] *Universal Service First Report and Order*, 12 FCC Rcd at 8913, para. 250 (criterion one).

disbursed almost $4.3 billion in high-cost support, of which $331 million was calculated on the basis of forward-looking costs.[30]

3. National Broadband Plan

9. On March 16, 2010, the Commission delivered to Congress the National Broadband Plan, which recommends the creation of a Connect America Fund to address the broadband availability gap in unserved areas and to provide any ongoing support necessary to sustain service in areas that require public funding, including those areas that already may have broadband.[31] The National Broadband Plan recommends that the Commission direct public investment toward meeting an initial national broadband availability target of 4 Mbps of actual download speed and 1 Mbps of actual upload speed.[32] The National Broadband Plan used an initial target of 4 Mbps actual download speed and 1 Mbps of actual upload speed to develop an analysis of the number of people that lack access to broadband capability today. The National Broadband Plan estimated that 14 million people living in seven million housing units in the United States currently do not have access to terrestrial broadband infrastructure capable of meeting this target, described as "the broadband availability gap."[33]

10. The National Broadband Plan states that the Commission's "long range goal should be to replace all of the legacy High-Cost programs with a new program that preserves the connectivity that Americans have today and advances universal broadband in the 21st century."[34] Specifically, the National Broadband Plan recommends that the Commission create a new Connect America Fund, and that the CAF should adhere to the following principles: (1) "CAF should only provide funding in geographic areas where there is no private sector business case to provide broadband and high-quality voice-grade service;" (2) "There should be at most one subsidized provider of broadband per geographic area;" (3) "The eligibility criteria for obtaining broadband support from CAF should be company- and technology-agnostic so long as the service provided meets the specifications set by the FCC;" (4) "The FCC should identify ways to drive funding to efficient levels, including market-based mechanisms where appropriate, to determine the firms that will receive CAF support and the amount of support they will receive;" and (5) "Recipients of CAF support must be accountable for its use and subject to enforceable timelines for achieving universal access."[35] In addition, the National Broadband Plan recommends that the Commission "create a fast-track program in CAF for providers to receive targeted funding for new broadband construction in unserved areas,"[36] and create a Mobility Fund "to provide one-time support for deployment of 3G networks, to bring all states to a minimum level of 3G (or better) mobile service availability."[37]

4. The National Broadband Plan Model

11. The National Broadband Plan concludes that private investment alone is unlikely to extend broadband in some areas of the country with low population density. In particular, "[b]ecause service providers in these areas cannot earn enough revenue to cover the costs of deploying and operating

[30] Universal Service Administrative Company 2009 preliminary disbursement data.

[31] *See* National Broadband Plan at 135, 144.

[32] *Id*. at 135.

[33] *Id*. at 136.

[34] *Id*. at 145.

[35] *Id*. (footnotes omitted).

[36] *Id*. at 144.

[37] *Id*. at 146.

broadband networks, including expected returns on capital, there is no business case to offer broadband services in these areas."[38]

12. To estimate the amount of additional funding required to close the broadband availability gap, Commission staff developed an economic model to estimate the level of additional funding that would be required to extend broadband service to the estimated 7 million housing units that presently are unserved by broadband that provides 4 Mbps actual download speed, 1 Mbps upload speed, and acceptable quality of service for the most common interactive applications.[39] First, Commission staff developed a baseline of the current state of broadband availability and infrastructure deployment throughout the nation, which included all the major types of terrestrial broadband infrastructure as they are deployed today, and as they likely will evolve over the next three to five years without public support.[40] Because the Commission does not presently have access to a comprehensive data set, at the required level of geographic granularity, regarding availability (i.e., which people have access to what services) and infrastructure (i.e., which people are passed by what types of network hardware), Commission staff combined several data sets and supplemented nationwide data with the output of a large multivariate regression model. Staff then used this regression model to predict availability by speed tier and to fill gaps, especially last mile gaps, in the infrastructure data.[41] Second, building on the infrastructure data, known and inferred, Commission staff's economic analysis calculated the incremental forward-looking cost of upgrading or extending existing infrastructure to provide broadband service consistent with the national broadband availability target, and the incremental revenues that might be expected to be generated by the network upgrades. From this, they calculated the net present value (NPV) of the gap between incremental costs and expected incremental revenues of broadband deployments in unserved areas. This NPV represents the amount of additional funding necessary to upgrade or extend existing infrastructure to the level necessary to support the target (4 Mbps download/1 Mbps upload).[42] Underlying the economic model is the principle that only profitable business cases will induce incremental network investments and the best measure of profitability is the net present value of a build.[43]

B. Discussion

13. The National Broadband Plan recommends establishing the CAF to support universal access to broadband and voice services, including providing any ongoing support necessary to sustain service in areas that already have broadband because of the existing high-cost universal service program.[44] As a first step in comprehensive universal service reform, we seek comment on three discrete groups of issues. First, we seek comment on use of a model as a competitively neutral and efficient tool for helping us to quantify the minimum amount of universal service support necessary to support networks that provide broadband and voice service, such that the contribution burden that ultimately falls on American consumers is limited. Second, we seek comment on potential approaches to providing such targeted funding on an accelerated basis in order to extend broadband networks in unserved areas, such as a competitive procurement auction. Third, in the accompanying NPRM, we seek comment on specific

[38] *Id*. at 136.

[39] Omnibus Broadband Initiative, The Broadband Availability Gap (OBI Technical Paper No. 1) at 1-3 (OBI, The Broadband Availability Gap); *see* Appendix C.

[40] *Id*. at 1.

[41] *Id*. at 1-2.

[42] *Id*. at 2-3.

[43] *Id*. at 1.

[44] National Broadband Plan at 144.

proposals to cap and cut the legacy high-cost programs and realize savings that can be shifted to targeted investment in broadband infrastructure.[45] We encourage input from Tribal governments on all of these issues, and specifically ask whether there are any unique circumstances in Tribal lands that would necessitate a different approach.[46] Similarly, we request comment on whether there are any unique circumstances in insular areas that would necessitate a different approach.

1. Model

14. We specifically seek comment on whether the Commission should use the National Broadband Plan model as the starting point for developing a cost model, or alternatively a cost/revenue model, to use in determining future support for broadband-capable networks that provide voice service. We seek comment on whether the analysis and economic model that Commission staff used to estimate the broadband availability gap in unserved areas provides a useful foundation for calculating the support levels needed for the CAF in a way that minimizes waste, fraud and abuse. We also seek comment on what modifications to the National Broadband Plan model would be required if the CAF is eventually to replace all of the legacy high-cost programs.

15. A detailed description of the National Broadband Plan model, The Broadband Availability Gap, is found in Appendix C and is available on the Commission's Broadband.gov Web site.[47] Additional model documentation includes technical documentation of how the model is constructed and more detail about the statistical model used to estimate availability and network infrastructure in areas where no data are available, which also will be available on Broadband.gov. A public notice will be released shortly regarding a workshop to discuss the technical paper.

16. Commenters are invited to comment on any aspect of the National Broadband Plan model that may be relevant to our consideration of how to reform the existing universal service support mechanisms. We highlight below only selected details relating to the National Broadband Plan model methodology, and specifically seek comment on several threshold design principles the Commission may consider before issuing a further notice of proposed rulemaking in this proceeding.

a. Use of a Model

17. We seek comment on whether the Commission should develop a nationwide broadband model to estimate support levels for the provision of broadband and voice service in areas that are currently served by broadband with the aid of legacy high-cost support, as well as areas that are unserved. A federal model could provide a more uniform and equitable basis for determining support than

[45] *See infra* section III.

[46] For the purposes of this NPRM, we define "Tribal lands" as any federally recognized Indian tribe's reservation, pueblo or colony, including former reservations in Oklahoma, Alaska Native regions established pursuant to the Alaska Native Claims Settlement Act (85 Stat. 688), and Indian allotments. The term "Tribe" means any American Indian or Alaska Native Tribe, Band, Nation, Pueblo, Village or Community which is acknowledged by the Federal government to have a government-to-government relationship with the United States and is eligible for the programs and services established by the United States. *See Statement of Policy on Establishing a Government-to-Government Relationship with Indian Tribes*, 16 FCC Rcd 4078, 4080 (2000). Thus, "Tribal lands" includes American Indian Reservations and Trust Lands, Tribal Jurisdiction Statistical Areas, Tribal Designated Statistical Areas, and Alaska Native Village Statistical Areas, as well as the communities situated on such lands. This would also include the lands of Native entities receiving Federal acknowledgement or recognition in the future. Although Native Hawaiians are not currently members of federally-recognized Tribes, we also seek comment on whether there are any unique circumstances that would warrant an alternative approach in Native Hawaiian homelands.

[47] *See* http://www.broadband.gov/plan/broadband-working-reports-technical-papers.html.

individual carrier cost studies or models submitted by interested parties.[48] A uniform federal model could provide a mechanism for determining support levels based on the geographic characteristics of the areas served, rather than the regulatory classification of the incumbent telephone company that serves the area.

18. One assumption underlying the National Broadband Plan's estimate of the level of public support needed to fill the broadband availability gap is that "whenever possible, a market-based mechanism will be used to select which providers receive support," . . . "and that there is competitive interest in receiving a subsidy to extend broadband to an unserved area."[49] One of the principles underlying the creation of the CAF is that the Commission "should identify ways to drive funding to efficient levels, including market-based mechanisms where appropriate, to determine the firms that will receive CAF support and the amount of support they will receive."[50]

19. The Commission has previously sought comment on using competitive bidding – that is, using a reverse auction, in which sellers, rather than buyers, compete and the lowest bid wins – to determine high-cost support amounts for voice telephony.[51] It tentatively concluded that "reverse auctions offer several potential advantages over current high-cost support distribution mechanisms."[52] The Commission reasoned that "[i]f a sufficient number of bidders compete in the auction, the winning bid might be close to the minimum level of subsidy required to achieve the desired universal service goals."[53] Similarly, the National Broadband Plan states that "[i]f enough carriers compete for support in a given area and the mechanism is properly designed, the market should help identify the provider that will serve the area at the lowest cost."[54]

20. We seek comment on whether a model would be an important tool, even if the Commission uses a market-based mechanism to identify supported entities and support levels under the CAF. For example, if the Commission uses some form of a reverse auction to determine CAF support levels, it would be important to establish a "reserve price," i.e., a maximum subsidy level that participants would be allowed to place as a bid, because there may be few bidders in certain geographic areas. Depending on the design of the market-based mechanism, reserve prices could play a critical role. A reserve price that is set too low is likely to discourage bidders from participating, while one that is set too high raises the possibility that too much support will be allocated to a particular area.

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[48] The Commission encourages interested parties to submit such information on the record, however, to assist us in developing an accurate and verifiable federal cost model. The Commission previously concluded that a national forward-looking model would provide a more consistent approach and found that relying on differing forward-looking cost methodologies would prevent meaningful comparisons and provide a less accurate picture of relative forward-looking costs. *See Federal-State Joint Board on Universal Service, Access Charge Reform*, Seventh Report & Order and Thirteenth Order on Reconsideration in CC Docket No. 96-45, Fourth Report & Order in CC Docket No. 96-262, and Further Notice of Proposed Rulemaking, 14 FCC Rcd 8078, 8104, para. 52 (1999).

[49] National Broadband Plan at 137.

[50] *Id*. at 145.

[51] Specific examples of reverse auctions include procurement auctions to identify the party willing to provide a good or service at the lowest cost to the buyer, and auctions to identify the least amount of support needed to induce a party to undertake a certain action.

[52] *High-Cost Universal Service Support, Federal-State Joint Board on Universal Service*, WC Docket No. 05-337, CC Docket No. 96-45, Notice of Proposed Rulemaking, 23 FCC Rcd 1495, 1500 para. 11 (2008) (*Reverse Auctions Notice*).

[53] *Id.*

[54] National Broadband Plan at 145.

21. If we ultimately use some form of market-based mechanism to determine CAF support, we seek comment on whether a model should be used to set reserve prices. Specifically, we seek comment on whether a model would provide advantages over the alternative of using a particular firm's current support levels to set reserve prices. Currently, high-cost support levels for voice telephony are based on statewide or study area average costs.[55] Moreover, high-cost support is based on the incumbent telephone companies' forward-looking or embedded costs to provide voice service, which is not necessarily the same as the costs of an efficient provider of both broadband and voice services. Some areas where broadband is not available today may be unserved because there is insufficient high-cost support available in the area to make a business case for deploying broadband-capable networks. In these cases, setting the reserve price at the current support levels could result in a reserve price that is too low and would not further our goal of extending broadband-capable networks to unserved areas. In other cases, setting the reserve price at current support levels could result in a reserve price that is too high, which would not help us "identify ways to drive funding to efficient levels."[56]

22. In addition to assisting the Commission in setting reserve prices, we seek comment on whether a model could be an important tool in determining appropriate support amounts (for example, in areas where the Commission determines that it is unable to use a competitive bidding mechanism). We also seek comment on the role of a model in identifying the most costly areas to serve, where the Commission may want to consider alternative approaches to providing access to broadband and voice services.[57] For example, the National Broadband Plan's estimate of the $24 billion broadband availability gap is based on the economics of terrestrial technologies only and on the assumption that satellite capacity in the foreseeable future does not appear sufficient to serve *every* unserved household.[58] The National Broadband Plan estimated that the most expensive 250,000 unserved housing units represent a disproportionate share of the total investment gap – $14 billion.[59] This represents less than two-tenths of one percent of all housing units in the United States; the average amount of funding for terrestrial broadband per household to close the gap for these units is an estimated $56,000.[60]

b. Cost Basis for Support

23. We seek comment on whether the Commission should base any new CAF support on the forward-looking economic costs of an efficient provider, rather than on historic, embedded costs. Basing support on forward-looking costs is consistent with the Commission's policy adopted in the *Universal Service First Report and Order* that support in high-cost areas should be based on forward-looking economic costs and the Commission's finding that using embedded costs to calculate support would lead

[55] To the extent that certain types of support may be targeted to wire centers, UNE zones, or disaggregated in some rural study areas, overall support levels are still determined based upon statewide or study area averages.

[56] National Broadband Plan at 145.

[57] *See id*. at 150 (suggesting that the Commission "should consider alternative approaches, such as satellite broadband, for addressing the most costly areas of the country to minimize the contribution burden on consumers across America").

[58] National Broadband Plan at 137. ("While satellite is capable of delivering speeds that meet the National Availability Target, satellite capacity can meet only a small portion of broadband demand in unserved areas for the foreseeable future. Satellite has the advantage of being both ubiquitous and having a geographically independent cost structure, making it particularly well suited to serve high-cost, low-density areas. However, while satellite can serve *any* given household, satellite capacity does not appear sufficient to serve *every* unserved household.") (footnotes omitted).

[59] *Id*. at 138.

[60] *Id*.

to inefficient subsidization of carriers and could create disincentives for carriers to operate efficiently.[61] Using forward looking costs also is consistent with the National Broadband Plan's recommendation that "CAF support levels should be based on what is necessary to induce a private firm to serve an area," and that "[s]upport should be based on the net gap (i.e., forward looking costs less revenues)."[62]

24. In addition, we seek comment on what technology platforms should be included in the forward-looking cost model if the Commission decides to base broadband support on the forward-looking economic costs of an efficient provider. The National Broadband Plan recommended that eligibility for obtaining Connect America Funding "should be company- and technology-agnostic,"[63] which is consistent with the "competitively neutrality" principle adopted by the Commission in the *Universal Service First Report and Order*.[64] The plan recommends that "[s]upport should be available to both incumbent and competitive telephone companies (whether classified today as 'rural' or 'non-rural'), fixed and mobile wireless providers, satellite providers and other broadband providers, consistent with statutory requirements."[65] We seek comment on this proposal to ensure competitive neutrality.

25. Consistent with the principle that eligibility for obtaining CAF support should be technology-agnostic, we seek comment on whether the Commission should develop a model that estimates the costs of all technologies currently being deployed (or soon to be deployed) that are capable of providing voice service and broadband service that meets the national broadband availability target. We also seek comment on how to ensure that any cost model used in conjunction with determining CAF support is capable of identifying the least-cost, most-efficient technology in unserved areas. A forward-looking economic cost model that estimates the costs of various technologies would enable the Commission to identify the least-cost, most-efficient technology currently being deployed, and thereby, provide only as much support as needed to achieve the Commission's goals for universal access.

26. We note, however, that while the costs of providing satellite service do not vary with geography and are fairly easy to identify, at present there is not sufficient satellite capacity to address all of the households that are unserved.[66] Thus we do not believe that we need to include satellite in the model. We seek comment on that view.

27. In defining forward-looking economic cost, we seek comment on the extent to which the Commission should consider any existing plant. We note in this regard that the Commission's forward-looking cost model adopted a "scorched node" approach, which assumed the incumbent LECs' central office (switch) locations as a given, rather than a total green field approach.[67] The National Broadband Plan model assumes existing infrastructure (for example, central office locations, cell towers), and estimates the incremental costs of brown field build outs and estimates green field build only where there is no nearby infrastructure. We seek comment on what existing infrastructure the model should assume.

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[61] *See supra* para. 4.

[62] National Broadband Plan at 145.

[63] *Id.*

[64] *Universal Service First Report and Order*, 12 FCC Rcd at 8801, para. 47 (explaining that "competitive neutrality means that universal service support mechanisms and rules neither unfairly advantage or disadvantage one provider over another, and neither unfairly favor or disfavor one technology over another").

[65] National Broadband Plan at 145.

[66] *Id.* at 137.

[67] *See, e.g., Universal Service First Report and Order*, Appendix J, 12 FCC Rcd at 9435, n. 628 ("A 'scorched node' model is one that models the network using the existing wire centers. A 'greenfield' model, by contrast, does not use the existing wire centers, but models a completely new network, including new wire centers.").

We also seek comment on which nodes are most analogous to a LEC central office in a scorched node approach for different technologies.

28. The Commission has extensive experience modeling the costs of wireline deployment, but prior to the National Broadband Plan proceeding, had not modeled the costs of deploying alternative technologies. Although the National Broadband Plan model includes wireless technologies, Commission staff noted that "[i]t is important to recognize that a wireless network has several layers of complexity that are not found in wireline networks, each of which affect the user experience and, therefore, network buildout costs and the investment gap."[68] For example, the user experience may be affected by the distance of the user from a cell site, the number of users sharing spectrum within a cell, the characteristics of the terrain, and the capability of end-user devices. We therefore seek comment on what modifications to the National Broadband Plan model, if any, would be appropriate to estimate wireless costs for purposes of universal service support.

29. Commission staff noted that determining the actual cost of a wireless deployment would require a finely calibrated propagation model.[69] However, Commission staff noted that conducting the radiofrequency (RF) propagation analysis in the field that would be required to calibrate such a model would be extremely time-consuming and expensive. According to Commission staff, such analysis is usually undertaken only at the time of an actual build-out, and may still not account for some effects, such as seasonal foliage. We seek comment on whether a propagation model would be required to accurately model the costs of wireless deployment. We also seek comment on the feasibility of developing such a model.

30. In the absence of a finely calibrated propagation model, Commission staff used a combination of approaches to ensure both adequate coverage and sufficient capacity to ensure access to service consistent with the target speed. The maximum cell radius is calculated from target uplink signal strength, with the radius in any given area adjusted for likely terrain-driven signal degradation. Capacity requirements for downlink capacity for the number of modeled end-users in a given cell drive cell splitting as required. Nonetheless, Commission staff concedes that "it is possible that the parameters in an actual network deployment are different from those that we estimated."[70] We seek comment on the assumptions underlying the parameters that the National Broadband Plan model uses to estimate the costs of a wireless network capable of providing service that provides 4 Mbps actual download and 1 Mbps actual upload capabilities. Is the National Broadband Plan approach an appropriate way to model wireless deployment costs for purposes of determining CAF support?

c. Types of Models

(i) HCPM vs. New Model

31. We seek comment on whether the Commission should develop a new model for determining appropriate universal service support levels for modern networks, rather than updating and modifying the Commission's existing HCPM used to determine high-cost support for the provision of voice telephony by non-rural carriers. Although the Commission previously stated that its forward-looking economic cost model should evolve as technology changes,[71] we do not believe that we should use the Commission's existing model as a starting point in developing a model to estimate CAF support

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[68] OBI, The Broadband Availability Gap at 66.

[69] *Id.*

[70] *Id.*

[71] *See Fifth Report and Order*, 13 FCC Rcd at 21330, para. 13; *Tenth Report and Order*, 14 FCC Rcd at 20170, para. 28.

levels. Since the Commission adopted its model, much progress has been made in developing computer cost models that estimate the cost of constructing modern networks. For example, in a 2009 notice of inquiry, the Commission sought comment on one such model.[72] More recently, Commission staff utilized CostQuest Associates as a contractor in developing the National Broadband Plan model that estimated the size of the broadband availability gap.

32. The National Broadband Plan model has several advantages over the Commission's existing HCPM that reflect improvements in cost modeling that have occurred within the industry and outside of Commission proceedings over the last several years. For example, the National Broadband Plan model relies on road and other rights-of-way data to route outside plant, which is a more realistic method than the Commission's existing model's use of rectilinear distances.[73] In addition, the National Broadband Plan model estimates the costs of multiple broadband technologies. Although the Commission's existing model could be modified relatively easily to estimate the costs of providing digital subscriber line (DSL) service over shorter copper loops by changing certain input values,[74] HCPM does not estimate the costs of other technologies such as wireless, hybrid fiber-coaxial cable, or fiber-to-the-premises, whereas the National Broadband Plan model does. The National Broadband Plan model also includes the costs of so-called "middle mile" facilities, whereas the only transport costs that HCPM estimates are the incumbent LECs' inter-office transport costs. We seek comment on whether the National Broadband Plan model is a better starting point for developing a broadband cost model than the Commission's existing HCPM. We seek comment on what other models we should consider if the Commission determines that it should develop a new model.

(ii) Total Costs vs. Incremental Costs

33. We seek comment on using a forward-looking economic cost model to determine support for broadband that estimates the total costs of broadband-capable networks, rather than the incremental costs of upgrading or extending existing networks to provide broadband in unserved areas. As noted above, the National Broadband Plan model identifies "unserved areas," i.e. areas without infrastructure that is capable of delivering broadband service meeting the national target, and estimates the incremental cost of augmenting existing infrastructure to provide broadband using various technologies. As discussed more fully below, the National Broadband Plan model estimates not only the incremental costs of deploying broadband to unserved areas, but also the expected incremental revenues associated with the new broadband deployment.[75] The National Broadband Plan model, however, does not take into account universal service support received under the current high-cost programs for those unserved areas. Rather, the National Broadband Plan model estimates only the incremental support amounts needed to deploy broadband in unserved areas and "assumes that existing networks will be available on an ongoing basis"

[72] *See Federal-State Joint Board on Universal Service, High-Cost Universal Service Support*, CC Docket No. 96-45, WC Docket No. 05-337, Notice of Inquiry, 24 FCC Rcd 4281, 4286-87 (2009) (seeking comment on CostQuest proposal that the Commission adopt an advanced services model for use in a reformed universal service system). *See also,* Comments of CostQuest Associates, CC Docket Nos. 96-45, 96-98, 99-68, 99-200, 01-92, WC Docket Nos. 03-109, 04-36, 05-337, 06-122 (filed Nov. 26, 2008) (CostQuest Comments) (attaching, among other things, a white paper by James Stegeman, Dr. Steve Parsons, and Mike Wilson, The Advanced Services Model: Proposal for a Competitive and Efficient Universal Service High-Cost Approach for a Broadband World (CostQuest Proposal)).

[73] *See* CostQuest Proposal at 22-26.

[74] Specifically, we could change the maximum copper loop length, which is currently set at 18,000 feet, to the maximums used in the broadband model (12,000, 5,000, and 3,000 feet), and update other inputs to include the costs of Digital Subscriber Line Access Multiplers (DSLAMs). We note however, that other inputs also should be updated to reflect current costs.

[75] *See infra* paras. 35-40.

without taking into consideration the role of existing universal service support.[76] For example, if a carrier in a high-cost area uses high-cost support to make voice and broadband available to eighty-five percent of its customers, the National Broadband Plan model estimates the cost of deploying broadband to the remaining fifteen percent, but does not estimate the costs associated with the eighty-five percent that already have access to broadband. The National Broadband Plan model does not estimate forward-looking economic costs in areas with existing broadband networks and, thus, provides no means of objectively evaluating whether current high-cost support levels are efficient, or how much support would be necessary to maintain broadband and voice services in areas currently receiving high-cost support. Nor does the National Broadband Plan model take into account any universal service support that carriers may currently receive for providing supported telephony services, whether or not they provide broadband.

34. The Commission's forward-looking cost model that is used to determine support for non-rural carriers estimates the total local exchange network costs of providing telephone service to all households and businesses within a geographic area. We seek comment on whether, if the Commission replaces its current high-cost funding mechanism with a new Connect America Fund to support both broadband and voice service, the Commission should adopt a total cost rather than an incremental cost model.

(iii) Cost vs. Cost and Revenue

35. We seek comment on whether the Commission should consider revenues, as well as costs, in determining CAF support. The Commission's current forward-looking cost model used to determine support levels for voice telephony for non-rural carriers estimates only costs, not revenues.[77] In contrast, the National Broadband Plan model, in addition to estimating the incremental costs of deploying broadband in unserved areas, estimates the expected incremental revenue from the new customers and services resulting from the new broadband build-out.[78]

36. The National Broadband Plan recommends that support should be based on the net gap, i.e., forward-looking costs less revenues and that "[r]evenues should include all revenues earned from broadband-capable network infrastructure, including voice, data and video revenues, and take into account the impact of other regulatory reforms that may impact revenue flows, such as ICC [intercarrier compensation], and funding from other sources, such as Recovery Act grants."[79] Because "[s]imply calculating the incremental costs of deploying broadband is not enough to determine the Broadband Investment Gap necessary to encourage operators to deploy," the National Broadband Plan model estimates "the amount of support necessary to cause the networks' economics to not only be positive, but to be sufficiently positive to motivate investment given capital scarcity and returns offered by alternative investments."[80]

[76] OBI, The Broadband Availability Gap at 35 ("One issue with this approach is that it assumes that existing networks will be available on an ongoing basis. To the extent that existing networks depend on public support, such as USF disbursements, the total gap for providing service in unserved areas could be significantly higher than the incremental calculation indicates.").

[77] None of the current high-cost support mechanisms consider expected revenues, except in the limited circumstances when subscriber line charge (SLC) revenues are imputed for purposes of calculating interstate common line support (ICLS). For example, high-cost loop support and local switching support are based on embedded costs without regard to revenues.

[78] OBI, The Broadband Availability Gap at 34-35, 45-50.

[79] National Broadband Plan at 145 (footnotes omitted).

[80] OBI, The Broadband Availability Gap at 33. Two key principles underlying the OBI model's design are that "[o]nly profitable business cases will induce incremental network investments" and that "[i]nvestment decisions are made on the incremental value they generate." *Id.*

37. We seek comment on whether to take into account the revenues earned from all services provided over broadband networks in calculating support under the CAF, such as broadband and video revenues, as opposed to basing support only on costs. If we include video revenues, should we also take into account costs associated with the provision of video services, such as programming costs? We seek comment on potential methods for estimating revenues and what revenues should be included, if the Commission were to consider revenues, as well as costs, in determining CAF support. We recognize that different services may be available in different parts of the country, and prices may vary in different areas. We also recognize that take rates for various services may vary depending upon a number of demographic factors. For example, the National Broadband Plan model uses demographic factors to estimate broadband adoption rates at the census block level.[81] What information should the Commission use in order to take into account revenues in determining support levels?

38. If the Commission were to include revenues in a model to determine broadband support, we seek comment on the methodology that the National Broadband Plan model uses to estimate incremental revenues. Incremental revenue in the National Broadband Plan model is the product of two main components: the number of incremental customers and the average revenue per user (ARPU).[82] The Commission staff analysis recognizes that some key assumptions on which the model is based may have a "disproportionately large" impact on the size of the investment gap.[83] Two of these major assumptions relate to the revenue calculation: "[t]he take rate for broadband in unserved areas will be comparable to the take rate in served areas with similar demographics;" and "[t]he average revenue per product or bundle will evolve slowly over time."[84] To estimate broadband adoption rates, Commission staff used broadband-adoption survey data that broke out responses by various demographic factors and a widely accepted technology adoption mathematical model to develop take rates for every census block in the nation.[85] These census block penetration rates were then scaled to estimate the take rate of related services (voice, video), the effect of bundled services, and the stratification of tiering (basic vs. premium).[86] To develop an approximation for ARPU, Commission staff estimated an individual ARPU value for each product category (data, voice, and video), as well as an ARPU value for the product bundle, and a low and high version of the data, voice, video and bundle product categories to reflect customer segmentation.[87]

39. We seek comment on the time frame within which any model can be expected reliably to forecast expected revenues. The National Broadband Plan model calculates the NPV of cash flows over 20 years. A forward-looking cost model estimates the costs of technologies currently being deployed and reasonably accurate input values can be developed by looking at current costs and equipment lifetimes.

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[81] The OBI analysis assumes, however, that the take rate for broadband in unserved areas will be comparable to the take rate in served areas with similar demographics. *See infra* para. 38.

[82] OBI, The Broadband Availability Gap at 35. The number of incremental customers is based on the technology modeled so that revenues are not double counted. For example, if the model calculates the costs of shortening loop lengths to deliver data and video services, only incremental data and video related revenue would be considered; voice revenues would not be included. *Id.*

[83] *Id.* at 42.

[84] *Id.*

[85] *See id*. at 45-50. The demographic variables used in the National Broadband Plan model that were positively correlated with broadband adoption were: income greater than $100,000; income between $75,000 – $100,000; college degree or greater education. Those that were negatively correlated were: less than high school education; senior citizen (65+); rural; and high school degree only. *Id.* at 45.

[86] *See id*. at 48-49.

[87] *See id*. at 50-51 & Exhibit 3-V.

The Commission staff estimate of revenues is primarily based on current prices and forecasts, although the revenue attributed to incremental voice revenue for telephone companies is set equal to the ARPU for a similar cable Voice over Internet Protocol (VoIP) product to account for recent market trends. How often should a revenue model be updated to reflect changes in prices and market trends? If calculations are made for a shorter time period, how should the model account for the residual value of assets whose lifetimes are longer than the study period (e.g., how does one account for the residual value of fiber in a ten-year study)?

40. The National Broadband Plan model uses 11.25% as the discount rate, identifies the expected cash flows associated with building and operating a network over the project's lifetime of 20 years, and computes the net present value of those cash flows.[88] We seek comment on whether this is an appropriate approach for purposes of determining CAF support amounts. We also seek comment more generally on how often key model inputs should be updated.

d. Geographic Areas

41. The National Broadband Plan model initially estimates the incremental costs of deploying broadband to unserved areas and the incremental revenues associated with that deployment at a very granular geographic level, the census block.[89] Commission staff reasoned that using the average cost per household of existing deployments, even if adjusted for differences in population density, would risk underestimating costs because unserved areas tend to have much lower densities than the country overall.[90] Although geographic granularity is important in capturing the real costs associated with providing broadband service in rural and remote areas, Commission staff concluded that it does not make sense to evaluate whether to build a network at the census block level.[91] In the real world, private sector firms typically will evaluate the profitability of deployment decisions at a larger, more aggregated service-area level than a census block.[92] Commission staff concluded that estimating lowest-cost technologies on a census block basis could lead to an unrealistic patchwork quilt of different technologies in contiguous census blocks and aggregated financial outputs to the county level. Thus, the National Broadband Plan model estimates the amount of additional funding required to close the broadband availability gap by assessing the gap of various technologies at the county level.[93]

42. We seek comment on what geographic area the Commission should use in calculating the cost of deploying a network and providing services, and on whether the Commission should use neutral geographic units, as recommended in the National Broadband Plan.[94] We seek comment on the advantages and disadvantages of using a particular geographic area to determine either the costs or the gap between costs and revenues. As Commission staff explains, if the geography is too big, there will be portions that would be more efficiently (less expensively) served by an alternate technology, but if the

[88] OBI, The Broadband Availability Gap at 33.

[89] One of the key principles underlying the model's design is: "Capturing the local (dis-)economies of scale that drive local profitability requires granular calculations of costs and revenues." *Id.*

[90] *Id.* at 38; *see also id.* at 8-9 & Exhibits 1-E, 1-F.

[91] *Id.* at 36.

[92] Another key principle underlying the model's design is: "Network-deployment decisions reflect service-area economies of scale." *Id.* at 35.

[93] *Id.* at 37.

[94] *See* National Broadband Plan at 145 ("The FCC should evaluate eligibility and define support levels on the basis of neutral geographic units such as U.S. Census-based geographic areas, not the geographic units associated with any particular industry segment.").

geography is too small it will be subscale, thereby leading to more inefficiency and higher costs (and support levels). The National Broadband Plan model uses counties because they "appear large enough in most cases to provide the scale benefits but not so large as to inhibit the deployment of the most cost-effective technology," while remaining technology neutral.[95] We seek comment on whether this is a workable approach for future CAF universal service funding decisions.

2. Expedited Process for Providing Funding to Extend Networks in Unserved Areas

43. We believe that it is critical to constrain growth in the legacy high-cost support mechanisms while we develop rules for a more efficient and accountable universal service funding mechanism. At the same time, we recognize that firms today are upgrading and modernizing their networks to offer a wide array of new services to consumers. The National Broadband Plan recommends that the Commission "create a fast-track program in CAF for providers to receive targeted funding for new broadband construction in unserved areas."[96] Such funding could, for instance, be provided to areas identified as "unserved" once the Broadband Data Improvement Act mapping is completed in February 2011.[97] We seek comment on the best way to create an accelerated process to distribute funding to support new deployment of broadband-capable networks in unserved areas during the period we are considering final rules to implement fully the new CAF funding mechanism. In particular, we seek comment on whether there is an efficient method for delivering a set amount of support, which does not require the use of a model.

44. For example, shortly after passage of the American Recovery and Reinvestment Act,[98] a group of economists recommended that a competitive procurement auction be used to allocate funding under the Recovery Act.[99] The group noted that "it is difficult to design a grant application system to ensure that firms receive only the minimum subsidy necessary to achieve the goal."[100] They argued that

[95] OBI, The Broadband Availability Gap at 37.

[96] National Broadband Plan at 144.

[97] *See* Broadband Data Improvement Act of 2008, Pub. L. No. 110-385, 122 Stat. 4096 (codified at 47 U.S.C. §§ 1301-1304) (BDIA). On July 2, 2009, the National Telecommunications Information Agency (NTIA) released a Notice of Funding Availability (NOFA), which defined several key terms for the purposes of the state broadband program. Department of Commerce, National Telecommunications and Information Administration, State Broadband Data and Development Grant Program, Docket No. 0660-ZA29, Notice of Funds Availability, 74 Fed. Reg. 32545, 32555 (July 8, 2009) (*NTIA State Mapping NOFA*). The NOFA defines "broadband" to include data-transmission technology with advertised speeds of at least 768 kbps downstream and at least 200 kbps upstream to end users. *NTIA State Mapping NOFA*, 74 Fed. Reg. at 32548. An area is "unserved" for purposes of the NOFA if 90% of households in the area lack access to facilities-based terrestrial broadband service. *Id.* NTIA later issued a clarification of the Technical Appendix to the *NTIA State Mapping NOFA*, and provided additional guidance to its implementation of the Program by posting responses to Frequently Asked Questions. *See* Department of Commerce, National Telecommunications and Information Administration, State Broadband Data and Development Grant Program, Docket No. 0660-ZA29, Notice of Funds Availability; Clarification. 74 Fed. Reg. 40569 (Aug. 12, 2009); NTIA, *State Broadband Data and Development Program (Broadband Mapping Program) Frequently Asked Questions*, http://www.ntia.doc.gov/broadbandgrants/BroadbandMappingFAQs%20_090812.pdf (rel. Aug. 12, 2009) (*NTIA Aug. 12 FAQs*).

[98] American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5, 123 Stat. 115 (2009) (Recovery Act). The Recovery Act was signed into law on February 17, 2009.

[99] Paul Milgrom, Gregory Rosston, Andrzej Skrzypacz & Scott Wallston, "Comments of 71 Concerned Economists: Using Procurement Auctions to Allocate Broadband Stimulus Grants," (April 13, 2009) (submitted to NTIA and Rural Utilities Service (RUS)) (71 Economists' Proposal); *see* Appendix B.

[100] *Id*. at 2.

"[a]n objective, 'mechanistic' approach that applies specific, quantitative criteria can be both easier to implement and lead to more efficient outcomes than traditional grant application review."[101] Among other things, such an approach can "inherently induce firms to contribute their own investment to increase the chance that their bid is accepted."[102]

45. The procurement auction proposal by this group of economists is similar in many ways to reverse auction proposals that have been previously considered by the Commission. In any reverse auction procedure, it is necessary to establish precise definitions of what parties are asked to bid for, including the geographic boundaries of the areas to be served and a precise definition of the service quality that winning bidders would be expected to provide.[103] The economists' proposal potentially differs from some reverse auction proposals in that bidding parties themselves would be allowed to specifically define the geographic units and other service characteristics associated with their bids.[104] To select winning proposals from those submitted, it would therefore be necessary to establish a scoring rule such that all proposals could be evaluated on an easily understood and unambiguous basis. Such a mechanism could be implemented relatively quickly without addressing the full complexities inherent in other reverse auction proposals. For example, it would not require the development of a cost or cost and revenue model to set reserve prices. In addition, it would minimize the potential problem with reverse auctions concerning few bidders in a specific area, because proposals for different areas would compete against each other. Thus, all bids for all unserved areas in the United States would be competing for a limited, defined amount of funding. There are limitations with such an approach, however. For instance, because this approach involves one-time grants, it does not appear suitable for areas where operating costs exceed revenues and thus where continuing support is required.

46. The National Broadband Plan concluded that "[i]n some areas, subsidizing all or part of the initial capex will allow a service provider to have a sustainable business. Elsewhere, subsidizing initial capex will not be enough; service providers will need support for continuing costs."[105] Based on available information, Commission staff estimated that "[s]upport for one-time deployment or upgrades will likely be enough to provide broadband to 46% of the seven million unserved housing units."[106] The National Broadband Plan stated that "USF resources are finite, and policymakers need to weigh tradeoffs in allocating those resources . . ." and recommended as a guiding principle that policymakers should seek to "maximize the number of households that are served by broadband meeting the National Broadband Availability Target."[107] If the Commission has a finite amount of funding available in a given year to support the new deployment of broadband-capable networks, could a competitive procurement auction be used to maximize the number of households that would gain access to broadband?

47. We seek comment on whether some form of competitive procurement auction could be an efficient mechanism to determine subsidies for the extension of new broadband-capable infrastructure in unserved areas. For instance, could such a competitive process be used to target one-time subsidies to extend broadband-capable networks in areas where revenues are likely to be sufficient to cover ongoing

[101] *Id.* at 3.

[102] *Id.* at 4.

[103] For example, build-out requirements and minimum speed and other quality standards would be pre-specified.

[104] Some reverse auction proposals have suggested a package bidding format based on pre-defined geographic units such as counties. Under the economists' proposal, bidders would be allowed to propose arbitrary geographic units based on their own business models.

[105] National Broadband Plan at 138.

[106] *Id.*

[107] *Id.* at 143.

costs of operation?[108] We also seek comment on the appropriate scoring function to use if a procurement auction mechanism is adopted for this purpose. The economists' proposals suggests that "[t]his could be a simple metric, such as 'newly served population' (defined as the population to which service above a minimum bandwidth threshold is newly available) or a more involved measure such as 'effective bandwidth supplied' (defined as the population to which service is newly available adjusted for the speed of service)."[109] One important aspect of a scoring rule is the set of weights used to evaluate new service to unserved areas based on perceived cost or customer density. For example, a simple rule that ranks proposals based on the minimum subsidy required per newly served household would tend to favor proposals to serve relatively low cost regions. We invite specific comments on rules that could be used to evaluate proposals to provide differing speeds of access in excess of 4 Mbps actual download and 1 Mbps actual upload, or differing qualities of access.

48. Parties are also invited to comment specifically on any other aspects of the procurement auction mechanism outlined in the economists' proposal, including build-out requirements and compliance and auditing features. For instance, what would be an appropriate time frame in which the winning bidder must make the required investment? What percentage of the winning bid should be provided before construction begins, and what conditions must a recipient meet before remaining installments are paid? What certifications regarding performance should be made, and how should the Commission verify that conditions have been satisfactorily met?

III. NOTICE OF PROPOSED RULEMAKING

A. Background

49. The Commission has acknowledged the benefits of comprehensive reform of the current high-cost mechanisms.[110] Indeed, the Joint Statement on Broadband recommends that the universal service fund and the intercarrier compensation system "be comprehensively reformed to increase accountability and efficiency, encourage targeted investment in broadband infrastructure, and emphasize the importance of broadband to the future of these programs."[111] The National Broadband Plan recommends significant changes to the current high-cost program, and this notice of proposed rulemaking

[108] By "one-time" we refer to a fixed amount of subsidy that could be paid in installments.

[109] 71 Economists' Proposal, at 5-6; *see* Appendix B.

[110] *See, e.g.*, *High-Cost Universal Service Support, Federal-State Joint Board on Universal Service*, WC Docket No. 05-337, CC Docket No. 96-45, Notice of Proposed Rulemaking, 23 FCC Rcd 1467 (2008) (*Identical Support Rule Notice*); *High-Cost Universal Service Support, Federal-State Joint Board on Universal Service*, WC Docket No. 05-337, CC Docket No. 96-45, Notice of Proposed Rulemaking, 23 FCC Rcd 1495 (2008) (*Reverse Auctions Notice*); *High-Cost Universal Service Support, Federal-State Joint Board on Universal Service*, WC Docket No. 05-337, CC Docket No. 96-45, Notice of Proposed Rulemaking, 23 FCC Rcd 1531 (2008) (*Joint Board Comprehensive Reform Notice*); *High-Cost Universal Service Reform; Federal-State Joint Board on Universal Service; Lifeline and Link Up; Universal Service Contribution Methodology; Numbering Resource Optimization; Implementation of the Local Competition Provisions in the Telecommunications Act of 1996; Developing a Unified Intercarrier Compensation Regime; Intercarrier Compensation for ISP-Bound Traffic; IP-Enabled Services*, CC Docket Nos. 96-45, 99-200, 96-98, 01-92, 99-68, WC Docket Nos. 05-337, 03-109, 06-122, 04-36, Order on Remand and Report and Order and Further Notice of Proposed Rulemaking, 24 FCC 6475 (2008) (*Comprehensive Reform FNPRM*), *aff'd Core Communications, Inc. v.FCC*, 592 F.3d 139 (D.C. Cir. 2010).

[111] *Joint Statement on Broadband*, GN Docket No. 10-66, Joint Statement on Broadband, FCC 10-42, para 3 (rel. Mar. 16, 2010) (*Joint Statement on Broadband*).

(NPRM) represents an important first step in seeking public comment on the roadmap to universal access to broadband.[112]

50. The National Broadband Plan recommends that the Commission cut inefficient funding of legacy voice service and refocus universal service funding to directly support modern communications networks that will provide broadband as well as voice services.[113] In this NPRM, we propose to contain growth in legacy high-cost support mechanisms as a critical first step to transitioning to a more efficient and accountable funding mechanism, recognizing that consumers across America ultimately pay for universal service. We propose specific reforms to the legacy high-cost program that could be initially implemented to create a pathway to a more efficient and targeted mechanism for funding broadband. We seek comment on these proposals. We encourage input from everyone. We are particularly interested in input from Tribal governments on these specific proposals, and we specifically ask whether there are any unique circumstances in Tribal lands that would necessitate a different approach. Similarly, we request comment on whether there are any unique circumstances in insular areas that would necessitate a different approach.

B. Discussion

1. Controlling the Size of the High-Cost Program

51. As an essential first step toward repurposing the universal service fund to support broadband as well as voice service, we must ensure that the size of the fund remains reasonable. The National Broadband Plan recommends that the Commission take steps to manage the universal service fund so that its total size remains close to its current level (in 2010 dollars) to minimize the burden of increasing universal service contributions on consumers.[114] The Commission already has taken action to control the overall size of the high-cost fund. In 2008, the Commission adopted on an interim basis an overall competitive eligible telecommunications carrier (ETC) high-cost cap of approximately $1.4 billion, pending comprehensive USF reform.[115] Similarly, today we seek comment on capping legacy high-cost support provided to incumbent telephone companies at 2010 levels, which would have the effect of creating an overall ceiling for the legacy high-cost program.[116] Such a cap would remain in place while the Commission determines how to distribute funds in a more efficient, targeted manner to those areas of the country where no firm can operate profitably without government support, while

[112] The American Recovery and Reinvestment Act of 2009 required the Commission to deliver a National Broadband Plan to Congress. *See* Pub. L. No. 111-5, 123 Stat. 115 (2009). The Commission delivered the National Broadband Plan to Congress on March 16, 2010. *FCC Sends National Broadband Plan to Congress*, FCC News Release (dated Mar. 16, 2010). Federal Communications Commission, *Connecting America: The National Broadband Plan*, Ch. 8 (rel. March 16, 2010) (*National Broadband Plan*).

[113] *National Broadband Plan* at 147-48.

[114] National Broadband Plan at 149.

[115] *High-Cost Universal Service Support; Federal-State Joint Board on Universal Service*, WC Docket No. 05-337, CC Docket No. 96-45, Order, 23 FCC Rcd 8834 (2008), *aff'd*, Rural Cellular Ass'n v. FCC, 588 F.3d 1095 (D.C. Cir. 2009). The Commission adopted a limited exception to the cap for competitive ETCs serving tribal lands or Alaska Native regions.

[116] In 2007, the Federal-State Joint Board on Universal Service recommended an overall cap for the high-cost support mechanisms and a transition in which existing funding mechanisms would be reduced, and all, or a significant share, of savings transferred to proposed new funds for broadband and mobility. *High-Cost Universal Service Support; Federal-State Joint Board on Universal Service*, WC Docket No. 05-337, CC Docket No. 96-45, Recommended Decision, 22 FCC Rcd 20477, 20484, paras. 26-27 (Fed.-State Jt. Bd. 2007).

minimizing burdens on American consumers who ultimately pay for universal service through carrier pass-through charges.

52. We seek comment on how the Commission could implement such a cap. Alternatively, we invite other proposals that would ensure that the overall size of the high-cost fund stays at or below current levels. Should the Commission impose an overall cap on legacy high-cost support for incumbent LECs at 2010 levels? Should the Commission impose a cap on each individual high-cost mechanism (to the extent each is not already capped) at 2010 levels? Should the Commission freeze per-line support for each carrier at 2010 levels? For example, the Alliance for Rural CMRS Carriers proposed that incumbent LEC support amounts per line be capped at either March 2008 or March 2010 levels.[117] We seek comment on this proposal. Alternatively, should the Commission freeze the total amount of support a carrier receives in a particular study area at 2010 levels? Are there other ways to implement such a cap? What rule changes would be required to implement this proposal? How would the Commission implement this proposal in conjunction with the reforms identified in the following paragraphs? In addition, what implications would this proposal have for other Commission rules, such as the Commission's current pricing rules, and should the implementation of this proposal be coordinated with any other regulatory actions?

2. Specific Steps to Cut Legacy High-Cost Support

53. As discussed in more detail below, the National Broadband Plan identifies several specific first steps that could reduce funding in the legacy high-cost support mechanisms and recommends that those savings be used to further the goals of universalizing broadband without increasing the overall size of the universal service fund. The National Broadband Plan recognizes that shifting funds could have transitional impacts and recommends that "[a]s the FCC considers this policy shift, it should take into account the impact of potential changes in free cash flows on providers' ability to continue to provide voice service and on future broadband network deployment strategies."[118] Below, we seek comment on the first steps set forth in the National Broadband Plan. To the extent that any commenter believes that these proposals, or the proposal to cap legacy high-cost support, would negatively affect affordable voice service for consumers today, we would encourage such a commenter to identify all assumptions and to provide data, including information on network investment plans over the next five years and free cash flows, to support that position. The intent of these proposals is to eliminate the indirect funding of broadband-capable networks today through our legacy high-cost programs,[119] which is occurring without

[117] *See* Letter from David LaFuria, Counsel for Alliance for Rural CMRS Carriers, to Marlene H. Dortch, Secretary, FCC, CC Docket No. 96-45, WC Docket No. 05-337, GN Docket No. 09-47, 09-51, 09-137 (Mar. 3, 2010) (urging the FCC to adopt an interim cap for incumbent telephone company support per line at either March 2010 or March 2008 levels, pending comprehensive USF reform). Specifically, the Alliance for Rural CMRS Carriers propose that: 1) ILECs would receive the amount of per-line support they are eligible to receive as of the effective date of the cap (either March 2008 or March 2010) until comprehensive reform of the federal universal service support mechanism is implemented; 2) Beginning on the date that the interim plan commences, ILEC support would be calculated each quarter by simply determining whether an ILEC's support has increased on a per-line basis since the effective date of the cap (either March 2008 or March 2010); 3) If an ILEC's per-line support has increased, support would be determined by multiplying the current number of access lines in service by the capped per-line amount; 4) If the ILEC's per-line support has decreased, then it will receive its support without any adjustments.

[118] National Broadband Plan at 147.

[119] Under the Commission's so-called "no barriers" policy, high-cost support for voice services indirectly supports the deployment of broadband capable networks. *See Rural Task Force Order*, 16 FCC Rcd at 11322, para. 200 ("The public switched telephone network is not a single-use network. Modern network infrastructure can provide access not only to voice services, but also to data, graphics, video, and other services. . . . Thus, although the high-cost loop support mechanism does not support the provision of advanced services, our policies do not impede the deployment of modern plant capable of providing access to advanced services.").

transparency or accountability for the use of funds to extend broadband service. We seek comment on the timing of implementing such reforms in conjunction with the creation of a more efficient and targeted framework that will provide support for broadband and voice. We encourage commenters to address when each rule change should be implemented and how specific reforms should be sequenced to provide regulatory clarity for ongoing private sector investment.

54. In addition, we seek comment on the relationship between such universal service reforms and carriers' rates, including intercarrier compensation rates, under the Commission's current pricing rules.[120] We seek comment both on the likely rate impacts under existing pricing rules that would arise from the possible universal service reforms and any appropriate responses. We also note that many rural rate-of-return carriers participate in the National Exchange Carrier Association (NECA) pooling process for their interstate access charges. If universal service support under the legacy programs were frozen for such carriers, are there special considerations resulting from operation of the NECA pool that would unfairly advantage or disadvantage certain carriers? The Commission previously has expressed concern about the risks of continued participation in NECA pools by carriers that were subject to incentive regulation.[121] We seek comment on whether such concerns would remain if all rate-of-return carriers converted to incentive regulation. Would the pool be able to continue to operate pursuant to regulation other than rate-of-return?

55. *Shifting Rate-of-Return Carriers to Incentive Regulation.* The National Broadband Plan recommends that the Commission "require rate-of-return carriers to move to incentive regulation."[122] We seek comment on requiring current rate-of-return companies to convert to some form of incentive regulation. We note that a number of companies have voluntarily converted to price cap regulation in the last two years.[123] In such cases, the Commission effectively converted the companies' interstate common

[120] For example, under the Commission's existing price cap rules, if a carrier no longer received IAS support to help meet its revenue requirement for particular regulated services, it could recover those revenues through new intercarrier compensation charges if its subscriber line charge (SLC) was at the applicable cap. 47 C.F.R. §§ 69.153 (presubscribed interexchange carrier charge), 69.154 (per-minute carrier common line charge). If the carrier's SLC was not at the applicable cap, the carriers likely could seek an exogenous cost adjustment, resulting first in an increase in the SLC, and only then in new intercarrier compensation charges, to the extent that additional cost recovery was necessary.

As another example, under the Commission's price cap rules, price cap carriers are allowed to increase their price cap indices if their earnings fall below 10.25%. 47 C.F.R. § 61.45(d)(1)(vii). Price cap carriers forego this right, however, if they avail themselves of "pricing flexibility" regulatory relief. 47 C.F.R. § 69.731.

[121] *Multi-Association Group (MAG) Plan for Regulation of Interstate Services of Non-Price Cap Incumbent Local Exchange Carriers and Interexchange Carriers, Federal-State Joint Board on Universal Service*, CC Docket Nos. 96-45, 00-256, Report and Order and Second Further Notice of Proposed Rulemaking, 19 FCC Rcd 4122, 4163, para. 91 (2004) (*MAG Second Further Notice*).

[122] National Broadband Plan at 147.

[123] A number of the mid-sized telephone companies recently have elected to convert to price-cap regulation. *See Windstream Petition for Conversion to Price Cap Regulation and for Limited Waiver Relief*, WC Docket No. 07-171, Order, 23 FCC Rcd 5294 (2008) (*Windstream Order*); *Petition of Puerto Rico Telephone Company, Inc. for Election of Price Cap Regulation and Limited Waiver of Pricing and Universal Service Rules; Consolidated Communications Petition for Conversion to Price Cap Regulation and for Limited Waiver Relief; Frontier Petition for Limited Waiver Relief upon Conversion of Global Valley Networks, Inc., to Price Cap Regulation*, WC Docket Nos. 07-292, 07-291, 08-18, Order, 23 FCC Rcd 7353 (Wireline Comp. Bur. 2008); *ACS of Alaska, Inc., ACS of Anchorage, Inc., ACS of Fairbanks, Inc. and ACS of the Northland, Inc., Petition for Conversion to Price Cap Regulation and Limited Waiver Relief*, WC Docket No. 08-220, Order, 24 FCC Rcd 4664 (Wireline Comp. Bur. 2009); *CenturyTel, Inc., Petition for Conversion to Price Cap Regulation and for Limited Waiver Relief*, WC Docket No. 08-191, Order, 24 FCC Rcd 4677 (Wireline Comp. Bur. 2009). *See also, e.g., Pleading Cycle*
(continued….)

line support (ICLS) to a frozen amount per line. We seek comment on whether the Commission should replace rate-of-return regulation with the price-cap framework recently adopted for voluntary conversions,[124] an alternative price-cap framework, or some other form of incentive regulation.[125] We seek comment on the costs and the benefits that would be realized by converting all rate-of-return carriers to price cap regulation or other incentive regulation. We seek comment on whether, in an increasingly competitive marketplace, and with carriers' service offerings expanding beyond regulated services, the current rate-of-return framework, which considers only regulated costs and revenues, has become less appropriate.

56. We seek comment on whether we should convert ICLS to a frozen amount per line, which would have the effect of limiting growth in the legacy high-cost program.[126] We seek comment on whether this reform should be implemented at the same time as any measures the Commission may adopt to provide targeted funding for the deployment of broadband-capable infrastructure to areas that are unserved, or should such a rule change occur before the development of the CAF, or otherwise be coordinated with some other regulatory action such as conversion to incentive regulation. The National Broadband Plan recognizes that the savings realized by eliminating future growth in the legacy ICLS program represent funding that could be redirected toward achieving broadband-related goals.[127] We seek comment on this proposal.

57. _Elimination of Interstate Access Support._ The National Broadband Plan also recommends that the Commission "redirect access replacement funding known as Interstate Access Support (IAS) toward broadband deployment."[128] Thus, we now seek comment on the elimination of

(Continued from previous page)
Established for Comments on Vitelco Petition for Conversion to Price Cap Regulation and Other Limited Waiver Relief, WC Docket No. 10-39, Public Notice, DA 10-272 (rel. Feb. 18, 2010); *Pleading Cycle Established for Comments on FairPoint Petition for Conversion to Price Cap Regulation and for Other Limited Waiver Relief*, WC Docket No. 10-47, Public Notice, DA 10-299 (rel. Feb. 25, 2010); *Pleading Cycle Established for Comments on Windstream Petition for Limited Waiver Relief*, WC Docket No. 10-55, Public Notice, DA 10-397 (rel. Mar. 9, 2010).

[124] In the *Windstream Order*, the Commission directed Windstream to establish initial price cap indexes for its price cap baskets using January 1st rates for the year of conversion and base period demand for the calendar year immediately prior to the conversion. The Commission required Windstream to target its average traffic-sensitive (ATS) rate to $0.0065 per ATS minute of use pursuant to section 61.3(qq) of the Commission's rules, using an X-factor of 6.5 percent. Finally, the Commission granted Windstream a waiver to allow it to continue to receive ICLS for the converted study areas. Windstream was required to forego any recovery of a presubscribed interexchange carrier charge or carrier common line charge and forego assessing a $7.00 non-primary residential line subscriber line charge in conjunction with its receipt of frozen per-line ICLS. *See generally, Windstream Order*, 23 FCC Rcd 5294.

[125] The Commission has sought comment in the past on other alternative incentive regulation schemes, and whether they might be appropriate for rate-of-return carriers. *See, e.g.*, *MAG Second Further Notice*, 19 FCC Rcd at 4153-64, paras. 68-94.

[126] Specifically, in the *Windstream Order*, the Commission required that Windstream's per-line ICLS be calculated at the preceding calendar year per-line disaggregated ICLS amounts, and frozen at those per-line levels going forward, and that its aggregate annual ICLS support be capped at an amount equal to its overall ICLS for the year preceding the conversion (after application of any required true-ups). *Windstream Order*, 23 FCC Rcd at 5302-04, paras. 20-21. As noted above, as a condition of its receipt of frozen per-line ICLS support, Windstream, among other things, committed to forgo the recovery of any PICC or CCL charge. *Id.* at 5300-01, para. 14.

[127] National Broadband Plan at 147-148.

[128] *Id*. at 147.

IAS. When the Commission created IAS in 2000, it said that it would revisit this funding mechanism "to ensure that such funding is sufficient, yet not excessive."[129] That re-examination has not occurred.

58. Specifically, we now seek comment on eliminating sections 54.800-54.809 of our rules and transferring any IAS funding levels as of the date of elimination to the new Connect America Fund to provide support for broadband-capable networks.[130] We invite commenters to propose an appropriate timeline for the elimination of these rules and any glide-path that may be necessary to ensure that recipients continue to be able to provide voice services during the transition.

59. Sprint and Verizon Wireless Voluntary Commitments. The National Broadband Plan also recommends that the Commission "issue an order to implement the voluntary commitments of Sprint and Verizon Wireless to reduce the High-Cost funding they receive as competitive ETCs to zero over a five-year period as a condition of earlier merger decisions."[131] The Commission will consider shortly an order clarifying how to implement Verizon Wireless's and Sprint's voluntary commitments.[132]

60. *Elimination of Competitive ETC High-Cost Support.* The National Broadband Plan recommends that the Commission phase out remaining competitive ETC funding under the existing funding mechanisms over a five-year period and target the savings toward the deployment of broadband-capable networks and other reforms in the plan.[133] We seek comment on this proposal.

61. We seek comment on whether we should ramp down competitive ETC support under the legacy programs, and if so, how the transition should occur. For example, should the Commission reduce support on a pro rata basis (e.g., 20% reduction each year) for each state? Should the Commission reduce support at an accelerated rate of decline? Should the Commission reduce support on a proportional basis for all states, or in some other manner, and if so, on what basis? Would there be any impact on existing subscribers of competitive ETCs if the Commission were to reduce competitive ETC support under the

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[129] *Access Charge Reform; Price Cap Performance Review for Local Exchange Carriers; Low-Volume Long Distance Users; Federal-State Joint Board on Universal Service*, CC Docket Nos. 96-262, 94-1, 99-249, 96-45, Sixth Report and Order, Report and Order, and Eleventh Report and Order, 15 FCC Rcd 12962, 13047, para. 203 (2000), *aff'd in part, rev'd in part, and remanded in part,* Texas Office of Public Util. Counsel et al. v. FCC, 265 F.3d 313 (5th Cir. 2001); *on remand, Access Charge Reform; Price Cap Performance Review for LECs; Low-Volume Long Distance Users; Federal-State Joint Board on Universal Service*, CC Docket Nos. 96-262, 94-1, 99-249, 96-45, Order on Remand, 18 FCC Rcd 14976 (2003).

[130] National Broadband Plan at 147-148.

[131] *Id*. at 147.

[132] Verizon Wireless agreed to a five-year phase-out of its competitive ETC high cost support for any properties that it retained after mandated divestitures. *Applications of Cellco Partnership d/b/a Verizon Wireless and Atlantis Holdings LLC for Consent to Transfer Control of Licenses, Authorizations, and Spectrum Manager and De Facto Transfer Leasing Arrangements and Petition for Declaratory Ruling that the Transaction is Consistent with Section 310(b)(4) of the Communications Act,* WT Docket No. 08-95, File Nos. 0003463892, et al., ITC-T/C-20080613-00270, et al., ISP-PDR-20080613-00012, Memorandum Opinion and Order and Declaratory Ruling, 23 FCC Rcd 17444, 17529–17532, paras. 192–197 (2008). Similarly, Sprint agreed to a five-year phase-out of its competitive ETC high-cost support as part of its transaction with Clearwire. *Applications of Sprint Nextel Corporation and Clearwire Corporation For Consent to Transfer Control of Licenses, Leases and Authorizations*, WT Docket No. 08-94, File Nos. 0003462540 et al., Memorandum Opinion and Order and Declaratory Ruling, 23 FCC Rcd 17570, 17612, para. 108 (2008). The National Broadband Plan recommended that this recaptured competitive ETC funding be used to implement the recommendations in the plan. National Broadband Plan at 147.

[133] National Broadband Plan at 147-148. Competitive ETC support per line is based on the incumbent telephone company's support per line. 47 C.F.R. § 54.307. As a consequence, the support a competitive ETC receives is not based on either its costs or the costs of the most efficient technology to support customers in a given area.

legacy funding mechanisms? How should reductions in legacy high-cost support for all competitive ETCs be coordinated with implementation of Verizon Wireless's and Sprint's voluntary commitments to phase-out legacy high-cost support over a five year period?

62. General Proposals. Commenters are invited to submit other proposals to eliminate or reduce funding levels in the legacy high-cost support mechanisms to transition to efficient funding levels in the Connect America Fund. We encourage parties that submit alternative proposals to identify specific rule changes and quantify the impact of such changes.

IV. PROCEDURAL MATTERS

A. Initial Regulatory Flexibility Analysis

63. As required by the Regulatory Flexibility Act of 1980, as amended,[134] the Commission has prepared an Initial Regulatory Flexibility Analysis (IRFA) for this NPRM, of the possible significant economic impact on a substantial number of small entities by the policies and rules proposed in this further notice. The IRFA is in Appendix A.[135] Written public comments are requested on this IRFA. Comments must be identified as responses to the IRFA and must be filed by the deadlines for comments on the NPRM. The Commission will send a copy of the NPRM, including this IRFA, to the Chief Counsel for Advocacy of the Small Business Administration.[136] In addition, the NPRM and IRFA (or summaries thereof) will be published in the Federal Register.[137]

B. Paperwork Reduction Act Analysis

64. This document discusses potential new or revised information collection requirements. The reporting requirements, if any, that might be adopted pursuant to this NPRM are too speculative at this time to request comment from the OMB or interested parties under section 3507(d) of the Paperwork Reduction Act.[138] Therefore, if the Commission determines that reporting is required, it will seek comment from the OMB and interested parties prior to any such requirements taking effect.[139] In addition, pursuant to the Small Business Paperwork Relief Act of 2002, we will seek specific comment on how we might "further reduce the information collection burden for small business concerns with fewer than 25 employees."[140] Nevertheless, interested parties are encouraged to comment on whether any new or revised information collection is necessary, and if so, how the Commission might minimize the burden of any such collection.

C. *Ex Parte Presentations*

65. These matters shall be treated as a "permit-but-disclose" proceeding in accordance with the Commission's *ex parte* rules.[141] Persons making oral *ex parte* presentations are reminded that memoranda summarizing the presentations must contain summaries of the substance of the presentations and not merely a listing of the subjects discussed. More than a one- or two-sentence description of the

[134] 5 U.S.C. § 603.

[135] *See* Appendix A.

[136] *See* 5 U.S.C. § 603(a).

[137] *Id.*

[138] *See* 44 U.S.C. § 3507(d).

[139] Paperwork Reduction Act of 1995, Pub. L. No. 104-13, 109 Stat. 163 (1995).

[140] Small Business Paperwork Relief Act of 2002, Pub. L. No. 107-198, 116 Stat. 729 (2002); 44 U.S.C. § 3506(c)(4).

[141] 47 C.F.R. §§ 1.1200-1.1216.

views and arguments presented is generally required.[142] Other requirements pertaining to oral and written presentations are set forth in section 1.1206(b) of the Commission's rules.[143]

D. Comment Filing Procedures

66. Pursuant to sections 1.415 and 1.419 of the Commission's rules,[144] interested parties may file comments and reply comments regarding the NOI and NPRM on or before the dates indicated on the first page of this document. Comments may be filed using: (1) the Commission's Electronic Comment Filing System (ECFS); (2) the Federal Government's e-Rulemaking Portal; or (3) by filing paper copies.[145]

67. Electronic Filers: Comments may be filed electronically using the Internet by accessing the ECFS: http://fjallfoss.fcc.gov/ecfs/ or the Federal e-Rulemaking Portal: http://www.regulations.gov.

68. Paper Filers: Parties who choose to file by paper must file an original and four copies of each filing. If more than one docket or rulemaking number appears in the caption of this proceeding, filers must submit two additional copies for each additional docket or rulemaking number.

69. Filings can be sent by hand or messenger delivery, by commercial overnight courier, or by first-class or overnight U.S. Postal Service mail. All filings must be addressed to the Commission's Secretary, Office of the Secretary, Federal Communications Commission.

70. All hand-delivered or messenger-delivered paper filings for the Commission's Secretary must be delivered to FCC Headquarters at 445 12th St., SW, Room TW-A325, Washington, DC 20554. All hand deliveries must be held together with rubber bands or fasteners. Any envelopes must be disposed of before entering the building. Commercial overnight mail (other than U.S. Postal Service Express Mail and Priority Mail) must be sent to 9300 East Hampton Drive, Capitol Heights, MD 20743. U.S. Postal Service first-class, Express, and Priority mail must be addressed to 445 12th Street, S.W., Washington DC 20554.

71. People with Disabilities: To request materials in accessible formats for people with disabilities (Braille, large print, electronic files, audio format), send an e-mail to fcc504@fcc.gov or call the Consumer & Governmental Affairs Bureau at 202-418-0530 (voice), 202-418-0432 (tty).

72. Parties should send a copy of their filings to Charles Tyler, Telecommunications Access Policy Division, Wireline Competition Bureau, Federal Communications Commission, Room 5-A452, 445 12th Street, S.W., Washington, D.C. 20554, or by e-mail to charles.tyler@fcc.gov. Parties shall also serve one copy with the Commission's copy contractor, Best Copy and Printing, Inc. (BCPI), Portals II, 445 12th Street, S.W., Room CY-B402, Washington, D.C. 20554, (202) 488-5300, or via e-mail to fcc@bcpiweb.com.

73. Documents in this proceeding will be available for public inspection and copying during business hours at the FCC Reference Information Center, Portals II, 445 12th Street S.W., Room CY-A257, Washington, D.C. 20554. The documents may also be purchased from BCPI, telephone (202) 488-5300, facsimile (202) 488-5563, TTY (202) 488-5562, e-mail fcc@bcpiweb.com.

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[142] 47 C.F.R. § 1.1206(b)(2).

[143] 47 C.F.R. § 1.1206(b).

[144] 47 C.F.R. §§ 1.415, 1.419.

[145] *See Electronic Filing of Documents in Rulemaking Proceedings*, GC Docket No. 97-113, Report and Order, 13 FCC Rcd 11322 (1998).

V. ORDERING CLAUSES

74. Accordingly, IT IS ORDERED that, pursuant to the authority contained in sections 1, 2, 4(i), 201-205, 214, 254, and 403 of the Communications Act of 1934, as amended, 47 U.S.C. §§ 151, 152, 154(i), 201-205, 214, 254, and 403 this notice of inquiry IS ADOPTED.

75. IT IS FURTHER ORDERED that, pursuant to the authority contained in sections 1, 2, 4(i), 201-205, 214, 254, and 403 of the Communications Act of 1934, as amended, 47 U.S.C. §§ 151, 152, 154(i), 201-205, 214, 254, and 403, and section 1.411 of the Commission's rules, 47 C.F.R. § 1.411, this notice of proposed rulemaking IS ADOPTED.

76. IT IS FURTHER ORDERED that the Commission's Consumer and Governmental Affairs Bureau, Reference Information Center, SHALL SEND a copy of this notice of proposed rulemaking, including the Initial Regulatory Flexibility Analysis, to the Chief Counsel for Advocacy of the Small Business Administration.

77. IT IS FURTHER ORDERED, pursuant to sections 1.4(b)(1) and 1.103(a) of the Commission's rules, 47 C.F.R. §§ 1.4(b)(1), 1.103(a), that this notice of notice of proposed rulemaking SHALL BE EFFECTIVE on the date of publication in the Federal Register.

FEDERAL COMMUNICATIONS COMMISSION

Marlene H. Dortch
Secretary

APPENDIX A

Initial Regulatory Flexibility Analysis

1. As required by the Regulatory Flexibility Act ("RFA"),[1] the Commission prepared this Initial Regulatory Flexibility Analysis ("IRFA") of the possible significant economic impact on small entities by the policies and rules proposed in this Notice of Proposed Rulemaking (NPRM). The Commission requests written public comments on this IRFA. Comments must be identified as responses to the IRFA and must be filed on or before the dates indicated on the first page of this NPRM. The Commission will send a copy of the NPRM, including this IRFA, to the Chief Counsel for Advocacy of the Small Business Administration (SBA).[2] In addition, the NPRM and IRFA (or summaries thereof) will be published in the Federal Register.[3]

I. Need for, and Objectives of, the Notice:

2. On March 16, 2010, the Commission released a Joint Statement on Broadband stating that "[t]he nearly $9 billion Universal Service Fund (USF) and the intercarrier compensation (ICC) system should be comprehensively reformed to increase accountability and efficiency, encourage targeted investment in broadband infrastructure, and emphasize the importance of broadband to the future of these programs."[4] On the same day, the Commission delivered to Congress a National Broadband Plan recommending that the Commission adopt cost-cutting measures for existing voice support and create a Connect America Fund (CAF), without increasing the overall size of the Fund, to support the provision of broadband communications in areas that would be unserved without such support or that depend on universal service support for the maintenance of existing broadband service.[5]

3. The National Broadband Plan recommends that the Commission take steps to manage the universal service fund so that its total size remains close to its current level (in 2010 dollars) to minimize the burden of increasing universal service contributions on consumers.[6] The NPRM seeks comment on specific common-sense reforms to contain growth in the legacy high-cost support mechanisms and identify savings that can be shifted toward broadband. Specifically, the NPRM seeks comment on capping legacy high-cost support provided to incumbent telephone companies at 2010 levels;[7] shifting rate-of-return carriers to incentive regulation and converting interstate common line support to a frozen amount per line;[8] eliminating interstate access support;[9] and eliminating high-cost support for competitive eligible telecommunications carriers.[10]

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[1] 5 U.S.C. § 603. The RFA, 5 U.S.C. §§ 601-612, has been amended by the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA), Public Law No. 104-121, Title II, 110 Stat. 857 (1996).

[2] 5 U.S.C. § 603(a).

[3] *Id.*

[4] *Joint Statement on Broadband*, GN Docket No. 10-66, Joint Statement on Broadband, FCC 10-42 (rel. Mar.16, 2010) at 2.

[5] Federal Communications Commission, *Connecting America: The National Broadband Plan*, (rel. Mar. 16, 2010) (National Broadband Plan) at 144.

[6] *See id.* at 149.

[7] *See* NPRM, paras. 51-52.

[8] *See id.*, paras. 55-56.

[9] *See id.*, paras. 57-58.

[10] *See id.*, paras. 60-61.

II. Legal Basis:

4. This legal basis for any action that may be taken pursuant to the NPRM is contained in sections 1, 2, 4(i), 201-205, 214, 254, and 403 of the Communications Act of 1934, as amended, 47 U.S.C. §§ 151, 152, 154(i), 201-205, 214, 254, and 403, and section 1.411 of the Commission's rules, 47 C.F.R. § 1.411.

III. Description and Estimate of the Number of Small Entities to which the Rules Will Apply:

5. The RFA directs agencies to provide a description of, and where feasible, an estimate of the number of small entities that may be affected by the proposed rules and policies, if adopted.[11] The RFA generally defines the term "small entity" as having the same meaning as the terms "small business," "small organization," and "small governmental jurisdiction."[12] In addition, the term "small business" has the same meaning as the term "small business concern" under the Small Business Act.[13] A "small business concern" is one which: (1) is independently owned and operated; (2) is not dominant in its field of operation; and (3) satisfies any additional criteria established by the SBA.[14]

6. **Small Businesses**. Nationwide, there are a total of approximately 29.6 million small businesses, according to the SBA.[15]

7. **Small Organizations**. Nationwide, as of 2002, there are approximately 1.6 million small organizations.[16] A "small organization" is generally "any not-for-profit enterprise which is independently owned and operated and is not dominant in its field."[17]

8. **Small Governmental Jurisdictions**. The term "small governmental jurisdiction" is defined generally as "governments of cities, towns, townships, villages, school districts, or special districts, with a population of less than fifty thousand."[18] Census Bureau data for 2002 indicate that there were 87,525 local governmental jurisdictions in the United States.[19] We estimate that, of this total, 84,377 entities were "small governmental jurisdictions."[20] Thus, we estimate that most governmental jurisdictions are small.

9. We have included small incumbent local exchange carriers in this present RFA analysis. As noted above, a "small business" under the RFA is one that, inter alia, meets the pertinent small

[11] 5 U.S.C. § 603(b)(3).

[12] 5 U.S.C. § 601(6).

[13] 5 U.S.C. § 601(3) (incorporating by reference the definition of "small-business concern" in the Small Business Act, 15 U.S.C. § 632). Pursuant to 5 U.S.C. § 601(3), the statutory definition of a small business applies "unless an agency, after consultation with the Office of Advocacy of the Small Business Administration and after opportunity for public comment, establishes one or more definitions of such term which are appropriate to the activities of the agency and publishes such definition(s) in the Federal Register."

[14] 15 U.S.C. § 632.

[15] *See* SBA, Office of Advocacy, "Frequently Asked Questions," http://web.sba.gov/faqs (accessed Apr. 2010).

[16] Independent Sector, The New Nonprofit Almanac & Desk Reference (2002).

[17] 5 U.S.C. § 601(4).

[18] 5 U.S.C. § 601(5).

[19] U.S. Census Bureau, Statistical Abstract of the United States: 2006, Section 8, p. 272, Table 415.

[20] We assume that the villages, school districts, and special districts are small, and total 48,558. *See* U.S. Census Bureau, Statistical Abstract of the United States: 2006, section 8, p. 273, Table 417. For 2002, Census Bureau data indicate that the total number of county, municipal, and township governments nationwide was 38,967, of which 35,819 were small. *Id.*

business size standard (*e.g*., a telephone communications business having 1,500 or fewer employees), and "is not dominant in its field of operation."[21] The SBA's Office of Advocacy contends that, for RFA purposes, small incumbent local exchange carriers are not dominant in their field of operation because any such dominance is not "national" in scope.[22] We have therefore included small incumbent local exchange carriers in this RFA analysis, although we emphasize that this RFA action has no effect on Commission analyses and determinations in other, non-RFA contexts.

10. **Incumbent Local Exchange Carriers ("ILECs")**. Neither the Commission nor the SBA has developed a small business size standard specifically for incumbent local exchange services. The appropriate size standard under SBA rules is for the category Wired Telecommunications Carriers. Under that size standard, such a business is small if it has 1,500 or fewer employees.[23] According to Commission data,[24] 1,311 carriers have reported that they are engaged in the provision of incumbent local exchange services. Of these 1,311 carriers, an estimated 1,024 have 1,500 or fewer employees and 287 have more than 1,500 employees. Consequently, the Commission estimates that most providers of incumbent local exchange service are small businesses that may be affected by our proposed action.

11. **Competitive Local Exchange Carriers ("CLECs"), Competitive Access Providers ("CAPs"), "Shared-Tenant Service Providers," and "Other Local Service Providers."** Neither the Commission nor the SBA has developed a small business size standard specifically for these service providers. The appropriate size standard under SBA rules is for the category Wired Telecommunications Carriers. Under that size standard, such a business is small if it has 1,500 or fewer employees.[25] According to Commission data,[26] 1005 carriers have reported that they are engaged in the provision of either competitive access provider services or competitive local exchange carrier services. Of these 1005 carriers, an estimated 918 have 1,500 or fewer employees and 87 have more than 1,500 employees. In addition, 16 carriers have reported that they are "Shared-Tenant Service Providers," and all 16 are estimated to have 1,500 or fewer employees. In addition, 89 carriers have reported that they are "Other Local Service Providers." Of the 89, all have 1,500 or fewer employees. Consequently, the Commission estimates that most providers of competitive local exchange service, competitive access providers, "Shared-Tenant Service Providers," and "Other Local Service Providers" are small entities that may be affected by our proposed action.

12. **Local Resellers**. The SBA has developed a small business size standard for the category of Telecommunications Resellers. Under that size standard, such a business is small if it has 1,500 or fewer employees.[27] According to Commission data,[28] 151 carriers have reported that they are engaged in the provision of local resale services. Of these, an estimated 149 have 1,500 or fewer employees and

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[21] 15 U.S. C. § 632.

[22] Letter from Jere W. Glover, Chief Counsel for Advocacy, SBA, to William E. Kennard, Chairman, FCC (May 27, 1999). The Small Business Act contains a definition of "small-business concern," which the RFA incorporates into its own definition of "small business." *See* 15 U.S.C. § 632(a) ("Small Business Act"); 5 U.S.C. § 601(3) ("RFA"). SBA regulations interpret "small business concern" to include the concept of dominance on a national basis. *See* 13 C.F.R. § 121.102(b).

[23] 13 C.F.R. § 121.201, North American Industry Classification System (NAICS) code 517110.

[24] FCC, Wireline Competition Bureau, Industry Analysis and Technology Division, "*Trends in Telephone Service*" at Table 5.3, Page 5-5 (Aug. 2008) ("*Trends in Telephone Service*"). This source uses data that are current as of November 1, 2006.

[25] 13 C.F.R. § 121.201, NAICS code 517110.

[26] "Trends in Telephone Service" at Table 5.3.

[27] 13 C.F.R. § 121.201, NAICS code 517310.

[28] "Trends in Telephone Service" at Table 5.3.

two have more than 1,500 employees. Consequently, the Commission estimates that the majority of local resellers are small entities that may be affected by our proposed action.

13. **Toll Resellers**. The SBA has developed a small business size standard for the category of Telecommunications Resellers. Under that size standard, such a business is small if it has 1,500 or fewer employees.[29] According to Commission data,[30] 815 carriers have reported that they are engaged in the provision of toll resale services. Of these, an estimated 787 have 1,500 or fewer employees and 28 have more than 1,500 employees. Consequently, the Commission estimates that the majority of toll resellers are small entities that may be affected by our proposed action.

14. **Interexchange Carriers ("IXCs")**. Neither the Commission nor the SBA has developed a small business size standard specifically for providers of interexchange services. The appropriate size standard under SBA rules is for the category Wired Telecommunications Carriers. Under that size standard, such a business is small if it has 1,500 or fewer employees.[31] According to Commission data,[32] 300 carriers have reported that they are engaged in the provision of interexchange service. Of these, an estimated 268 have 1,500 or fewer employees and 32 have more than 1,500 employees. Consequently, the Commission estimates that the majority of IXCs are small entities that may be affected by our proposed action.

15. **Satellite Telecommunications and All Other Telecommunications**. These two economic census categories address the satellite industry. The first category has a small business size standard of $15 million or less in average annual receipts, under SBA rules.[33] The second has a size standard of $25 million or less in annual receipts.[34] The most current Census Bureau data in this context, however, are from the (last) economic census of 2002, and we will use those figures to gauge the prevalence of small businesses in these categories.[35]

16. The category of Satellite Telecommunications "comprises establishments primarily engaged in providing telecommunications services to other establishments in the telecommunications and broadcasting industries by forwarding and receiving communications signals via a system of satellites or reselling satellite telecommunications."[36] For this category, Census Bureau data for 2002 show that there were a total of 371 firms that operated for the entire year.[37] Of this total, 307 firms had annual receipts of under $10 million, and 26 firms had receipts of $10 million to $24,999,999.[38] Consequently, we estimate that the majority of Satellite Telecommunications firms are small entities that might be affected by our action.

17. The second category of All Other Telecommunications comprises, *inter alia*, "establishments primarily engaged in providing specialized telecommunications services, such as satellite tracking, communications telemetry, and radar station operation. This industry also includes

[29] 13 C.F.R. § 121.201, NAICS code 517310.

[30] "Trends in Telephone Service" at Table 5.3.

[31] 13 C.F.R. § 121.201, NAICS code 517110.

[32] "Trends in Telephone Service" at Table 5.3.

[33] 13 C.F.R. § 121.201, NAICS code 517410.

[34] 13 C.F.R. § 121.201, NAICS code 517919.

[35] 13 C.F.R. § 121.201, NAICS codes 517410 and 517910 (2002).

[36] U.S. Census Bureau, 2007 NAICS Definitions, "517410 Satellite Telecommunications"; http://www.census.gov/naics/2007/def/ND517410.HTM.

[37] U.S. Census Bureau, 2002 Economic Census, Subject Series: Information, "Establishment and Firm Size (Including Legal Form of Organization)," Table 4, NAICS code 517410 (issued Nov. 2005).

[38] *Id.* An additional 38 firms had annual receipts of $25 million or more.

establishments primarily engaged in providing satellite terminal stations and associated facilities connected with one or more terrestrial systems and capable of transmitting telecommunications to, and receiving telecommunications from, satellite systems."[39] For this category, Census Bureau data for 2002 show that there were a total of 332 firms that operated for the entire year.[40] Of this total, 303 firms had annual receipts of under $10 million and 15 firms had annual receipts of $10 million to $24,999,999.[41] Consequently, we estimate that the majority of All Other Telecommunications firms are small entities that might be affected by our action.

18. **Wireless Telecommunications Carriers (except Satellite)**. Since 2007, the Census Bureau has placed wireless firms within this new, broad, economic census category.[42] Prior to that time, such firms were within the now-superseded categories of "Paging" and "Cellular and Other Wireless Telecommunications."[43] Under the present and prior categories, the SBA has deemed a wireless business to be small if it has 1,500 or fewer employees.[44] Because Census Bureau data are not yet available for the new category, we will estimate small business prevalence using the prior categories and associated data. For the category of Paging, data for 2002 show that there were 807 firms that operated for the entire year.[45] Of this total, 804 firms had employment of 999 or fewer employees, and three firms had employment of 1,000 employees or more.[46] For the category of Cellular and Other Wireless Telecommunications, data for 2002 show that there were 1,397 firms that operated for the entire year.[47] Of this total, 1,378 firms had employment of 999 or fewer employees, and 19 firms had employment of 1,000 employees or more.[48] Thus, we estimate that the majority of wireless firms are small.

19. **2.3 GHz Wireless Communications Services**. This service can be used for fixed, mobile, radiolocation, and digital audio broadcasting satellite uses. The Commission defined "small business" for the wireless communications services ("WCS") auction as an entity with average gross revenues of $40 million for each of the three preceding years, and a "very small business" as an entity with average gross revenues of $15 million for each of the three preceding years.[49] The SBA has

[39] U.S. Census Bureau, 2007 NAICS Definitions, "517919 All Other Telecommunications"; http://www.census.gov/naics/2007/def/ND517919.HTM#N517919.

[40] U.S. Census Bureau, 2002 Economic Census, Subject Series: Information, "Establishment and Firm Size (Including Legal Form of Organization)," Table 4, NAICS code 517910 (issued Nov. 2005).

[41] *Id.* An additional 14 firms had annual receipts of $25 million or more.

[42] U.S. Census Bureau, 2007 NAICS Definitions, "517210 Wireless Telecommunications Categories (Except Satellite)"; http://www.census.gov/naics/2007/def/ND517210.HTM#N517210.

[43] U.S. Census Bureau, 2002 NAICS Definitions, "517211 Paging"; http://www.census.gov/epcd/naics02/def/NDEF517.HTM.; U.S. Census Bureau, 2002 NAICS Definitions, "517212 Cellular and Other Wireless Telecommunications"; http://www.census.gov/epcd/naics02/def/NDEF517.HTM.

[44] 13 C.F.R. § 121.201, NAICS code 517210 (2007 NAICS). The now-superseded, pre-2007 C.F.R. citations were 13 C.F.R. § 121.201, NAICS codes 517211 and 517212 (referring to the 2002 NAICS).

[45] U.S. Census Bureau, 2002 Economic Census, Subject Series: Information, "Establishment and Firm Size (Including Legal Form of Organization," Table 5, NAICS code 517211 (issued Nov. 2005).

[46] *Id.* The census data do not provide a more precise estimate of the number of firms that have employment of 1,500 or fewer employees; the largest category provided is for firms with "1000 employees or more."

[47] U.S. Census Bureau, 2002 Economic Census, Subject Series: Information, "Establishment and Firm Size (Including Legal Form of Organization," Table 5, NAICS code 517212 (issued Nov. 2005).

[48] *Id.* The census data do not provide a more precise estimate of the number of firms that have employment of 1,500 or fewer employees; the largest category provided is for firms with "1000 employees or more."

[49] *Amendment of the Commission's Rules to Establish Part 27, the Wireless Communications Service (WCS)*, Report and Order, 12 FCC Rcd 10785, 10879, para. 194 (1997).

approved these definitions.[50] The Commission auctioned geographic area licenses in the WCS service. In the auction, which was conducted in 1997, there were seven bidders that won 31 licenses that qualified as very small business entities, and one bidder that won one license that qualified as a small business entity.

20. **1670-1675 MHz Services**. An auction for one license in the 1670-1675 MHz band was conducted in 2003. One license was awarded. The winning bidder was not a small entity.

21. **Wireless Telephony**. Wireless telephony includes cellular, personal communications services, and specialized mobile radio telephony carriers. As noted, the SBA has developed a small business size standard for Wireless Telecommunications Carriers (except Satellite).[51] Under the SBA small business size standard, a business is small if it has 1,500 or fewer employees.[52] According to *Trends in Telephone Service* data, 434 carriers reported that they were engaged in wireless telephony.[53] Of these, an estimated 222 have 1,500 or fewer employees and 212 have more than 1,500 employees.[54] We have estimated that 222 of these are small under the SBA small business size standard.

22. **Broadband Personal Communications Service**. The broadband personal communications services ("PCS") spectrum is divided into six frequency blocks designated A through F, and the Commission has held auctions for each block. The Commission has created a small business size standard for Blocks C and F as an entity that has average gross revenues of less than $40 million in the three previous calendar years.[55] For Block F, an additional small business size standard for "very small business" was added and is defined as an entity that, together with its affiliates, has average gross revenues of not more than $15 million for the preceding three calendar years.[56] These small business size standards, in the context of broadband PCS auctions, have been approved by the SBA.[57] No small businesses within the SBA-approved small business size standards bid successfully for licenses in Blocks A and B. There were 90 winning bidders that qualified as small entities in the Block C auctions. A total of 93 "small" and "very small" business bidders won approximately 40 percent of the 1,479 licenses for Blocks D, E, and F.[58] In 1999, the Commission reauctioned 155 C, D, E, and F Block licenses; there were 113 small business winning bidders.[59]

23. In 2001, the Commission completed the auction of 422 C and F Broadband PCS licenses in Auction 35. Of the 35 winning bidders in this auction, 29 qualified as "small" or "very small" businesses.[60] Subsequent events, concerning Auction 35, including judicial and agency determinations, resulted in a total of 163 C and F Block licenses being available for grant. In 2005, the Commission completed an auction of 188 C block licenses and 21 F block licenses in Auction 58. There were 24

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[50] *See Alvarez Letter 1998*.

[51] 13 C.F.R. § 121.201, NAICS code 517210.

[52] *Id*.

[53] "Trends in Telephone Service" at Table 5.3.

[54] "Trends in Telephone Service" at Table 5.3.

[55] *See Amendment of Parts 20 and 24 of the Commission's Rules – Broadband PCS Competitive Bidding and the Commercial Mobile Radio Service Spectrum Cap*, Report and Order, 11 FCC Rcd 7824, 7850-7852, paras. 57-60 (1996) ("*PCS Report and Order*"); *see also* 47 C.F.R. § 24.720(b).

[56] *See PCS Report and Order*, 11 FCC Rcd at 7852, para. 60.

[57] *See Alvarez Letter 1998*.

[58] FCC News, "Broadband PCS, D, E and F Block Auction Closes," No. 71744 (rel. Jan. 14, 1997).

[59] *See* "C, D, E, and F Block Broadband PCS Auction Closes," *Public Notice*, 14 FCC Rcd 6688 (WTB 1999).

[60] *See* "C and F Block Broadband PCS Auction Closes; Winning Bidders Announced," *Public Notice*, 16 FCC Rcd 2339 (2001).

winning bidders for 217 licenses.[61] Of the 24 winning bidders, 16 claimed small business status and won 156 licenses. In 2007, the Commission completed an auction of 33 licenses in the A, C, and F Blocks in Auction 71.[62] Of the 14 winning bidders, six were designated entities.[63] In 2008, the Commission completed an auction of 20 Broadband PCS licenses in the C, D, E and F block licenses in Auction 78.[64]

24. **Advanced Wireless Services**. In 2008, the Commission conducted the auction of Advanced Wireless Services ("AWS") licenses.[65] This auction, which as designated as Auction 78, offered 35 licenses in the AWS 1710-1755 MHz and 2110-2155 MHz bands ("AWS-1"). The AWS-1 licenses were licenses for which there were no winning bids in Auction 66. That same year, the Commission completed Auction 78. A bidder with attributed average annual gross revenues that exceeded $15 million and did not exceed $40 million for the preceding three years ("small business") received a 15 percent discount on its winning bid. A bidder with attributed average annual gross revenues that did not exceed $15 million for the preceding three years ("very small business") received a 25 percent discount on its winning bid. A bidder that had combined total assets of less than $500 million and combined gross revenues of less than $125 million in each of the last two years qualified for entrepreneur status.[66] Four winning bidders that identified themselves as very small businesses won 17 licenses.[67] Three of the winning bidders that identified themselves as a small business won five licenses. Additionally, one other winning bidder that qualified for entrepreneur status won 2 licenses.

25. **700 MHz Band Licenses**. The Commission previously adopted criteria for defining three groups of small businesses for purposes of determining their eligibility for special provisions such as bidding credits.[68] The Commission defined a "small business" as an entity that, together with its affiliates and controlling principals, has average gross revenues not exceeding $40 million for the preceding three years.[69] A "very small business" is defined as an entity that, together with its affiliates and controlling principals, has average gross revenues that are not more than $15 million for the preceding three years.[70] Additionally, the lower 700 MHz Service had a third category of small business status for Metropolitan/Rural Service Area ("MSA/RSA") licenses. The third category is "entrepreneur," which is defined as an entity that, together with its affiliates and controlling principals, has average gross revenues that are not more than $3 million for the preceding three years.[71] The SBA

[61] *See* "Broadband PCS Spectrum Auction Closes; Winning Bidders Announced for Auction No. 58," *Public Notice,* 20 FCC Rcd 3703 (2005).

[62] *See* "Auction of Broadband PCS Spectrum Licenses Closes; Winning Bidders Announced for Auction No. 71," *Public Notice*, 22 FCC Rcd 9247 (2007).

[63] *Id*.

[64] *See* Auction of AWS-1 and Broadband PCS Licenses Rescheduled For August 13, 3008, Notice of Filing Requirements, Minimum Opening Bids, Upfront Payments and Other Procedures For Auction 78, *Public Notice*, 23 FCC Rcd 7496 (2008) ("AWS-1 and Broadband PCS Procedures Public Notice").

[65] *See* AWS-1 and Broadband PCS Procedures Public Notice, 23 FCC Rcd 7496. Auction 78 also included an auction of Broadband PCS licenses.

[66] *Id*. at 23 FCC Rcd at 7521-22.

[67] *See* "Auction of AWS-1 and Broadband PCS Licenses Closes, Winning Bidders Announced for Auction 78, Down Payments Due September 9, 2008, FCC Forms 601 and 602 Due September 9, 2008, Final Payments Due September 23, 2008, Ten-Day Petition to Deny Period", *Public Notice*, 23 FCC Rcd 12749-65 (2008).

[68] *See Reallocation and Service Rules for the 698-746 MHz Spectrum Band (Television Channels 52-59)*, Report and Order, 17 FCC Rcd 1022 (2002) ("*Channels 52-59 Report and Order*").

[69] *See Channels 52-59 Report and Order*, 17 FCC Rcd at 1087-88, ¶ 172.

[70] *See id*.

[71] *See id,* 17 FCC Rcd at 1088, ¶ 173.

approved these small size standards.[72] The Commission conducted an auction in 2002 of 740 licenses (one license in each of the 734 MSAs/RSAs and one license in each of the six Economic Area Groupings (EAGs)). Of the 740 licenses available for auction, 484 licenses were sold to 102 winning bidders. Seventy-two of the winning bidders claimed small business, very small business or entrepreneur status and won a total of 329 licenses. [73] The Commission conducted a second auction in 2003 that included 256 licenses: 5 EAG licenses and 476 Cellular Market Area licenses.[74] Seventeen winning bidders claimed small or very small business status and won 60 licenses, and nine winning bidders claimed entrepreneur status and won 154 licenses.[75] In 2005, the Commission completed an auction of 5 licenses in the lower 700 MHz band (Auction 60). There were three winning bidders for five licenses. All three winning bidders claimed small business status.

26. In 2007, the Commission adopted the *700 MHz Second Report and Order*.[76] The *Order* revised the band plan for the commercial (including Guard Band) and public safety spectrum, adopted services rules, including stringent build-out requirements, an open platform requirement on the C Block, and a requirement on the D Block licensee to construct and operate a nationwide, interoperable wireless broadband network for public safety users. In 2008, the Commission commenced Auction 73 which offered all available, commercial 700 MHz Band licenses (1,099 licenses) for bidding using the Commission's standard simultaneous multiple-round ("SMR") auction format for the A, B, D, and E block licenses and an SMR auction design with hierarchical package bidding ("HPB") for the C Block licenses. Later in 2008, the Commission concluded Auction 73.[77] A bidder with attributed average annual gross revenues that did not exceed $15 million for the preceding three years (very small business) qualified for a 25 percent discount on its winning bids. A bidder with attributed average annual gross revenues that exceeded $15 million, but did not exceed $40 million for the preceding three years, qualified for a 15 percent discount on its winning bids. There were 36 winning bidders (who won 330 of the 1,090 licenses won) that identified themselves as very small businesses. There were 20 winning bidders that identified themselves as a small business that won 49 of the 1,090 licenses won.[78] The provisionally winning bids for the A, B, C, and E Block licenses exceeded the aggregate reserve prices for those blocks. However, the provisionally winning bid for the D Block license did not meet the applicable reserve price and thus did not become a winning bid.[79]

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[72] *See* Letter from Aida Alvarez, Administrator, SBA, to Thomas Sugrue, Chief, WTB, FCC (Aug. 10, 1999) ("*Alvarez Letter 1999*").

[73] *See* "Lower 700 MHz Band Auction Closes," *Public Notice*, 17 FCC Rcd 17272 (WTB 2002).

[74] *See* "Lower 700 MHz Band Auction Closes," *Public Notice*, 18 FCC Rcd 11873 (WTB 2003).

[75] *See id.*

[76] Service Rules for the 698-746, 747-762 and 777-792 MHz Band, WT Docket No. 06-150, *Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems,* CC Docket No. 94-102, *Section 68.4(a) of the Commission's Rules Governing Hearing Aid-Compatible Telephone,* WT Docket No. 01-309, *Biennial Regulatory Review – Amendment of Parts 1, 22, 24, 27, and 90 to Streamline and Harmonize Various Rules Affecting Wireless Radio Services,* WT Docket No. 03-264, *Former Nextel Communications, Inc. Upper700 MHz Guard Band Licenses and Revisions to Part 27 of the Commission's Rules,* WT Docket No. 06-169, *Implementing a Nationwide, Broadband Interoperable Public Safety Network in the 700 MHz Band,* PS Docket No. 06-229, *Development of Operational, Technical and Spectrum Requirements for Meeting Federal, State, and Local Public Safety Communications Requirements Through the Year 2010,* WT Docket No. 96-86, Second Report and Order, FCC 07-132 (2007) ("700 MHz Second Report and Order"), 22 FCC Rcd 15289 (2007).

[77] Auction of 700 MHz Band Licenses Closes, Winning Bidders Announced for Auction 73, Down Payments Due April 3, 2008, FCC Forms 601 and 602 April 3, 2008, Final Payment Due April 17, 2008, Ten-Day Petition to Deny Period, *Public Notice*, 23 FCC Rcd 4572 (2008).

[78] *Id*. 23 FCC Rcd at 4572-73.

[79] *Id.*

27. **700 MHz Guard Band Licenses**. In the 700 MHz Guard Band Order, the Commission adopted size standards for "small businesses" and "very small businesses" for purposes of determining their eligibility for special provisions such as bidding credits and installment payments.[80] A small business in this service is an entity that, together with its affiliates and controlling principals, has average gross revenues not exceeding $40 million for the preceding three years.[81] Additionally, a very small business is an entity that, together with its affiliates and controlling principals, has average gross revenues that are not more than $15 million for the preceding three years.[82] SBA approval of these definitions is not required.[83] In 2000, the Commission conducted an auction of 52 Major Economic Area ("MEA") licenses.[84] Of the 104 licenses auctioned, 96 licenses were sold to nine bidders. Five of these bidders were small businesses that won a total of 26 licenses. A second auction of 700 MHz Guard Band licenses commenced and closed in 2001. All eight of the licenses auctioned were sold to three bidders. One of these bidders was a small business that won a total of two licenses.[85]

28. **Specialized Mobile Radio**. The Commission awards "small entity" bidding credits in auctions for Specialized Mobile Radio (SMR) geographic area licenses in the 800 MHz and 900 MHz bands to firms that had revenues of no more than $15 million in each of the three previous calendar years.[86] The Commission awards "very small entity" bidding credits to firms that had revenues of no more than $3 million in each of the three previous calendar years.[87] The SBA has approved these small business size standards for the 900 MHz Service.[88] The Commission has held auctions for geographic area licenses in the 800 MHz and 900 MHz bands. The 900 MHz SMR auction was completed in 1996. Sixty bidders claiming that they qualified as small businesses under the $15 million size standard won 263 geographic area licenses in the 900 MHz SMR band. The 800 MHz SMR auction for the upper 200 channels was conducted in 1997. Ten bidders claiming that they qualified as small businesses under the $15 million size standard won 38 geographic area licenses for the upper 200 channels in the 800 MHz SMR band.[89] A second auction for the 800 MHz band was conducted in 2002 and included 23 BEA licenses. One bidder claiming small business status won five licenses.[90]

29. The auction of the 1,053 800 MHz SMR geographic area licenses for the General Category channels was conducted in 2000. Eleven bidders won 108 geographic area licenses for the General Category channels in the 800 MHz SMR band qualified as small businesses under the $15

[80] *See Service Rules for the 746-764 MHz Bands, and Revisions to Part 27 of the Commission's Rules*, Second Report and Order, 15 FCC Rcd 5299 (2000) ("*746-764 MHz Band Second Report and Order*").

[81] *See 746-764 MHz Band Second Report and Order*, 15 FCC Rcd at 5343, para. 108.

[82] *See id.*

[83] *See id.*, 15 FCC Rcd 5299, 5343, para. 108 n.246 (for the 746-764 MHz and 776-794 MHz bands, the Commission is exempt from 15 U.S.C. § 632, which requires Federal agencies to obtain SBA approval before adopting small business size standards).

[84] *See* "700 MHz Guard Bands Auction Closes: Winning Bidders Announced," *Public Notice*, 15 FCC Rcd 18026 (2000).

[85] *See* "700 MHz Guard Bands Auction Closes: Winning Bidders Announced," *Public Notice*, 16 FCC Rcd 4590 (WTB 2001).

[86] 47 C.F.R. § 90.814(b)(1).

[87] 47 C.F.R. § 90.814(b)(1).

[88] *See Alvarez Letter 1999*.

[89] *See* "Correction to Public Notice DA 96-586 'FCC Announces Winning Bidders in the Auction of 1020 Licenses to Provide 900 MHz SMR in Major Trading Areas,'" *Public Notice*, 18 FCC Rcd 18367 (WTB 1996).

[90] *See* "Multi-Radio Service Auction Closes," *Public Notice*, 17 FCC Rcd 1446 (WTB 2002).

[91] In an auction completed in 2000, a total of 2,800 Economic Area licenses in the lower 80 channels of the 800 MHz SMR service were awarded.[92] Of the 22 winning bidders, 19 claimed small business status and won 129 licenses. Thus, combining all three auctions, 40 winning bidders for geographic licenses in the 800 MHz SMR band claimed status as small business.

30. In addition, there are numerous incumbent site-by-site SMR licensees and licensees with extended implementation authorizations in the 800 and 900 MHz bands. We do not know how many firms provide 800 MHz or 900 MHz geographic area SMR pursuant to extended implementation authorizations, nor how many of these providers have annual revenues of no more than $15 million. One firm has over $15 million in revenues. In addition, we do not know how many of these firms have 1500 or fewer employees.[93] We assume, for purposes of this analysis, that all of the remaining existing extended implementation authorizations are held by small entities, as that small business size standard is approved by the SBA.

31. **Cellular Radiotelephone Service**. Auction 77 was held to resolve one group of mutually exclusive applications for Cellular Radiotelephone Service licenses for unserved areas in New Mexico.[94] Bidding credits for designated entities were not available in Auction 77.[95] In 2008, the Commission completed the closed auction of one unserved service area in the Cellular Radiotelephone Service, designated as Auction 77. Auction 77 concluded with one provisionally winning bid for the unserved area totaling $25,002.[96]

32. **Private Land Mobile Radio ("PLMR")**. PLMR systems serve an essential role in a range of industrial, business, land transportation, and public safety activities. These radios are used by companies of all sizes operating in all U.S. business categories, and are often used in support of the licensee's primary (non-telecommunications) business operations. For the purpose of determining whether a licensee of a PLMR system is a small business as defined by the SBA, we use the broad census category, Wireless Telecommunications Carriers (except Satellite). This definition provides that a small entity is any such entity employing no more than 1,500 persons.[97] The Commission does not require PLMR licensees to disclose information about number of employees, so the Commission does not have information that could be used to determine how many PLMR licensees constitute small entities under this definition. We note that PLMR licensees generally use the licensed facilities in support of other business activities, and therefore, it would also be helpful to assess PLMR licensees under the standards applied to the particular industry subsector to which the licensee belongs.[98]

33. As of March 2010, there were 424,162 PLMR licensees operating 921,909 transmitters in the PLMR bands below 512 MHz. We note that any entity engaged in a commercial activity is eligible

[91] *See* "800 MHz Specialized Mobile Radio (SMR) Service General Category (851-854 MHz) and Upper Band (861-865 MHz) Auction Closes; Winning Bidders Announced," *Public Notice*, 15 FCC Rcd 17162 (2000).

[92] *See*, "800 MHz SMR Service Lower 80 Channels Auction Closes; Winning Bidders Announced," *Public Notice*, 16 FCC Rcd 1736 (2000).

[93] *See generally* 13 C.F.R. § 121.201, NAICS code 517210.

[94] *See* Closed Auction of Licenses for Cellular Unserved Service Area Scheduled for June 17, 2008, Notice and Filing Requirements, Minimum Opening Bids, Upfront Payments, and Other Procedures for Auction 77, *Public Notice*, 23 FCC Rcd 6670 (2008).

[95] *Id.* at 6685.

[96] *See* Auction of Cellular Unserved Service Area License Closes, Winning Bidder Announced for Auction 77, Down Payment due July 2, 2008, Final Payment due July 17, 2008, *Public Notice*, 23 FCC Rcd 9501 (2008).

[97] *See* 13 C.F.R. § 121.201, NAICS code 517210.

[98] *See generally* 13 C.F.R. § 121.201.

to hold a PLMR license, and that any revised rules in this context could therefore potentially impact small entities covering a great variety of industries.

34. **Fixed Microwave Services**. Fixed microwave services include common carrier,[99] private operational-fixed,[100] and broadcast auxiliary radio services.[101] At present, there are approximately 22,015 common carrier fixed licensees and 61,670 private operational-fixed licensees and broadcast auxiliary radio licensees in the microwave services. The Commission has not created a size standard for a small business specifically with respect to fixed microwave services. For purposes of this analysis, the Commission uses the SBA small business size standard for the category Wireless Telecommunications Carriers (except Satellite), which is 1,500 or fewer employees.[102] The Commission does not have data specifying the number of these licensees that have no more than 1,500 employees, and thus are unable at this time to estimate with greater precision the number of fixed microwave service licensees that would qualify as small business concerns under the SBA's small business size standard. Consequently, the Commission estimates that there are 22,015 or fewer common carrier fixed licensees and 61,670 or fewer private operational-fixed licensees and broadcast auxiliary radio licensees in the microwave services that may be small and may be affected by the rules and policies proposed herein. We note, however, that the common carrier microwave fixed licensee category includes some large entities.

35. **39 GHz Service**. The Commission created a special small business size standard for 39 GHz licenses – an entity that has average gross revenues of $40 million or less in the three previous calendar years.[103] An additional size standard for "very small business" is: an entity that, together with affiliates, has average gross revenues of not more than $15 million for the preceding three calendar years.[104] The SBA has approved these small business size standards.[105] The auction of the 2,173, 39 GHz licenses, began and closed in 2000. The 18 bidders who claimed small business status won 849 licenses.

36. **Local Multipoint Distribution Service**. Local Multipoint Distribution Service ("LMDS") is a fixed broadband point-to-multipoint microwave service that provides for two-way video telecommunications.[106] The auction of the 986 LMDS licenses began and closed in 1998. The

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[99] *See* 47 C.F.R. §§ 101 *et seq*. for common carrier fixed microwave services (except Multipoint Distribution Service).

[100] Persons eligible under parts 80 and 90 of the Commission's Rules can use Private Operational-Fixed Microwave services. *See* 47 C.F.R. Parts 80 and 90. Stations in this service are called operational-fixed to distinguish them from common carrier and public fixed stations. Only the licensee may use the operational-fixed station, and only for communications related to the licensee's commercial, industrial, or safety operations.

[101] Auxiliary Microwave Service is governed by Part 74 of Title 47 of the Commission's Rules. *See* 47 C.F.R. Part 74. This service is available to licensees of broadcast stations and to broadcast and cable network entities. Broadcast auxiliary microwave stations are used for relaying broadcast television signals from the studio to the transmitter, or between two points such as a main studio and an auxiliary studio. The service also includes mobile television pickups, which relay signals from a remote location back to the studio.

[102] 13 C.F.R. § 121.201, NAICS code 517210.

[103] *See Amendment of the Commission's Rules Regarding the 37.0-38.6 GHz and 38.6-40.0 GHz Bands*, ET Docket No. 95-183, Report and Order, 12 FCC Rcd 18600 (1997).

[104] *Id.*

[105] *See* Letter from Aida Alvarez, Administrator, SBA, to Kathleen O'Brien Ham, Chief, Auctions and Industry Analysis Division, WTB, FCC (Feb. 4, 1998); *see* Letter from Hector Barreto, Administrator, SBA, to Margaret Wiener, Chief, Auctions and Industry Analysis Division, WTB, FCC (Jan. 18, 2002).

[106] *See Rulemaking to Amend Parts 1, 2, 21, 25, of the Commission's Rules to Redesignate the 27.5-29.5 GHz Frequency Band, Reallocate the 29.5-30.5 Frequency Band, to Establish Rules and Policies for Local Multipoint Distribution Service and for Fixed Satellite Services*, Second Report and Order, Order on Reconsideration, and Fifth (continued….)

Commission established a small business size standard for LMDS licenses as an entity that has average gross revenues of less than $40 million in the three previous calendar years.[107] An additional small business size standard for "very small business" was added as an entity that, together with its affiliates, has average gross revenues of not more than $15 million for the preceding three calendar years.[108] The SBA has approved these small business size standards in the context of LMDS auctions.[109] There were 93 winning bidders that qualified as small entities in the LMDS auctions. A total of 93 small and very small business bidders won approximately 277 A Block licenses and 387 B Block licenses. In 1999, the Commission re-auctioned 161 licenses; there were 32 small and very small businesses winning that won 119 licenses.

37. **Rural Radiotelephone Service**. The Commission has not adopted a size standard for small businesses specific to the Rural Radiotelephone Service.[110] A significant subset of the Rural Radiotelephone Service is the Basic Exchange Telephone Radio System ("BETRS").[111] In the present context, we will use the SBA's small business size standard applicable to Wireless Telecommunications Carriers (except Satellite), *i.e.*, an entity employing no more than 1,500 persons.[112] There are approximately 1,000 licensees in the Rural Radiotelephone Service, and the Commission estimates that there are 1,000 or fewer small entity licensees in the Rural Radiotelephone Service that may be affected by the rules and policies proposed herein.

38. **1.4 GHz Band Licensees**. The Commission conducted an auction of 64 1.4 GHz band licenses [113] in 2007.[114] In that auction, the Commission defined "small business" as an entity that, together with its affiliates and controlling interests, had average gross revenues that exceed $15 million but do not exceed $40 million for the preceding three years, and a "very small business" as an entity that, together with its affiliates and controlling interests, has had average annual gross revenues not exceeding $15 million for the preceding three years.[115] Neither of the two winning bidders sought designated entity status.[116]

39. **Incumbent 24 GHz Licensees**. This analysis may affect incumbent licensees who were relocated to the 24 GHz band from the 18 GHz band, and applicants who wish to provide services in the 24 GHz band. The applicable SBA small business size standard is that of Wireless Telecommunications Carriers (except Satellite). This category provides that such a company is small if it employs no more than 1,500 persons.[117] The broader census data notwithstanding, we believe that there are only two licensees in the 24 GHz band that were relocated from the 18 GHz band, Teligent[118] and TRW, Inc. It is

(Continued from previous page)
Notice of Proposed Rule Making, 12 FCC Rcd 12545, 12689-90, ¶ 348 (1997) ("*LMDS Second Report and Order*").

107 *See LMDS Second Report and Order*, 12 FCC Rcd at 12689-90, ¶ 348.

108 *See id.*

109 *See Alvarez to Phythyon Letter 1998*.

110 The service is defined in § 22.99 of the Commission's Rules, 47 C.F.R. § 22.99.

111 BETRS is defined in §§ 22.757 and 22.759 of the Commission's Rules, 47 C.F.R. §§ 22.757 and 22.759.

112 13 C.F.R. § 121.201, NAICS code 517210.

113 *See* "*Auction of 1.4 GHz Bands Licenses Scheduled for February 7, 2007*," Public Notice, 21 FCC Rcd 12393 (WTB 2006).

114 *See* "*Auction of 1.4 GHz Band Licenses Closes; Winning Bidders Announced for Auction No. 69*," Public Notice, 22 FCC Rcd 4714 (2007) ("*Auction No. 69 Closing PN*").

115 *Auction No. 69 Closing PN*, Attachment C.

116 *See Auction No. 69 Closing PN*.

117 13 C.F.R. § 121.201, NAICS code 517210.

118 Teligent acquired the DEMS licenses of FirstMark, the only licensee other than TRW in the 24 GHz band whose (continued….)

our understanding that Teligent and its related companies have fewer than 1,500 employees, though this may change in the future. TRW is not a small entity. There are approximately 122 licensees in the Rural Radiotelephone Service, and the Commission estimates that there are 122 or fewer small entity licensees in the Rural Radiotelephone Service that may be affected by the rules and policies proposed herein.

40. **Future 24 GHz Licensees**. With respect to new applicants in the 24 GHz band, we have defined "small business" as an entity that, together with controlling interests and affiliates, has average annual gross revenues for the three preceding years not exceeding $15 million.[119] "Very small business" in the 24 GHz band is defined as an entity that, together with controlling interests and affiliates, has average gross revenues not exceeding $3 million for the preceding three years.[120] The SBA has approved these definitions.[121] The Commission will not know how many licensees will be small or very small businesses until the auction, if required, is held.

41. **Broadband Radio Service and Educational Broadband Service**. Broadband Radio Service systems, previously referred to as Multipoint Distribution Service ("MDS") and Multichannel Multipoint Distribution Service ("MMDS") systems, and "wireless cable," transmit video programming to subscribers and provide two-way high speed data operations using the microwave frequencies of the Broadband Radio Service ("BRS") and Educational Broadband Service ("EBS") (previously referred to as the Instructional Television Fixed Service ("ITFS")).[122] In connection with the 1996 BRS auction, the Commission established a small business size standard as an entity that had annual average gross revenues of no more than $40 million in the previous three calendar years.[123] The BRS auctions resulted in 67 successful bidders obtaining licensing opportunities for 493 Basic Trading Areas ("BTAs"). Of the 67 auction winners, 61 met the definition of a small business. BRS also includes licensees of stations authorized prior to the auction. At this time, we estimate that of the 61 small business BRS auction winners, 48 remain small business licensees. In addition to the 48 small businesses that hold BTA authorizations, there are approximately 392 incumbent BRS licensees that are considered small entities.[124] After adding the number of small business auction licensees to the number of incumbent licensees not already counted, we find that there are currently approximately 440 BRS licensees that are defined as small businesses under either the SBA or the Commission's rules. In 2009, the Commission conducted Auction 86, the sale of 78 licenses in the BRS areas.[125] The Commission offered three levels of bidding credits: (i) a bidder with attributed average annual gross revenues that exceed $15 million and

(Continued from previous page)
license has been modified to require relocation to the 24 GHz band.

[119] *Amendments to Parts 1, 2, 87 and 101 of the Commission's Rules To License Fixed Services at 24 GHz*, Report and Order, 15 FCC Rcd 16934, 16967, ¶ 77 (2000) ("*24 GHz Report and Order*"); *see also* 47 C.F.R. § 101.538(a)(2).

[120] *24 GHz Report and Order*, 15 FCC Rcd at 16967, para. 77; *see also* 47 C.F.R. § 101.538(a)(1).

[121] *See* Letter from Gary M. Jackson, Assistant Administrator, SBA, to Margaret W. Wiener, Deputy Chief, Auctions and Industry Analysis Division, WTB, FCC (July 28, 2000).

[122] *Amendment of Parts 21 and 74 of the Commission's Rules with Regard to Filing Procedures in the Multipoint Distribution Service and in the Instructional Television Fixed Service and Implementation of Section 309(j) of the Communications Act – Competitive Bidding*, MM Docket No. 94-131 and PP Docket No. 93-253, Report and Order, 10 FCC Rcd 9589, 9593, ¶ 7 (1995) ("*MDS Auction R&O*").

[123] 47 C.F.R. § 21.961(b)(1).

[124] 47 U.S.C. § 309(j). Hundreds of stations were licensed to incumbent MDS licensees prior to implementation of Section 309(j) of the Communications Act of 1934, 47 U.S.C. § 309(j). For these pre-auction licenses, the applicable standard is SBA's small business size standard.

[125] Auction of Broadband Radio Service (BRS) Licenses, Scheduled for October 27, 2009, Notice and Filing Requirements, Minimum Opening Bids, Upfront Payments, and Other Procedures for Auction 86, *Public Notice*, 24 FCC Rcd 8277 (2009).

do not exceed $40 million for the preceding three years (small business) will receive a 15 percent discount on its winning bid; (ii) a bidder with attributed average annual gross revenues that exceed $3 million and do not exceed $15 million for the preceding three years (very small business) will receive a 25 percent discount on its winning bid; and (iii) a bidder with attributed average annual gross revenues that do not exceed $3 million for the preceding three years (entrepreneur) will receive a 35 percent discount on its winning bid.[126] Auction 86 concluded in 2009 with the sale of 61 licenses.[127] Of the ten winning bidders, two bidders that claimed small business status won 4 licenses; one bidder that claimed very small business status won three licenses; and two bidders that claimed entrepreneur status won six licenses.

42. In addition, the SBA's Cable Television Distribution Services small business size standard is applicable to EBS. There are presently 2,032 EBS licensees. All but 100 of these licenses are held by educational institutions. Educational institutions are included in this analysis as small entities.[128] Thus, we estimate that at least 1,932 licensees are small businesses. Since 2007, Cable Television Distribution Services have been defined within the broad economic census category of Wired Telecommunications Carriers; that category is defined as follows: "This industry comprises establishments primarily engaged in operating and/or providing access to transmission facilities and infrastructure that they own and/or lease for the transmission of voice, data, text, sound, and video using wired telecommunications networks. Transmission facilities may be based on a single technology or a combination of technologies."[129] The SBA has developed a small business size standard for this category, which is: all such firms having 1,500 or fewer employees. To gauge small business prevalence for these cable services we must, however, use current census data that are based on the previous category of Cable and Other Program Distribution and its associated size standard; that size standard was: all such firms having $13.5 million or less in annual receipts.[130] According to Census Bureau data for 2002, there were a total of 1,191 firms in this previous category that operated for the entire year.[131] Of this total, 1,087 firms had annual receipts of under $10 million, and 43 firms had receipts of $10 million or more but less than $25 million.[132] Thus, the majority of these firms can be considered small.

43. **Cable Television Distribution Services**. Since 2007, these services have been defined within the broad economic census category of Wired Telecommunications Carriers; that category is defined as follows: "This industry comprises establishments primarily engaged in operating and/or providing access to transmission facilities and infrastructure that they own and/or lease for the transmission of voice, data, text, sound, and video using wired telecommunications networks.

[126] *Id.* at 8296.

[127] Auction of Broadband Radio Service Licenses Closes, Winning Bidders Announced for Auction 86, Down Payments Due November 23, 2009, Final Payments Due December 8, 2009, Ten-Day Petition to Deny Period, *Public Notice*, 24 FCC Rcd 13572 (2009).

[128] The term "small entity" within SBREFA applies to small organizations (nonprofits) and to small governmental jurisdictions (cities, counties, towns, townships, villages, school districts, and special districts with populations of less than 50,000). 5 U.S.C. §§ 601(4)-(6). We do not collect annual revenue data on EBS licensees.

[129] U.S. Census Bureau, 2007 NAICS Definitions, "517110 Wired Telecommunications Carriers" (partial definition); http://www.census.gov/naics/2007/def/ND517110.HTM#N517110.

[130] 13 C.F.R. § 121.201, NAICS code 517110.

[131] U.S. Census Bureau, 2002 Economic Census, Subject Series: Information, Table 4, Receipts Size of Firms for the United States: 2002, NAICS code 517510 (issued November 2005).

[132] *Id.* An additional 61 firms had annual receipts of $25 million or more.

Transmission facilities may be based on a single technology or a combination of technologies."[133] The SBA has developed a small business size standard for this category, which is: all such firms having 1,500 or fewer employees. To gauge small business prevalence for these cable services we must, however, use current census data that are based on the previous category of Cable and Other Program Distribution and its associated size standard; that size standard was: all such firms having $13.5 million or less in annual receipts.[134] According to Census Bureau data for 2002, there were a total of 1,191 firms in this previous category that operated for the entire year.[135] Of this total, 1,087 firms had annual receipts of under $10 million, and 43 firms had receipts of $10 million or more but less than $25 million.[136] Thus, the majority of these firms can be considered small.

44. **Cable Companies and Systems**. The Commission has also developed its own small business size standards, for the purpose of cable rate regulation. Under the Commission's rules, a "small cable company" is one serving 400,000 or fewer subscribers, nationwide.[137] Industry data indicate that, of 1,076 cable operators nationwide, all but eleven are small under this size standard.[138] In addition, under the Commission's rules, a "small system" is a cable system serving 15,000 or fewer subscribers.[139] Industry data indicate that, of 6,635 systems nationwide, 5,802 systems have under 10,000 subscribers, and an additional 302 systems have 10,000-19,999 subscribers.[140] Thus, under this second size standard, most cable systems are small.

45. **Cable System Operators**. The Communications Act of 1934, as amended, also contains a size standard for small cable system operators, which is "a cable operator that, directly or through an affiliate, serves in the aggregate fewer than 1 percent of all subscribers in the United States and is not affiliated with any entity or entities whose gross annual revenues in the aggregate exceed $250,000,000."[141] The Commission has determined that an operator serving fewer than 677,000 subscribers shall be deemed a small operator, if its annual revenues, when combined with the total annual revenues of all its affiliates, do not exceed $250 million in the aggregate.[142] Industry data indicate that, of 1,076 cable operators nationwide, all but ten are small under this size standard.[143] We

[133] U.S. Census Bureau, 2007 NAICS Definitions, "517110 Wired Telecommunications Carriers" (partial definition); http://www.census.gov/naics/2007/def/ND517110.HTM#N517110.

[134] 13 C.F.R. § 121.201, NAICS code 517110.

[135] U.S. Census Bureau, 2002 Economic Census, Subject Series: Information, Table 4, Receipts Size of Firms for the United States: 2002, NAICS code 517510 (issued November 2005).

[136] *Id*. An additional 61 firms had annual receipts of $25 million or more.

[137] 47 C.F.R. § 76.901(e). The Commission determined that this size standard equates approximately to a size standard of $100 million or less in annual revenues. *Implementation of Sections of the 1992 Cable Act: Rate Regulation,* Sixth Report and Order and Eleventh Order on Reconsideration, 10 FCC Rcd 7393, 7408 (1995).

[138] These data are derived from: R.R. Bowker, *Broadcasting & Cable Yearbook 2006*, "Top 25 Cable/Satellite Operators," pages A-8 & C-2 (data current as of June 30, 2005); Warren Communications News, *Television & Cable Factbook 2006*, "Ownership of Cable Systems in the United States," pages D-1805 to D-1857.

[139] 47 C.F.R. § 76.901(c).

[140] Warren Communications News, *Television & Cable Factbook 2008*, "U.S. Cable Systems by Subscriber Size," page F-2 (data current as of Oct. 2007). The data do not include 851 systems for which classifying data were not available.

[141] 47 U.S.C. § 543(m)(2); *see* 47 C.F.R. § 76.901(f) & nn. 1-3.

[142] 47 C.F.R. § 76.901(f); *see* Public Notice*, FCC Announces New Subscriber Count for the Definition of Small Cable Operator*, DA 01-158 (Cable Services Bureau, Jan. 24, 2001).

[143] These data are derived from: R.R. Bowker, *Broadcasting & Cable Yearbook 2006*, "Top 25 Cable/Satellite Operators," pages A-8 & C-2 (data current as of June 30, 2005); Warren Communications News, *Television & Cable Factbook 2006*, "Ownership of Cable Systems in the United States," pages D-1805 to D-1857.

note that the Commission neither requests nor collects information on whether cable system operators are affiliated with entities whose gross annual revenues exceed $250 million,[144] and therefore we are unable to estimate more accurately the number of cable system operators that would qualify as small under this size standard.

46. **Open Video Systems**. The open video system ("OVS") framework was established in 1996, and is one of four statutorily recognized options for the provision of video programming services by local exchange carriers.[145] The OVS framework provides opportunities for the distribution of video programming other than through cable systems. Because OVS operators provide subscription services,[146] OVS falls within the SBA small business size standard covering cable services, which is "Wired Telecommunications Carriers."[147] The SBA has developed a small business size standard for this category, which is: all such firms having 1,500 or fewer employees. To gauge small business prevalence for such services we must, however, use current census data that are based on the previous category of Cable and Other Program Distribution and its associated size standard; that size standard was: all such firms having $13.5 million or less in annual receipts.[148] According to Census Bureau data for 2002, there were a total of 1,191 firms in this previous category that operated for the entire year.[149] Of this total, 1,087 firms had annual receipts of under $10 million, and 43 firms had receipts of $10 million or more but less than $25 million.[150] Thus, the majority of cable firms can be considered small. In addition, we note that the Commission has certified some OVS operators, with some now providing service.[151] Broadband service providers ("BSPs") are currently the only significant holders of OVS certifications or local OVS franchises.[152] The Commission does not have financial or employment information regarding the entities authorized to provide OVS, some of which may not yet be operational. Thus, again, at least some of the OVS operators may qualify as small entities.

47. **Cable Television Relay Service**. This service includes transmitters generally used to relay cable programming within cable television system distribution systems. This cable service is defined within the broad economic census category of Wired Telecommunications Carriers; that category is defined as follows: "This industry comprises establishments primarily engaged in operating and/or providing access to transmission facilities and infrastructure that they own and/or lease for the transmission of voice, data, text, sound, and video using wired telecommunications networks. Transmission facilities may be based on a single technology or a combination of technologies."[153] The

[144] The Commission does receive such information on a case-by-case basis if a cable operator appeals a local franchise authority's finding that the operator does not qualify as a small cable operator pursuant to § 76.901(f) of the Commission's rules. *See* 47 C.F.R. § 76.909(b).

[145] 47 U.S.C. § 571(a)(3)-(4). *See Annual Assessment of the Status of Competition in the Market for the Delivery of Video Programming, Thirteenth Annual Report,* 24 FCC Rcd 542, 606 ¶ 135 (2009) ("*Thirteenth Annual Cable Competition Report*").

[146] *See* 47 U.S.C. § 573.

[147] U.S. Census Bureau, 2007 NAICS Definitions, "517110 Wired Telecommunications Carriers"; http://www.census.gov/naics/2007/def/ND517110.HTM#N517110.

[148] 13 C.F.R. § 121.201, NAICS code 517110.

[149] U.S. Census Bureau, 2002 Economic Census, Subject Series: Information, Table 4, Receipts Size of Firms for the United States: 2002, NAICS code 517510 (issued November 2005).

[150] *Id.* An additional 61 firms had annual receipts of $25 million or more.

[151] A list of OVS certifications may be found at http://www.fcc.gov/mb/ovs/csovscer.html.

[152] *See Thirteenth Annual Cable Competition Report*, 24 FCC Rcd at 606-07 ¶ 135. BSPs are newer firms that are building state-of-the-art, facilities-based networks to provide video, voice, and data services over a single network.

[153] U.S. Census Bureau, 2007 NAICS Definitions, "517110 Wired Telecommunications Carriers" (partial definition); http://www.census.gov/naics/2007/def/ND517110.HTM#N517110.

SBA has developed a small business size standard for this category, which is: all such firms having 1,500 or fewer employees. To gauge small business prevalence for cable services we must, however, use current census data that are based on the previous category of Cable and Other Program Distribution and its associated size standard; that size standard was: all such firms having $13.5 million or less in annual receipts.[154] According to Census Bureau data for 2002, there were a total of 1,191 firms in this previous category that operated for the entire year.[155] Of this total, 1,087 firms had annual receipts of under $10 million, and 43 firms had receipts of $10 million or more but less than $25 million.[156] Thus, the majority of these firms can be considered small.

48. **Multichannel Video Distribution and Data Service**. MVDDS is a terrestrial fixed microwave service operating in the 12.2-12.7 GHz band. The Commission adopted criteria for defining three groups of small businesses for purposes of determining their eligibility for special provisions such as bidding credits. It defined a very small business as an entity with average annual gross revenues not exceeding $3 million for the preceding three years; a small business as an entity with average annual gross revenues not exceeding $15 million for the preceding three years; and an entrepreneur as an entity with average annual gross revenues not exceeding $40 million for the preceding three years.[157] These definitions were approved by the SBA.[158] On January 27, 2004, the Commission completed an auction of 214 MVDDS licenses (Auction No. 53). In this auction, ten winning bidders won a total of 192 MVDDS licenses.[159] Eight of the ten winning bidders claimed small business status and won 144 of the licenses. The Commission also held an auction of MVDDS licenses on December 7, 2005 (Auction 63). Of the three winning bidders who won 22 licenses, two winning bidders, winning 21 of the licenses, claimed small business status.[160]

49. **Internet Service Providers**. The 2007 Economic Census places these firms, whose services might include voice over Internet protocol (VoIP), in either of two categories, depending on whether the service is provided over the provider's own telecommunications connections (*e.g.* cable and DSL, ISPs), or over client-supplied telecommunications connections (*e.g.* dial-up ISPs). The former are within the category of Wired Telecommunications Carriers,[161] which has an SBA small business size standard of 1,500 or fewer employees.[162] The latter are within the category of All Other

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[154] 13 C.F.R. § 121.201, NAICS code 517110.

[155] U.S. Census Bureau, 2002 Economic Census, Subject Series: Information, Table 4, Receipts Size of Firms for the United States: 2002, NAICS code 517510 (issued November 2005).

[156] *Id*. An additional 61 firms had annual receipts of $25 million or more.

[157] *Amendment of Parts 2 and 25 of the Commission's Rules to Permit Operation of NGSO FSS Systems Co-Frequency with GSO and Terrestrial Systems in the Ku-Band Frequency Range; Amendment of the Commission's Rules to Authorize Subsidiary Terrestrial Use of the 12.2-12.7 GHz Band by Direct Broadcast Satellite Licenses and their Affiliates; and Applications of Broadwave USA, PDC Broadband Corporation, and Satellite Receivers, Ltd. to provide A Fixed Service in the 12.2-12.7 GHz Band*, ET Docket No. 98-206, Memorandum Opinion and Order and Second Report and Order, 17 FCC Rcd 9614, 9711, ¶ 252 (2002).

[158] *See* Letter from Hector V. Barreto, Administrator, U.S. Small Business Administration, to Margaret W. Wiener, Chief, Auctions and Industry Analysis Division, WTB, FCC (Feb.13, 2002).

[159] *See* "*Multichannel Video Distribution and Data Service Auction Closes*," Public Notice, 19 FCC Rcd 1834 (2004).

[160] *See* "*Auction of Multichannel Video Distribution and Data Service Licenses Closes; Winning Bidders Announced for Auction No. 63*," Public Notice, 20 FCC Rcd 19807 (2005).

[161] U.S. Census Bureau, 2007 NAICS Definitions, "517110 Wired Telecommunications Carriers", http://www.census.gov/naics/2007/def/ND517110.HTM#N517110.

[162] 13 C.F.R. § 121.201, NAICS code 517110 (updated for inflation in 2008).

Telecommunications,[163] which has a size standard of annual receipts of $25 million or less.[164] The most current Census Bureau data for all such firms, however, are the 2002 data for the previous census category called Internet Service Providers.[165] That category had a small business size standard of $21 million or less in annual receipts, which was revised in late 2005 to $23 million. The 2002 data show that there were 2,529 such firms that operated for the entire year.[166] Of those, 2,437 firms had annual receipts of under $10 million, and an additional 47 firms had receipts of between $10 million and $24,999,999.[167] Consequently, we estimate that the majority of ISP firms are small entities.

50. The ISP industry has changed dramatically since 2002. The 2002 data cited above may therefore include entities that no longer provide Internet access service and may exclude entities that now provide such service. To ensure that this IRFA describes the universe of small entities that our action might affect, we discuss in turn several different types of entities that might be providing Internet access service.

51. We note that, although we have no specific information on the number of small entities that provide Internet access service over unlicensed spectrum, we include these entities in our IRFA.

IV. Description of Projected Reporting, Recordkeeping and Other Compliance Requirements:

52. As discussed above, the NPRM seeks comment on a number of specific reforms to contain the growth in the legacy high-cost support mechanisms and identify savings that can be shifted toward broadband.[168] Under the Commission's current rules, eligible telecommunications carriers (ETCs) file certain information with the Commission, the Universal Service Administrative Company (USAC), and/or the National Carrier Exchange Association (NECA) that is used to determine the amount of high-cost support each ETC receives. The proposals in the NPRM to cap or eliminate support, if eventually adopted, are not likely to substantially change the current reporting, recordkeeping, and compliance requirements, and would, in some cases, reduce such burdens. The proposal to shift rate-of-return carriers to incentive regulation likely would result in certain one-time reporting requirements related to the conversion, such as establishing initial price cap indexes for price cap baskets.[169] In addition, some ongoing reporting, recordkeeping and other compliance requirements may change after the conversion from rate-of-return regulation, but may result in less burdensome requirements, in some cases. We do not have an estimate of potential reporting, recordkeeping, and compliance burdens, because it is too speculative at this time to anticipate the number of carriers that would be required to convert to incentive regulation, or what type of incentive regulation would be required. We anticipate that commenters will provide the Commission with reliable information on any costs and burdens on small entities.

V. Steps Taken to Minimize Significant Economic Impact on Small Entities, and Significant Alternatives Considered:

[163] U.S. Census Bureau, 2007 NAICS Definitions, "517919 All Other Telecommunications"; http://www.census.gov/naics/2007/def/ND517919.HTM#N517919.

[164] 13 C.F.R. § 121.201, NAICS code 517919 (updated for inflation in 2008).

[165] U.S. Census Bureau, "2002 NAICS Definitions, "518111 Internet Service Providers"; http://www.census.gov/eped/naics02/def/NDEF518.HTM.

[166] U.S. Census Bureau, 2002 Economic Census, Subject Series: Information, "Establishment and Firm Size (Including Legal Form of Organization)," Table 4, NAICS code 518111 (issued Nov. 2005).

[167] An additional 45 firms had receipts of $25 million or more.

[168] *See supra* para. 3.

[169] *See* NPRM, para. 55 note 122.

53. The RFA requires an agency to describe any significant alternatives that it has considered in reaching its approach, which may include the following four alternatives, among others: (1) the establishment of differing compliance or reporting requirements or timetables that take into account the resources available to small entities; (2) the clarification, consolidation, or simplification of compliance or reporting requirements under the rule for small entities; (3) the use of performance, rather than design, standards; and (4) an exemption from coverage of the rule, or any part thereof, for small entities.[170]

54. As discussed above, the NPRM seeks comment the NPRM seeks comment on capping legacy high-cost support provided to incumbent telephone companies; shifting rate-of-return carriers to incentive regulation and converting interstate common line support to a frozen amount per line; eliminating interstate access support; and eliminating high-cost support for competitive eligible telecommunications carriers.[171] The NPRM seeks comment generally on the proposed universal service reforms and carriers' rates under the Commission's current pricing rules, and specifically seeks comment on whether there are special considerations resulting from the operation of the NECA pool that would unfairly advantage or disadvantage certain carriers.[172] The NPRM also seeks comment on the costs and benefits that would be realized by converting all rate-of-return carriers to price cap or other incentive regulation.[173] We anticipate that the record will reflect whether the overall benefits of such a requirement would outweigh the burdens on small entities, and if so, suggest alternative ways in which the Commission could lessen the overall burdens on small entities. We encourage small entity comment.

VI. Federal Rules that May Duplicate, Overlap, or Conflict with the Proposed Rules:

55. None.

[170] 5 U.S.C. § 603.

[171] *See supra*, para. 3.

[172] *See* NPRM, para. 54. The NECA pool is composed of rate-of-return carriers that generally are much smaller than the price cap carriers.

[173] *See* NPRM, para. 55.

APPENDIX B

Comments of 71 Economists

Comments of 71 Concerned Economists

Using Procurement Auctions to Allocate Broadband Stimulus Grants

Submitted to the National Telecommunications Information Agency (NTIA)

and Rural Utilities Service (RUS)

April 13, 2009

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Executive Summary

The signatories to this document are economists who have studied telecommunications, auctions, and competition policy.[1] While we may disagree about the stimulus package, we believe that it is important to implement mechanisms that make stimulus spending as efficient as possible. To that end, we have come together to encourage the National Telecommunications Information Agency (NTIA) and Rural Utilities Service (RUS) to adopt auction mechanisms to allocate broadband stimulus grants.

The broadband stimulus NOI asks which mechanisms NTIA and RUS should use to distribute grants and how those mechanisms address shortcomings in traditional grant and loan programs. In this note we explain why procurement auctions are more efficient and more consistent with the stimulus goals of allocating funds quickly than a traditional grant review process. We recommend that NTIA/RUS use procurement auctions to distribute at least part of the stimulus funds.

The American Recovery and Reinvestment Act (ARRA) requires NTIA/RUS to distribute $7.2 billion in broadband subsidies. The broadband component of the Act has dual, and not entirely consistent, objectives of providing immediate economic stimulus and improving broadband service. NTIA/RUS faces a formidable challenge in determining how to spend the money quickly and efficiently in ways that meet these goals. The traditional grant application process is long, complicated, and involves subjective and arbitrary decisions regarding which projects to fund. In other words, requesting and reviewing grant applications is not an effective way to implement the plan.

Procurement auctions, in contrast, provide a mechanism that can allocate grant money quickly, efficiently, and according to well-defined rules. As a result, procurement auctions offer NTIA/RUS the most promising method of maximizing broadband improvement while also creating some level of "temporary, timely, and targeted" stimulus. We therefore strongly recommend that NTIA/RUS adopt procurement auctions as its preferred method of distributing grants.

This memo has three parts. First, it explains why the traditional grant application process is unsuitable for this task and why procurement auctions are better suited. Second, it sketches out a procurement auction plan. This plan is intended to be a starting point from which auction design experts would proceed to build and implement a fully functional auction. Finally, we explain that even if policymakers are skeptical of procurement auctions, one could be implemented quickly as part of an initial tranche of stimulus funding in order to test its efficacy relative to traditional approaches. This approach would allow NTIA/RUS to quickly expand upon or modify the procurement auction program in subsequent funding rounds.

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[1] The analysis and opinions here in are the sole responsibility of the signatories to these comments. The signatories are not appearing on behalf of any other person or entity and have received no compensation for the production of these comments.

Table of Contents

I. Introduction

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The broadband stimulus NOI asks which mechanisms NTIA and RUS should use to distribute grants and how those mechanisms address shortcomings in traditional grant and loan programs.[3] In this note we explain why procurement auctions are more efficient and more consistent with the stimulus goals of allocating funds quickly than a traditional grant review process. We recommend that NTIA/RUS use procurement auctions to distribute at least part of the stimulus funds.[4]

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[3] Section 5a asks: "What mechanisms for distributing stimulus funds should be used by NTIA and USDA in addition to traditional grant and loan programs?" Section 5b asks: "How would these mechanisms address shortcomings, if any, in traditional grant or loan mechanisms in the context of the Recovery Act?" Because the legislation appears to forbid the of use demand-side vouchers for the vast majority of the stimulus money, we have focussed on supply-side mechanisms.

[4] The term "reverse auction" has been used in the context of universal service as a synonym for procurement auction.

auction. Finally, we explain that even if policymakers are skeptical of procurement auctions, one could be implemented quickly as part of an initial tranche of stimulus funding in order to test its efficacy relative to traditional approaches. This approach would allow NTIA/RUS to quickly expand upon or modify the procurement auction program in subsequent funding rounds.

II. Procurement Auctions are more Efficient than Traditional Grantmaking Approaches

A. Traditional Approaches for Distributing Grants are Cumbersome and Slow

Traditionally, subsidy programs require firms to submit lengthy applications and the government to pick the "best ones" after reviewing all the competing applications. This approach has at least three problems for the purpose of distributing the funds from the stimulus bill.

First, the traditional approach is inherently time-consuming. Firms must complete complex proposals that government officials must subsequently spend time reviewing. USDA's Rural Utility Service (RUS), whose awards include broadband support, noted in its 2007 Annual Report that in 2006 the average application took six months to process (and this was an improvement from previous years when the average processing time was nearly a year).[5] That estimate does not include time firms spent preparing those applications. Complex broadband grants have taken far longer—several years in some instances.[6] Such delays are inconsistent with the goals of speedy stimulus grants.

Second, the qualitative nature of the applications makes it difficult to compare one project to another. For example, it will be difficult to choose between, say, a fiber project in Texas and a wireless project in North Dakota. Reviewing and deciding between large numbers of grant applications will inevitably lead to inconsistent and seemingly arbitrary decisions. And, the unpredictability of decisions will make it harder for companies to determine and propose the most appropriate projects.

Third, it is difficult to design a grant application system to ensure that firms receive only the minimum subsidy necessary to achieve a goal. To determine the "correct" subsidy level the government could attempt to calculate the necessary subsidy using available information, but this effort would be time-intensive, costly, and inaccurate. Alternatively, it could rely on the applicant's own estimate, but applicants have little incentive to ask for the bare minimum required. Either approach will result in a suboptimal allocation of subsidy dollars.

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[5] USDA Rural Utility Service. 2007. *USDA Rural Development: Bringing Broadband to Rural America*. http://www.rurdev.usda.gov/rd/pubs/RDBroadbandRpt.pdf

[6] Open Range Communications disclosed that it had spent over three years and submitted over 30,000 pages of application materials before its RDUP loan was granted. See http://www.businesswire.com/news/google/20071022006575/en

Reviewing grant applications is not an appropriate way to distribute broadband stimulus grants. NTIA/RUS requires a more objective and efficient methodology. Competitive bidding by procurement auction is the best approach.

B. Procurement Auctions Can Allocate Funds Flexibly, Efficiently and Fairly

An objective, "mechanistic" approach that applies specific, quantitative criteria can be both easier to implement and lead to more efficient outcomes than traditional grant application review. Procurement auctions, in particular, can lead to more efficient grant disbursal than traditional qualitative approaches.[7]

An auction is a mechanism for making smart allocation choices when confronted with overwhelming amounts of information and no relevant market exists. In a typical auction for a good, bids increase until the auction identifies the entity willing to pay the most for the good being auctioned. In the simplest procurement or "reverse" auction, bids consist of how much an entity must be paid to provide a good or service. The procurement auction thus identifies the entity willing to provide the good or service for the smallest amount of money.

Though it may sound exotic, a procurement auction is just a competitive bidding process and analogous to any government procurement. When the government needs to purchase something, it describes specifically what it wants, firms submit bids to provide the service, and the government picks the firm that submits the best bid.[8] The best bid may be the lowest, but the government may also take other factors into account when making the decision, especially in the case of complex projects.[9]

In procurement auctions for broadband, the government would specify its objective and ask firms to bid for the right to meet that objective. Consider, for example, a rural area with no broadband service. The government can ask firms to bid for a subsidy that would make it profitable for the firm to provide service. Firms and other organizations would compete against each other by bidding down the subsidy they need to offer service. The firm that commits to provide broadband in that area for the smallest subsidy would win the grant.

Procurement auctions have several advantages over traditional methods of distributing grants. First, once the auction rules are in place they relieve the government of the task of

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[7] The Federal Communications Commission (FCC) and Congress realized more than a decade ago that the traditional proposal-review approach was inefficient. Historically the FCC had granted spectrum licenses based on comparative hearings. These hearings could not be done quickly and put the FCC in the impossible position of processing tractor trailer-loads of paperwork to decide which companies were best suited to providing services in a given spectrum band. In 1994, the FCC began to allocate spectrum via auctions, which could occur quickly and allocate spectrum far more efficiently than could any administrative comparative process. This model has been used successfully in the U.S. and around the world ever since.

[8] See some federal procurement guidelines here: http://www.whitehouse.gov/omb/procurement/index_guides.html

[9] While it is easier to conduct this process for simple products, the government also uses it to supply highly complex goods like weapons systems See, for example, http://www.nytimes.com/2008/03/10/business/worldbusiness/10tanker.html?fta=y and www.gao.gov/cgi-bin/getrpt?GAO-06-364.

identifying the "best" projects – the government sets forth its objectives in advance of the auction. This also enables and encourages bidders to tailor their projects to the government's actual criteria. Second, because auctions use competition among providers to determine the subsidy required to achieve any particular goal, the government does not have to estimate the subsidy actually required for any given project. Reducing the subsidy for any given project frees up money that can be used for additional projects. Finally, they inherently induce firms to contribute their own investment to increase the chance that their bid is accepted.[10]

C. Clear Selection Criteria are Critical for any Selection Program

Crucial to the success of any plan, not just procurement auctions, is having clear objectives. In the case of the broadband stimulus the objectives include creating new jobs and improving broadband. It is not possible to maximize both objectives simultaneously. From the language of the Act and public discussions about it thus far we can assume that the most important objective is to maximize new broadband availability subject to creating some minimum level of new economic activity.

In general, stimulus funds would be awarded to those bidders that maximize broadband expansion with the lowest subsidy amount. Through the auction process bidders would be able to "bid down" the subsidy as they compete with other bidders seeking the same stimulus dollars.

Careful auction design is crucial to ensuring an efficient outcome. It is important to keep in mind two general points. First, the criteria on which the bids will be scored or ranked must be clear. As a simple example, bids could consist of subsidy requested per household connected or per household to which broadband service is newly available.[11] Then bids could be ranked from smallest subsidy requested to the largest, and funds distributed according to that ranking.

Second, the ability to "game" the procurement process increases with the ambiguity of the rules and the number of criteria included in a bid. For example, an auction in which firms had to demonstrate that their bid was in the "public interest" and specify a subsidy per household, the number of new households served, the service speeds, reliability, latency, mobility, and price would probably not work well due to the ambiguity of what, exactly, "public interest" means and the large number of criteria on which firms bid.

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[10] Procurement auctions are sound and have been used successfully around the world to bring telecommunications services to areas that previously had none. Experiences in other countries, including Australia, India, Chile, Peru, and others demonstrate that procurement auctions can substantially bring down the subsidies required to induce buildout. Their experiences also teach us that it will be important to get the details right.

[11] It will be important not to confuse supply and demand for broadband. About half of all people without broadband say that they are not interested in it. Because the stimulus focuses primarily on supply, we may want to focus on newly available broadband as opposed to newly adopted.

Note that the need to identify unambiguous, simple criteria on which to judge bids in advance of the auction is actually an advantage, not a disadvantage, of procurement auctions. It may appear at first blush that traditional grant reviews do not face similar problems, but that is incorrect. If a grant review process does not undergo the same identification task then it will likely lead to arbitrary and inconsistent decisions.

In addition to those very general points, this auction must be designed in a way that does not arbitrarily benefit one technology over another. Organizations could, therefore, bid to upgrade copper services in order to make DSL feasible, upgrade or install coaxial cable to facilitate cable broadband, or upgrade or install wireless and satellite broadband equipment. With scoring rules set out in advance bidders could know how they would have to bid and consider competing technologies or providers in other geographic areas.

III. A Straw-Man Procurement Auction Plan for Allocating NTIA/RUS Broadband Subsidies

A. Auction Design

This section describes economic methodology and other considerations for devising an effective procurement auction program. The detailed rules of the auction will be crucial, as they will affect the outcome.[12] NTIA/RUS will have to make several decisions as it creates these rules. We list some of the issues below.

The first step is the same for both a procurement auction and a traditional grant review process: NTIA/RUS must identify and define unserved and underserved regions. Ideally, most of these regions would be specified to have similar numbers of unserved/underserved households, so that the service costs across regions can be easily compared, and to be just large enough that projects of that scale are meaningful to the bidders. NTIA/RUS could identify these areas using existing data or bidders could propose and certify unserved areas. Each eligible project would need to offer qualifying service to at least 95% of the unserved households in the region.[13]

Having defined either the regions or the mechanism for defining the regions, the rules for the procurement auction begin to diverge from the traditional grant review process. NTIA/RUS should set out a framework for scoring projects in terms of a standard unit of supply. This could be a simple metric, such as "newly served population" (defined as the population to which service above a minimum bandwidth threshold is newly available) or a more involved measure such as "effective bandwidth supplied" (defined as the population

[12] If there is enough time, it would be useful to design experiments to test auction rules. In section III, we suggest allocating the money in tranches to learn about the process and make changes based on those outcomes.

[13] The required percentage of homes in the area could be set at a different level, or it could be set by the bidders and scored as part of the auction evaluation.

to which service is newly available adjusted for the speed of service.[14]) Each bid would be characterized in terms of effective supply and cost. We advise against introducing additional dimensions to the evaluation. It is particularly problematic to introduce subjective criteria, which undermine the quick and objective comparisons required by an effective auction.

In a sealed-bid auction, the winning bids maximize the total effective supply, subject to the government's spending and other constraints.

Ideally, the government would include multiple regions with a limited budget in a single auction, in order to encourage competition among bidders offering diverse services in different areas. Particularly in large auctions, the government should allow bidders to specify a maximum number of projects that they might win from any non-overlapping sets of projects and a further maximum for collections of such sets of projects. By protecting bidders from the risk of winning too many projects in any set and overall, this feature encourages firms to submit additional proposals, increasing the level of competition.

Auctions are adaptable to respect a wide range of policy concerns. The government could use instruments similar to ones that have been employed in FCC auctions, such as limiting the number of projects won by any single bidder or offering bidding credits to small businesses. And, to spread the effects of the subsidy geographically, the government could give greater weight to the first households served in a state or region than to additional households.

We recommend that pay-as-bid pricing applies: winning bidders should provide the project and receive the subsidy described in their bids. This system is simple and pay-as-bid pricing is common in procurement auctions.

The variations we have described relate to characteristics of the bidder or the region being served. It is easy in principle to add other sorts of factors to the bidding menu. However, the more dimensions on which firms bid, the more likely it becomes that there are easy ways for firms to game the system. We recommend limiting the factors to price and effective supply, especially in the first implementation to test the auction system. With a straightforward first step, auctions can be implemented rapidly and realize most of the competitive benefits from moving to this type of system.

B. Process Considerations

As a threshold matter, procurement auctions are allowed under ARRA. The Broadband Technology Opportunities Program was established to provide "competitive grants."[15] While ARRA does not separately define the term "competitive grant," procurement auctions

[14] An adjustment factor would reward bidders for providing higher speed service to unserved population. For example, 1 mbps service could have a factor of 1, 10 mbps a factor of 1.5, 50 mbps, a factor of 2 and 100 mbps, a factor of 3.

[15] ARRA, Sec. 6001(g).

are simply a methodology for implementing a competitive grant program, and in this respect should be seen as the fairest and most transparent way of doing so.[16]

The framework around which an effective procurement auction can be built is simple, and immediately suggests where substantial improvements over traditional grant review or other types of procurement auction can be made.

Indication of Intent and Prescreening. In order to avoid an extended post-bidding process of weeding out and correcting frivolous bidding and overbidding, a procurement auction process must include a pre-bid indication of intent from prospective bidders and a simple prescreening process. Prescreening could be as simple as a statement committing to meet all requirements of ARRA and the procurement auction rules, coupled with a showing that the bidder can (1) meet ARRA's 20% contribution requirement and (2) pay debts up to the subsidies it receive.[17]

Substantive Preconditions. In order to limit the considerations for award as much as possible, everything extraneous to price should be made a precondition to bid – that is, any bid will assume the preconditions and any cost of compliance to be included in the bid. Doing so will increase transparency and limit the subjectivity of the final decision-making process. For example, in implementing the open access requirement, NTIA should set its rule and require bidders to meet it – bids that do not comply with the rule will be rejected. Allowing bidders to opt out of specific substantive requirements would invite gaming and undermine the objectivity of the procurement auction, removing the rationale for using an auction in the first place. Thus, NTIA should establish specific requirements for how it wants bidders to meet the substantive requirements set forth in Section 6001(e) through (h) of ARRA. Moreover, bids that fail to include clear metrics and reporting intervals consistent with these requirements should be rejected.

Combinatorial Bids and Trading. Just as ARRA requires that competitive grants be technologically neutral, the size and scope of bidders has also been left open. Indeed, ARRA appears to encourage a broad range of types and sizes of bidders. This range reflects an underlying emphasis in ARRA's broadband sections on flexibility and creativity – letting the market figure out the best way of allocating funds and expanding broadband. Rules for procurement auctions should further the goal of flexibility by making clear that bidders may combine to serve specific areas, or combine areas, as their bids may specify. Furthermore, subject to full compliance with implementing rules, NTIA should allow rights to receive the subsidy, once won, to be freely traded. Winners should be allowed to subcontract or transfer their obligation to another entity that would have otherwise been qualified to bid in the original auction. A precondition for a workable trading system, however, is that there are clear and enforced benchmarks and buildout expectations.

[16] For a regulation to survive a challenge under the Administrative Procedure Act, a court must conclude that the regulation was not "arbitrary and capricious" or an "abuse of discretion." Given the benefits of using procurement auctions to distribute competitive grants, and ARRA's clear emphasis on speedy distribution of grants, an agency deciding to distribute funds under ARRA that opted for a less efficient and less transparent method would likely be required to explain what other factors made its decision reasonable.

[17] In order to avoid tipping their hands too early, a series of ranges of subsidies can be established, with the rules specifying that combined bids would be assumed to be able to meet the total of the combined ranges.

Provided that the underlying build out and other performance requirements are met, creating a trading system will allow winners to consolidate or diversify their obligations in a rational and efficient manner.

Transparency of Information. To the maximum extent possible, and consistent with how other auctions such as spectrum auctions have been conducted, information about the winning bidder or bidders, the amounts bid, and performance assurances must be made public and easily accessible online. It has already been established that transparency of information in a procurement auction does not violate any confidentiality of bidders that might otherwise be protected under the Federal Procurement Regulations.[18] Accordingly, NTIA should make this explicit in its implementing regulations, and explain that transparency of the process is essential not only to ensure fairness of the auction itself but also to aid in compliance.

C. Compliance and Accountability

Any subsidy or procurement plan—auction or otherwise—must include a strong mechanism for determining that firms fulfill their obligations. Performance and related assurances, such as performance bonds and other mechanisms apply to any grant program and are not unique to procurement auctions. No matter what mechanism NTIA might choose to allocate competitive grants, it will still have to address compliance and auditing. To some extent, simple prescreening of bidders will address compliance issues by ensuring that only serious bidders are engaging in the process. However, NTIA must also apply traditional performance assurance mechanisms, which are briefly discussed here.

It may be possible to require winning firms to put money in escrow that will be returned to them once they can certify that they have met their obligations (or returned in tranches as they show progress towards the goal). Forfeiture bonds are another approach. The auction design itself may be an important factor in determining whether post-auction obligations are met.

Winning bidders must make good on their bids. Holding them accountable and making sure that the subsidy actually created new economic activity requires two conditions to be true.

First, the firm must undertake the promised investment within a specified period of time. The firm should be given part of the subsidy immediately so that it can begin construction and receive the remainder in increments related to the number of households to which it has provided access. Firms that do not meet the promises made in their bids should be penalized to ensure that they have sufficient incentive to meet their obligations.

Second, the investment must not have occurred without the subsidy. Whether the investment is inframarginal is very difficult to know and it may not be possible to determine the answer conclusively for any given firm. Nevertheless, evaluating the outcome may make it possible to discern the amount of new investment created.

[18] *Matter of: MTB Group, Inc.*, 2005 WL 433615, 2005 U.S. Comp. Gen. LEXIS 34 (2006)

IV. NTIA/RUS Should Use Procurement Auctions to Allocate a At Least A Portion of the First Wave of Broadband Stimulus Funding and Expand the Program if Successful

We realize that using competitive auctions for disbursing subsidy grants may be viewed as a change in process and that there may be some risk. As such, if auctions are not used for the entire subsidy process, we think that at least some real world analysis should take place to see how auctions perform compared to the traditional process rather than rejecting auctions completely. This section describes how such an incremental approach to using auctions could be implemented in the grant system.

As NTIA/RUS have indicated, the stimulus awards are likely to be awarded over time. We believe that that NTIA/RUS would be wise to disburse broadband grants in successive waves or rounds, so that it can improve its disbursal mechanisms iteratively throughout the lifecycle of the program. Within this context, we recommend that NTIA/RUS designate one or more geographical regions in which the first wave of funds is distributed exclusively through a procurement auction process.

This approach sets up a natural experiment allowing comparison of procurement auctions to the traditional approach. If the experiment is successful, the procurement auction mechanism can be expanded in scope to encompass other regions and stimulus dollars (potentially all remaining stimulus funds). Regardless of what mechanism is ultimately used, the lessons from the procurement auction pilot will help NTIA/RUS to learn and adapt its award mechanisms.

A procurement auction can be implemented quickly. While there are many options for designing the auction system, that fact should not serve as an argument against auctions: auctions can be implemented rapidly. In fact, auctions may take a little more time to design upfront than a generic submission system, but the investment upfront is likely to speed the overall process because it will make selection much more rapid and less arbitrary (and hence less subject to *ex post* litigation). Other countries have proposed and implemented procurement auctions for universal service rapidly and successfully.[19]

One way to use auctions for a portion of the first wave of stimulus grants would be to divide the country into large geographical regions. The “Regional Economic Area Grouping” (REAG) used by the FCC in spectrum auctions is one possible scheme to consider. In this scheme, the continental United States is divided into six regions, each containing roughly 50 million citizens and encompassing both rural and urban areas. An alternative would be to designate similarly-sized regions as aggregations of states. Whatever scheme is used, it is important that the regions are roughly similar in terms of population size and urban/rural mix.

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[19] *See* Wallsten, Scott, “Reverse Auctions and Universal Telecommunications Service: Lessons from Global Experience” Federal Communications Law Journal. http://www.law.indiana.edu/fclj/pubs/v61/no2/9-WALLSTENFINAL.pdf

Then, in the first wave of stimulus disbursal, regions consisting of one-third of the U.S. population (roughly 100 million citizens) would be served through procurement auction of stimulus funds. The remaining two-thirds would be served by a conventional grant review process. A timeline would be established requiring that the first wave of funds—whether by procurement auction or by traditional grant review—shall be completed within six months. The amount of funding allocated to the first wave should reflect a practical assessment of what is feasible to disburse using the traditional process in a six-month timeframe. At the end of the period, the NTIA/RUS should take one month to compare results of the two programs and to assess the results, before making a determination whether to use procurement auctions in subsequent rounds.

Should NTIA/RUS decide to continue or expand the use of procurement auctions, the mechanism can be tweaked to incorporate lessons from the first wave. However, even if NTIA/RUS decides to proceed through entirely conventional means, the procurement auction will undoubtedly provide important lessons (e.g., bidder receptiveness to quantitative targets) that will inform refinements to the conventional approach.

V. Conclusion

A traditional grant application review process may prove to be inadequate to the herculean task of distributing broadband stimulus grants. It is likely to be slow, cumbersome, and will result in a suboptimal allocation of resources. By contrast, competitive bidding, through the use of procurement auctions, can allocate the funds quickly and efficiently. While we advocate using procurement auctions to distribute all of the broadband stimulus money, allocating even a portion of the funds using procurement auctions would be useful as an experiment. At a minimum, the broadband stimulus funds present a golden opportunity to implement rigorous evaluation techniques, which will generate knowledge that can be applied to other current and future programs. To that end it is important to include procurement auctions as one approach to be tested.

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APPENDIX C

Omnibus Broadband Initiative, The Broadband Availability Gap

THE BROADBAND AVAILABILITY GAP

OBI TECHNICAL PAPER NO. 1

TABLE OF CONTENTS

LIST OF EXHIBITS

LIST OF ASSUMPTIONS

This table provides important information about the different assumptions used in the creation of charts throughout this document. The assumptions implicit in each chart are appropriate for the context in which the chart appears. However, it may be the case that assumptions vary between similar charts, leading to what appear to be different results. This table synthesizes the different assumptions to allow the reader to interpret and compare charts in this document.

			Key assumptions	
Chart	Description	Technology	4G Areas	Non-4G areas
1-A	Base-case Broadband Availability Gap Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-B	Breakout of Ongoing Costs by Category Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-C	Gap by Census Blocks Ordered by Population density The second lowest cost technology is determined at the county level and assigned to the census blocks. All unserved census blocks then are sorted into centiles by their gap.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-D	Broadband Investment Gap per County	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-E	Broadband Investment Gap per Housing Unit in Each County	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-G	Broadband Investment Gap, by County Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-H	Ongoing Support for Each Housing Unit per Month	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-I	Investment Gap per Housing Unit by Lowest-Cost Technology for Each County	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.

			Key assumptions	
Chart	Description	Technology	4G Areas	Non-4G areas
1-J	Lowest Cost Technology All unserved areas are included.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
3-A	Impact of Discount Rate on Investment Gap Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
3-D	Gap for Funding One Wired and One Wireless Network Profitable counties for each technology are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
3-E	The Cost of Funding Two Wired Networks Profitable counties for each technology are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes one competitor.
		FTTP	Assumes one competitor.	Assumes one competitor.
3-G	Quantifying the Impact of Competition: Investment Gap by Number of Providers Profitable counties are excluded.	12,000-foot DSL	Assumes 0-3 competitors as indicated by label.	Assumes 0-3 competitors as indicated by label.
		Fixed Wireless	Assumes 0-3 competitors as indicated by label. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes 0-3 competitors as indicated by label. Recognizes only Fixed revenue as incremental.
3-H	Broadband Investment Gap by Percent of Unserved Housing Units The second-lowest-cost technology is determined at the county level and assigned to the census blocks. All unserved census blocks then are sorted into centiles by their gap.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
3-I	Total Investment Cost for Various Upgrade Paths	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network.	Assumes no competitors.
		5,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		3,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		FTTP	Assumes one competitor.	Assumes no competitors.
3-M	Dependence of the Broadband Investment Gap on Speed of Broadband Considered Profitable counties are excluded.	15,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
		5,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		3,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		FTTP	Assumes one competitor.	Assumes no competitors.
		HFC	Assumes one competitor.	Assumes no competitors.

Chart	Description	Technology	Key assumptions 4G Areas	Key assumptions Non-4G areas
3-U	Sensitivity of Gap to Take Rate Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
3-W	ARPU Sensitivity Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
3-Z	Sensitivity of Build-Out Cost and Investment Gap to Terrain Classification Parameters Profitable counties are excluded.	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
4-C	Present Value of Total Costs for All Technologies in Unserved Areas The second lowest cost technology is determined at the county level and assigned to the census blocks. All unserved census blocks then are sorted into centiles by their gap.	12,000-foot DSL	Assumes no competitors.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network.	Assumes no competitors.
		5,000-foot DSL	Assumes no competitors.	Assumes no competitors.
		3,000-foot DSL	Assumes no competitors.	Assumes no competitors.
		FTTP	Assumes no competitors.	Assumes no competitors.
		Cable	Assumes no competitors.	Assumes no competitors.
4-W	Investment Gap for Wireless networks Profitable counties are excluded.	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
4-Y	Sensitivity of Investment Gap to Terrain Classification Profitable counties are excluded.	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
4-Z	Sensitivity of Costs and Investment Gap to Subscriber Capacity Assumptions Profitable counties are excluded.	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
4-AA	Impact of Spectrum Availability on FWA Economics Considers all unserved areas for first column of data; profitable counties are excluded in the other columns.	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
4-AB	Cost Breakdown of Wireless Network Over 20 Years Considers all unserved areas (including profitable counties).	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network.	Assumes no competitors.
4-AC	Cost of Deploying a Wireless Network in Unserved Areas Considers all unserved areas (including profitable counties).	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network.	Assumes no competitors.

Chart	Description	Technology	Key assumptions	
			4G Areas	Non-4G areas
4-AD	Cost of an HFM Second Mile Backhaul Architecture	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network.	Assumes no competitors.
4-AK	Economic Breakdown of 12,000-foot DSL Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
4-AP	Economics of Terrestrially Served if Most Expensive Housing Units are Served with Satellite Includes all unserved areas (including profitable counties).	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
4-AV	Breakout of FTTP Gap Profitable counties are excluded.	FTTP	Assumes no competitors.	Assumes no competitors.
4-BE	Breakout of 3,000-Foot DSL Gap Profitable counties are excluded.	3,000-foot DSL	Assumes no competitors.	Assumes no competitors.
4-BF	Breakout of 5,000-Foot DSL Gap Profitable counties are excluded.	5,000-foot DSL	Assumes no competitors.	Assumes no competitors.
4-BG	Breakout of 15,000-Foot DSL Gap Profitable counties are excluded.	15,000-foot DSL	Assumes one competitor.	Assumes no competitors.

INTRODUCTION

The American Recovery and Reinvestment Act directed the Federal Communications Commission (FCC) to include, as part of the National Broadband Plan (NBP), "an analysis of the most effective and efficient mechanisms for ensuring broadband access by all people of the United States."[1] As the NBP indicated, the level of additional funding to extend broadband to those who do not have access today is $23.5 billion; more detail about the gap and results of this analysis are presented in Chapter 2. This document details the underlying analyses, assumptions and calculations that support the $23.5 billion funding gap.[2]

The question implicit in the Congressional mandate is deceptively simple: What is the minimum level of public support necessary to ensure that all Americans have access to broadband? In fact, there are multiple layers of complexity: The analysis must account for existing deployments, both to the extent that they enable current service and can be used to extend service to currently unserved areas; and it must include an analysis of the capabilities and economics of different, competing technologies that can provide service. The analysis therefore comprises two main components: The first focuses on *Availability*, or understanding the state of existing network deployments and services; the second focuses on the *Funding Shortfall*, the capabilities and economics associated with different broadband networks.[3] See Exhibit A.

The *Availability* analysis focuses on determining the state of existing deployments: who has access, and of greater concern, who lacks access to broadband consistent with the National Broadband Availability Target. In addition, this analysis must develop a key input to the Funding Shortfall analysis: data regarding the location of existing network infrastructure to facilitate determining the cost of extending service into unserved areas. Developing this detailed baseline requires a very granular geographic view of the capabilities of all the major types of broadband infrastructure as they are deployed today, and as they will likely evolve over the next three to five years without public support.

Unfortunately, there is a lack of data at the required level of granularity, both in terms of availability—which people have access to what services—and of infrastructure—which people are passed by what types of network hardware. To solve the problem, we combine several data sets for availability and infrastructure, supplementing nationwide data with the output of a large multivariate regression model. We use this regression model to predict availability by speed tier and to fill in gaps, especially last-mile gaps, in our infrastructure data. The approach to developing this baseline is described in Chapter 2.

The second major component focuses on the *Funding Shortfall* by examining the capabilities and economics of different network technologies. To facilitate this analysis, we built a robust economic model that calculates the amount of support necessary to upgrade or extend existing infrastructure to the unserved to provide service consistent with the target. The economic analysis builds on the infrastructure data—known and inferred—from the first step, calculating the cost to augment existing infrastructure to provide broadband service consistent with the target for multiple technologies.

This calculation ultimately provides the gap between likely commercial deployments and the funding needed to extend universal broadband access to the unserved. Underlying the model's construction are a number of principles that guided its design.

➤ **Only profitable business cases will induce incremental network investments.** Private capital will only be available to fund investments in broadband networks where it is possible to earn returns in excess of the cost of capital. In short, only profitable networks will attract the investment required. Cost, while a significant

BOX A

The Broadband Availability Gap Model

Models are one tool to analyze complex problems such as the Broadband Availability Gap. It is important to recognize, however, that models have limits. An engineering-based, multi-technology economic model of broadband deployment, like the one created as part of the National Broadband Plan (NBP) effort, requires a multitude of inputs and can be used to answer many different questions. The types of inputs range from simple point estimates, such as the cost of a piece of hardware—a Digital Subscriber Line Access Multiplexer (DSLAM) card or chassis, for example— estimates of per-product revenue, assumptions about the evolution of competitive dynamics in different market segments and the likely behavior of service providers. We form hypotheses about all of these types of inputs to calculate the Broadband Availability Gap; of necessity, some of these hypotheses are more speculative than others.

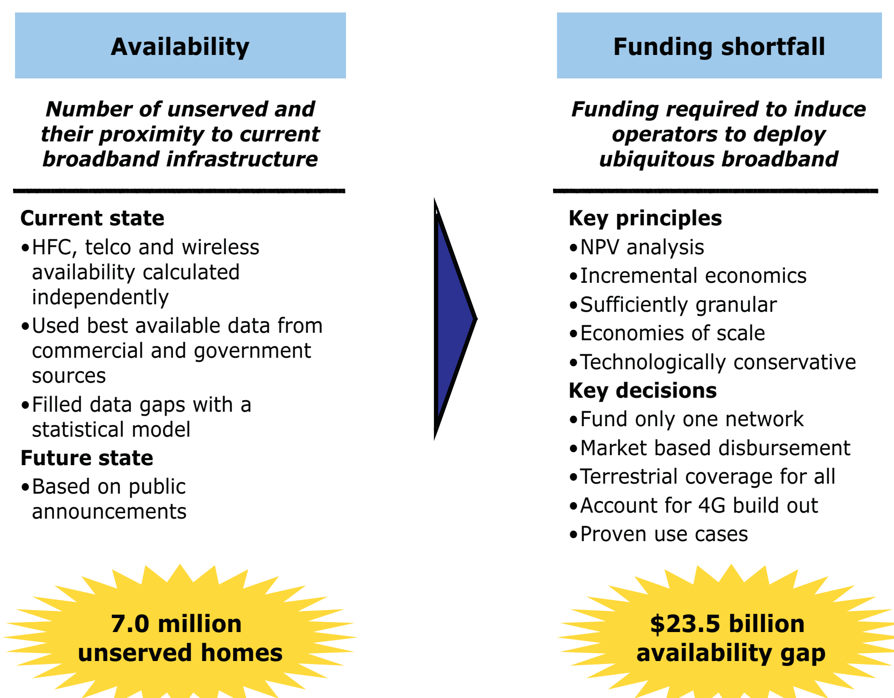
This paper describes the design and use of this model in providing input into the NBP, as well as the underlying views about the relevant technologies. Others may make different assumptions or test different hypotheses or seek to answer somewhat different questions. The model and its associated documentation provide an unprecedented level of transparency and should spur debate. The intent is for this debate to ultimately improve our understanding of the economics related to offering broadband service so that public policy can be made in a data-driven manner.

driver of profitability, is not sufficient to measure the attractiveness of a given build; rather, the best measure of profitability is the net present value (NPV) of a build. This gap to profitability in unserved areas is called the Broadband Availability Gap in the NBP; throughout this paper, we will refer to this financial measure as the Investment Gap.

- ➤ **Investment decisions are made on the incremental value they generate.** While firms seek to maximize their overall profitability, investment decisions are evaluated based on the incremental value they provide. In some instances, existing assets reduce the costs of deployment in a given area. The profitability of any build needs to reflect these potential savings, while including only incremental revenue associated with the new network build-out.
- ➤ **Capturing the local (dis-)economies of scale that drive local profitability requires granular calculations of costs and revenues.** Multiple effects, dependent on local conditions, drive up the cost of providing service in areas that currently lack broadband: Lower (linear) densities and longer distances drive up the cost of construction, while providing fewer customers over whom to amortize costs. At the same time, lower-port-count electronics have higher costs per port. In addition, these lower densities also mean there is less revenue available per mile of outside plant or per covered area.
- ➤ **Network-deployment decisions reflect service-area economies of scale.** Telecom networks are designed to provide service over significant distances, often larger than five miles. In addition, carriers need to have sufficient scale, in network operations and support, to provide service efficiently in that local area or market. Given the importance of reach and the value of efficient operations, it can be difficult to evaluate the profitability of an area that is smaller than a local service area.
- ➤ **Technologies must be commercially deployable to be considered part of the solution set.** Though the economic model is forward-looking and technologies continue to evolve, the model only includes technologies that have been shown to be capable of providing carrier-class broadband. While some wireless 4G technologies arguably have not yet met this threshold, successful market tests and public commitments from carriers to their deployment provide some assurance that they will be capable of providing service.

Implicit within the $23.5 billion gap are a number of key decisions about how to use the model. These decisions reflect

Exhibit A: Approach to Determining the Availability Gap[4]



beliefs about the role of government support and the evolution of service in markets that currently lack broadband. In short, these decisions, along with the assumptions that follow, describe how we used the model to create the $23.5 billion base case.

- ➤ **Fund only one network in each currently unserved geographic area.** The focus of this analysis is on areas where not even one network can operate profitably. In order to limit the amount of public funds being provided to private network operators, the base case includes the gap for funding only one network.
- ➤ **Capture likely effects of disbursement mechanisms on support levels.** Decisions about how to disburse broadband-support funds will affect the size of the gap. Market-based mechanisms, which may help limit the level of government support in competitive markets, may not lead to the lowest possible Investment Gap in areas currently unserved by broadband—areas where it is difficult for even one service provider to operate profitably.
- ➤ **Focus on terrestrial solutions, but not to the exclusion of satellite-based service.** Satellite-based service has some clear advantages relative to terrestrial service for the most remote, highest-gap homes: near-ubiquity in service footprint and a cost structure not influenced by low densities. However, satellite service has limited capacity that may be inadequate to serve all consumers in areas where it is the lowest-cost technology. Uncertainty about the number of unserved who can receive satellite-based broadband, and about the impact of the disbursement mechanisms both on where satellite ultimately provides service and the size of the Investment Gap, all lead us to not explicitly include satellite in the base-case calculation.
- ➤ **Support any technology that meets the network requirements.** Broadband technologies are evolving rapidly, and where service providers are able to operate networks profitably, the market determines which technologies "win." Given that, there appears to be little-to-no benefit to pick technology winners and losers in areas that currently lack broadband. Therefore, the base case includes any technology capable of providing service that meets the National Broadband Availability Target to a significant fraction of the unserved.
- ➤ **Provide support for networks that deliver proven use cases, not for future-proof build-outs.** While end-users are likely to demand more speed over time, the evolution of that demand is uncertain. Given current trends, building a future-proof network immediately is likely more expensive than paying for future upgrades.

Also implicit in the $23.5 billion gap are a number of major assumptions. In some sense, every input for the costs of network hardware or for the lifetime of each piece of electronics is an assumption that can drive the size of the Investment Gap. The focus here is on those selected assumptions that may have a disproportionately large impact on the gap or may be particularly controversial. By their nature, assumptions are subject to disagreement; Chapter 3 includes an estimate of the impact on the gap for different assumptions in each case.

- ➤ Broadband service requires 4 Mbps downstream and 1 Mbps upstream access-network service.
- ➤ The take rate for broadband in unserved areas will be comparable to the take rate in served areas with similar demographics.
- ➤ The average revenue per product or bundle will evolve slowly over time.
- ➤ In wireless networks, propagation loss due to terrain is a major driver of cost that can be estimated by choosing appropriate cell sizes for different types of terrain and different frequency bands.
- ➤ The cost of providing fixed wireless broadband service is directly proportional to the fraction of traffic on the wireless network from fixed service.
- ➤ Disbursements will be taxed as regular income just as current USF disbursements are taxed.
- ➤ Large service providers' current operating expenses provide a proxy for the operating expenses associated with providing broadband service in currently unserved areas.

These principles, decisions and assumptions are discussed in detail in Chapter 3.

In addition to the key assumptions above, there are numerous other assumptions that we made for each broadband technology we examined. In order to accurately model each technology, we had to understand both the technical capabilities and the economic drivers; a description of our treatment of each technology is provided in Chapter 4.

In addition to this technical paper, there is supplementary documentation describing our analysis and methods including CostQuest Model Documentation: Technical documentation of how the model is constructed, including more detail about the statistical model used to estimate availability and network infrastructure in areas where no data are available.

ENDNOTES

[1] American Recovery and Reinvestment Act of 2009, Pub.L. No. 111-5, § 6001(k)(2)(D), 123 Stat. 115, 516 (2009) (Recovery Act).

[2] Note the figure differs slightly from Exhibit 8-B of the first printing of the National Broadband Plan (NBP). While the gap remains $24 billion, the data in this paper are updated since the release of the NBP; future releases of the NBP will include these updated data.

[3] As a threshold matter, the level of service to be supported must be set. This service is the National Broadband Availability Target which specifies downstream speeds of at least 4 Mbps and upstream speeds of at least 1 Mbps. Support for this target is discussed briefly in Section 4 and in detail in the Omnibus Broadband Initiative's (OBI) technical paper entitled Broadband Performance (forthcoming).

[4] Homes are technically housing units. Housing units are distinct from households. "A housing unit is a house, an apartment, a mobile home, a group of rooms, or a single room that is occupied (or if vacant, is intended for occupancy) as separate living quarters." In contrast, "A household includes all the persons who occupy a housing unit. . . . The occupants may be a single family, one person living alone, two or more families living together, or any other group of related or unrelated persons who share living arrangements." There are 130.1 million housing units and 118.0 million households in the United States. U.S. Census Bureau, Households, Persons Per Household, and Households with Individuals Under 18 Years, 2000, http://quickfacts.census.gov/qfd/meta/long_71061.htm (last visited Mar. 7, 2010).

I. THE INVESTMENT GAP

Our analysis indicates that there are 7 million housing units (HUs) without access to terrestrial broadband infrastructure capable of meeting the National Broadband Availability Target of 4 Mbps download and 1 Mbps upload. Because the total costs of providing broadband service to those 7 million HUs exceed the revenues expected from providing service, it is unlikely that private capital will fund infrastructure capable of delivering broadband that meets the target.

We calculate the amount of support required to provide 100% coverage to the unserved consistent with the availability target to be $23.5 billion. As shown in Exhibit 1-A, the $23.5 billion gap is the net shortfall, including initial capital expenditures (capex), ongoing costs and revenue associated with providing service across the life of the asset.

Ongoing costs comprise ongoing capex, network operating expenses and selling, general and administrative expenses; the present values of these costs are shown in Exhibit 1-B.

Costs and the gap vary dramatically with population density, with the least densely populated areas accounting for a disproportionate share of the gap (see Exhibit 1-C). As noted in the NBP, and discussed more fully in the *Satellite* portion of Chapter 4, the highest-gap 250,000 housing units account for $13.4 billion of the total $23.5 billion investment gap.

In fact, deployment costs and the gap are driven largely by the density of the unserved, as will be discussed here and in Chapter 2 (see, for example, Exhibits 1-F and 2-D). Therefore, satellite-based broadband, which can provide service to almost any subscriber regardless of location and at roughly the same cost, could be an attractive part of the overall solution.

We rely on these results to represent an aggregate, nation-wide figure. We are more cautious with results in specific geographies because the estimates of the availability of broadband capable networks are in part based on a statistical model (see Chapter 2 for more detail). When examined at a very granular level, the availability model will sometimes overestimate and sometimes underestimate service levels, but should tend to balance out when aggregated to larger geographic areas. In the maps throughout this section we aggregate outputs to the county, but data should still be considered only directionally accurate. Further analysis and improved source data would be required to refine estimates for particular geographies.

The map in Exhibit 1-D presents the Investment Gap for each county in the country. The gap in each county is calculated by adding the gap of all census blocks in that county. Since most counties have at least some census blocks with a net present value (NPV) gap, most counties have an NPV gap. Census blocks with a positive NPV (i.e., blocks where the gap is negative) offset losses in census blocks that are NPV negative. Thus, counties can have no gap if they are currently fully served (i.e., have no unserved), or if the total NPV in the county is positive. Note that dark blue counties have a gap at least 20 times higher than the gap in the light green counties.

Exhibit 1-A: Base-case Broadband Availability Gap—Cash Flows Associated With Investment Gap to Universal Broadband Availability[1]

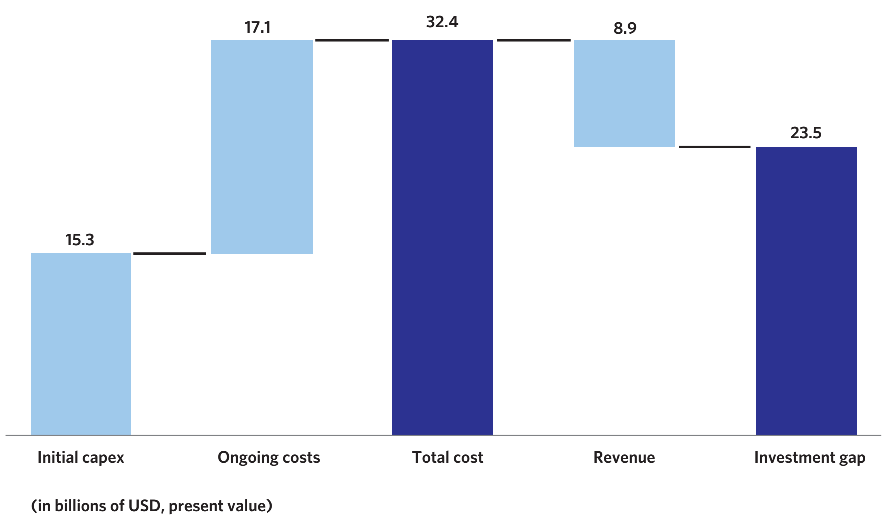
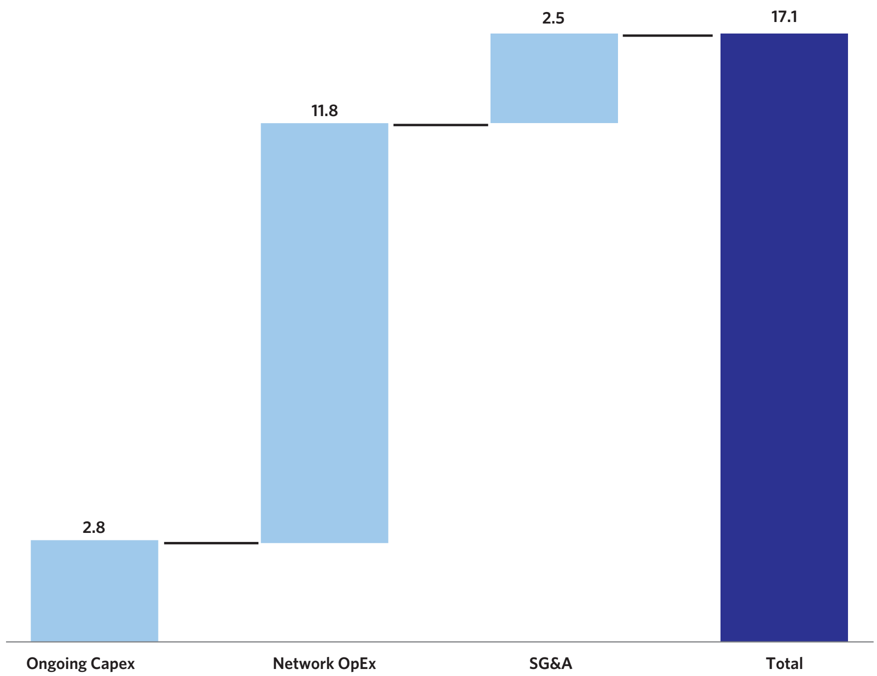
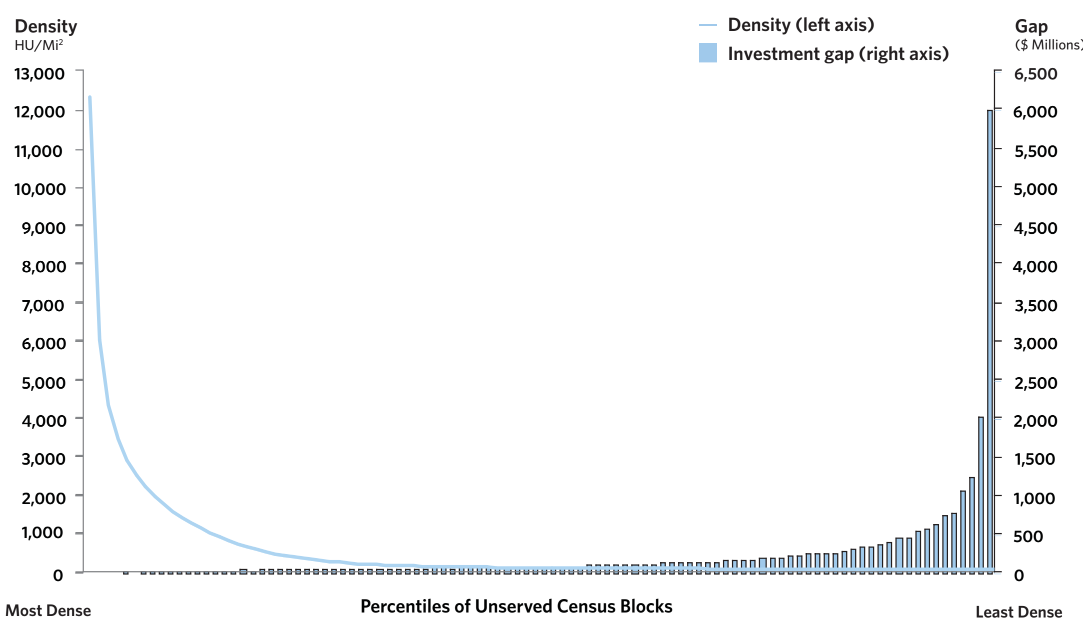


Exhibit 1-B:
Breakout of Ongoing Costs by Category



(in billions of USD, present value)
Numbers do not sum due to rounding.

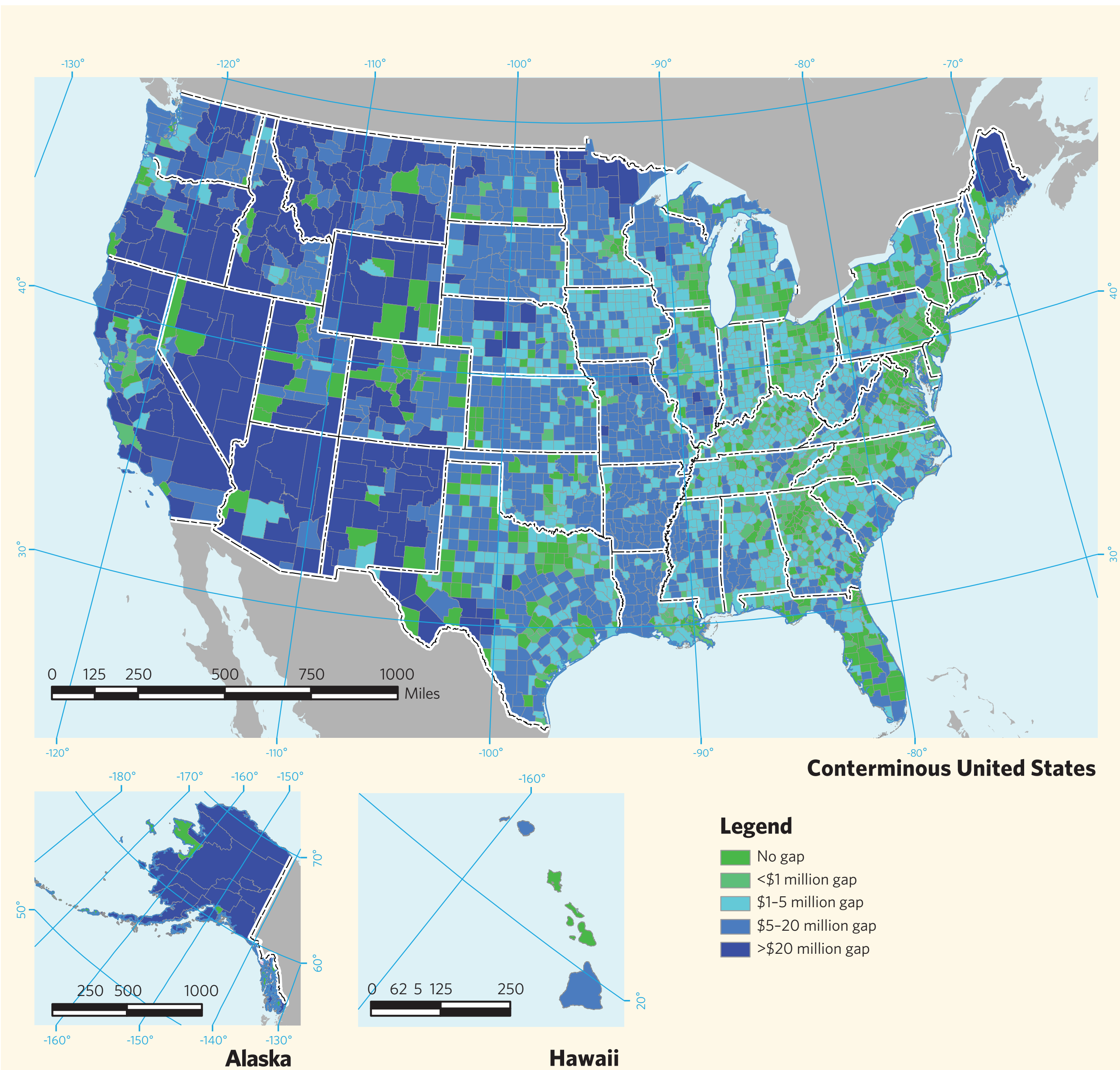
Exhibit 1-C:
Gap by Census Blocks Ordered by Population density



(in millions of USD, present value)

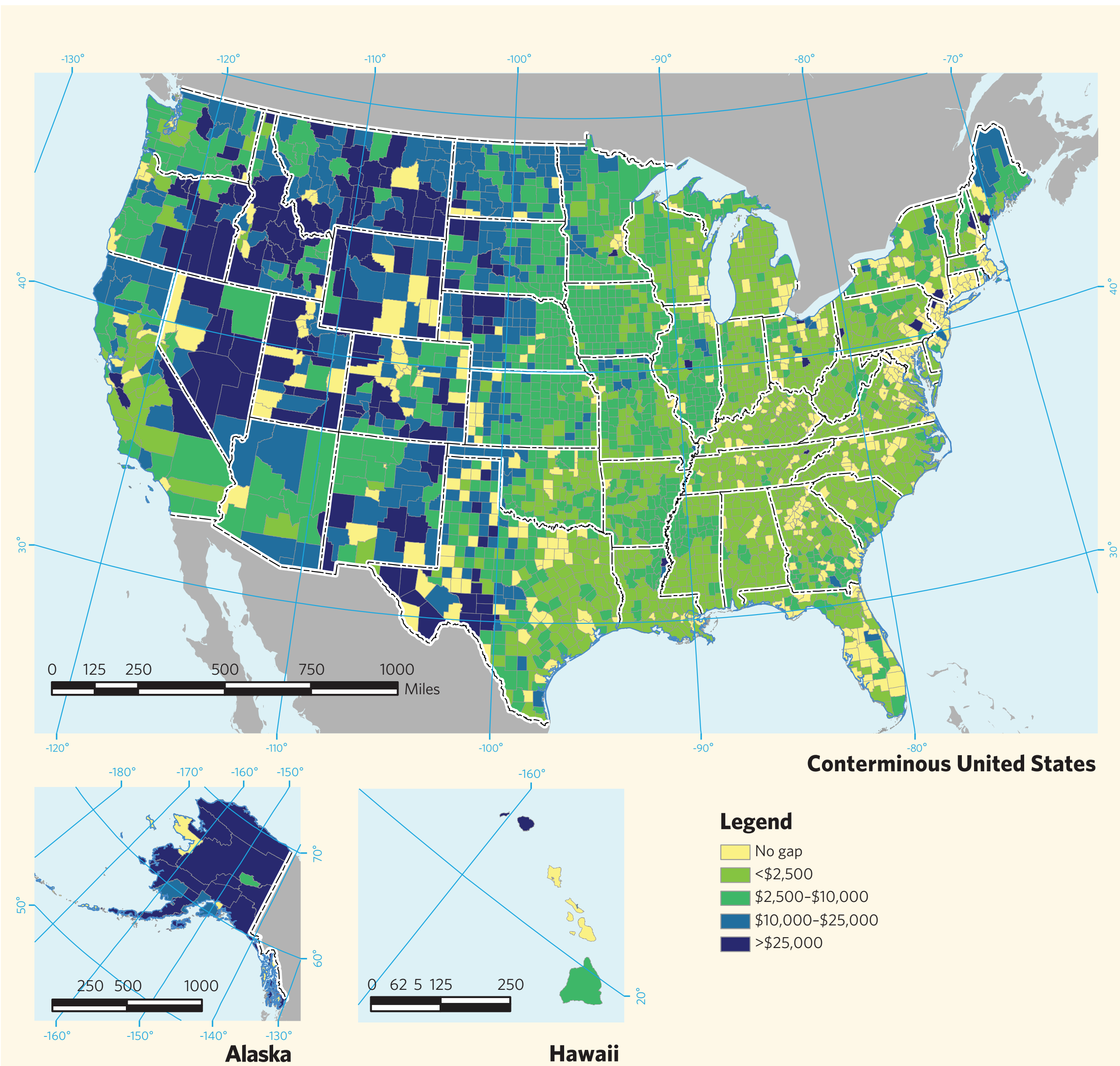
However, the total gap per county tells only part of the story. High county-level gaps can be driven by large numbers of relatively low-gap housing units and/or by small numbers of very high-gap housing units. Examining the gap per housing unit, as shown in Exhibit 1-E, highlights counties where the average gap per home is particularly high. This calculation simply takes the total gap in each county as described above, and divides by the number of unserved housing units in that county. The dark blue counties have a gap per home at least 10 times higher than the gap per home in the green counties.

Exhibit 1-D:
Broadband Investment Gap per County



As one might expect, one of the major drivers of cost, and consequently the gap, is the density of unserved housing units (i.e., the number of unserved housing units per square mile, averaged across each county). Areas with higher density as shown in Exhibit 1-F generally have lower gaps per housing unit; note the correlation between low densities in Exhibit 1-F with higher gap per housing unit in Exhibit 1-E. Although density is not the only driver of gap, it is a significant one.

Exhibit 1-E:
Broadband Investment Gap per Housing Unit in Each County



In some areas, the gap exceeds the initial capex required to build out the area. These areas have ongoing costs that are in excess of their revenue—meaning even a network with construction fully subsidized by public funds will not be able to operate profitably. Exhibit 1-G shows the gap for each county, highlighting those where the gap is larger than the initial capex (i.e., markets that require ongoing support), colored in light blue. Areas that require ongoing support generally have larger gaps.

Exhibit 1-F:
Density of Unserved Housing Units per Square Mile

The map in Exhibit 1-H shows the distribution of counties requiring ongoing support across the country. Ongoing support is the monthly annuity required per unserved housing unit to offset ongoing losses (i.e., the amount by which ongoing costs exceed revenues, assuming the network build out is fully subsidized). The darkest colors indicate areas where the highest levels of ongoing support are needed; counties shaded in pink will not need ongoing support.

In Exhibit 1-I, areas in blue are more economic to serve with wireless, and areas in red are cheaper to serve with DSL. For each, darker colors indicate counties with a higher gap per unserved housing unit. This technology comparison is made at the county level, not at a more granular level (See Chapter 3).

Wireline tends to be cheaper in low-density areas (compare Exhibit 1-I with Exhibit 1-F), particularly where terrain drives the need for smaller cell sites that drive up the cost of wireless (see Chapter 4 on wireless technology).

To establish the $23.5 billion gap, it is necessary to make a determination as to which last mile technology is likely to be least expensive given existing infrastructure, density, terrain and other factors. These estimates notwithstanding, this approach and the NBP are technologically neutral: These estimates do ***not*** reflect choices ***or*** recommendations that a particular last mile technology be utilized in any given area. Note, that as described later in this section in "**Creating the base-case scenario and output**," the focus in this analysis is on 12,000-foot-loop DSL and fixed wireless.

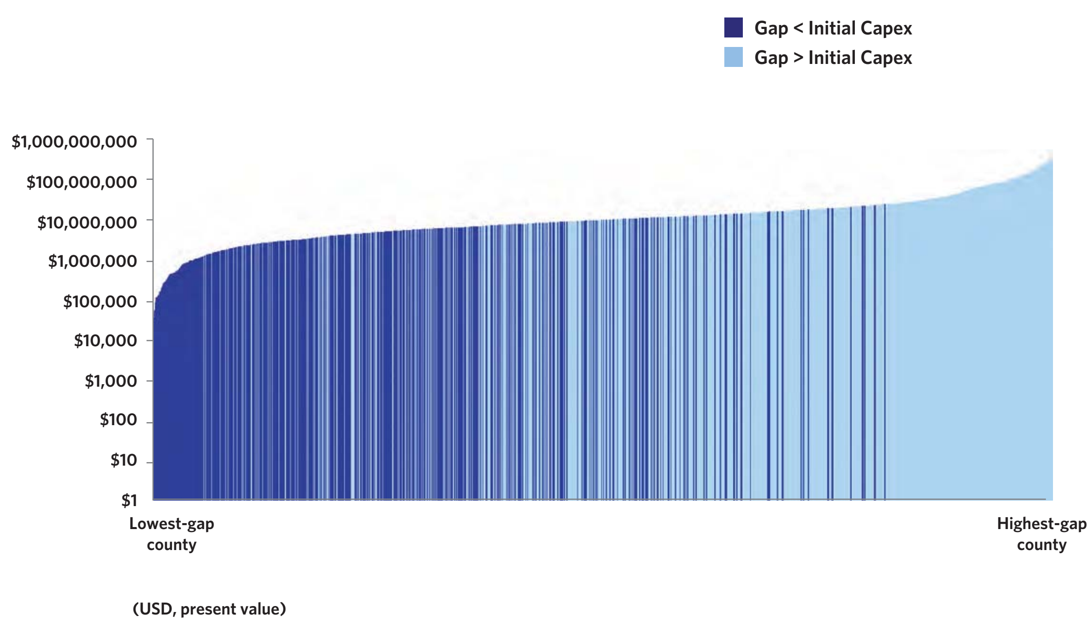
The map is somewhat misleading about the number of unserved housing units where wireline service is cheaper. In fact, while 42% of the geographic area is covered by counties where wired service has a lower gap, only 15% of counties with only 10% of the unserved housing units are in these areas; see Exhibit 1-J. Over time, these figures, which are based on the calculation of the investment gap for different technologies, may over- or under-estimate the role of any technology for a number of reasons. End-user behavior, specifically take rates or revenue per user, could differ from assumptions made in the model (see Chapter 3). In addition, the capabilities of different technologies could improve more or less quickly than assumed, or their costs could differ from what is modeled (see Chapter 4 for detail about capabilities and costs of different technologies). Finally, the impact of the disbursement mechanisms on individual service providers is impossible to include in these calculations.

The assumptions that underlie each of these calculations, and the method by which these technologies' costs are combined to reach the $23.5 billion gap, are discussed across the remainder of this document.

CREATING THE BASE-CASE SCENARIO AND OUTPUT

The base-case outputs, including the $23.5 billion gap, represent the shortfall of a particular combination of technologies across all unserved geographies. Since a single model run provides information about a single technology with a single set of assumptions, combining calculations for different technologies

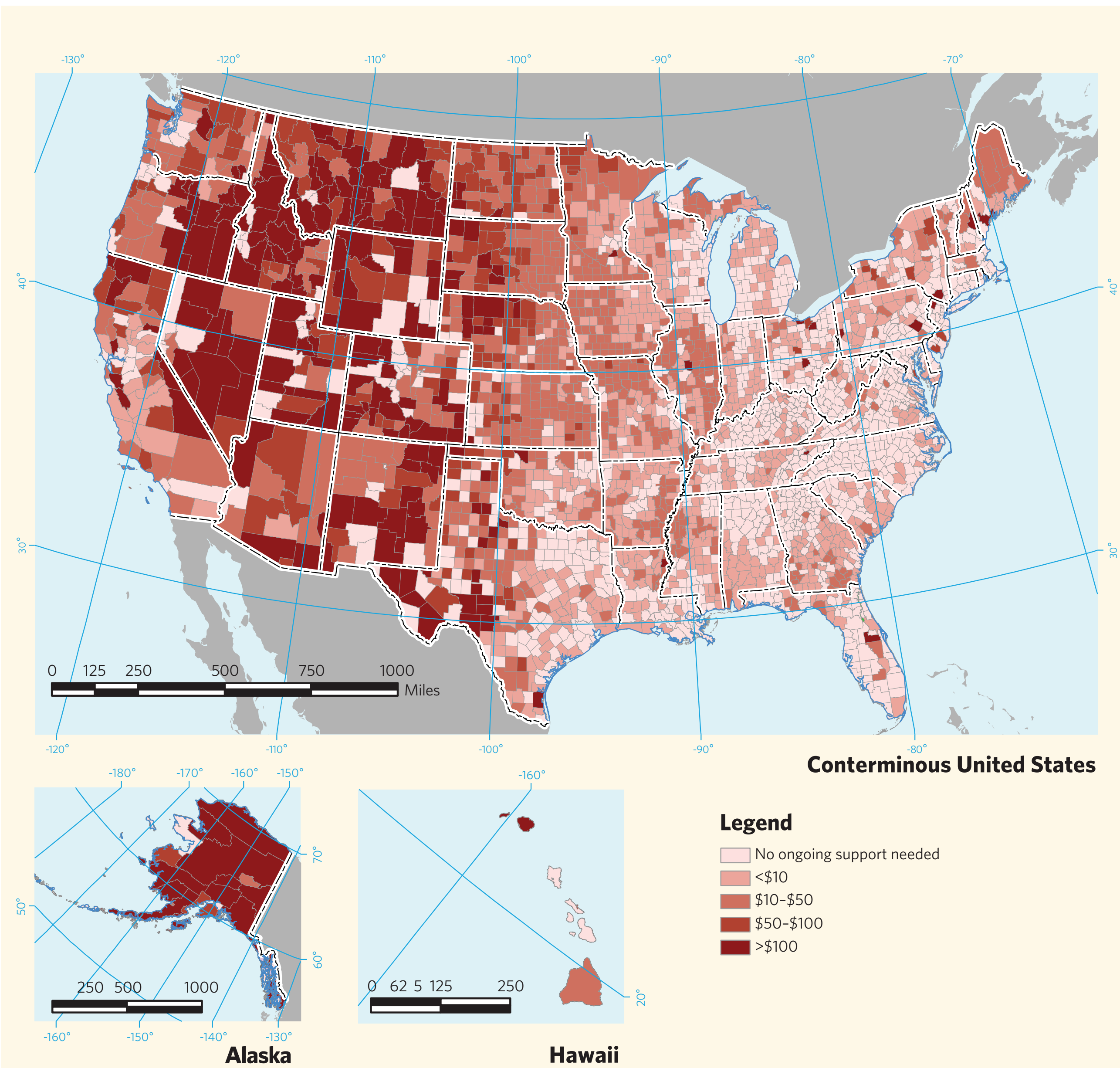
Exhibit 1-G: Broadband Investment Gap, by County



requires multiple model runs. This section describes the various models run as well as the manual post-processing required to create the single base case of $23.5 billion. Post processing of this type is required for each of the different scenarios and sensitivities shown in this document.

To create the base case, we calculate the gap for each of the two lowest-cost technologies: fixed wireless and 12,000-foot DSL (see Exhibit 4-C). Calculating the fixed wireless gap is quite complex, and requires eight different sets of model output. DSL is less complex, and requires only two sets of model

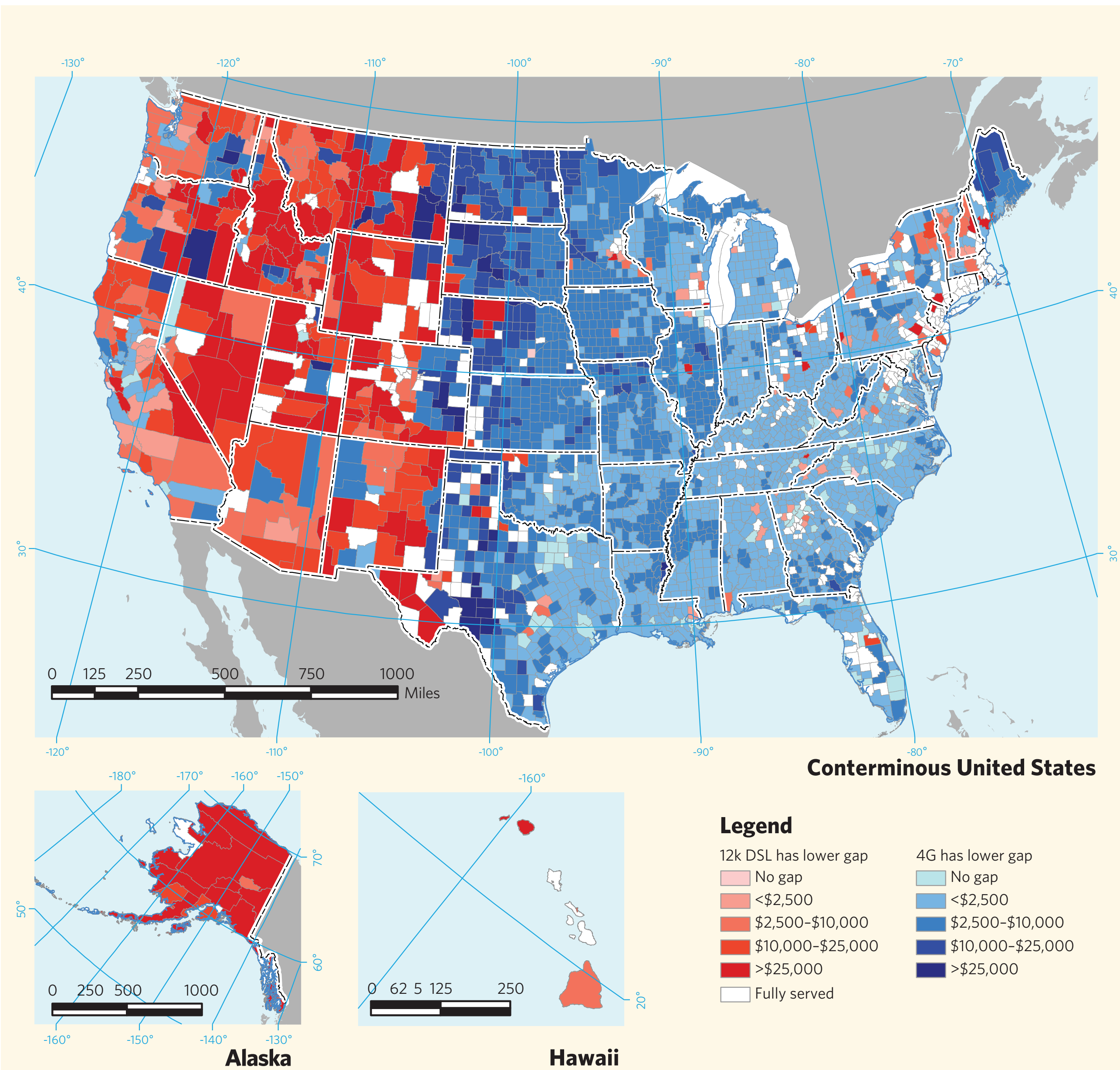
Exhibit 1-H:
Ongoing Support for Each Housing Unit per Month



output. Of course, we also calculate the gap for other technologies, which will be discussed in Chapter 4.

For wireless, we require a total of eight different runs to generate the output data and account for two different kinds of information: 1) the presence of planned commercial 4G deployments and 2) which of four different cell radii is required for each census block to provide adequate signal density given terrain-driven attenuation. The base case requires output for each combination.

Exhibit 1-I:
Investment Gap per Housing Unit by Lowest-Cost Technology for Each County



The first issue is the presence of commercial 4G deployments. A substantial fraction of the unserved are in areas we expect will be covered by commercial 4G build-outs. We treat these 4G and non-4G areas differently in our analysis to account for the costs and revenues associated with each and, consequently, need one run for each area. In 4G areas, as noted in the NBP, it is not clear whether these commercial build-outs will provide adequate service without incremental investments. The gap in these 4G areas needs to account for the fact that costs associated with the incremental investments are lower than they would be for a greenfield build. In non-4G areas, we calculate the costs for a greenfield build (note that, as will be discussed in the wireless portion of Chapter 3, we capture the cost savings available from existing cell sites, as appropriate).

Another key driver of the wireless gap is the cell radius in each area. Rather than assume a uniform cell radius across the entire country, the approach is to calculate the cost associated with different cell radii (two, three, five and eight-mile radii) and chose an “optimized” radius, which accounts for topology, for each area.

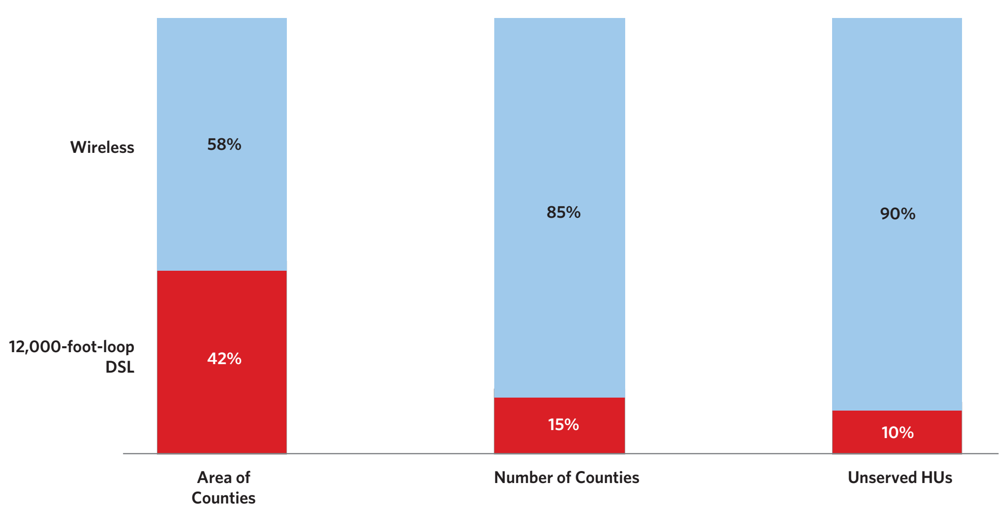
In total, then, there are eight wireless model runs: four runs (one for each radius) for the costs and gap associated with 4G areas; and four runs for the costs and gap associated with non-4G areas. For each geography (census block), we select the costs, revenues and gap from the appropriate run for each census block, depending on whether the area is in a 4G or non-4G area and what the optimized cell radius is.

The wired, 12,000-foot DSL solution is more straightforward and requires only two runs, which are required to account for the potential competitive impact of commercial 4G overlap on end-user revenue for the wired provider. While it is clear that a wireless carrier would need to make incremental investments to serve every unserved housing unit, wireless carriers will be able to serve some potentially large fraction of those within the commercial 4G footprint. Therefore, we assume that within the expected 4G footprint, DSL providers will face one fixed-broadband competitor (i.e., will split the end-user revenue with another carrier); in non-4G areas, we assume that DSL providers will not face any competition. The result is that the wired base case requires two model runs: one for 4G areas (with competition) and one for non-4G areas (without competition). The base case assumes wired solutions are all brownfield deployments where the incumbent builds out DSL service using existing twisted-pair copper.

The base case then involves calculating the lowest-cost and second-lowest-cost technology in each area. To make these comparisons at the service-area level (county level), we roll census blocks up into counties. These geographic roll-ups are made with Structured Query Language or SQL queries of the large, census-block-level output of the model and provide the essential outputs including costs, revenues and the gap for each model run or combination of model runs.

The model uses levelized costs and revenues. Levelization, often used in regulatory proceedings, calculates the annuitized equivalent—i.e., the effective annual value of cash flows—of the costs and revenues associated with building and operating a network. A levelized calculation provides a steady cash-flow stream, rather than trying to model or guess the timing of largely unpredictable yet sizable real-world payouts like those for upgrading and repairing equipment. The net present value (NPV) of a levelized cash flow is equal to the NPV of actual cash flows.

Exhibit 1-J.
Lowest Cost Technology



CHAPTER 1 ENDNOTES

1 Note that this exhibit differs slightly from Exhibit 8-B of the first printing of the NBP. While the gap remains at $24 billion, the data in this paper are updated since the release of the NBP; future revisions of the NBP will include these updated data.

II. BROADBAND AVAILABILITY

Before determining the size of the Investment Gap, it is necessary to determine the current state of broadband deployment. This includes the level of service currently supported (or which will be in the near-term without government support) as well as the proximity of unserved areas to broadband infrastructure that can be leveraged to serve the area.

The complexity of this analysis is driven by the need for a very granular geographic view of the capabilities of all the major types of broadband infrastructure as they are deployed today, and as they will likely evolve over the next three to five years without additional public support.

These data are not available: There is a lack of data at the required level of granularity, both in terms of which people have access to which services, and of which people are passed by different types of physical infrastructure. To solve this problem, we combine commercial and public data on availability and infrastructure with statistical techniques to predict or infer the data needed to complete our data set.

In some cases we use broadband availability data to predict the location of broadband infrastructure, and in some cases we use the location of broadband infrastructure to predict the availability of broadband capable networks. In areas where we do not have data, we combine data from other geographies with limited physical infrastructure data in a large multi-variant regression model. We use this regression model to predict availability by speed tier and to fill in gaps, especially last mile gaps, in our infrastructure data.

Once current availability is determined, we forecast the future state by relying on recent publicly announced network build-out plans.

Where the quality of data is limited, broadband-gap calculations will be affected. For example, there are 12 wire centers in Alaska that show no population within their boundaries and an additional 18 wire centers that have no paved public-use roads (i.e., no roads other than 4-wheel-drive or forest-service roads). All 30 of these wire centers were excluded from wired broadband-gap calculations; however, all areas with population were covered by the wireless calculations. In addition, due to insufficient demographic and infrastructure data to calculate baseline availability for Puerto Rico and the U.S. Virgin Islands in the Caribbean, and Guam, American Samoa and the Northern Marianas in the Pacific, these areas are excluded from further analysis.

CURRENT STATE

Although 123 million housing units already have broadband networks available that are capable of providing service that meets the National Broadband Availability Target of at least 4 Mbps download and 1 Mbps upload, many Americans do not. Currently, 7 million housing units representing 14 million people are left without broadband that meets the National Broadband Availability Target. See Exhibit 2-A.

Exhibit 2-A: Highest Speed Capability of Available Wired Broadband Networks in the United States[1]

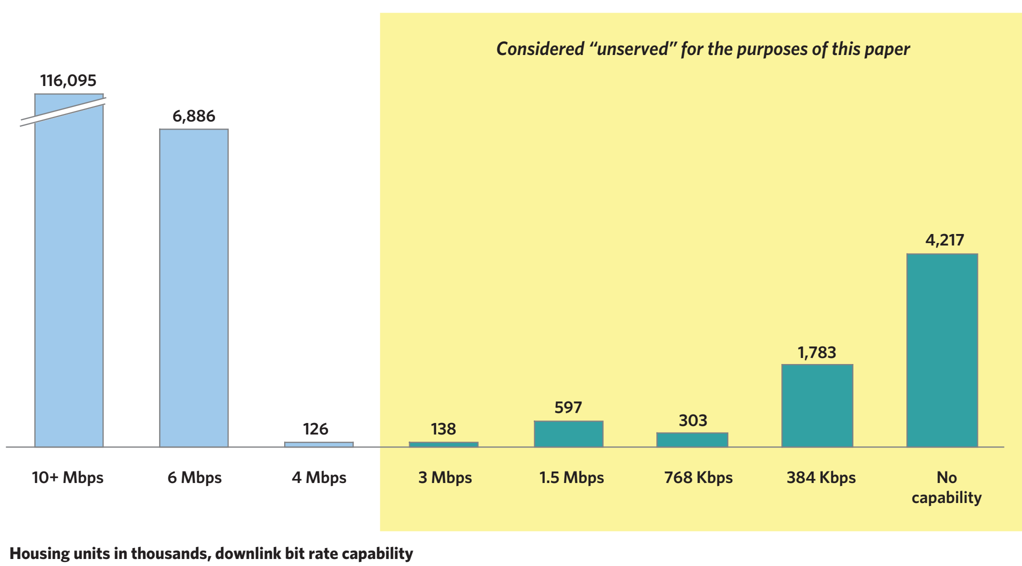
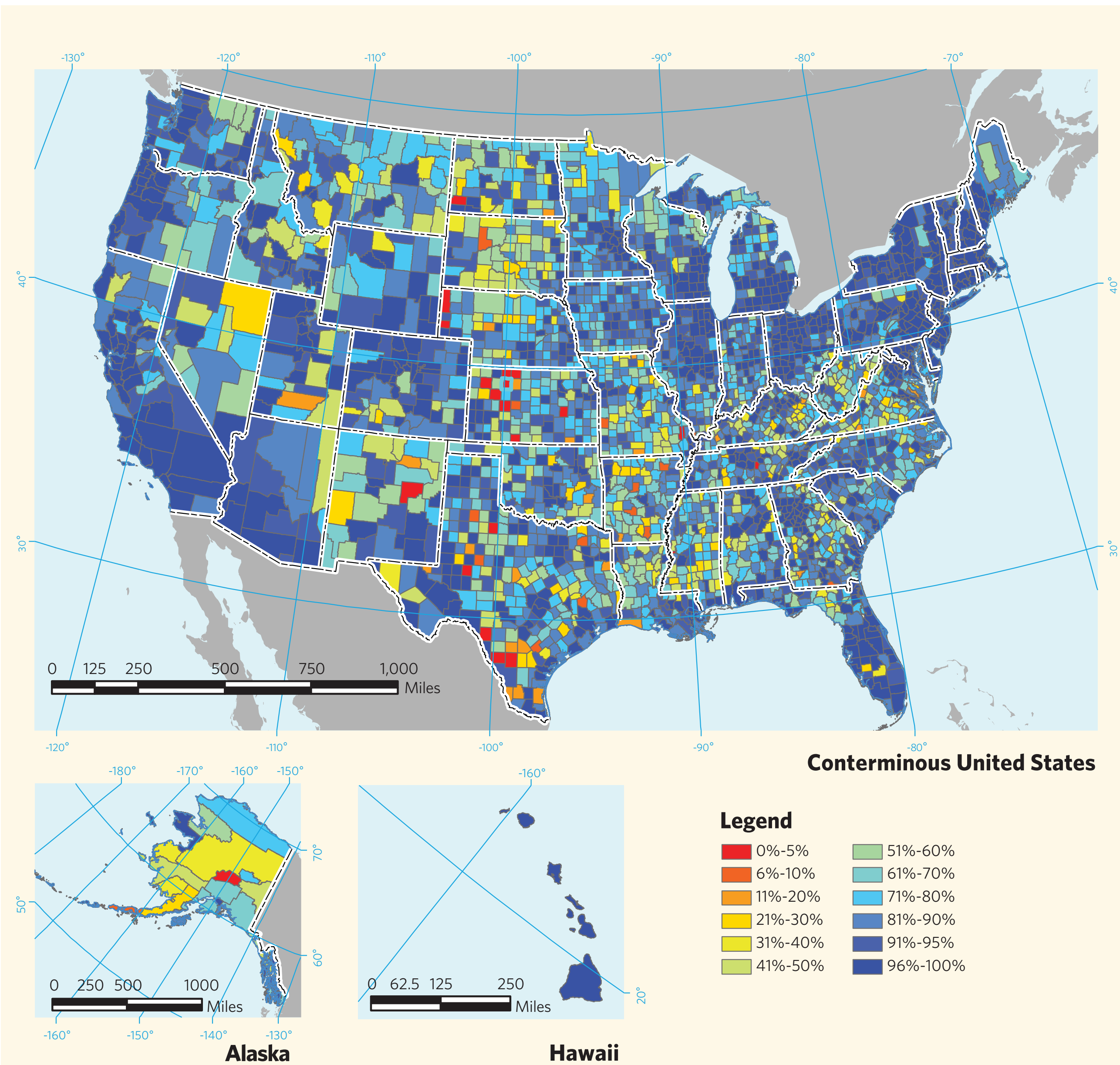


Exhibit 2-B presents the distribution of these 7 million housing units across the United States. The number of unserved housing units in each county is calculated based on the methodology described below. That number is then divided by the total number of housing units in the county to get the percentage of homes served.

Exhibit 2-B:
Availability of Broadband Networks Capable of Meeting the National Broadband Target



Purpose of the Analysis

Before determining the size of the Investment Gap, it is necessary to determine who is unserved as well as the adjacent broadband infrastructure that could be leveraged to serve them. The distance and density dependencies of both current availability and the cost of providing service to those who do not currently have it required that we take into account the geography of each unserved area at a very granular level. That, in turn, requires that we create a geographically based view of current networks and broadband capabilities in order to calculate the Investment Gap.

Our current-state model calculates the likely broadband performance from multiple technologies at the census-block level to determine the highest level of broadband service available for each census block nationwide.

This model serves two main purposes:

- ➤ It determines the number and location of housing units and businesses that do not have broadband infrastructure available that meets our performance target.
- ➤ It provides the location of network infrastructure that can be used as the foundation for building out broadband networks to these unserved housing units; these infrastructure data provide an essential input into the economic model.

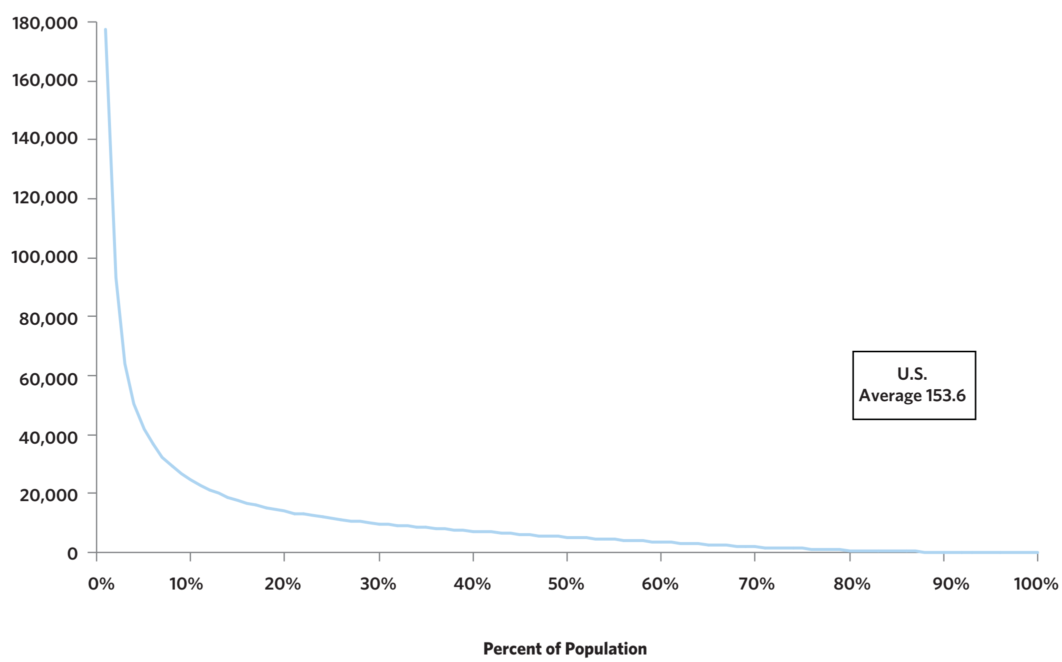
Number and location of the unserved

Once the availability of each network technology is determined at the census block level, we determine the highest speed broadband service available for each census block nationwide. Using this speed availability data and the national broadband target, we are able to determine what census blocks are currently "unserved." Then using census data for each block, we are able to determine the number of unserved housing units along with the demographic characteristics of the unserved.

Due to higher network costs per home passed, most of the unserved are located in less dense and/or rural areas. Although more sparsely populated states tend to have a larger portion of residents that are unserved, nearly every state has unserved areas. When examining the population density of the entire United States as in Exhibit 2-C, not just the unserved, one can see that a large portion of the population lives in areas of relatively low population density.

The average population density of populated census blocks in the United States is 153.6 people per square mile, though approximately three quarters of the population lives in areas of lower density. Unserved census blocks have a much lower density, with an average of only 13.8 people per square mile. The population density of the unserved follows a similar pattern to that of the country, with some areas being far more rural than others (see Exhibit 2-D). These areas of extremely low

Exhibit 2-C: Population Density of the United States, Per Square Mile of Inhabited Census Block



population density are some of the most difficult and expensive areas to serve.

The U.S. Census Bureau has categorized areas as urban areas, urban clusters and all other areas. Exhibit 2-E shows statistics of the unserved in terms of these definitions. As we can see, the deployment problem is one that predominantly exists outside of urban areas.

Since fixed broadband connects homes, not people, and most broadband networks are built along roads, either buried or on telephone/electric poles, an even more important driver of the cost to serve rural areas than population density is the number of road miles per housing unit of an area. Areas with more road miles per housing unit are even more likely to be unserved than areas of low population density. This is because the few homes in a rural area are sometimes clustered, which would decrease the number of road miles as well as the cost to serve.

The average number of road miles per housing unit in the United States is 0.07, which is much lower than the average unserved area of 0.41. But the average does not tell the whole story. A small portion of the population lives in areas with very high road-mile-to-housing-unit ratio, which tend to be the areas of the country that are unserved. Even within those unserved areas, there are portions that have an extremely high number of road miles per housing unit, which will be far more costly to serve than others. See Exhibits 2-F and 2-G.

Given the fact that the unserved are overwhelmingly in rural areas, one might expect that the unserved are in the territories of rural telecom companies. In fact, this is not the case: 52% of unserved housing units are in census blocks where one of the three Regional Bell Operating Companies, or RBOCs, (AT&T, Qwest or Verizon) is the dominant local exchange carrier; an additional 15% of unserved housing units are in census blocks

Exhibit 2-D:
Population Density of the Unserved, Per Square Mile of Inhabited Census Block

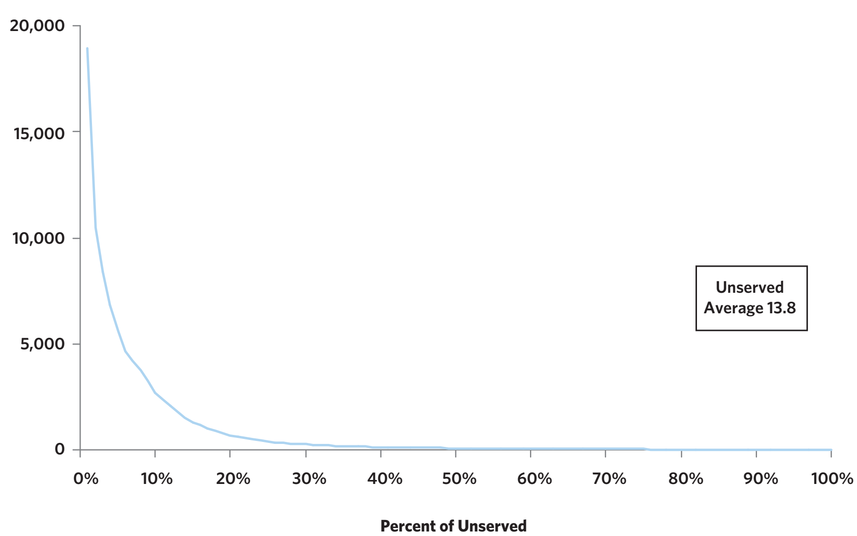


Exhibit 2-E:
Statistics of Urban Areas/ Clusters, and All Other Areas

Categories	AveragePeople/Sq. Mile	% of Population Unserved	# of Unserved Housing Units	Total Housing Units
Urban Areas/Clusters	2,900	1%	.7M	100M
All other areas	19	20%	6.3M	30M
Total	153.6	5%	7.0M	130M

Numbers do not sum due to rounding.

where a mid-size price-cap carrier is the dominant provider.[2] Only one-third of housing units are in census blocks where a rate-of-return carrier is the dominant provider.

Location of network infrastructure

We model each broadband network type independently to ensure a comprehensive view of infrastructure availability. Knowing where each type of network is currently deployed gives us the ability to calculate the incremental costs to upgrade the performance of an existing network as well as determine the likely location of middle and second mile fiber[3] that could be used to calculate the costs of deploying a new network.

There is a lack of comprehensive and reliable data sufficiently granular for the analysis we have described. To estimate the current state of broadband capable networks, we use the best available commercial and public data sources that meet our granularity, budget and timing requirements. We use infrastructure and speed availability data from a handful of states that were collected prior to the National Telecommunications and Information Administration (NTIA) mapping effort that is currently underway.[4] After evaluating numerous commercial data sets, we license the subset that best meets our needs.[5] We also examine Form 477 data and Form 325 data collected by the FCC but ultimately determine that these data are insufficiently granular.

The NTIA mapping effort will be complete in early 2011, and along with further revisions of the Form 477 data, they may be useful in refining our models in the future, but this will depend on the granularity of the data collected.

Network technologies modeled

The following sections include a description of our approach, data sources used, assumptions and risks for each of the three network technologies we modeled: cable, telco and wireless.

Cable

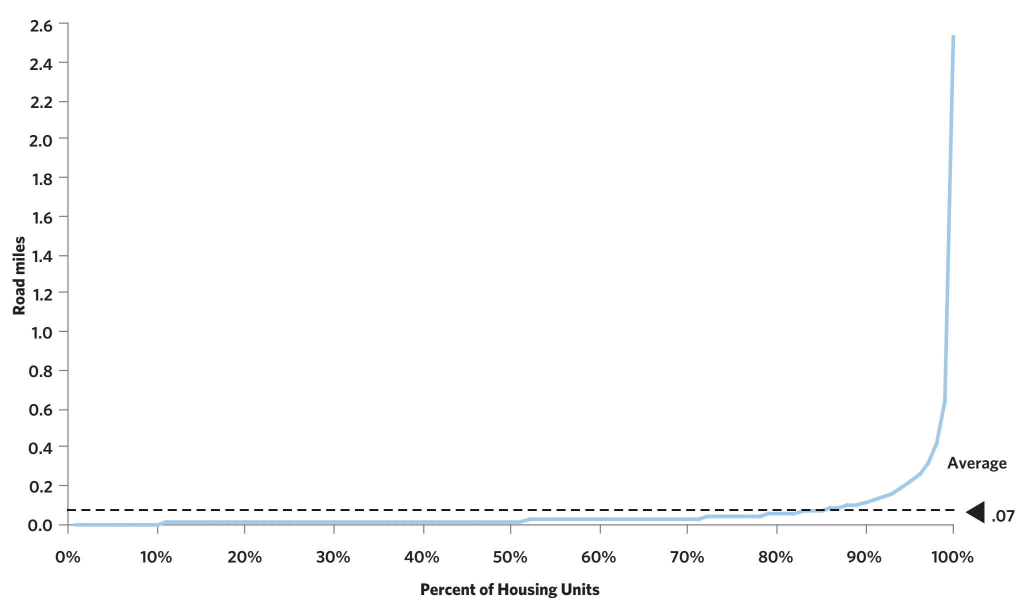
In order to determine broadband performance availability and infrastructure locations for cable networks, we use network availability data and estimated infrastructure locations based on cable engineering principles.

Data sources

In order to identify areas where cable broadband networks are located we license availability data from a commercial source[6] and collect publicly available infrastructure data from the state of Massachusetts.

We license a commercial data set from Warren Media called MediaPrints that provides data about nationwide availability of cable networks.[7] This data set includes geographic franchise boundaries as well as network capability information for cable

Exhibit 2-F:
Linear Density of the United States, Ratio of Road Mile to Housing Units



Road miles per housing unit of inhabited census blocks operators nationwide. We use network capability information to exclude franchise areas where operators are still operating networks that have not been upgraded to provide two-way broadband access— i.e., we rely on a field indicating that the cable operator provides Internet services. Without detailed data on the specific services offered by each cable system, we have to make assumptions about one-way and two-way cable plant. We assume that all two-way cable plant is DOCSIS-enabled since we estimate the incremental revenue of providing broadband would likely exceed the DOCSIS upgrade costs once a cable network has been upgraded to two-way plant. We assume that the cost of upgrading areas with one-way cable to a network that supports broadband is equal to a greenfield build (i.e., we treat areas with one-way cable plant the same way we treat areas unserved by cable). We are also aware that MediaPrints may not include every cable network, but we believe the ones it excludes are smaller and are more likely to be one-way plants.

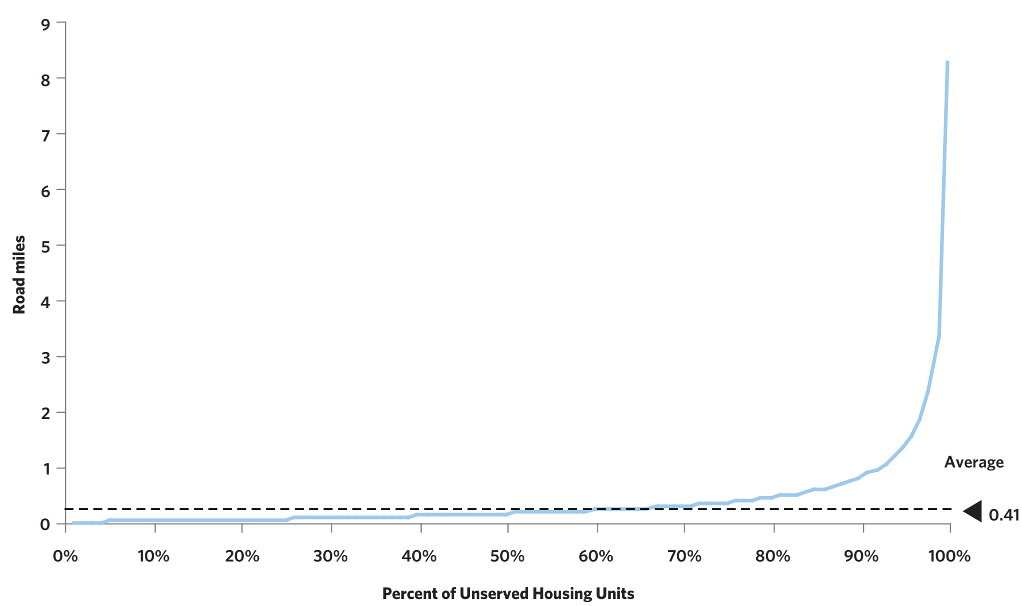
Another limitation is that the MediaPrints data do not allow us to distinguish between areas that have been upgraded from DOCSIS 2.0 to DOCSIS 3.0. In the absence of a data source that identifies the areas where DOCSIS 3.0 has been rolled out, we resort to mapping only the markets where we were able to find public announcements about DOCSIS 3.0 deployments at the time of analysis. This method understates the number of homes passed by DOCSIS 3.0 especially since the DOCSIS 3.0 rollouts proceeded quickly even as the analysis continued. But given that DOCSIS 2.0 areas exceed the broadband target speed of 4 Mbps download and 1Mbps upload, this underestimation does not affect the number of unserved or, therefore, the Investment Gap.

We are not able to acquire cable infrastructure data aggregated by any commercial or public source other than in the state of Massachusetts. These data are of limited use in the state of Massachusetts and, as we explain below, are of limited value for our nationwide analysis.

Risks

As stated previously, we may underestimate the number of housing units served in some areas since MediaPrints does not have data for every cable system, but we believe this number is small. This underestimation may be balanced by the fact that broadband availability is likely slightly overstated in the areas where MediaPrints has franchise data; this is due to the fact that cable operators do not typically build out service to every housing unit in their franchise area. We do not believe this overestimation to be significant because even large cable operators with large franchise areas tend to build out broadband to the vast majority of homes passed.[8] See Exhibit 2-H.

Exhibit 2-G: Linear Density of the Unserved, Ratio of Road Miles to Housing Units



Road-miles-per-housing-unit of uninhabited census blocks

We attempt to correct for this overestimation by comparing the MediaPrints franchise boundaries with actual cable strand maps from the state of Massachusetts.[9] In Massachusetts, operators must provide strand maps to the franchise board, which then publishes them into the public record. Unfortunately, with limited actual information available, we are unable to do a comprehensive comparison. As a result, there is not a pattern to the overestimation that could be applied nationwide.

Capabilities

As discussed in the section on hybrid fiber-coaxial (HFC) technology later in this document, we assume broadband-enabled cable networks are capable of delivering at least 10 Mbps actual download speeds, and those that have been upgraded to DOCSIS 3.0 are assumed to deliver 50 Mbps actual download.

Telco

Since we are not able to acquire a nationwide data set of either availability as a functon of broadband speed or telco infrastructure, we have to take a different approach to model telco. For telco networks we take a five-step approach to calculating availability nationwide:

1. Map availability data in areas where these data are available
2. Use telco infrastructure and engineering assumptions to estimate availability in areas where infrastructure data are available
3. Create a multivariable regression equation using demographic data (the independent variables) to predict broadband availability (the dependent variable), using states where availability data are available as sources for the regression
4. Apply regression equation to areas of the country where only demographic data exist to estimate speed availability
5. Use engineering principals and assumptions to infer infrastructure for estimated speed availability

Data sources

Although a nationwide data set of broadband availability consistent with the 4 Mbps download target is not available, there are a few states that have published availability data at different performance levels. The analysis relies on availability data from the states of California, Minnesota and Pennsylvania, and a combination of availability and infrastructure data is used from the states of Alabama and Wyoming.[10]

Some nationwide telco infrastructure data are used in conjunction with engineering principles and performance availability to more accurately estimate infrastructure locations. These data include locations of telco network nodes, such as central offices and regional tandems, from the Telcordia's LERG database, wire center boundaries from TeleAtlas and location of fiber infrastructure from GeoTel and GeoResults.

In addition to performance availability data and infrastructure data, demographic data are in the regression. These data are based on census forecasts from Geolytics for consumers and GeoResults for businesses.

We are forced to use a statistical model for telco plant because we are not able to acquire a nationwide data source of availability or telco infrastructure locations. An ideal data set for these purposes would focus on actual speed available (not on demand or subscribership), would be geographically granular (to distinguish among service speeds at longer loop lengths) and would provide information about the location of infrastructure (to feed into the economic model).

Unfortunately, no available data source meets all these requirements. Telcordia states that the CLONES database has the locations of all relevant telco infrastructure nationwide, but the FCC was not able to negotiate mutually agreeable license terms.

Data from the FCC's Form 477 are useful for many types of analysis; but, given that Form 477 data are collected at the census tract level, they are not granular enough to accurately estimate service availability and speed as noted in the September 2009 Open Commission Meeting. In the upper left

Exhibit 2-H: Cable Broadband Deployment for a Few Large MSOs as a Percentage of Homes Passed

Company	Cable Broadband Deployment (as of March 31, 2009)	Homes Passed (Millions)	Percent of Cable Homes Passed
Cablevision	100.0%	4.8	4%
Charter	94.9%	11.3	9%
Comcast	99.4%	50.6	40%
Mediacom	100.0%	2.8	2%
TWC	99.5%	26.8	21%

of Exhibit 2-I, we create an example of what perfect information on availability might look like. However, as noted in the lower left, Form 477 data provide information about the number of subscribers at a given speed, not the availability of service. Therefore, using Form 477 data to estimate availability requires making several assumptions as noted in the upper right of the exhibit. The result of these assumptions, as noted in the lower right, is that we are likely to overestimate the availability of service by relying on data collected at the census-tract level.

The ongoing efforts by states to map broadband availability, as coordinated by the NTIA as part of the Broadband Data Improvement Act[11] and funded by the Recovery Act,[12] may lead to a nationwide availability map that will be useful in this type of analysis, but the map will not be available until early 2011.

Statistical modeling where data did not exist

To estimate availability where no actual performance availability or infrastructure data exist, we create a regression equation that represents the relationship between demographic data and broadband availability data. The multivariable regression is based on more than 100 variables from population density to income levels to education levels. After determining how best to express the variables (in many cases by using their logarithms), initial models are estimated at all target speeds (ranging from 768 kbps to 6.0 Mbps) for each census block, using both forward and backward stepwise logistic regression. We use a logit regression rather than continuous so that we could use different variables and different weightings for each of the target speeds. Separate regressions are made for different speeds (768 kbps, 1.5 Mbps, 3.0 Mbps, 4.0 Mbps and 6.0 Mbps) inside and outside the cable franchise boundaries, for a total of 10 logit regressions. Accuracy rates among the 10 models were typically between 80% and 90%. Additional information on development of these statistical equations can be found in Attachment 4 of CostQuest Model Documentation.

We then use that series of statistical equations to predict broadband availability (from telco networks) at different speeds in each census block based on their demographics. This availability estimate is used to help determine what census blocks are unserved. Next, we estimate the location of network infrastructure necessary to provide that predicted level of service according to the approach outlined below. The network infrastructure location information generated by this current state model is fed into the economic model so the costs of upgrading and extending networks can be estimated accurately.

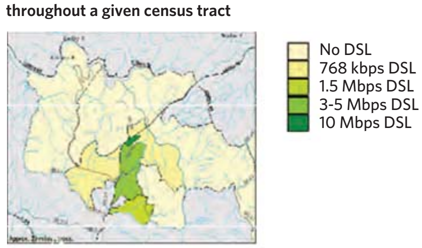
Risks

As with any statistical method, there will be errors (either over- or under-predicting the availability at a given speed) in any single, particular, small geography. However, we believe the results should be correct in aggregate. Even though we are able to achieve accuracy rates between 80% and 90% when we apply the regression to areas of known performance, the main risk in this approach is the possibility of systematic differences between the states for which we have data and the states for which we do not.

Since the statistical regression relies on a small number of states, to the extent that the tie between demographics and

Exhibit 2-I: Assumptions Required to Use Tract-Level Data Likely Overestimate Availability

It is **unlikely that service is evenly distributed** throughout a given census tract



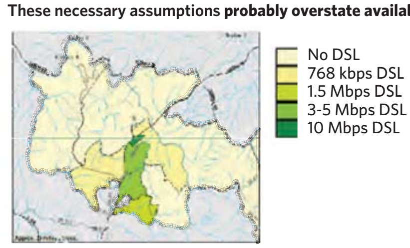
Form 477 was **not designed to address this distribution question**

Census tract	Housing Units	Total ADSL subs	ADSL: 768k–1.5Mbps	ADSL: 1.5–3.0Mbps	...
3749265	1,229	208	6	97	

As a result, minimal **assumptions are necessary** in order to make any estimate

1. Service available anywhere in a tract is available to every housing unit (HU) in that tract
2. The speed provided to the highest-speed HU in each tract is available to every HU in that tract

These necessary assumptions **probably overstate availability**



Sources: Census Bureau; March 2009 Form 477 data; OBI analysis network availability in the rest of the country is not the same as these states, the regression will not be accurate. The states we used in our analysis have a wide variety of rural and urban areas and have varied geographic challenges which are advantageous, but there is no way to verify our outputs without additional data.

Aligning infrastructure with availability data

We estimate the current state of broadband-capable networks using speed availability data and infrastructure data. In the areas where we have infrastructure data we use engineering assumptions to estimate speed availability. In areas where we have availability by speed we use engineering assumptions to estimate the likely location of infrastructure. In this way we are able to estimate both availability by speed and infrastructure locations nationwide.

Exhibit 2-J illustrates these two approaches. On the right-hand side is an illustration of determining speed availability from infrastructure. Imagine that data indicate the presence of a Digital Subscriber Line Access Multiplexer (DSLAM) at No. 1. Using the location of the DSLAM as a starting point, we can trace out a distance along road segments that corresponds to availability for a given speed; for 4 Mbps service, that distance is approximately 12,000 feet.

On the left-hand side is an illustration of determining infrastructure from speed availability. Imagine that we have data for the area shaded in blue that indicates it has 4 Mbps DSL. We know then that homes can be a maximum of 12,000 feet from a DSLAM. Standard engineering rules, combined with clustering and routing algorithms, allow the model to calculate the likely location of efficiently placed infrastructure. See CostQuest Model Documentation for more information.

Wireless

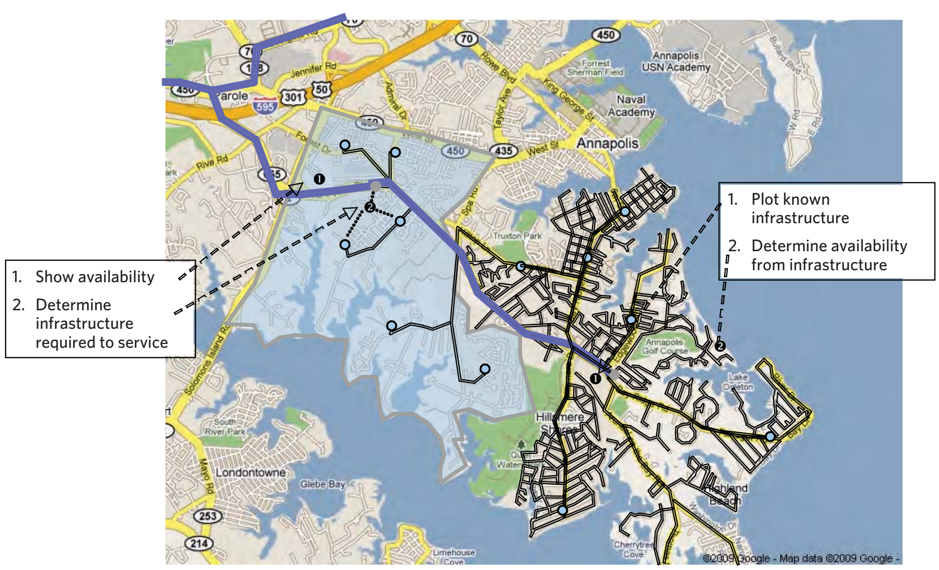
We rely on a nationwide data set of performance availability for wireless networks as well as infrastructure data in the form of tower site locations. With these two data sets we are able to estimate current availability as well as potential infrastructure locations that could be used to deploy into unserved areas. We do not create a full propagation model but rather, rely on coverage data to determine availability.

Data sources

In order to identify areas where wireless networks are located, we license a commercial data set from American Roamer. This data set provides wireless coverage by operator and by network technology deployed. The wireless technology deployed allows us to estimate the speeds available. As noted in the National Broadband Plan, American Roamer data may overstate coverage actually experienced by consumers as they rely on advertised coverage as provided by many carriers, who may all use different definitions of coverage. These definitions may differ on signal strength, bitrate or in-building coverage.

American Roamer only recently started mapping Wireless Internet Service Providers (WISP) coverage and estimates it has mapped only 20% of WISPs. We do not include WISP coverage in our model due to the current scarcity and reliability of the data.

Exhibit 2-J:
Aligning Infrastructure with Availability



Like telco infrastructure, wireless infrastructure location information (typically towers) is fed into the economic model so the costs of upgrading and extending networks can be calculated accurately. We used Tower Maps data to identify the location of wireless towers in unserved areas that could be used for fixed wireless deployments.

Risks

We potentially overstate the current footprint because what is commercially available is typically based on carrier reported data, perhaps at relatively low signal strength. Overstating the current footprint could lead us to underestimate the cost of future wireless build outs to provide service to the areas currently unserved.

FUTURE STATE

We do not expect the number of unserved housing units to decline materially between now and 2013. Our analysis indicates that most unserved areas are NPV negative to serve with broadband, and so we have made the conservative assumption that there will be few new or upgrade builds in these areas. While significant investments are being made to upgrade the speed and capacity of broadband networks, those investments tend to be made in areas that are already well served. Moreover, those network upgrades are not ubiquitous throughout currently served areas. Therefore, as applications become more advanced and higher performance networks are required—i.e., if the broadband target grows significantly over time—the number of people with insufficient broadband access may actually increase.

Wired network upgrades

Both telephone and cable companies are upgrading their networks to offer higher speeds and greater-capacity networks. Cable companies are upgrading to DOCSIS 3.0, which will allow them to transfer to broadband some of the network capacity that is currently used for video. Telephone companies are extending fiber closer to end-users, in some cases all the way to the home, in order to improve the capacity and speed of the network. Besides providing a faster, higher-capacity broadband network, once fiber is within approximately 5,000 feet of the home, the network has the ability to offer multi-channel video services in addition to broadband and voice.

The Columbia Institute for Tele-Information recently released a report called "Broadband in America" in which it tried to identify as many of the major publically announced network upgrades as possible. Verizon has announced that it plans to pass 17 million homes by 2010 with its fiber-to-the-premises (FTTP) service called FiOS.[13] Many other small incumbent local exchange carriers (ILECs) also plan to aggressively build FTTP networks where it makes financial sense.[14] AT&T has announced that it will build out FTTN to 30 million homes by 2011.[15] This means that at least 50 million homes will be able to receive 20 Mbps+ broadband from their local telco within the next two years. The cable companies have also announced upgrades to DOCSIS 3.0 over the next few years with analysts predicting cable operators will have DOCSIS 3.0 covering 100% of homes passed by the end of 2013.[16] Exhibit 2-K highlights some of the major publicly announced upgrades to wired broadband networks.

As shown in Exhibit 2-L, for proven technologies, when operators publically announce plans to upgrade their network, they tend to complete those builds on time.

Using these public announcements and our current availability assessment, we create a forecast of wired broadband availability in 2013. We assume that FTTP and upgrades will take place in markets with cable that will be upgraded

Exhibit 2-K: Publicly Announced Wired Broadband Upgrades

Technology	Companies	2009	2010	2011
FTTP	• Verizon • Cincinnati Bell • Tier 3 ILECs	• All providers (17.2MM—as of Sept) • Verizon FiOS (14.5MM– as of June)	• Verizon FiOS (17MM)	
FTTN	• AT&T • Qwest	• Qwest (3MM)	• Qwest (5MM)	• AT&T U-verse (30MM)
DOCSIS 3.0	• Comcast • Cablevision • Cox • Knology • Time Warner • Charter • Mediacom • RCN	• Comcast (40MM) • Charter (St. Louis) • Mediacom (50% of footprint) • Knology (50% of footprint) • RCN (begin deployment)	• Comcast (50MM) • Cablevision (entire footprint) • Cox (entire footprint) • Time Warner (New York City) • Knology (entire footprint)	

Exhibit 2-L:
With the Exception of Satellite, Most Announced Broadband Deployments are Completed on Schedule

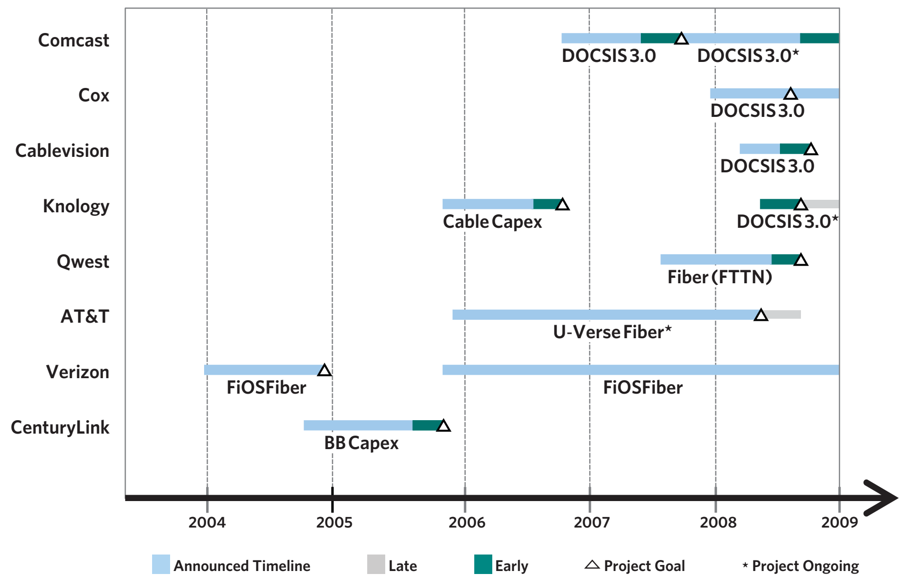
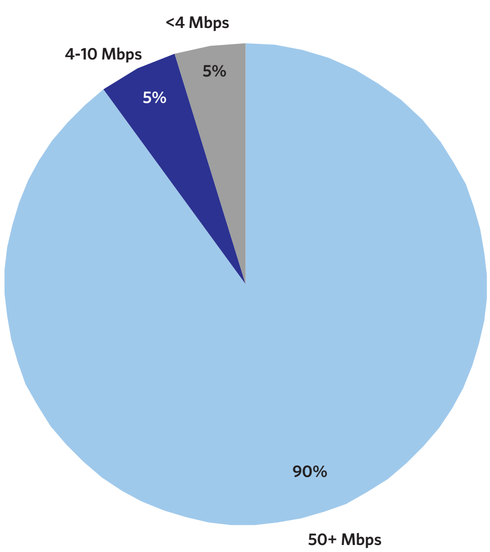


Exhibit 2-M:
Projected 2013 Availability of Broadband Capable Networks



Fastest downlink speed capability of broadband networks
Percent of U.S. population with network availability, Mbps

to DOCSIS 3.0. Therefore, as Exhibit 2-M shows, all of the announced upgrades will likely take place in areas that were already served. Without government investment, the difficult-to-reach areas will remain unserved while the rest of the country receives better broadband availability.

Wireless network upgrades

The wireless broadband networks are still in the nascent stages of development and continue to evolve rapidly with new technologies, applications and competitors.

Many operators still have significant areas covered by 2G technologies but have already announced upgrades to 4G data networks. Mobile operators are investing heavily in network upgrades in order to keep pace with exploding demand for mobile data services.

By 2013, Verizon plans to roll out Long Term Evolution (LTE) technology to its entire footprint, which covered 288 million people at the end of 2008.[17] AT&T has announced that it will undertake trials in 2010 and begin its LTE rollout in 2011. Through its partnership with Clearwire, Sprint plans to use WiMAX as its 4G technology. WiMAX has been rolled out in few markets already and Clearwire announced that it plans to cover 120 million people by the end of 2010.

For well-known technologies, when operators publically announce plans to upgrade their network, they tend to complete those builds on time. However, as was the case with WiMAX, when a technology is still being developed, technological issues can significantly delay planned deployments. LTE is an example of a new wireless technology that has not been deployed yet commercially on a wide scale so we must be cautious about planned deployment schedules.

As we discuss later in this document these commercial 4G build outs may not fully meet the National Broadband Availability Target without incremental investment; but the commercial investments in these deployments will certainly improve the incremental economics of 4G fixed wireless networks in those areas.

Due to the lack of geographic specificity and overlapping coverage areas we were not able to precisely forecast future wireless coverage speeds that will be available in years to come based on public announcements.

Satellite network upgrades

The capacity of a single satellite will increase dramatically with the next generation of high throughput satellites (HTS) expected to be launched in the next few years. ViaSat Inc., which acquired[18] WildBlue Communications in December 2009, and Hughes Communications Inc. plan to launch HTS in 2011 and 2012, respectively.[19] [20] These satellites each will have a total capacity of more than 100 Gbps, with some designated for upstream and some for downstream. After the launch of the new satellites, ViaSat expects to offer 2-10 Mbps downstream while Hughes suggests it will offer advertised download speeds in the 5-25 Mbps range.[21] Despite this additional capacity, our analysis suggests it will be insufficient to address more than 3.5% of the unserved. See Chapter 4 on satellite.

Conclusion

While such investments in technology and broadband networks may help bring faster speeds to those who are already served, and could potentially reduce the average cost per subscriber, it is far from certain that they will decrease the number of unserved.

Exhibit 2-N:
Publicly Announced 4G Wireless Deployments

Technology	Companies	2009	2010	2011	By 2013
LTE	• Verizon • AT&T • MetroPCS • Cox		• Verizon (100MM) • AT&T (Trials)	• AT&T (start deployment) • Cox (start deployment) • MetroPCS (start deployment)	• Verizon (entire network)
WiMAX	• Clearwire • Open Range • Small WISPs	• Clearwire (30MM) • WISPs (2MM)	• Clearwire (120MM)		• Open Range (6MM)

Exhibit 2-O:
Specific Company Historical Performance Against Announced Completion Dates

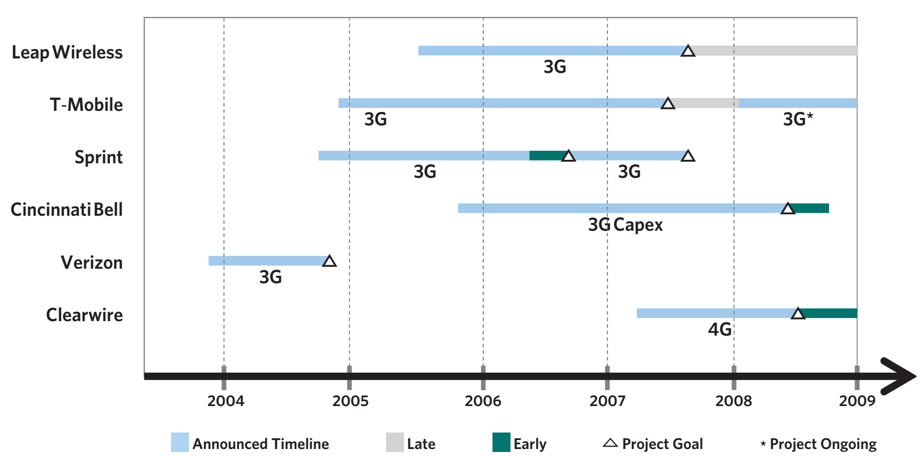


Exhibit 2-P:
Publicly Announced Total Near Term Satellite Broadband Capacity[22]

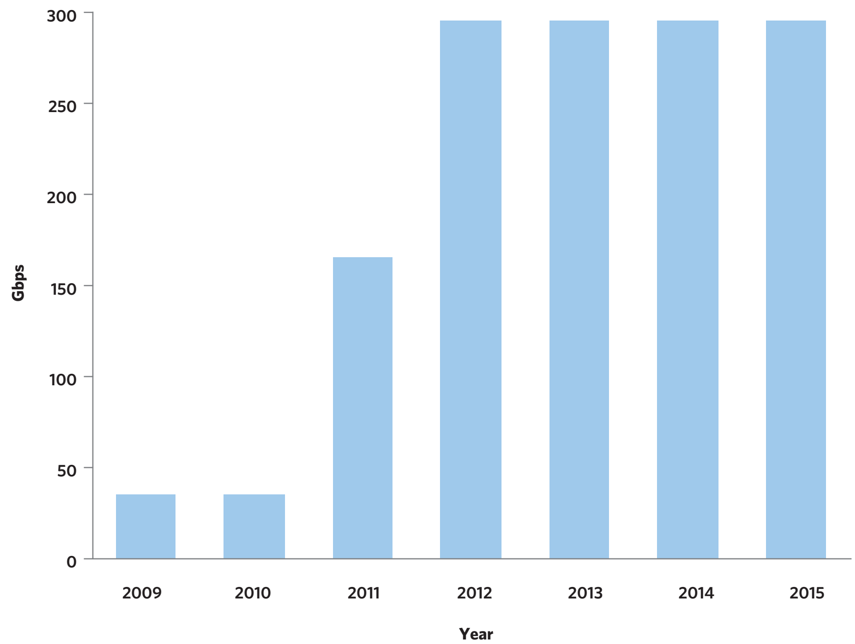


Exhibit 2-Q:
Commercial Data Sources Used to Calculate Availability

Vendor	Database	Use
American Roamer	Advanced Services	Wireless service footprint
Geolytics	2009 block estimates	Block level census estimates
	Estimates professional	Block group level estimates
GeoResults	National Business Database	Fiber served building (flag); business locations and demographics
GeoTel(imap)	MetroFiber	Metro Fiber Routes (GDT and Navteq)
	LATA Boundaries	Used for middle mile map to group switches into latas
	Fiber Lit Buildings (point)	Used to flag wire center boundaries as likely having fiber infrastructure
Telcordia	LERG	Switch office locations
TeleAtlas	Wire center boundaries	Wire center boundaries, domswitch, OCN, carrier name
	Zip code boundaries	Zip code boundaries
Tower Maps		Location of towers and sites
Warren Media	Warren Media	Cable-franchise boundary (by block group)

Exhibit 2-R:
Public Data Sources Used to Calculate Availability

Data Source	Database	Location
Alabama	State broadband availability	http://www.connectingalabama.com/ca/maps.aspx <http://www.connectingalabama.com/ca/maps/CBResults072909.zip>
California	State broadband availability	ftp://ftp.cpuc.ca.gov/Telco/Existing_Broadband_Service_Aggregated_072409.zip
Pennsylvania	State broadband availability	Available from Technology Investment Office
Minnesota	State broadband availability	Available from Technology Investment Office
Wyoming	State broadband availability	Available from State CIO
US Census	Tiger 2008	Blocks, Counties, Roads, Block Group Boundaries
	SF1	Summary File 1, US Census 2000
	SF3	Summary File 3, US Census 2000
FCC	Varies	Market Data Boundaries (adjusted for Census County Updates)
NECA	Tariff 4	PDF as filed 9/2009
Congressional Districts	110 Congress	http://www.nationalatlas.gov/atlasftp.html?openChapters=chpbound#chpbound

CHAPTER 2 ENDNOTES

1 DOCSIS 2.0 is capable of delivering ~10 Mbps, while DOCSIS 3.0 is capable of delivering ~50 Mbps. FTTN and FTTP can offer speeds well over 6 Mbps; however, the statistical-regression methodology used to estimate availability as a function of speed, combined with the source data for that regression, do not allow us to make estimates for telco-based service above 6 Mbps. *See* the Telco portion of this section for more detail.

2 Mid-size carriers include Alaska Communications Systems, CenturyLink, Cincinnati Bell, Citizens Communications, Consolidated Communications, FairPoint Communications, Hawaiian Telecom, Iowa Telecom and Windstream.

3 *See* Exhibit 4-BT for a description of middle versus second mile.

4 The Broadband Data Improvement Act (BDIA), Pub. L. No. 110-385, 122 Stat. 4096 (2008).

5 *See* Exhibits 2-Q and 2-R for a complete list of licensed data that we used.

6 *See* Warren Media MediaPrints database, http://www.mediaprints.com/index.htm (accessed Aug. 2009) (on file with the FCC) (Warren Media database).

7 *See* Warren Media MediaPrints database

8 ROBERT C. ATKINSON & IVY E. SCHULTZ, COLUMBIA INSTITUTE FOR TELE-INFORMATION, BROADBAND IN AMERICA: WHERE IT IS AND WHERE IT IS GOING (ACCORDING TO BROADBAND SERVICE PROVIDERS) at 57 (2009) (“CITI BROADBAND REPORT”), available at http://www4.gsb.columbia.edu/citi/.

9 Massachusetts General Laws Chapter 166A § 4 states, in part: “each applicant shall set forth as completely as possible the equipment to be employed, the routes of the wires and cables, the area or areas to be served.” Upon its own investigation (Investigation of the Cable Television Division of the Department of Telecommunications and Energy on its Own Motion to Review the Form 100, CTV 03-3, November 30, 2004), the department (which became known as the “Department of Telecommunications and Cable” in April 2007) found, in part, at pages 18-19, that the statutory requirement referred to above is meant to promote “general use,” and finds that “a strand map identifying the presence and location of the cable system within a specific community is sufficient to satisfy the statutory requirement.” This order also finds that an issuing authority (a municipality) may request more detailed, technical information about a cable system than the cable plant map is required for general use, provided it is willing to enter into a non-disclosure agreement with the cable operator if requested.

10 Infrastructure data were not accessed by the FCC directly but were analyzed for the FCC by a contractor with access to these data.

11 The Broadband Data Improvement Act (BDIA), Pub. L. No. 110-385, 122 Stat. 4096 (2008).

12 American Recovery and Reinvestment Act of 2009, Pub.L. No. 111-5, § 6001(k)(2)(D), 123 Stat. 115, 516 (2009) (Recovery Act).

13 CITI BROADBAND REPORT AT 7.

14 CITI BROADBAND REPORT AT 7.

15 CITI BROADBAND REPORT AT 7.

16 T. McElgunn, “DOCSIS 3.0 Deployment Forecast,” Pike & Fischer, 2009.

17 CITI BROADBAND REPORT AT 8.

18 On October 1, 2009, ViaSat announced it had signed a definitive agreement to acquire privately held WildBlue. On December 15, 2009, ViaSat announced the completion of the announced acquisition; see ViaSat, WildBlue Communications Acquisition Closes, http://www.viasat.com/news/wildblue-communications-acquisition-closes (last visited Feb. 12, 2010).

19 Letter from Mark Dankberg, Chairman & CEO, ViaSat, to Blair Levin, Executive Director of OBI, FCC, GN Docket Nos. 09-47, 09-51, 09-137 (Jan. 5, 2010) (“ViaSat Jan. 5, 2010 Ex Parte”) at 2.

20 Letter from Stephen D. Baruch, Counsel for Hughes Communications, Inc., to Marlene H. Dortch, Secretary, FCC (Oct. 26, 2009) (“Hughes Oct. 26, 2009 Ex Parte”) at 6.

21 CITI BROADBAND REPORT AT 57.

22 Note that this forecast only includes publicly announced launches and not additional, planned launches that are likely. *See* Northern Sky Research, How Much HTS Capacity is Enough? (2009), http://www.nsr.com/AboutUs/PressRoom.html (last visited Jan. 20, 2010).

III. CALCULATING THE INVESTMENT GAP

To calculate the amount of money required to offer service in areas that would otherwise remain unserved, we must make a number of decisions about how to approach the problem, design an analysis that accurately models the problem and make a number of assumptions to conduct the analysis. To this end, we created an economic model to calculate the lowest amount of external support needed to induce operators to deploy broadband networks that meet the National Broadband Availability Target in all unserved areas of the country.

KEY PRINCIPLES

The FCC developed its broadband economic model to calculate the gap between likely commercial deployments and the funding needed to ensure universal broadband access. Underlying the model's construction are a number of principles that guided its design.

- **Only profitable business cases will induce incremental network investments.**
- **Investment decisions are made on the incremental value they generate.**
- **Capturing the local (dis-)economies of scale that drive local profitability requires granular calculations of costs and revenues.**
- **Network-deployment decisions reflect service-area economies of scale.**
- **Technologies must be commercially deployable to be considered part of the solution set.**

Only profitable business cases will induce incremental network investments. *Private capital will only be available to fund investments in broadband networks where it is possible to earn returns in excess of the cost of capital. In short, only profitable networks will attract the investment required. Cost, while a significant driver of profitability, is not sufficient to measure the attractiveness of a given build; rather, the best measure of profitability is the net present value (NPV) of a build. This gap to profitability in unserved areas is called the Broadband Availability Gap in the NBP; throughout this paper, we will refer to this financial measure as the Investment Gap.*

The calculation of the $23.5 billion Investment Gap is based on the assumption that the government will not own or operate the network itself, but rather will provide funding to induce private firms to invest in deploying broadband. This is primarily because private firms can provide broadband access more efficiently and effectively due to their ownership of complementary assets and experience in operating networks. By subsidizing only a portion of the costs, the government provides the markets with the incentive to continue to innovate and improve the efficiency of buildouts and operations. In addition, since private firms will be investing a significant portion of the costs, the amount of public money required is greatly reduced.

Simply calculating the incremental costs of deploying broadband is not enough to determine the Broadband Investment Gap necessary to encourage operators to deploy. To ensure that firms seeking an adequate return on their invested capital will build broadband networks in unprofitable areas, we solve for the amount of support necessary to cause the networks' economics to not only be positive, but to be sufficiently positive to motivate investment given capital scarcity and returns offered by alternative investments.

The model assumes an 11.25% discount rate; by calculating the NPV gap as the point where NPV = 0, we equivalently set the internal rate of return (IRR) of these incremental broadband buildouts to 11.25%. This rate is the same one determined by the FCC in 1990 to be an appropriate rate for telecom carriers earning a rate of return on interstate operations.[1]

In order to determine the level of support needed to encourage operators to build broadband networks, we identify the expected cash flows associated with building and operating a network over the project's lifetime of 20 years. Next, we compute the NPV of those cash flows to arrive at the Investment Gap. In other words, the gap is the present value of the amount by which operators fail to produce an 11.25% IRR. It is important to note that ongoing expenses include incremental deployment and operational costs (initial capex, ongoing and replacement capex, opex, SG&A) as well as depreciation, cost of money and tax components for an incremental broadband investment; revenues include all incremental revenue from the modeled network with average revenue per user (ARPU) and take rates calculated as discussed below. As a result, when the NPV analysis yields a value of zero, it means that the project's revenues are sufficient to cover all expenses while providing a rate of return on invested capital of 11.25%.

In fact, if a carrier has a weighted-average cost of capital (WACC) above the 11.25% rate, even a guarantee to reach the 11.25% IRR would not cause it to build.

In contrast, if a carrier has a WACC lower than 11.25%, it will earn profits above the 11.25% IRR proportional to the size of the spread between WACC and discount rate. Having the IRR above WACC does not necessarily mean that operators are earning outsize returns, however. Since the support level is based on forecasts of both revenue and cost across the lifetime of the asset, carriers are taking on significant risk by investing or committing to invest in network maintenance and operations. The extent to which IRR provides returns in excess of WACC reflects the operational risk of providing service in unserved areas, where the economics are generally unfavorable. Service providers are likely to have other investment opportunities with strong risk-return profiles at their WACCs.

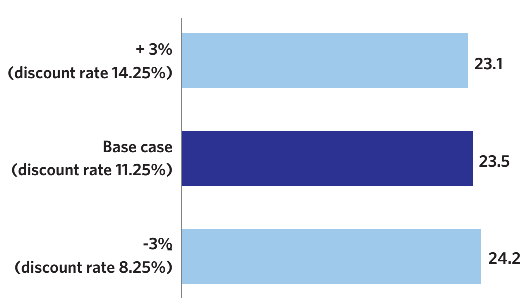
One result of this execution risk is that carriers with WACC below the 11.25% discount rate might tend to favor a guaranteed annuity over time that would lock in the 11.25% return. Receiving support as an upfront payment, either in whole or in part, would require the operator to take on this higher execution risk, making the investment potentially less attractive.

After receiving the one-time payment, the telecom operators can reinvest the funds in their operations. Investments that yield a return above 11.25% will result in an economic benefit to the telecom provider.

Since the operators in any specific area, their associated WACCs and the disbursement mechanism are all unknown at this point, we make the simplifying assumption that carriers will be indifferent to receiving an upfront one-time payment, a series of payments over time or a combination of the two.

While the discount rate typically has significant impact on the NPV of a project, in this case the impact is mitigated for two main reasons. First, initial capital expenditures, which take place at the start of the project and, therefore, are not discounted, account for 65.1% of the Broadband Investment Gap. Second, because revenue and ongoing costs offset one another to a large extent (see Exhibit 1-A), the impact of changes in the discount rate is small. As shown in Exhibit 3-A, even significant changes in the discount rate (of up to 300 basis points) yield modest changes in the base-case Investment Gap of less than $1 billion.

Exhibit 3-A:
Impact of Discount Rate on Investment Gap



Time horizon for calculations

Calculating the value of long-life investments such as fiber builds or cell-site construction requires taking one of two approaches: explicitly forecasting and modeling over the entire useful life of the asset, or calculating either the salvage value of remaining assets or the terminal value of operations. Although neither choice is optimal, we use a 20-year explicit model period, which corresponds to the long-life assets in broadband networks. We do not include any terminal or salvage value at the end of a shorter explicit forecast period.

Calculating the ongoing terminal value of operations in this context is challenging at best since the modeled cash flows never reach a steady state. As we note below, when describing key assumptions, the take rate grows across the entire calculation period, and levelized take rate for a five- or 10-year forecast dramatically understates the final take rate. The result is that a terminal value calculation will not accurately reflect the ongoing value generated by the investment. Consequently, we must explicitly model over the full 20-year life of the network assets. Although utilizing a 20-year forecast is not atypical for businesses making capital planning decisions, such forecasts obviously require making speculative long-range assumptions about the evolution of costs and revenues.

It is also worth noting that the calculation models the value of an incremental broadband network investment, not the value of the company. Consequently, we assume that at the end of the 20-year explicit period there is no substantial value remaining for two reasons. First, from the accounting perspective—and based on an estimate of actual useful life[2]—most of the assets have been fully depreciated, and those that have some value remaining only have value in a fully operating network. Second, from a technological perspective, it is unclear that there will be any incremental value from the existing 20-year-old network relative to a greenfield build.

Investment decisions are made on the incremental value they generate. *While firms seek to maximize their overall profitability, investment decisions are evaluated based on the incremental value they provide. In some instances, existing assets reduce the costs of deployment in a given area. The profitability of any build needs to reflect these potential savings, while including only incremental revenue associated with the new network buildout.*

The model takes existing infrastructure into account and only calculates the incremental costs and incremental revenues of deploying broadband. This means that in most areas the costs of offering broadband are the costs associated with upgrading the existing telco, cable or wireless network to offer broadband. Exhibit 3-B illustrates the incremental buildout for a telco network. This minimizes support and is consistent with how firms typically view the sunk costs of existing infrastructure.

The full cost of the network is necessary only in areas that require a greenfield build, i.e. in areas with a complete lack of infrastructure or when the greenfield build of one technology has a lower investment gap than upgrading an existing network. Revenues are treated the same way as costs. Only the incremental revenues associated with new services are used to offset costs in the calculation of the gap.

For example, millions of homes are already "wired" by a telephone network with twisted pair copper lines that provide voice telephony service. These telephone networks require only incremental investments to handle digital communications signals capable of providing broadcast video, broadband data services and advanced telephony. Incremental costs of upgrading these networks include investments in: fiber optic cable and optic/electronics in large portions of the copper plant, the replacement and redesign of copper distribution architecture within communities to shorten the copper loops between homes and telephone exchanges, the deployment of new equipment in the exchanges and homes to support high capacity demands of broadband, and sophisticated network management and control systems. The incremental revenues are the revenues associated with the newly enabled broadband and video services.

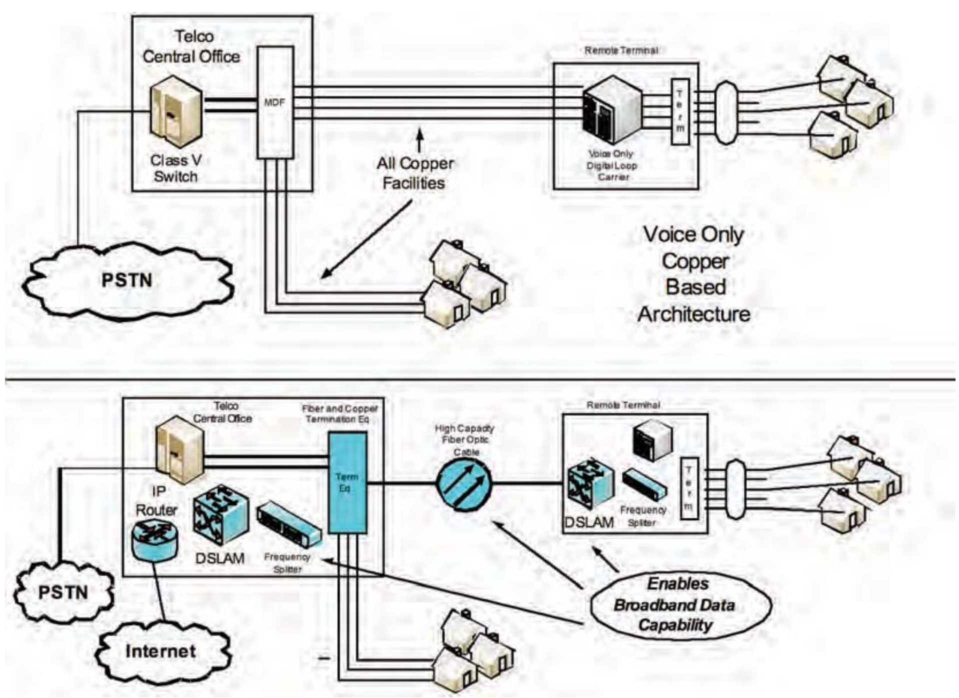
One issue with this approach is that it assumes that existing networks will be available on an ongoing basis. To the extent that existing networks depend on public support, such as USF disbursements, the total gap for providing service in unserved areas could be significantly higher than the incremental calculation indicates.

For the purposes of the financial model, we consider only incremental revenue, which is the product of two main components: the number of incremental customers and ARPU.

The number of incremental customers is based on the technology that is ultimately implemented. Throughout the modeling process, we take care to not "double-count" revenues for operators who upgrade their existing networks with broadband data or video capabilities. For example, if an incumbent telco decides to shorten loop lengths in order to deliver data and video services, only incremental data and video-related revenue should be considered. Incremental revenues from voice products will not be considered since those products are already being offered. Exhibit 3-C shows which products are considered to be incremental for each technology.

Capturing the local (dis-)economies of scale that drive local profitability requires granular calculations of costs and revenues. *Multiple effects, dependent on local conditions, drive up the cost of providing service in areas that*

Exhibit 3-B: Incremental Network Elements Necessary to Upgrade a Telephone Network to Offer Broadband



currently lack broadband: Lower (linear) densities and longer distances drive up the cost of construction while providing fewer customers over whom to amortize costs. At the same time, lower-port-count electronics have higher costs per port. In addition, these lower densities also mean there is less revenue available per mile of outside plant or per covered area.

Using the average cost per household of existing deployments, even when adjusted for differences in population density, presents a risk that costs may be underestimated in rural areas. Even when considering local population and linear densities, costs in many rural markets will be subscale, rendering inaccurate a top-down analysis of average costs. Attempting to calculate profitability without taking these variations into account—for example by extrapolating from cost curves in other areas—would necessarily lead to questionable, or even misleading, conclusions. Therefore, we take a bottom-up approach that provides sufficient geographic and cost-component granularity to accurately capture the true costs of subscale markets.

An example of this is evident when we consider the cost allocation of a digital subscriber line access multiplexer (DSLAM) chassis in an area with very low population density. If only one home is connected to the DSLAM, the entire cost of that DSLAM should be allocated to the home rather than a fraction based on the DSLAM capacity. In order to calculate the costs with this level of accuracy, we need geographic and cost-component granularity throughout. Accounting for granularity with respect to geography is particularly important because so many network costs are distance dependent. Calculations are needed at a fine geographic level; therefore, we model the census block as the basic geographic unit of calculation.[3]

Capturing cost-component granularity is important due to the fixed-cost nature of network deployments. For example, one must capture the costs associated with trenching fiber facilities, which are shared among many end-users, differently than the cost associated with line cards and installation, which may be directly attributed to a given customer. We provide more details about the cost calculations of each technology in Chapter 4.

Network-deployment decisions reflect service-area economies of scale. *Telecom networks are designed to provide service over significant distances, often larger than 5 miles. In addition, carriers need to have sufficient scale, in network operations and support, to provide service efficiently in that local area or market. Given the importance of reach and the value of efficient operations, it can be difficult to evaluate the profitability of an area that is smaller than a local service area.*

Though geographic granularity is important in capturing the real costs associated with providing broadband service in rural and remote areas, it does not make sense to evaluate whether to build a network at the census block level. Rather, the modeling needs to capture deployment decisions made at a larger, aggregated "service area" level.

Using the census blocks as a market is problematic for several reasons. First, telecom infrastructure typically has some efficient scale length associated with it. For wireless, that distance is the cell-site radius; for FTTN or DSL the distance is the maximum loop length.[5] These lengths are typically 1 to 3 miles for twisted pair copper and 2 to 5 miles for wireless towers, and span multiple census blocks. As a result, carriers will make deployment decisions based on larger areas.

From a modeling perspective, evaluation at the census block level is problematic as well. Evaluations of which technology has the lowest investment gap done at the census block level could lead to contiguous census blocks with a patchwork of different technologies that no company would actually build.

Even more problematic is that the cost in any one area is driven in part by the costs of shared infrastructure. For example, the cost of a fiber connecting several new DSLAMs to the local central office is shared among all the census blocks served by those DSLAMs. If wireless were found to be cheaper in one of those census blocks and one, therefore, assumed that one of those DSLAMs would not be deployed, the (allocated) cost of the fiber would increase for all remaining DSLAMs. That could lead to another block where wireless is made cheaper, again increasing the cost of the remaining DSLAMs.

Exhibit 3-C: Incremental Revenue by Product and Network Type

	Data	Voice	Video
Telco 12k	Yes	No	N/A
Telco 5k/3k/FTTP	Yes	No	Yes
Cable[4]	Yes	Yes	Yes
Wireless-Fixed	Yes	Yes	N/A
Wireless-Mobile (Non-4G)	Yes	Yes	N/A
Wireless-Mobile (4G)	No	No	N/A

There is no perfect solution to this problem. If the geography is too big there will be portions that would be more efficiently served by an alternate technology, but if the geography is too small it will be subscale, thereby driving up costs. Although the model is capable of evaluating at any aggregation of census blocks, in order to avoid a patchwork of technologies that are all subscale, we have evaluated the cost of technologies at the county level. Counties appear large enough in most cases to provide the scale benefits but not so large as to inhibit the deployment of the most cost-effective technology.

Note that this geography is also technology neutral since it is not aligned with any network technology's current footprint. No network technology boundaries line up exactly with those of counties. Cable networks are defined by their franchise area; wireless spectrum is auctioned in several different geographies, for example, by cellular market areas; and telco networks operate in study areas, LATAs or wire centers. Since the model is capable of evaluating at any aggregation of census blocks, it is possible to evaluate at more granular levels (where the patchwork problems become more likely) or at more aggregated levels.

Technologies must be commercially deployable to be considered part of the solution set. *Though the economic model is forward looking and technologies continue to evolve, the model only includes technologies that have been shown to be capable of providing carrier-class broadband. While some wireless 4G technologies arguably have not yet met this threshold, successful market tests and public commitments from carriers to their deployment provide some assurance that they will be capable of providing service.*

With the exception of 4G wireless, we only include technologies that are widely deployed and have proven they can deliver broadband. Although network technologies continue to advance, enabling operators to provide more bandwidth over existing infrastructure or to provide new services ever-more-cheaply, the promise surrounding technological innovation often outstrips reality.

To avoid a situation where we assume uncertain, future technological advances are essential to a particular solution—where the solution with the lowest investment gap is reliant on unproven technologies—this analysis focuses on technologies which have been substantially proven in commercial deployments. Over long periods, this may tend to overestimate some costs; however, a significant fraction of deployment costs are insensitive to technology (for example, the cost of trenching) while other costs are technology independent (for example, the cost of a DSLAM chassis would be independent of what type of DSL is being used), meaning that overall impact should be minimal.

One notable exception is our treatment of wireless. Our focus on wireless, whether for fixed or mobile, is on 4G technologies that have only just begun to be deployed commercially. Initial trials and our research with service providers and equipment vendors give us confidence in 4G's ability to provide the stated performance at the stated costs—enough confidence to warrant including 4G in our analysis.[6] In addition, because of the significant advancements of 4G relative to current capabilities and the widespread 4G deployment forecasts, we would run the risk of overstating the Investment Gap significantly if we were to exclude it from our analysis.

As noted in the CITI report[7], a significant fraction of areas served by wireless today are likely to be upgraded to 4G service by wireless operators without external (public) support.

Only one U.S. carrier, Clearwire, has deployed a mobile 4G (WiMAX) network commercially, making it difficult to know how much of the unserved population will be covered by 4G. For our model, we take Verizon's announced build-out as the 4G footprint because Verizon is the only operator that has announced precisely where its 4G builds will take place. Verizon has committed to rolling out 4G to its entire 3G service footprint (including those areas acquired with Alltel). The net result is that we assume 5 million of the 7 million unserved housing units will have access to 4G service (i.e., 5 million housing units are within Verizon Wireless's current 3G footprint, which the company has committed to upgrading to 4G).

No wireless carrier, including Verizon Wireless, has committed to offering service consistent with the National Broadband Availability Target. This uncertainty in the ability of wireless-network deployments to deliver fixed-replacement service points to the need for incremental investment by wireless carriers. Simply put, networks designed for relatively low-bandwidth (typically mobile) applications, potentially lack the cell-site density or network capacity to deliver 4 Mbps downstream, 1 Mbps upstream service.

Our calculations for 4G fixed wireless includes incremental investments sufficient to ensure networks capable of delivery consistent with the National Broadband Availability Target. See the section on wireless in Chapter 4 and the Assumptions discussion later in this chapter for more details.

KEY DECISIONS

Implicit within the $23.5 billion gap are a number of key decisions about how to use the model. These decisions reflect beliefs about the role of government support and the evolution of service in markets that currently lack broadband. In short, these decisions, along with the assumptions that follow, describe how we used the model to create the $23.5 billion base case.

- ➤ Fund only one network in each currently unserved geography.
- ➤ Capture likely effects of disbursement mechanisms on support levels.
- ➤ Focus on terrestrial solutions, but not to the exclusion of satellite-based service.
- ➤ Support any technology that meets the network requirements.
- ➤ Provide support for networks that deliver proven use cases, not for future-proof buildouts.

Fund only one network in each currently unserved geography. *The focus of this analysis is on areas where not even one network can operate profitably. In order to limit the amount of public funds being provided to private network operators, the base case includes the gap for funding only one network.*

The $23.5 billion Investment Gap is based on the decision, for modeling purposes, that only one network will be funded in each unserved area. The reason for funding only one network is to keep the amount of public money required to a minimum.

Alternative approaches that would fund more than one network per area—for example, funding one wireline and one fixed-wireless network—would increase the total gap significantly for several reasons. First, the gap must include the costs associated with building and operating both networks. Second, because the two providers are competing for the same customers, each will have a lower take rate and, therefore, lower revenue.[8] While this lower revenue will be partially offset by lower variable costs—stemming from savings tied to costs like customer support and CPE—the net effect will be much higher costs per subscriber. For example, having both one wireline and fixed-wireless provider moves the Investment Gap up 45%, from $23.5 billion to $34.2 billion.

Funding two wireline competitors (instead of one wireline and one wireless) in these unserved areas has an even larger impact. Since only the first facilities-based service provider can make use of the existing twisted-pair copper network, the second facilities-based provider must deploy a more expensive, greenfield FTTP network (whether telco based or cable-based RFOG; see Chapter 4 discussion of FTTP and HFC). As shown in Exhibit 3-E, having two wireline providers in unserved areas shifts the investment gap to $87.2 billion.

While funding only one broadband provider in each currently unserved market leads to the lowest gap, this choice may carry costs of a different sort. In areas where a wireless provider receives support to provide both voice and broadband service, the incumbent wireline voice provider may need to be relieved of any carrier-of-last-resort obligations to serve customers in that area. In such a circumstance, it may be that only wireless operators will provide service in these areas. If, at some point in the future, the National Broadband Availability Target is revised in such a way that a wireless carrier can no longer economically provide service, a wireline provider may need to build a new, higher-speed network.

As noted above, competition impacts the take rate for each operator. In addition, we assume that competition leads to lower average revenue per user (ARPU). See Exhibit 3-F.

Exhibit 3-D:
Gap for Funding One Wired and One Wireless Network

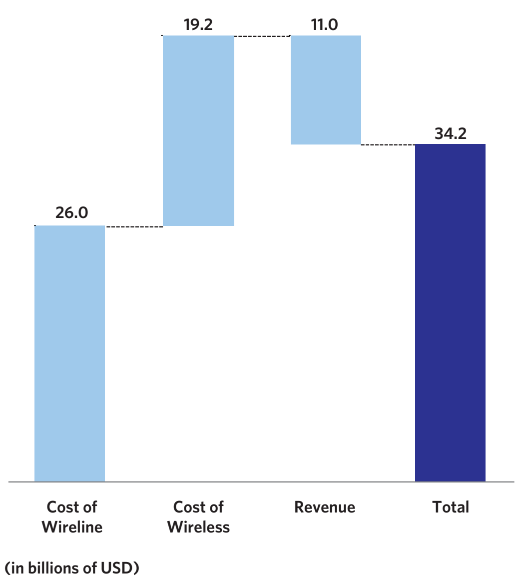
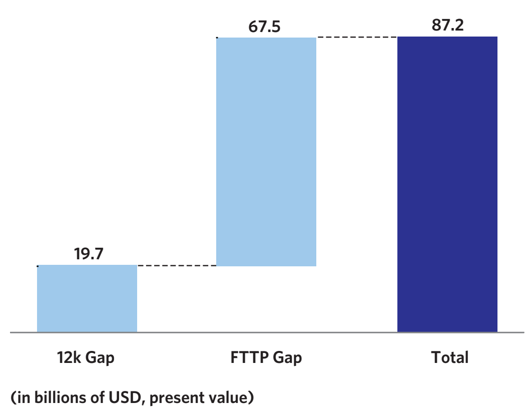


Exhibit 3-E:
The Cost of Funding Two Wired Networks



Since costs are calculated based on demand, reducing take rate will also reduce some costs. In particular, CPE costs are driven directly by the number of competitors. In addition, the cost of some network equipment, including last-mile equipment like DSLAMs, is sized according to the number of customers. This calculation will capture both the reduction in total cost and the increase in cost per user that comes from having fewer customers.

Exhibit 3-G shows the impact of competition on the investment gap for both 12,000-foot FTTN and wireless solutions. Remember that the base-case Investment Gap is calculated from a mix of technologies in markets across the country.[9]

Capture likely effects of disbursement mechanisms on support levels. *Decisions about how to disburse broadband-support funds will affect the size of the gap. Market-based mechanisms, which may help limit the level of government support in competitive markets, may not lead to the lowest possible Investment Gap in areas currently unserved by broadband—areas where it is difficult for even one service provider to operate profitably.*

A mechanism that selects the most profitable (or least unprofitable) technology in each area would minimize the overall size of the NPV gap. In highly competitive markets, market-based mechanisms, including reverse auctions, can play that role.[10] However, in unserved areas, where the economics of providing service are challenging, the impact of market-based mechanisms is less clear.[11]

Since the incremental economics of deploying broadband for each technology depend on the infrastructure that is already deployed, there may only be a single operator capable of profitably deploying a given technology in a given area. In these cases where there are no competing bidders with similar economics, the bidder with the lowest investment gap may not bid based on its economics but rather the economics of the next-lowest-gap technology. In other words, the lowest-gap provider may be in a position to set its bid to be almost as high as the next lowest-gap competitor. Due to this reality, we have calculated the gap based on the second-lowest gap technology, so that we do not grossly underestimate the gap in these areas.

The lowest-gap provider may not always be able to extract the highest level of support because it may have imperfect information about its competitor's economics, or fear that it does. However, we believe calculating the gap based on the second-lowest gap technology is conservative and will be closer to reality in these markets.

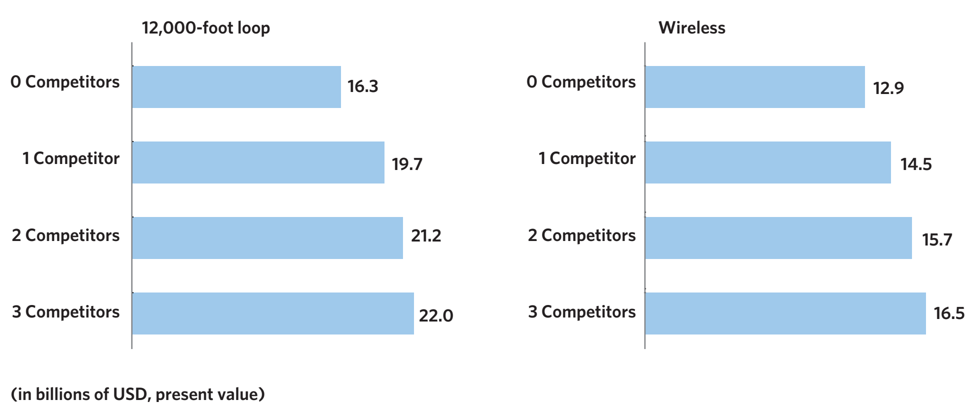
A calculation of the gap, assuming the lowest-cost operator provides service to all currently unserved areas, is $8.0 billion. The gap assuming the second-lowest-cost-gap provider in unserved areas is $23.5 billion. Since wireless appears to be the lowest gap technology in most unserved markets, and there is

Exhibit 3-F: Quantifying the Treatment of Competition

	Reduction in ARPU*	Reduction in Take Rate
0 Competitors	0.0%	0.0%
1 Competitor	4.3%	50.0%
2 Competitors	14.8%	66.7%
3 Competitors	28.2%	75.0%

* average revenue per user

Exhibit 3-G: Quantifying the Impact of Competition: Investment Gap by Number of Providers



a large disparity in cost between the first and second wireline competitor, excluding wireless from the analysis has a disproportionately large effect on the gap. As noted previously, the second wireline competitor in an area will not be able to take advantage of existing last-mile infrastructure and will, therefore, need to deploy a network connection all the way to the home. As such, the second wireline competitor has much higher costs than the first. If wireless is not part of the analysis and the second-lowest-gap provider uses wired technology, the gap moves up to $62 billion.

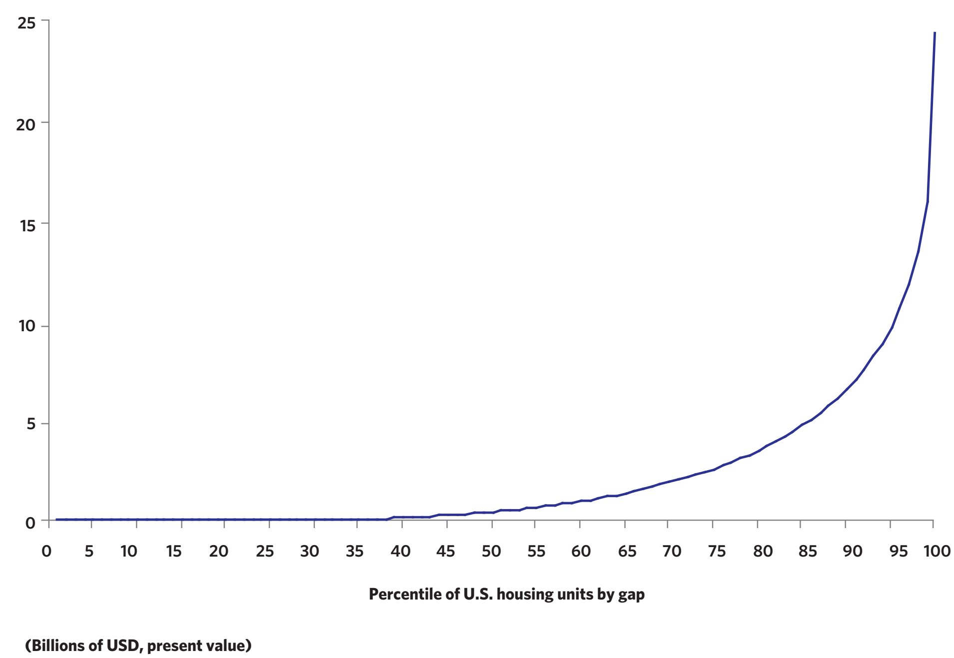
Focus on terrestrial solutions, but not to the exclusion of satellite-based service. *Satellite-based service has some clear advantages relative to terrestrial service for the most remote, highest-gap homes: near-ubiquity in service footprint and a cost structure not influenced by low densities. However, satellite service has limited capacity that may be inadequate to serve all consumers in areas where it is the lowest-cost technology. Uncertainty about the number of unserved who can receive satellite-based broadband, and about the impact of the disbursement mechanisms both on where satellite ultimately provides service and the size of the investment gap, all lead us to not explicitly include satellite in the base-case calculation.*

The $23.5 billion Investment Gap calculation estimates the gap to providing service to all housing units in the country with terrestrial service, either wired or wireless. While it seems likely that satellite will be an important part of the solution to the problem of serving the high-cost unserved, the current analysis includes only terrestrial solutions. Satellite has the advantage of being both ubiquitous and having a cost structure that does not vary with geography, making it particularly well suited to serve high-cost, low-density areas. Nevertheless, the focus of the model analysis remains on terrestrial providers.

While satellite is nearly universally available and can serve any given household, satellite capacity does not appear sufficient to serve every unserved household. In addition, the exact role of satellite-based broadband, and its ultimate impact on the total cost of universalizing access to broadband, depends on the specific disbursement mechanism used to close the broadband gap. The optimal role could be in serving housing units that have the highest per-home gap, or in ensuring that satellite can function as a ubiquitous bidder in a range of auctions. Moreover, while satellite firms can increase their capacity through incremental launches—noting that the current analysis includes all known future launches—the timing for bringing this capacity on-line may be problematic for closing the broadband gap, given the time required to design, build and launch a new satellite.

As noted in Exhibit 1-C, the most expensive counties have a disproportionately large investment gap. That same pattern—the most expensive areas drive a very high fraction of the gap—is repeated at smaller and smaller geographies. Exhibit 3-H shows the gap for all the unserved. The most expensive

Exhibit 3-H. *Broadband Investment Gap, by Percent of Unserved Housing Units Served*



3.5% of the unserved (250,000 housing units, representing < 0.2% of all U.S. housing units) account for 57% or $13.4 billion of the total gap. Were that group served by, for example, satellite broadband, even with a potential buy-down of retail prices, the gap could be reduced to $10.1 billion.[12]

Increasing the number of homes not served by terrestrial broadband leads to diminishing benefit, however. Moving the most expensive 15% of the unserved off of terrestrial options yields a gap of $3.8 billion. In other words, the savings from moving the first 3.5% off of terrestrial options ($13.4 billion) is more than twice the savings from moving the next roughly 12%.[13]

Support any technology that meets the network requirements. *Broadband technologies are evolving rapidly, and where service providers are able to operate networks profitably, the market determines which technologies "win." Given that, there appears to be little-to-no benefit to pick technology winners and losers in areas that currently lack broadband. Therefore, the base case includes any technology capable of providing service that meets the National Broadband Availability Target to a significant fraction of the unserved.*

The purpose of the Investment Gap calculation is not to pick technology winners and losers, but to calculate the minimum gap between likely private investment and the amount required for universal broadband. Therefore, the model is designed to calculate the profitability of multiple technologies to understand the cost and profitability of each.

The focus on profitability—on minimizing an area's investment gap—will lead to calculating the gap based on the least unprofitable mix of technologies. However, this is not an endorsement of any technology over another, or a recommendation for serving demand in any given area with a specific technology.

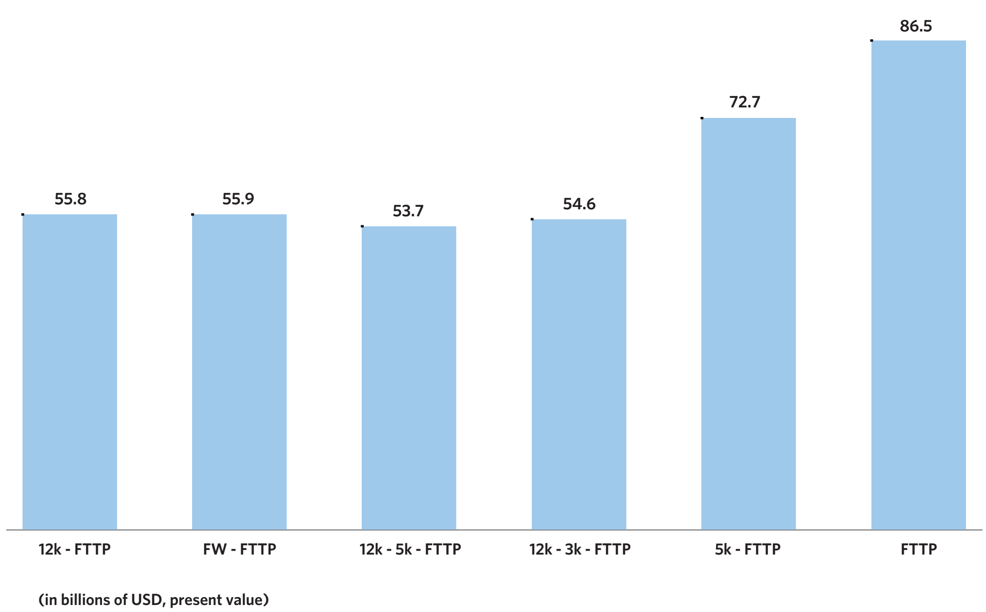
Over time, it may be the case that several technologies' capabilities improve, or their costs fall, more quickly than has been calculated—in which case, multiple competing technologies could profitably serve demand with a subsidy smaller than the one we calculate. Also, individual providers may have, or believe they have, the ability to provide service more cheaply.

Ultimately, the model assumes that any technology that meets the National Broadband Availability Target will be eligible to provide service.

Provide support for networks that deliver proven use cases, not for future-proof buildouts. *While end-users are likely to demand more speed over time, the evolution of that demand is uncertain. Given current trends, building a future-proof network immediately is likely more expensive than paying for future upgrades.*

The calculation of the $23.5 billion Investment Gap is focused on ensuring universal delivery of broadband over the next decade. However, given historical growth rates, it may eventually be the case that networks designed to deliver 4 Mbps downstream/1 Mbps upstream will be incapable of meeting future demand. In such a case, additional investments

Exhibit 3-I:
Total Investment Cost for Various Upgrade Paths



beyond those included in the $23.5 billion gap calculation might be required. Whether historical growth rates continue is dependent on a variety of factors that cannot be predicted. If, however, we make assumptions about growth over time, we can estimate the impact on deployment economics.[14]

For example, the growth rate in the speed of broadband in recent years of approximately 20% suggests that broadband networks might be called upon to deliver speeds higher than 4 Mbps (downstream) and 1 Mbps (upstream) across the next decade or more. Simply put: if required speeds continue to double roughly every three years, demand will outstrip the capabilities of 4G and 12,000-foot-loop DSL.

To account for the current investments as well as these potential future investments, we calculated the lifetime cost of different technology upgrade paths. We evaluate the cost of deploying different technologies including the cost of future upgrades driven by the evolution in network demand, discounted to today. Although the lowest lifetime-cost technology will differ by market, it is possible to calculate the costs associated with various upgrade paths for the unserved areas as a whole, as shown in Exhibit 3-I.

To calculate the total cost for potential upgrade paths, a number of assumptions are necessary. The most important assumptions are the growth rate in broadband speed and the amount of salvage value remaining in a network when it is upgraded. For this calculation, the broadband speed is set to 1 Mbps (downstream) in 2010 and is grown at a rate of approximately 26% per year. When a network is upgraded, the capex required for the upgrade is reduced by the salvage value of the existing network – an upgrade that makes use of many of the assets of the original build will be cheaper. For example, fiber runs used to shorten loops to 12,000 feet will defray the cost of further loop shortening.

In this lifetime-cost calculation, an initial FTTP build-out is the most expensive because none of the initial capex is discounted. Regardless of which path is chosen, deferring the FTTP build-out lessens the total cost burden due to the time value of money. A number of the wireline upgrade paths have similar results. Again, the main differences between these options are salvage value and time value of money, given the assumed broadband growth rate.

This approach disadvantages fixed wireless relative to the other technology paths. Since the calculation only takes into account the ability to provide fixed broadband service, when the requirements for bandwidth outstrip the wireless networks' capability to provide economical fixed service, this calculation assumes that there is no value in wireless networks once they are overbuilt. In reality, and not captured in the calculation, wireless networks would have substantial salvage value in providing mobile service; i.e., once wireless networks can no longer meet the demands of fixed broadband, they can continue to generate value by delivering mobile services. This is in contrast to investments made in second-mile FTTN fiber that reduce the costs of future FTTP buildouts. However, despite this disadvantage, the fixed-wireless-to-FTTP upgrade path has the same total cost as the 12-kft-DSL-to-FTTP upgrade. Fixed wireless has lower initial capex; this lower capex offsets both higher opex for the wireless network and the cost savings from re-using fiber deployments made for a 12,000-foot-loop deployment. See, for example, Exhibits 4-W and 4-AK.

Note that this calculation is very sensitive to the growth rate assumed in required service speeds. If demand for speed grows only at 15% annually, the cost of the second upgrade path (fixed wireless upgraded to FTTP) drops by 23% as future upgrades are pushed out into the future and discounted further; these cost savings are partially offset by the higher opex of the fixed wireless network remaining in operation for more years. The cost of the first upgrade path (12,000-foot-loops upgraded to FTTP) drops even more, by 26%, as the FTTP investment is delayed.

KEY ASSUMPTIONS

Also implicit in the $23.5 billion gap are a number of major assumptions. In some sense, every input for the costs of network hardware or for the lifetime of each piece of electronics is an assumption that can drive the size of the Investment Gap. The focus here is on those select assumptions that may have a disproportionately large impact on the gap or may be particularly controversial. By their nature, assumptions are subject to disagreement; the section includes an estimate of the impact on the gap for different assumptions in each case.

- Broadband service requires 4 Mbps downstream and 1 Mbps upstream access-network service.
- The take rate for broadband in unserved areas will be comparable to the take rate in served areas with similar demographics.
- The average revenue per product or bundle will evolve slowly over time.
- In wireless networks, propagation loss due to terrain is a major driver of cost that can be estimated by choosing appropriate cell sizes for different types of terrain and different frequency bands.
- The cost of providing fixed wireless broadband service is directly proportional to the fraction of traffic on the wireless network from fixed service.
- Disbursements will be taxed as regular income just as current USF disbursements are taxed.
- Large service providers' current operating expenses provide a proxy for the operating expenses associated with providing broadband service in currently unserved areas.

Assumption: Broadband service requires 4 Mbps downstream and 1 Mbps upstream access-network service.[15]

This analysis takes the speed requirements of the National Broadband Availability Target as a given. That is to say that while there are ample analyses to support the target,[16] for the purposes of this analysis the required speed is an input. Below are some brief highlights from the research about speeds available and the impact of different assumptions about speed on the size of the financial gap.

Briefly, there are two independent but complementary approaches to setting the speed target for this analysis. The first approach examines the typical (median) user's actual speed delivered. As shown in Exhibit 3-J, median users receive 3.1 Mbps. In other words, half of all broadband subscribers currently receive less than 3.1 Mbps. These data are from the first half of 2009; based on growth rates (as described elsewhere), the median will likely be higher than 4 Mbps by end of 2010. Updated data from a smaller sample show a median of 3.6 Mbps in January of 2010.

The second approach is to examine the use of applications by end-users to determine what level of broadband speed is required to support that level of use. Typical usage patterns today correspond to the "emerging multimedia" tier shown in Exhibit 3-K, with a growing portion of subscribers being represented best by the "full media" tier. Advanced Telecommunications Capability, including high-speed video, would seem to require at least the 4 Mbps "full media" tier.

While this suggests that speeds as low as 1 Mbps might be sufficient, it is worth noting that demand for broadband speeds has grown quickly, as shown in Exhibit 3-L. In fact, broadband speeds have grown approximately 20% annually since 1997.

Taken together, the median actual speed subscribed (3.1 Mbps, approaching 4 Mbps by year end) and the applications usage (1 Mbps but doubling every three-to-four years) suggest that a download speed of 4 Mbps will provide an adequate target with headroom for growth for universalizing purposes. Although not "future proof," this headroom provides some protection against rapid obsolescence of a high sunk-cost investment.

The calculations in this document focus on the National Broadband Availability Target. However, we built the tool with sufficient flexibility to calculate the gap across a range of target performance levels.

For example, if consumers demand only 1.5 Mbps, fewer housing units would be considered unserved (i.e., those with service above 1.5 Mbps but below 4 Mbps would be considered to have service). In addition, at the lower speed a lower-cost technology, DSL with 15,000 foot loops, becomes viable.

Should consumers demand higher speeds, in contrast, more people would be considered unserved. At the same time, only technologies capable of delivering higher speeds will be part of the solution set (e.g., 3,000-or 5,000-foot-loop FTTN, or FTTP).[17] See Exhibit 3-M.

Exhibit 3-J: Distribution of Users by Actual Maximum Download Speeds (Mbps)[18]

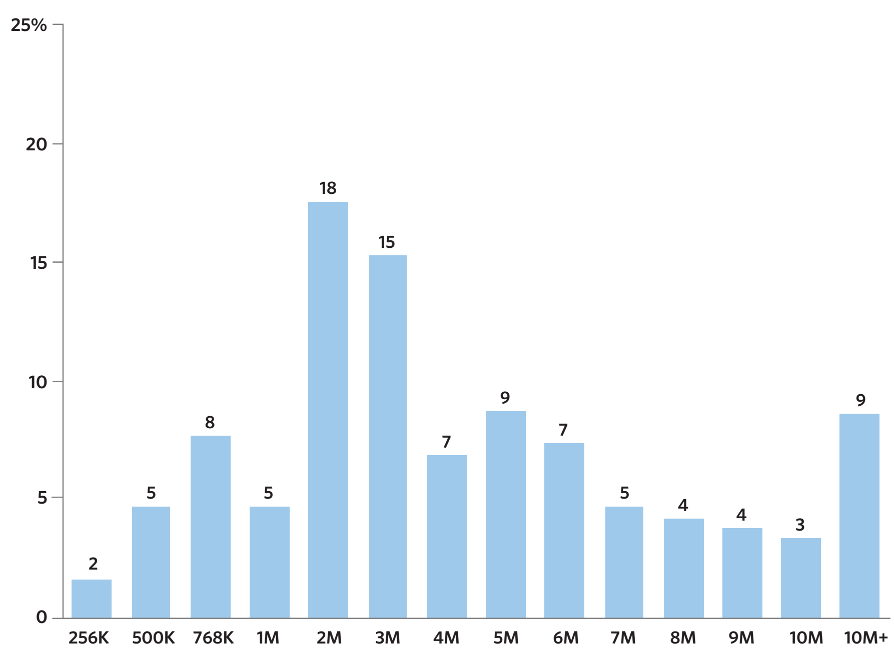


Exhibit 3-K:
Actual Download Speeds Necessary to Run Concurrent Applications (Mbps)

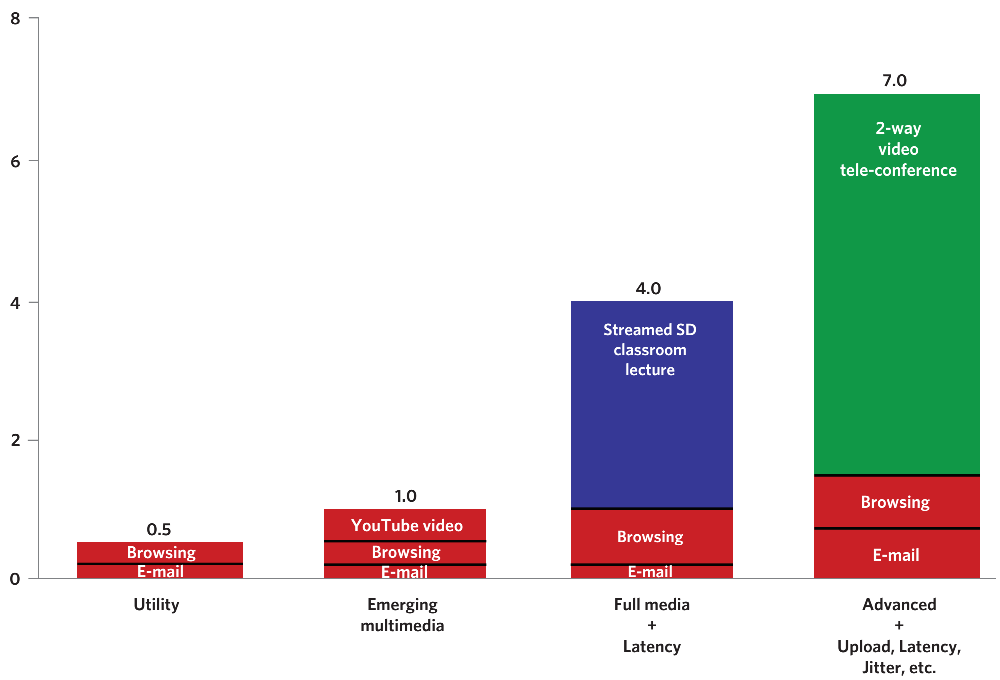
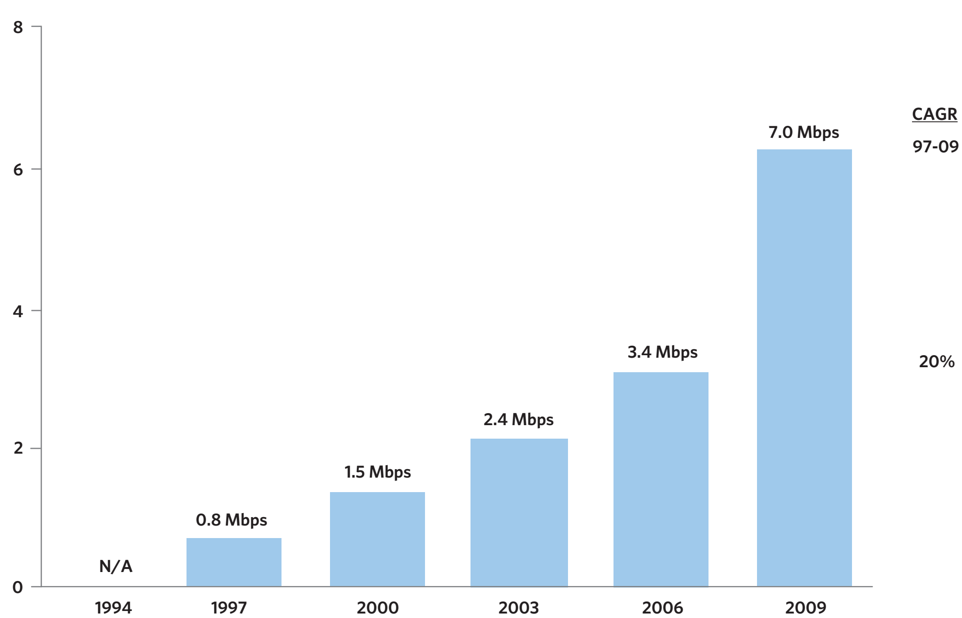


Exhibit 3-L:
Typical (Median) "Up To" Advertised Download Speeds of Most Commonly Deployed and Chosen Consumer Household Broadband (Mbps)



Assumption: The take rate for broadband in unserved areas will be comparable to the take rate in served areas with similar demographics.

We need a measure of adoption over time to understand how quickly operators would attract customers—and accordingly revenue—to offset costs. Moreover, to be consistent with the granularity we have built into the model, it is necessary to make adoption sensitive to demographics.

In order to determine penetration rates of new broadband deployments in unserved areas, we choose to perform a combination of several statistical and regression analyses. Our primary data source is a table of home broadband adoption metrics from the Pew Internet & American Life Project. Since 2001, the Pew Research Center has conducted extensive, anonymous phone surveys on broadband adoption in the United States, breaking out responses by various demographics. Its surveys reveal positive and negative correlation factors between certain demographic characteristics and broadband adoption.[19] The Pew study noted the most significant factors, which are shown in Exhibit 3-N, in order of importance.

We obtained the results of the Pew study on broadband adoption covering 19 survey periods from October 2001 to November 2009. These data aggregate adoption percentages in each period by race, income, education level, rural/non-rural and overall.

Preliminary findings of the data revealed that the trends in broadband adoption matched those of standard technology adoption lifecycles. Our approach to this analysis is to understand the shape and characteristics of the Pew adoption curves in an attempt to incorporate the results into a mathematical model, by which future broadband adoption, or adoption in currently unserved areas, could then be forecast. We begin by examining a popular mathematical model used to forecast technology adoption: the Gompertz model.[20] Exhibit 3-O explains the highlights of the Gompertz model.

Exhibit 3-P illustrates the cumulative characteristics of the Gompertz model as a percentage of the installed base:

From an *incremental* standpoint, the period-to-period technology adoption unfolds as shown in 3-Q.

Note the characteristic "inflection point"—that is, the point at which the incremental curve is maximized and the cumulative curve flips over.[21] The inflection point should be considered the point where technology adoption reaches its maximum growth rate.

Our analysis of the Pew data consists of fitting each demographic data breakout (overall, race, income, age, education Level, rural/non-rural) into a Gompertz curve using a least

Exhibit 3-M: Dependence of the Broadband Investment Gap on Speed of Broadband Considered[22]

Broadband Speed (downstream)	Number of unserved HUs (millions)	Technology	Total cost ($ billions)	Investment gap per technology ($ billions)
1.5 Mbps	6.3	15,000-foot DSL	21.9	15.3
4 Mbps (base-case)	7.0	12,000-foot DSL	26.2	18.6
		4G wireless	18.3	12.9
6 Mbps	7.1	5,000-foot DSL	62.8	43.4
		3,000-foot DSL	76.9	57.3
50 Mbps	13.7	HFC/RFoG	124.9	85.0
100 Mbps[23]	130.0	FTTP	669.6	321.8

Exhibit 3-N: Broadband Take-Rate Drivers

Positively Correlated	Negatively Correlated
Income greater than $100K	Less than high school education
Income between $75K–$100K	Senior citizen (65+)
College degree or greater eduction	Rural
	High school degree only

Exhibit 3-O:
Model for Technology Adoption

Model	Equation	When Used	Examples
Gompertz	$y=e^{-e^{-b(t-a)}}$	When substitution is driven by superior technology, but purchase depends on consumer choice.	Digital television, mobile phones

Exhibit 3-P:
Modeled Cumulative Adoption

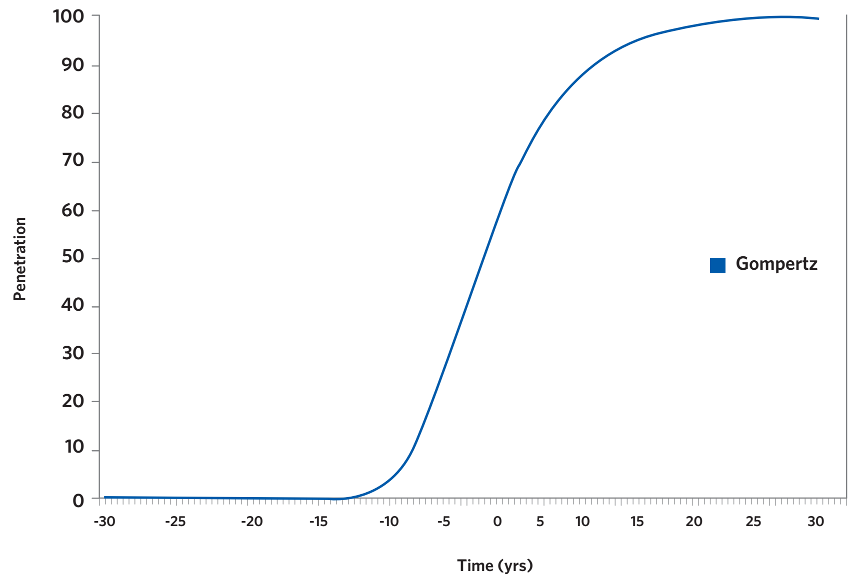
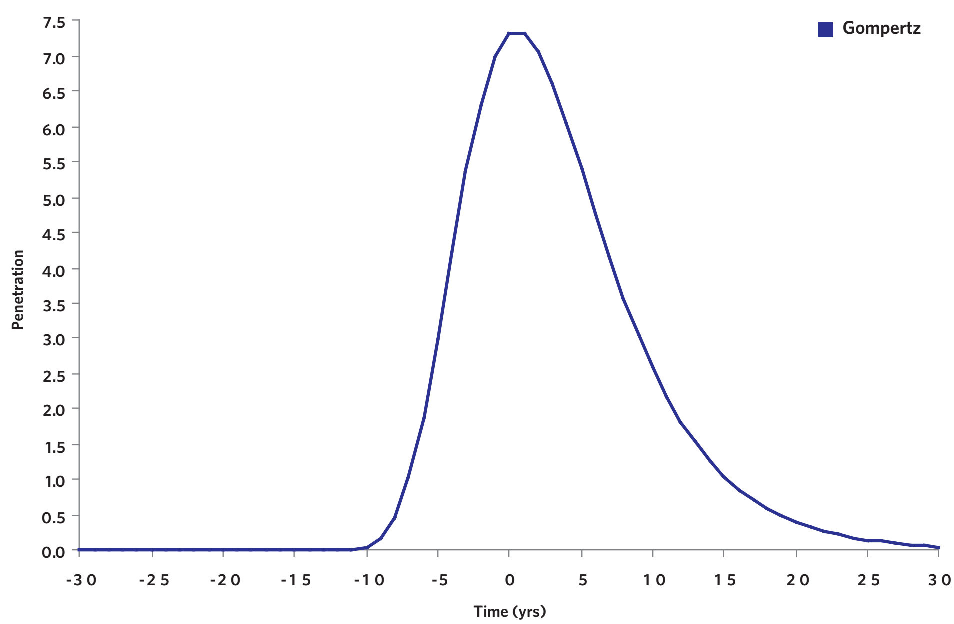


Exhibit 3-Q:
Incremental Adoption



squares approach.[24] With a semiannual time period adjustment, the results indicated the Pew data segments can be fit on a corresponding Gompertz cumulative curve with very reasonable least squares accuracy. One such curve fit for a particular demographic (college graduates) is shown in Exhibit 3-R.

Our analysis provides us with Gompertz curves by each demographic in the Pew survey. However, consider that the Pew research starts with an arbitrary date of October 2001. This date does not presume the "start" of broadband in each surveyed area; it only represents the date at which surveys began. Therefore we must provide a time-based adjustment for every demographic curve. The solution we determine as most appropriate is to develop a series of demographic adoption curves relative to the overall adoption curve. Exhibit 3-S illustrates the relative Gompertz curve fits for every demographic segment. Here, the overall adoption curve inflects at zero on an adjusted time scale.[25]

Reinforcing the conclusions of the Pew study, the Income over $75K and College or Greater Education curves are farthest to the left (representing more rapid adoption relative to the mean), while the High School or Less, Rural and 65+ curves are farthest to the right (representing slower adoption relative to the mean).

It is worth noting that the Gompertz curves are based on adoption in areas across time, largely when broadband was first introduced—i.e., in greenfield areas. In brownfield deployments, however, builders are leveraging previous deployments to capture consumers who have already been educated on the benefits of broadband. We therefore allow for an additional time adjustment where brownfield builds are taking place.

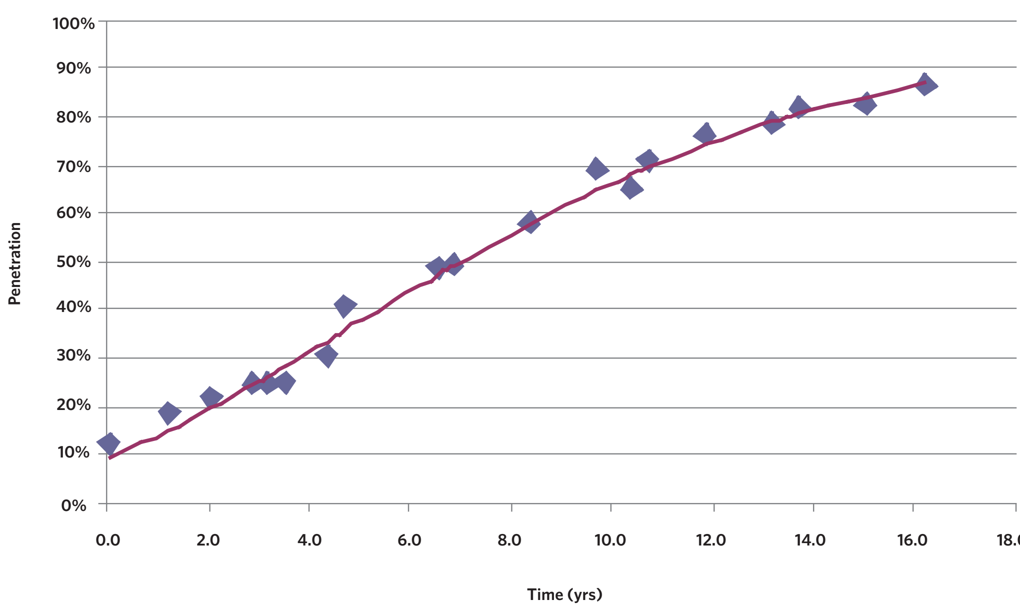
These results provide relative Gompertz curves by every demographic measured in the Pew study; however for a number of reasons, we chose to limit the prediction model to only the demographic factors with the largest positive and negative correlation to broadband adoption. While it would technically be possible to measure adoption changes across all the available demographics on the Pew study, it does not improve results meaningfully to do so—either the remaining demographics had minimal influence on broadband adoption, or the demographic data in question were not readily available at the appropriate demographic level.

The demographic variables we chose to predict broadband adoption are the following:

- Income greater than $100K
- Income between $75K – $100K
- College degree or greater education
- Senior citizen (65+)
- Less than high school education
- Rural
- High school degree only

Using the Gompertz coefficients for each demographic, combined with demographic data at the census block level,[26] we can build Gompertz curves for every census block in the nation. To build these custom curves, we weight the demographic Gompertz

Exhibit 3-R:
Broadband Adoption Curve



coefficients (a and b) by the incremental demographics prevalent in the area. For example, if the demographics within the overall curve show 18.5% of households have incomes above $100K, but a particular census block contains 20% of households with over $100K income, each "Over $100K" Gompertz coefficient would be weighted by the incremental difference (20% – 18.5% = 1.5%) and added to the overall Gompertz coefficient. By summing up the weightings off each significant variable, our Gompertz equation for each census block would take shape.

The additional step in forecasting broadband penetration rate is to determine how to factor in a brownfield effect, if any, into the census block time coefficient (a). If the census block is revealed to have a prior broadband deployment, the census block curve would be shifted left a designated number of periods. The number of periods to shift is held constant across all brownfield deployments.

The final step of developing the census block curve is to determine where to set the inflection point. The zero point on the horizontal axis scale is intended to represent the point at which the overall curve inflects, but the time at which the scale hits zero must be determined. We initially chose this scale to be two years from the start of deployment; essentially, the overall broadband adoption would reach its maximum growth rate in 24 months. To account for the initial mass influx of customers in the first 24 months, we chose to start with zero subscribers at initial deployment, then trend towards the number of subscribers at 24 months by dividing them into four equal 6-month periods of subscriber adoption. After 24 months, the penetration rates reflected in the Gompertz curve would be in effect. The selection of an inflection point, while initially set at 24 months, is one that can potentially be re-examined and adjusted as needed.

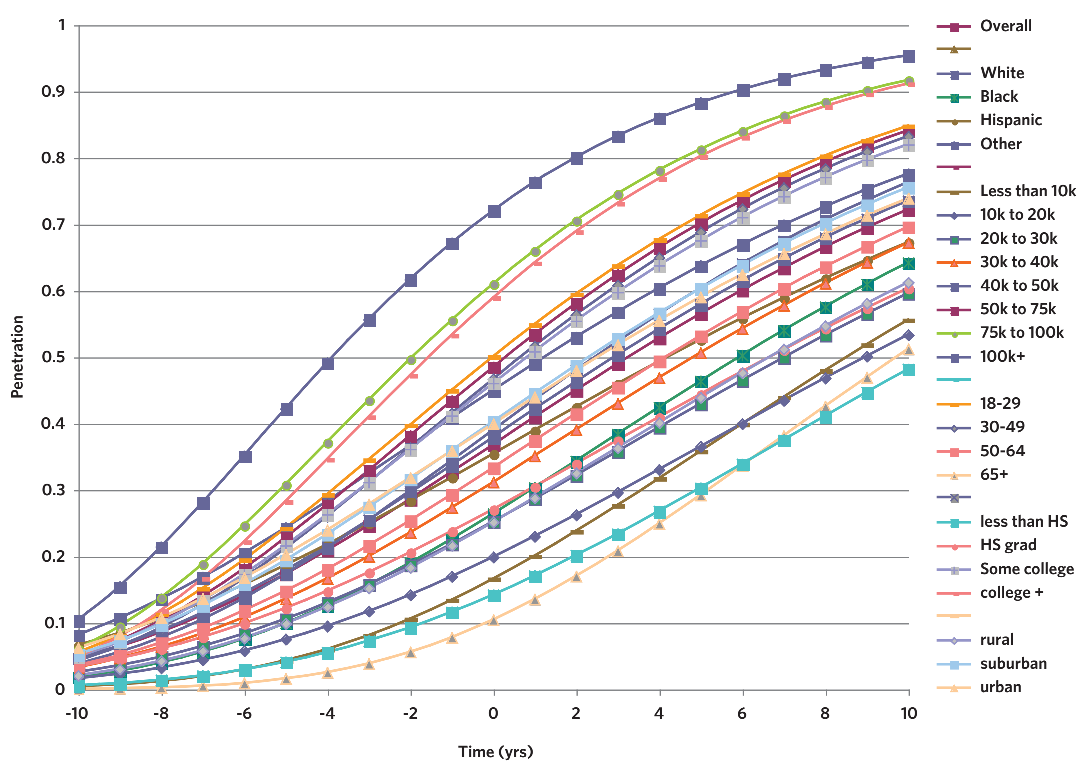
Additional factors

The resulting census block penetration rate determines the standard broadband adoption rate for that census block. It does not, however, factor in the subscribers of related incremental services (e.g., voice, video), the effect of bundled services or the stratification of tiering (basic vs. premium). To account for each of these, we developed factors from which we could adjust the baseline number of expected broadband adopters in every census block. Each factor is discussed below.

Scaling factor

A scaling factor, in this instance, refers to a multiplying factor developed to predict voice and video subscribers by technology (DOCSIS, FTTP, FTTN and Fixed Wireless) based on the number of broadband subscribers.[27] The presumption is that

Exhibit 3-S: Gompertz Curves for Broadband Take Rate With Demographics



each technology exhibits a constant and unique relationship between broadband subscribers and subscribers to other services like voice and video. In other words, if one knows the number of broadband subscribers for a particular technology, one can predict the number of voice or video subscribers as well.

Bundling percentages

Customers who subscribe to broadband services belong to one of two groups: those that purchase a la carte, or those that purchase as a bundle. Industry analysis confirmed that the relationship between the two subscriber bases is relatively constant for each technology.[28] Using these data, we developed a "bundling" percentage based on the broadband subscribers, in order to arrive at the number of bundled subscribers. The number of bundled customers can then be subtracted from the total number of voice and video subscribers to arrive at the number of a la carte subscribers for each. The percent of users who take bundles for each technology is shown in Exhibit 3-T.

Tiering percentages

Tiering, in this case, refers to the tiered services offered by carriers. To limit unneeded complexity, we limit the number of tiers in the model to two levels: a basic introductory level of service and a "top-shelf" premium service. These low/high tiers are applicable to video (for example, basic vs. premium cable), data (entry-level vs. top speed) and even bundles. Using industry data we are able to develop percentages by technology that break out the respective service subscribers into low-end and high-end tiers.[29] These "tiering" percentages are then applied to the number of broadband, video and bundled subscribers to arrive at low-tier subscribers and high-tier subscribers for each.

Take-rate sensitivities

The Gompertz curve for data product penetration is driven by the demographics at the census block group level and is independent of changes in price. Treating broadband data products as relatively demand inelastic is consistent with the recent findings by Dutz et al (2009), who estimated own-price elasticity for broadband in 2008 to be -0.69.[30] Despite these findings, it is important to understand the impact of adjusting the market penetration levels up and down to show the sensitivity of take rate on costs and revenues. Exhibit 3-U illustrates the impact on the overall private investment gap at different market penetration levels. Note that the bulk of the difference in the gap comes from changes in revenues rather than changes in costs.

Exhibit 3-T:
Assumed Percentage of Customers with Bundles

Data	Percent with Bundles
FTTN	65% (data, voice and video where appropriate)
Wireless	98% (data and voice)
Cable	40% (data, voice and video)
FTTP	67% (data, voice and video)

Assumption: The average revenue per product or bundle will evolve slowly over time.

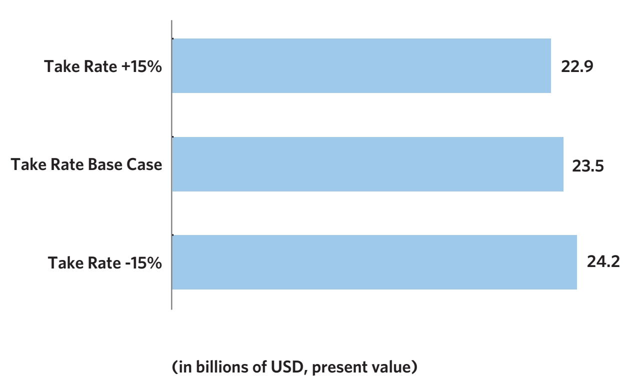
ARPU forecast

In order to develop a close approximation for ARPU, two main issues must be resolved. First, each product category (data, voice, and video) must have an individual ARPU value and the product bundle must also have an ARPU value. An additional level of sophistication, customer segmentation, is added by including a low and high version of the data, voice, video, and bundle product categories. Second, the current disparity in pricing between telco and cable voice products must be resolved.

The complexities of the market create additional challenges. Using estimates of current revenue streams may overestimate, perhaps significantly, the revenue available in the future. Both voice ARPU and the number of residential lines are under pressure from a confluence of technical evolution and new competitive models.[31]

In real terms, the average price of a residential access line has fallen since 1940 by about 50%.[32] Simultaneously, interstate and international per minute revenues have

Exhibit 3-U:
Sensitivity of Gap to Take Rate



dropped steadily since 1985, even in nominal dollars.[33] These trends are the result of competition from wireless and cable, capacity expansion and the advent of Voice-over-IP (VoIP). As these drivers (especially VoIP growth) accelerate, voice ARPU is expected to continue to decline. To account for this market price shift, revenue attributed to incremental voice customers for telcos is set equal to the ARPU for a similar cable VOIP product.

Video ARPU may also be challenged in the years to come. The FCC's cable pricing survey indicates video ARPU has increased year-over-year since 1995 with 55-60% of that increase attributable to programming cost.[34] Cable's video business was protected from competitive threats for much of this historical period, which may change with the recent rise of telco, satellite and "over-the-top" (OTT) or Internet video offerings like Hulu and Netflix. Just as wireline telephone revenues and margins began to shrink after Congress mandated competition in the local telephone market in 1996, it is possible that video ARPU will come under pressure going forward.

Despite these downward trends in per-product ARPUs, annual spending on voice and video services has remained nearly constant as a percentage of total household spending. The annual Consumer Expenditure Survey by the Bureau of Labor Statistics and the FCC's Cable Industry Prices report shows that aggregate annual household expenditure for telephone (wired and wireless) and video has remained between 3.0% and 3.4% of total expenditures between 1995 and 2007.[35]

It is unclear how these trends will play out over time and whether a rise in data-services ARPU will offset expected erosion in voice and video ARPU. The ARPU assumptions in the model are based on a moderate view, where ARPUs evolve slowly over time. Model ARPUs are shown in Exhibit 3-V; note that these ARPUs are the levelized figures across the study time period.

Finally, a number of products either do not yet exist or do not have a long pricing history (e.g. fixed wireless LTE data services). While the average price per minute for a mobile voice call continues to fall or be replaced by unlimited plans, industry forecasts show continued growth in mobile data revenue. As more and more consumers begin using mobile devices as broadband connections, the pricing dynamic between voice and data may shift. While this shift may take place, ultimately we believe the total ARPU per customer as noted above will remain relatively flat.

Drawing on the data and forecast methodology described above, we assume the ARPUs described in Exhibit 3-V.

ARPU sensitivity

Given the product dynamics and uncertainty around the evolution of ARPU in the future discussed above, we conducted a number of sensitivities for overall revenue to estimate the impact of a change in ARPU on the investment gap. Exhibit 3-W shows the change in the amount of support required when the ARPU is scaled up and down by a number of percentages.

Assumption: In wireless networks, propagation loss due to terrain is a major driver of cost that can be estimated by choosing appropriate cell sizes for different types of terrain and different frequency bands.

The cost of wireless deployment varies greatly based on terrain due to reduced propagation in areas with significant elevation change. Simply put: more mountainous areas are harder and more expensive to serve, a fact reflected in the existing wireless coverage of mountainous areas.

General principles for the design of a wireless network (discussed further in the wireless section of Chapter 4) can be used to calculate cell size in areas without geographic interference for a given frequency and required bandwidth. Determining the actual cost of a wireless deployment would require a tuned propagation model.[36] We take an approach somewhere between applying the general principles of wireless network design and a tuned propagation model to take into account the impact of terrain on cell sizes and therefore costs.

To try to capture some of these terrain dependencies, the model adjusts the cell size based on the ruggedness of the terrain. Flat areas are assigned larger cell radii, and therefore lower costs, while hilly and mountainous areas have smaller cell radii and higher costs.

Exhibit 3-V: Summary of Modeled ARPUs

		Data		Video		Bundle	
	Voice	Low	High	Low	High	Low	High
Telco	33.46	36.00	44.00	50.00	80.00	95.57	130.00
Cable	33.46	36.00	44.00	50.00	80.00	95.57	130.00
Wireless (4G footprint)	33.46	36.00	36.00	-	-	56.00	56.00
Wireless (non-4G footprint)	51.96	43.00	43.00	-	-	80.00	80.00

We are able to take into account the different costs across a variety of terrains by first calculating the cost associated with serving each populated census block in the country with two-, three-, five- and eight-mile cell radii—in other words, the total cost of a nationwide network build is calculated for each cell radius, with costs allocated down to census blocks. Census blocks are then aggregated into census tracts.

We then calculate the standard deviation of elevation in each census tract. See Exhibit 3-X to see the variation of elevation across the country.

Areas with high standard deviations have large elevation variability and require smaller two-mile cell sizes; flatter areas have lower standard deviations and are assigned larger cell sizes. See Exhibit 3-Y, which shows cell-size overlaid on the terrain map. The areas with largest cell sizes, indicated in dark blue, are primarily along the coasts and the Mississippi plain. Smaller cell sizes, in green and yellow, are in mountainous areas of the East (along the Appalachians and Berkshires) and in the West.

More detail about cell radii and the impact of wireless model assumptions can be found below in the section on wireless technology.

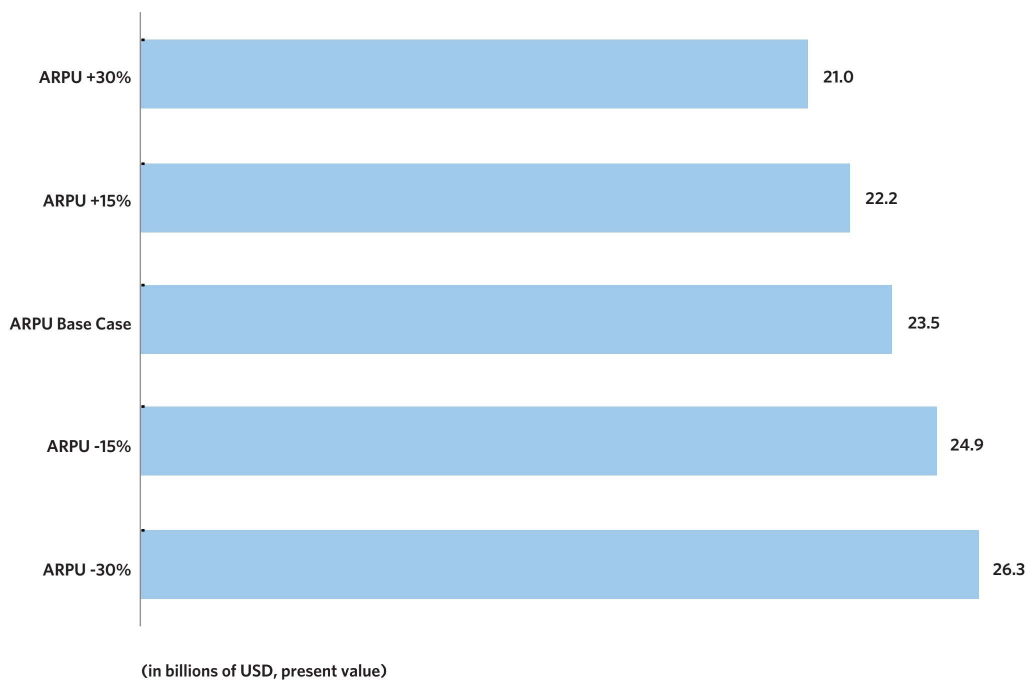
Exhibit 3-Z illustrates the results of making different assumptions about what cell sizes are appropriate in what kinds of terrain. The graph includes the cost of the wireless build; the gap associated with that build; and the overall gap, which because it is driven by the second-lowest-cost technology, varies by less than 10%. In fact, we find that the percentage of unserved housing units served by wireless drops very little (to 89.1% from 89.9% in the most extreme case tested), thus explaining the relatively small impact terrain classification has on the overall investment gap. The analysis and assumptions that led to Exhibit 3-Z are discussed more fully in Chapter 4 (leading up to Exhibit 4-Y).

Assumption: The cost of providing fixed wireless broadband service is directly proportional to the fraction of traffic on the wireless network from fixed service.

The presence of commercial wireless 4G buildouts in areas unserved by terrestrial broadband today can have a major impact on cost and the investment gap. Such commercial buildouts are driven by each company's strategic plans, meaning that the builds could be profitable on their own (i.e., that mobile revenue tied to that location exceeds the cost of deployment), or could be important for other reasons (e.g., to differentiate based on network coverage or to reduce dependence on roaming partners).

Regardless of why such networks are built, their presence has a dramatic impact on local wireless-network economics, since the costs of providing fixed-broadband service will be lower for a service provider that already operates a network that provides mobile services. At issue is the fraction of the total cost required to upgrade commercial buildouts designed

Exhibit 3-W:
ARPU Sensitivity



to provide 4G mobile service to the signal density required to provide fixed service at 4 Mbps downstream/1 Mbps upstream. In addition, the operator would have some amount of revenue even without the fixed-network upgrade. Consequently, we estimated both incremental cost and revenue.

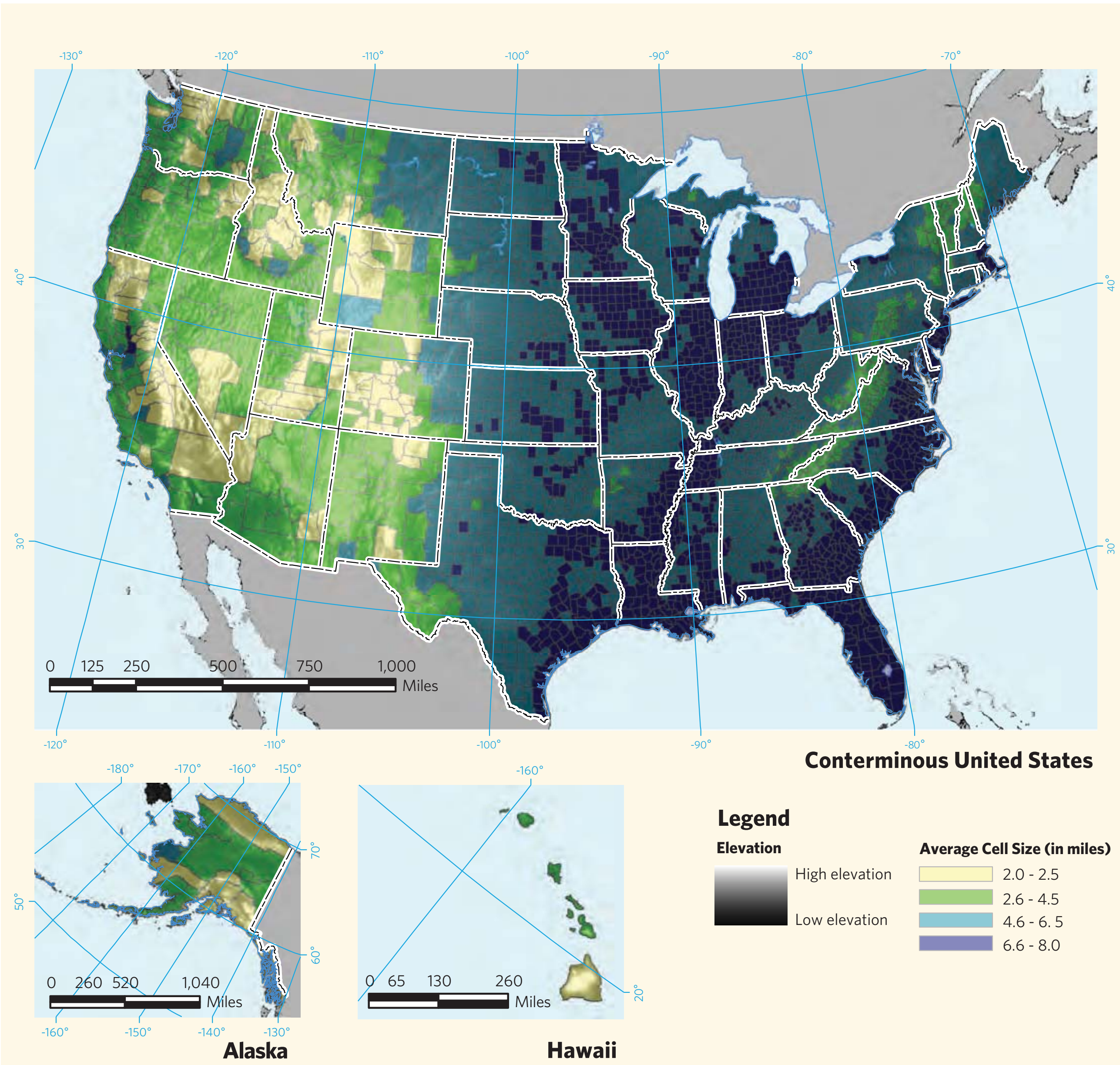
To estimate incremental costs, we allocate costs between the fixed and mobile businesses. While both fixed and mobile businesses benefit from improvements to their shared infrastructure, the fixed business drives many of the costs. Fixed service drives more traffic per connection and, as will be

Exhibit 3-X:
Elevation Across the U.S.

discussed later in the wireless portion of Chapter 4, network requirements for fixed broadband service lead to the need for more and smaller cells.

Therefore, the model allocates costs by the amount of traffic driven by fixed and mobile service. The average mobile user with a broadband handset used 65 MB[37] of capacity per month in 2009, while the average fixed user consumed 9.2 GB;[38] however, mobile data usage per user is currently growing at 84%,[39] while fixed usage per user is growing at "only" about 30%.[40] Assuming that there are two mobile users for every fixed

Exhibit 3-Y:
Estimated Average Cell Size in Each County and Terrain



user,[41] and that growth in mobile bandwidth slows to match the growth rate in fixed after five years, fixed service will account for 73% of traffic across the modeled period. Based on these assumptions for traffic allocation, the model allocates 73% of cost to fixed traffic. In other words, the model assumes that mobile carriers can allocate 27% of the build out and operations cost to mobile products, reducing the cost of providing fixed service. If the costs were evenly divided such that 50% of the cost is allocated to fixed and 50% to mobile, the Investment Gap for wireless would decrease to $10.8 billion. If 100% of the cost were allocated to fixed, the Investment Gap for wireless would increase to $15.8 billion.

Offsetting these cost savings is the fact that existing operators may not have significant incremental mobile revenue. The assumption in the model is that there is no incremental mobile revenue within the assumed 4G footprints as defined above (i.e., the carrier does not gain new mobile revenue by building out a network capable of providing 4/1 Mbps fixed service). In other words, the model (conservatively) assumes that a wireless carrier will not increase its share of mobile revenue by adding fixed service.

Outside the assumed 4G footprint, there is no allocation issue: all revenue (fixed and mobile) and all costs are incremental in these areas. The model calculations, therefore, include both fixed and mobile revenue, and 100% of the cost of building and operating the network in those areas outside the 4G footprint.

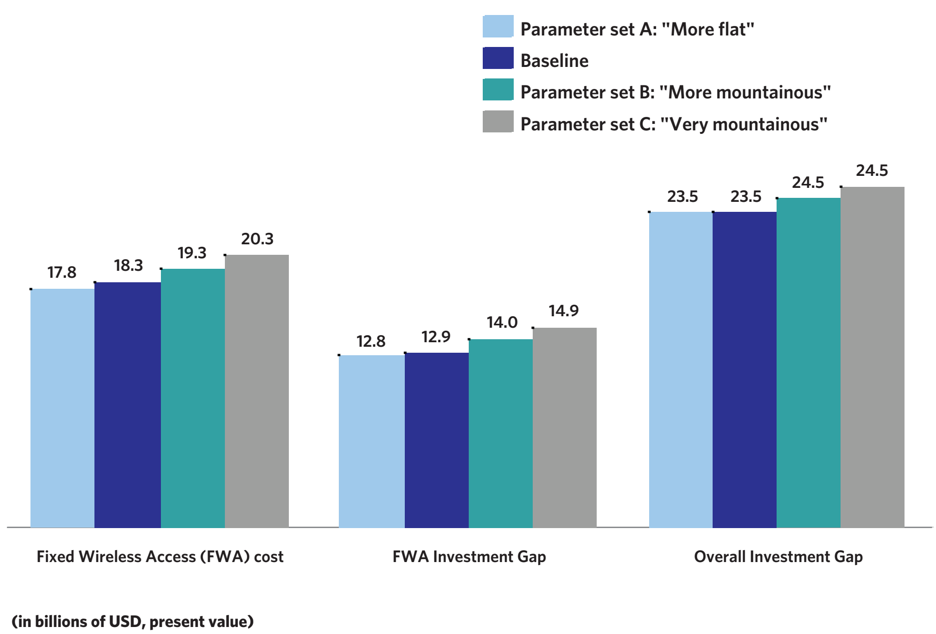
If one does not allocate some fraction of cost to mobile traffic—if, in other words, one requires the fixed network to provide returns without the benefit of mobile revenue—the Investment Gap for wireless grows to $16.5 billion. On the other hand, the overall Investment Gap, which is set by the second-least-expensive technology, moves very little, to $25.6 billion.

A new entrant would not have the same starting point. All revenue and all cost would be incremental for a new operator. However, within the 4G footprint, a new operator would face competition in both fixed and mobile markets—and would, therefore, have lower take rate and/or ARPU (as noted above).

Outside the 4G footprint, the Investment Gap calculation is relatively straightforward. Whoever provides broadband service will need to assume all deployment costs and will benefit from both fixed and mobile revenues—though carriers are likely to face some amount of (at least 2G) competition for mobile revenue.[42] Inside the 4G footprint, the gap calculation is more complex. For a major wireless company, likely to build out some amount of 4G commercially, the calculation needs to focus on incremental revenue—revenue for fixed service;[43] and incremental cost—the cost for upgrading to offer 4 Mbps downstream, 1 Mbps upstream service.

Assumption: Disbursements will be taxed as regular income just as current USF disbursements are taxed. Generally, gross income means all income from whatever source derived.[44] Therefore, taxpayers other than nonprofit or governmental entities must include governmental grants in gross income absent a specific exclusion. In certain circumstances, governmental grants to a corporation[45] may qualify for

Exhibit 3-Z: Sensitivity of Build-Out Cost and Investment Gap to Terrain Classification Parameters [46]



exclusion from gross income as a non-shareholder contribution to capital under section 118 of the Internal Revenue Code. In United States v. Chicago, Burlington & Quincy Railroad Co., 412 U.S. 401 (1973), the Supreme Court adopted a two part inquiry to identify a non-shareholder contribution to capital: (1) the contributor motivation test and (2) the economic effect of the transferee test. The transferor's intent must be to enlarge the transferee corporation's capital to expand its trade or business for the benefit of the community at large and not to receive a direct or specific benefit for the transferor. For the requisite economic effect on the transferee corporation, the following five factors must be present:

- The contribution becomes a permanent part of taxpayer's working capital structure
- The contribution may not be compensation, such as direct payment for specific, quantifiable service provided for transferor by transferee
- The contribution must be bargained for
- The contributed asset must foreseeably result in benefit to the transferee in an amount commensurate with its value
- The contributed asset ordinarily, if not always, will be employed in or contribute to the production of additional income[47]

The U.S. Treasury has stated that disbursements that may be used for operating expenses will not qualify as a non-shareholder contribution to capital, while disbursements that are made to a corporation, restricted solely to the acquisition of capital assets to be used to expand the recipient's business—and satisfying the five factors—could be exempt from federal income tax. Such a favorable tax treatment on disbursements could reduce the broadband investment gap by up to $2.2 billion. Ultimately, the impact of taxes incurred will depend on the disbursement mechanism, as well as the tax situation of the service providers receiving support.

Assumption: Large service providers' current operating expenses provide a proxy for the operating expenses associated with providing broadband service in currently unserved areas.

As seen in Exhibits 1-A and 1-B, operating expenses (opex) make up a significant fraction of total costs. Complicating matters is that opex comprises many disparate cost elements: everything from the cost of operating the network (network opex) to the cost of sales and marketing, business support services, power, leases and property taxes (collectively overhead or SG&A). And because each service provider operates differently—there are no standards for how many lawyers, administrative-support staff or network technicians a company needs to hire per mile of plant or number of customers—it is not possible to calculate opex in a "bottom-up" approach.

To find a reasonable approximation of the opex associated with these networks, the team compiled publicly available data sources and ran a series of regressions. These regressions calculate the relationship between opex and already-calculated quantities like revenue or network capex (see CostQuest documentation for more information). Separate regressions are run for cable, telco and wireless companies; for each network type, opex is broken out according to the categories available in the data sources.

For each opex category, the analysis calculates the primary driver (i.e., the known quantity that most strongly correlates with the opex category). Thus some opex categories, like telco network opex, are driven off of network investments; wireless tower operations costs are driven off site counts; while other costs, such as marketing or bad debt, are calculated as a function of revenue. The ratio between the driver and the opex category (the coefficient of the regression) is calculated for different size operators in different geographies, though in some cases the impact of these factors is negligible.

Using this approach to estimate the real-world opex of actual companies (the same opex and companies that formed the source data) suggests that the approach is reasonable. Variations between the calculated and actual values of opex ranged from less than 1% to roughly 10%, depending on the cases studied.

Throughout the calculations described above, we assume that the opex associated with large telco and wireless providers is appropriate. If one instead assumed that a small telco and small wireless operator provided service, the gap would grow to $26.4 billion.[48 49]

CHAPTER 3 ENDNOTES

1 *In the Matter of Represcribing the Authorized Rate of Return for Interstate Services of Local Exchange Carriers*, CC Docket No. 89-624, Order, 5 FCC Rcd 7507 (1990).

2 Note that model runs completed with a shorter time horizon (*see* User Guide for more information) will not include a terminal value. They will, instead, accelerate the depreciation and replacement of longer-lived assets, effectively requiring returns on those long-life assets in a shorter period of time.

3 Note that for census blocks with the largest area (likely the lowest-density census blocks); even census blocks may be too aggregated. *See*, for example, "State Broadband Data and Development Grant Program; Notice of Funds Availability, Clarification," 74 Federal Register 154 (12 Aug. 2009), pp. 40569 -40570.

4 Cable deployments are all new deployments that expand the cable plant; therefore all revenue is incremental.

5 HFC and FTTP networks also have scale lengths associated with them related to the distances of signal propagation in coaxial cable and fiber.

6 Verizon's LTE field trials in Boston and Seattle have shown average downlink rates of 5Mbps to 12Mbps and average uplink speeds of 2Mbps to 5Mbps at the time of this writing. *See* http://www.computerworld.com/s/article/9167258/LTE_speeds_faster_than_expected_in_Verizon_trials.

7 CITI BROADBAND REPORT AT 57.

8 In this example, we assume that the two networks are owned and operated by different entities. The cost impact of supporting two networks may be less severe in cases in which one company owns both networks.

9 The gap, specifically, is built from the *second*-least-expensive technology in each county across the country. Wireless with no competitors is used in all geographies; 12,000-foot-loop FTTN with one competitor is used in areas assumed to have 4G service, and with no competitors in other areas. *See* "Creating the base-case scenario and output" at the end of Chapter 1.

10 *High-Cost Universal Service Support; Federal-State Joint Board on Universal Service*, WC Docket No. 05-337, CC Docket No. 96-45, Notice of Proposed Rulemaking, 23 FCC Rcd 1495, para. 11 (2008).

11 The National Broadband Plan recommends identifying "ways to drive funding to efficient levels, including market-based mechanisms where appropriate."

12 The retail price of satellite service could exceed the price of terrestrial broadband. A "buy down" would ensure that those receiving satellite-based services would not face higher monthly rates than those served by terrestrial providers in other geographies. There is a sample buy-down calculation in Satellite portion of Chapter 4.

13 Satellite broadband and its ability and capacity to provide terrestrial-replacement service are discussed in Chapter 4.

14 *See* broadband-speed assumption section. *See also* Omnibus Broadband Initiative, *Broadband Performance* (OBI Working Paper, forthcoming) (Bowen, *Broadband Performance*).

15 All speeds throughout this paper are "actual" speeds. As with the National Broadband Plan itself, "actual speed" refers to the data throughput delivered between the network interface unit (NIU) located at the end-user's premises and the service provider Internet gateway that is the shortest administrative distance from that NIU.

16 *See* OBI, Broadband Performance.

17 Note that there were not enough data to complete an accurate predictive model of DSL actual speeds above 6 Mbps; therefore for speeds above 6 Mbps, the cable footprint is taken as the footprint of served housing units without augmentation from telco plant.

18 comScore, Inc., Jan.–June 2009 Consumer Usage database (sampling 200,000 machines for user Web surfing habits) (on file with the FCC) (comScore database).

19 Horrigan, John. Home Broadband Adoption 2009. Pew Internet & American Life Project: June 2009. *See* http://www.pewinternet.org/~/media/Files/Reports/2009/Home-Broadband-Adoption-2009.pdf.

20 Vanston, Lawrence K. and Vanston, John H. Introduction to Technology Market Forecasting. Austin, TX: Technology Futures, Inc, 1996. Note that we considered the Fisher-Pry model but ultimately concluded that, since it is geared toward modeling the substitution of a superior technology for an inferior one, it was not appropriate to use in this instance.

21 Geometrically speaking, the inflection point on the cumulative curve is the point at which the curve moves from convex to concave. The slope of the tangential line along the cumulative curve is highest at the inflection point, indicating maximum acceleration of adoption. Mathematically, the incremental curve is the first derivative of the cumulative, and the inflection point is at the maximum slope of the cumulative or maximum of the incremental curve.

22 Note that these calculations represent the investment gap for each individual technology; the $23.5 billion base case takes the second-lowest-gap technology in each county as described above, not the gap for any one technology.

23 Because we lacked precise data on the location of existing FTTP deployments, the figures for FTTP cost and investment gap are for a run that covers the entire country. Actual costs and gap would be reduced by the roughly 17 million HUs that are already passed by FTTP facilities.

24 The best fit, between modeled data (Gompertz) and observed data (Pew), in its least-squares sense, is an instance of the model for which the sum of squared residuals has its least value, where a residual is the difference between an observed value and the value provided by the model.

25 Each period on the x-axis represents one year, with the inflection point at zero.

26 Note that some demographic data, such as income, are calculated only at the census block group level; these geographically coarser data are applied "down" to the subordinate census blocks.

27 For Telco: 1) Proprietary CostQuest information and industry data/ financials (publically available) 2) Table 5 from FCC's June 30, 2008 Broadband Report
For Wireless: 1) http://wirelessfederation.com/news/17341-att-adds-1.4mn-mobile-subscribers-in-q2-usa/ (last accessed Mar. 24, 2010) 2) *See* SNL Kagan (a division of SNL Financial LC), "U.S. 10 year mobile wireless projections" 3) FCC "High Speed lines by Information Transfer Rates" as of June 30, 2008.
For Cable: 1) *See* SNL Kagan (a division of SNL Financial LC), http://www.snl.com/interactivex/CableMSOOperatingMetrics.aspx (Login required) templates that contained Q1 2004 – Q2 2009 data for: Basic Penetration; Basic Subscribers; Basic Homes Passed; Video Penetration Rates; Video Subscribers; Video Homes Passed; HSD Penetration Rates; HSD Subscribers; HSD Homes Passed; Voice Penetration Rate; Voice Subscribers; Voice Home Passed 2) *See* SNL Kagan (a division of SNL Financial LC), "Cable TV Projections, 2008-2019" 3) Publically available financials for the cable companies, including RCN; Knology; and General.

28 For Telco: Data were obtained from publicly available AT&T investor reports on U-VERSE (http://www.att.com/Common/merger/files/pdf/3Q09_U-verse-Update_10.22.pdf) as well as proprietary CostQuest information.
For Cable: Data were obtained from Forester: Williams, Douglas, et al. "MULTI-PLAY SERVICES: Driving Subscriptions in a Maturing Market and Down Economy", Volume 2, 2008.
For Wireless: Data were obtained from the Wireless Federation article, http://wirelessfederation.com/news/17341-att-adds-1.4mn-mobile-subscribers-in-q2-usa/ (last accessed Mar. 24, 2010).

29 *See*, for example, SNL Kagan (a division of SNL Financial LC), "Cable TV Projections, 2008-2019".

30 Dutz, Mark, Jonathan Orszag, and Robert Willig, "The Substantial Consumer Benefits of Broadband Connectivity for US Households," (July 14, 2009). *See* http://internetinnovation.org/files/special-reports/CONSUMER_BENEFITS_OF_BROADBAND.pdf.

31 *See* FCC, Industry Analysis and Technology Division, Wireline Competition Bureau, *Trends in Telephone Service Report ("Trends in Telephone* Service Report, Table 3.2 & 7.1 (August 2008), available online at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-284932A1.pdf.

32 *See* FCC, Industry Analysis and Technology Division, Wireline Competition Bureau, *Trends in Telephone Service Report ("Trends in Telephone* Service Report, Table 13.3 (August 2008), available online at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-284932A1.pdf.

33 *See* FCC, Industry Analysis and Technology Division, Wireline Competition Bureau, *Trends in Telephone Service Report ("Trends in Telephone* Service Report, Table 1.2 (August 2008), available online at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-284932A1.pdf.

34 In the Matter of Implementation of Section 3 of the Cable Television Consumer Protection and Competition Act of 1992 Statistical Report on Average Rates for Basic Service, Cable Programming Service, and Equipment, MM Docket No. 92-266, 21 FCC Rcd 2503 (December 2006) *available online at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-06-179A1.pdf.

35 *See* FCC, Industry Analysis and Technology Division, Wireline Competition Bureau, *Trends in Telephone Service Report ("Trends in Telephone* Service Report, Table 3.1 (August 2008), available online at http://hraunfoss.

CHAPTER 3 ENDNOTES

fcc.gov/edocs_public/attachmatch/DOC-284932A1.pdf; *See also* In the Matter of Implementation of Section 3 of the Cable Television Consumer Protection and Competition Act of 1992 Statistical Report on Average Rates for Basic Service, Cable Programming Service, and Equipment, MM Docket No. 92-266, 21 FCC Rcd 2503 (December 2006) *available online at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-06-179A1.pdf.

36 Tuning a propagation model involves significant drive testing to ensure simulated signal density correctly accounts for foliage, buildings, terrain and other factors which result in attenuation.

37 Cisco Ex-Parte Filing; A National Broadband Plan for Our Future, GN Docket No. 09-51, Cisco VNI Mobile Data (FCC filed 25 March, 2010).

38 ComScore 200,000 panel of machine survey (Jan-Jun 2009).

39 Cisco Ex-Parte Filing; A National Broadband Plan for Our Future, GN Docket No. 09-51, Cisco VNI Mobile Data (FCC filed 25 March, 2010).

40 *See* OBI, Broadband Performance.

41 2:1 assumption based on the average number of people per household and wireless penetration.

42 While the mobile voice ARPU of a user is $37 per month in model calculations, assuming one competitor on average in non-4G areas leads to a weighted-average mobile voice ARPU of $18.50.

43 Assuming, in other words, that a national carrier will not gain incremental revenue from deploying a fixed-broadband network.

44 26 U.S.C. § 61(a).

45 Includes Limited Liability Companies (LLCs) treated as a corporation for federal income tax purposes. This tax treatment would not apply to noncorporate entities such as partnerships, including LLCs treated as a partnership for federal income tax purposes.

46 The baseline classification is based on parameters in Exhibit 4-K in the following section. The remaining parameter sets alter the classification of flat and hilly terrains, as shown in Exhibit 4-Y. We highlight the changes in the parameters from the baseline for convenience.

47 Letter from William J. Wilkins, Chief Counsel, U.S. Department of Treasury, to Cameron K. Kerry, General Counsel, U.S. Department of Commerce (Mar.4, 2010).

48 The model attempts to capture the scale effects of operations by examining publicly available data. It is possible that there are additional scale effects not captured in this calculation; or that smaller companies could face costs even higher than in the source data.

49 This gap value is different from Exhibit 3-G. In this example, since we are comparing against the base case, the telco faces one competitor in 4G areas and zero in non-4G areas. Exhibit 3-G assumes the telco faces zero competitors in all areas.

IV. NETWORK ECONOMICS

The United States has a diversity of both wired and wireless broadband networks which provides the vast majority of Americans with choices as to their broadband providers: most homes have a choice between wired broadband provided by a telephone network or a cable network. Telephone and cable networks were originally built for and funded by voice and video services respectively; but now, through upgrades, both are able to provide high-speed broadband to much of the country. Large investments in these networks are being made to further increase speed and capacity in the most profitable areas of the country. In addition to wired networks, there have been significant investments in wireless networks to provide broadband terrestrially via mobile and fixed wireless networks or via satellite. Like wired broadband, mobile broadband is likely to be provided over a network originally built for a different purpose—in this case mobile voice. Strong 3G mobile broadband adoption from smartphones, data cards and netbooks has driven operators to commit to large-scale upgrades to their wireless data networks using new 4G technologies. These new 4G technologies (WiMAX and LTE) can be used to provide broadband in higher speed mobile networks, fixed wireless networks and even hybrid fixed/mobile networks. Due to high costs and low capacity, satellites have primarily targeted customers in remote areas without other broadband options, but recently developed high-throughput satellites may change this.

BASIC NETWORK STRUCTURE

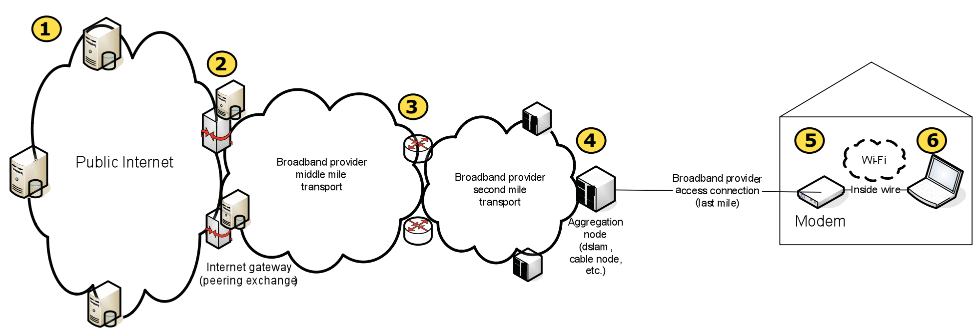
Exhibit 4-A is a diagram of the different portions of a broadband network that connect end-users to the public Internet. Starting at the public Internet, (1) content is sourced from various geographies and providers, data flow through the first peering point of the broadband provider (2), through the "middle mile" aggregation point (3) and "second mile" aggregation point (4), before being transported over either a wired or wireless "last mile" connection to the customer modem (5), which can either be embedded in a mobile device or standalone customer premise equipment (CPE), in the case of a fixed network. Once inside the premises broadband is connected to a device (6) through either wired or wireless connections (e.g. WiFi).

LAST-MILE TECHNOLOGY COMPARISON

We model the deployment economics of DSL/FTTN, FTTP, HFC, Satellite and 4G fixed wireless technologies. Each technology is modeled separately using detailed data and assumptions. Our model shows that fixed wireless and 12,000-foot-loop DSL have the best economics in delivering 4 Mbps down- and 1 Mbps up-stream to the unserved areas of the country.

Fixed wireless networks have favorable economics in most unserved areas, as the high fixed costs of wireless towers are amortized over many customers. In the least dense areas, particularly in mountainous terrain, however, there are few customers per tower and wired technologies are more economically efficient. Among wired networks, 12 kilofeet (kft) DSL has the best economics while still meeting the National Broadband Availability Target because it requires the least amount of network replacement/building. Although satellite capacity is

Exhibit 4-A:
Basic Network Structure



DEFINITIONS

1. **Public Internet content:** Public Internet content that is hosted by multiple service providers, content providers and other entities in a geographically diverse (worldwide) manner
2. **Internet gateway:** Closest peering point between broadband provider and public Internet for a given consumer connection
3. **Link between second mile and middle mile:** Broadband provider managed interconnection between middle and last mile
4. **Aggregation node:** First aggregation point for broadband provider (e.g. DSLAM, cable node, satellite, etc.)
5. **Modem:** Customer premise equipment (CPE) typically managed by a broadband provider as the last connection point to the managed network (e.g. DSL modem, cable modem, satellite modem, optical networking terminal (ONT), etc.)
6. **Consumer device:** Consumer device connected to modem through internal wire or Wi-Fi (home networking), including hardware and software used to access the Internet and process content (customer-managed)

limited by the number of satellites, and latency can be an issue for some applications, the fact that costs are not dependent on population density makes it an attractive option for serving the most remote areas of the country. We model FTTP, HFC and 3-5 kft DSL as well, and even though the performance and revenue opportunities are better with these technologies, they have unfavorable economics in areas with low population density relative to the other technologies mentioned, due to the high fixed costs of building or replacing large parts of the network.

In order to accurately model each technology, we need to understand both the technical capabilities as well as the economic drivers. First, we determine which of the network technologies could meet end-user speed requirements. Then, we collect detailed cost data required to accurately model the build of a network with the required network capacity. Finally, we determine the incremental revenues that could be generated from each technology.

Network Capabilities

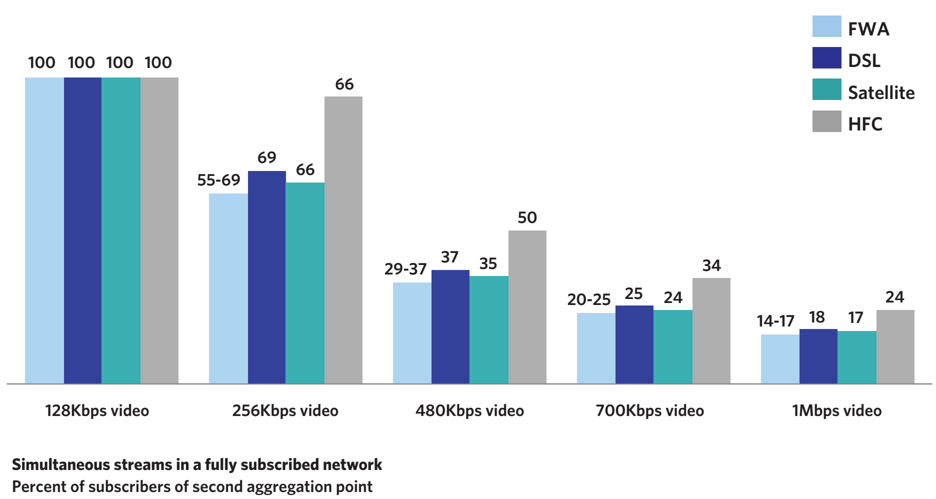
The National Broadband Availability Target is download speeds of 4 Mbps and upload speeds of 1 Mbps. As we shall see in later sections, we dimension the DSL/FTTN, HFC, FTTP, fixed wireless and satellite networks in our network model to meet the National Broadband Availability Target. Further, the sustained data rate capabilities of the networks are comparable.

For example, we compare the streaming capacities of the DSL, wireless, HFC and satellite networks as modeled in our analysis in Exhibit 4-B. For each of the cases, we consider a fully subscribed network, i.e., a network with the maximum prescribed subscriber capacity at the aggregation point nearest the end-users (a cell site in the case of wireless, a DSLAM/backhaul for DSL and a spot-beam for satellite). The details for each technology will be presented in following sections. For this analysis we assume the following: for wireless, a network of cell sites with 2x20MHz of spectrum, each with 650 subscribers;[1] for DSL, a network with about 550 subscribers[2] being served by a Fast-E second-mile backhaul link.

The exhibit shows the percentage of subscribers in each network that can simultaneously experience video streams of various rates. Thus, for example, we estimate that 29-37% of the wireless subscribers in the cell site can simultaneously enjoy a 480 kbps video stream.[3] For DSL and next-generation satellites, those numbers are 37% and 35%, respectively. So, each of the networks as dimensioned has comparable capabilities. We note that the capacity of an under-subscribed or under-utilized network will, of course, be higher. Thus, for example, if we used a Fast-E backhaul to serve a single 384-port DSLAM, then nearly 55% of subscribers can simultaneously enjoy a 480 kbps video stream.

However, the methods by which each technology can expand to meet growing capacity demand in the last mile differ. For example, with DSL, increased demand can necessitate two types of capacity upgrades that have very different remedies. First, when speed needs for a given user exceed the loop length capabilities on a DSLAM port (unshared network portion), the DSLAM is extended closer to the user so that the shortened copper loop can provide higher speed. This will involve fiber extension, electronics upgrades and significant outside plant reconstruction and rearrangement. This can be a very costly

Exhibit 4-B:
Streaming Capacity of Modeled Broadband Networks [4]



process that involves many aspects of "new" construction, such as pole transfers/make-ready costs, fiber trenching and general overbuild of portions of the outside plant. And second, if the capacity expansion is a result of aggregate demand growth among the users sharing the second-mile backhaul of the network, and not the last mile, one only needs to upgrade DSLAM ports and increase backhaul capacity. Undoubtedly, this carries significant cost, but is relatively straightforward as it primarily involves electronics upgrades.

In the case of HFC, RF signals for data transmission are modulated onto coaxial cables and shared among all of the subscribers who are connected and active on the coaxial portion of the HFC network. Therefore, the last mile is a shared resource. One process for capacity expansion is cable node splitting, which involves electronics upgrades similar to DSL but often also requires significant outside plant reconstruction and rearrangement. Thus, it involves many aspects of "new" cable construction, such as pole transfers/make ready costs, fiber trenching and general overbuild of portions of the outside plant. While this process is not without significant cost and lead time, it is well understood and has been practiced for several years. In addition, there are a number of other often-used methods for increasing capacity as will be discussed in the HFC section.

Similarly, the last mile is shared in FTTP/PON networks. More precisely, optical signals are modulated onto fiber optic cables, which are then distributed to individual homes between the PON splitter and the home. Capacity expansion is again a matter of upgrading electronics either at the headend, home or both, and certainly requires rearrangement of PON splitters and other passive outside plant equipment but does not require a fundamental design and architecture change.

In the case of wireless communications, the primary shared resource in the last mile is the RF spectrum. Multiple wireless devices, such as mobile phones and wireless data cards, simultaneously transmit/receive over the same shared spectrum. In fact, an average cell site covers more than 4,000 people, often referred to as POPs or population.[5] As we will see later, the wireless networks that we model to deliver broadband will be capable of serving up to 650 homes per cell tower using a paired 2x20 MHz[6] of spectrum. Capacity expansion in the last mile typically involves using more spectrum or adding more cell sites or both.[7] Since wireless spectrum is a scarce resource, wireless capacity expansion can be expensive, involving many of the high costs of outside plant/tower construction, etc. (similar to wired technologies discussed above), unless the provider has adequate spectrum holdings. With adequate spectrum, however, capacity expansion is straightforward and relatively inexpensive. Spectrum needs in *unserved rural areas*—with low population densities—are expected to be limited. Given the amount of spectrum currently available and the additional spectrum likely to become available in the next several years,[8] we expect that capacity expansion in wireless should be relatively inexpensive in *these* areas.

Capacity expansion with satellites will ultimately involve launching additional satellites which are capable of providing more total bandwidth and higher spatial reuse of the available spectrum. New launches, however can cost up to $400 million and require potentially long lead times, as will be discussed later in this chapter.

All of the technology comparisons in this chapter are based on network builds that can meet the target, with an effective busy hour load assumption of 160 kbps (see later section on Network Dimensioning). A fundamental tenet is that the networks have been modeled such that users will receive an equivalent level of service and performance whether they are serviced by the fixed wireless 4G access network or a 12 kft DSL architecture.

Cost Comparison

Our model allows us to calculate the relative cost structure of different last mile technologies as a function of population density in unserved areas. As shown in Exhibit 4-C, the costs associated with all technologies are competitive in the highest densities and diverge as we move toward lower population densities. Note that Exhibit 4-C represents the present value of costs, not the gap associated with each technology.

HFC and FTTP costs are comparable and both are among the most costly in all densities. As one might expect, the cost of running a new connection to every home in low-density areas is very high. In effect, carriers face the cost of deploying a greenfield network in these areas.

Short-loop FTTN deployments (3,000- and 5,000-foot loops) realize some cost savings relative to FTTP from being able to avoid the last few thousand feet of buildout. These savings are particularly valuable in denser areas where operators are more likely to find more homes within 3,000 or 5,000 feet of a given DSLAM location. At the other extreme, in the least-dense areas, where a carrier might have only one customer within 3,000 feet of a DSLAM location, 3,000-foot FTTN is actually more expensive than FTTP; a fiber drop is less costly than a DSLAM. Longer-loop (12,000-foot) DSL is particularly low cost in higher-density areas, where the cost of a DSLAM can be amortized over more customers.

Wireless solutions are among the lowest cost solutions and wireless costs grow less quickly as density falls. As discussed in Chapter 3, and in more detail below, a major driver of wireless cost is cell size. The assumptions made about cell size in hillier terrain are larger drivers of cost than density; however, when ordering census blocks by density, as in Exhibit 4-C, this effect is averaged away and lost. More detail about the impact of cell size on cost is included later in this chapter.

Exhibit 4-C includes only costs, both capex and ongoing costs, and does not include revenue. Technologies that enable higher revenue could have lower investment gaps than costlier alternatives. Thus, it is possible that FTTP deployment could have a lower investment gap in some census blocks than FTTN or wireless. In addition, given the assumptions made about take rate and ARPU, wireless often will have a lower investment gap than a less-costly 12,000-foot-DSL solution.

However, as noted in Chapter 3, evaluating the economics of technologies over areas as small as a census block makes little sense. Counties or other service areas draw census blocks from across multiple densities. Therefore this revenue-driven advantage is muted when census blocks are aggregated into counties or other service areas and wireless and 12,000-foot-loop DSL are the lowest investment-gap terrestrial solutions overall.

TECHNOLOGIES INCLUDED IN THE BASE CASE

As seen in Exhibit 4-C, our model indicates fixed wireless and 12 kft DSL are the low-cost terrestrial solutions that are capable of delivering speeds consistent with the Broadband Availability Target in unserved areas. We will focus on those technologies and satellite across the next three sections, before returning to those technologies with higher deployment costs.

Wireless Technology

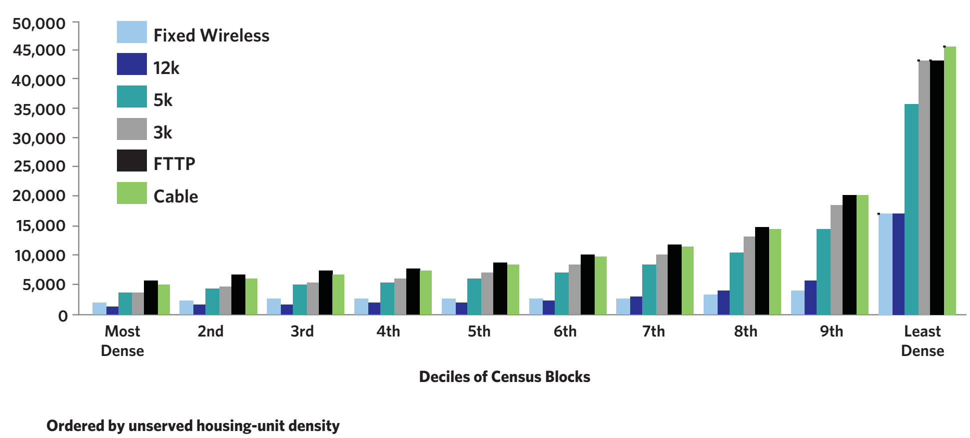
The first mobile networks were built when the FCC approved commercial car-phone service in 1946 but the first commercial cellular telephony service in the United States came in 1983 using AMPS technology. AMPS was an analog phone service that was still in use in some regions of the United States as recently as 2008. As wired communications started going digital in the 1980s, so did wireless telephony. In the 1990s there were four different 2G digital wireless technologies used in the United States: CDMA-based IS-95, TDMA-based IS-54 (often called Digital AMPS or D-AMPS), GSM and iDEN. Initially, these technologies provided voice services and some limited circuit-switched data services like SMS with peak data rates of 9.6 kbps.

CDMA and GSM became the predominant technologies in the United States, with more than 71% of subscribers in 2004.[9] For GSM, the first real step towards packet-based data services was GPRS, which was later replaced by EDGE. Even with EDGE, the average data rates were still only 100-130 kbps. The big step towards mobile broadband for GSM providers came with UMTS or WCDMA, a CDMA-based air interface standard; average user data rates were 220-320 kbps. Over time, the standards bodies created HSDPA for the downlink and HSUPA for the uplink, collectively referred to as HSPA today. User data rates of up to several Mbps became possible,[10] allowing GSM-family providers to offer true 3G service. See Exhibit 4-D.

Like GSM, CDMA rapidly evolved, first into CDMA2000 1xRTT which delivered peak data rates of 307 kbps and later into CDMA2000 EV-DO that is capable of delivering data rates of up to 3.1 Mbps.

There are two competing 4G standards that can be used in wireless broadband networks:[11] LTE, which is an evolution of the GSM family of standards, and WiMAX. Both of these technologies use OFDMA modulation instead of CDMA and, as such, are not backward compatible with either HSPA or EV-DO. The 4G technologies are only beginning to be deployed and adopted. In fact, LTE, one of the most anticipated

Exhibit 4-C:
Present Value of Total Costs for All Technologies in Unserved Areas [12]



4G technologies, has yet to be commercially deployed in the United States as of the time of this writing, while WiMAX covers less than 3% of the population.[13]

Evolution of the Performance of Wireless Technologies

As wireless technologies have evolved, so have their performances. In a broad sense, with every evolution the industry has achieved higher peak throughputs, improved spectral efficiencies and lower latencies. Additionally, with 4G the wireless signal can be transmitted over wider bandwidths of up to 20MHz,[14] which further increases spectral efficiency and network capacity, while letting the user experience higher data rates. Additionally, 4G uses a native, all-IP architecture, thus benefitting from the technology and economic efficiencies of IP networks.

The most important dimension of performance—at least as far as capacity of the wireless network is concerned—is spectral efficiency, which is the number of bits/second that a sector can transmit per hertz of spectrum. As such, spectral efficiency drives average downlink data capacity of a cell site linearly. Exhibit 4-E shows the evolution of the average downlink and uplink data capacities of a single sector in a three-sector cell site for the GSM family of standards.[16]

Note that there is no known analytic form for Shannon capacity for a multi-user, multi-site wireless network today. However, one can estimate the Shannon limit for a single user on a single cell site. Further, scheduling efficiency gains from multi-user scheduling are well understood.[17] One can therefore estimate the capacity of a multi-user, multi-site network.[18] But, this estimate does not take into account potential future gains in wireless technology and networks from, for example, coordinated transmission of data to users from multiple cell sites. Nonetheless, this estimated limit suggests that gains in spectral efficiency—and the ability of networks to cheaply improve performance or capacity—will likely be limited in the future.

In fact, as illustrated in Exhibit 4-E, we estimate that the latest release of the LTE standard brings us to within 25% to 30% of the maximum spectral efficiency achievable in a mobile network. Going forward, improvements in spectral efficiency are likely to result from techniques that include the use of new network architectures and multiple-antennas.[19] Specifically:

- Multiple-antenna techniques, such as spatial multiplexing in the uplink and improved support for beamforming
- Network enhancements:
  - Coordinated transmission of data to users from multiple cell sites
  - Relays or repeaters to improve coverage and user experience at cell edges with low additional infrastructure cost
- Carrier or spectrum aggregation to achieve higher user burst data rates

The 4G network architecture represents an evolution as well. 3G networks, having evolved from legacy 2G architectures that were primarily designed for circuit-switched traffic, were hierarchical in design and included many more network elements. 4G, on the other hand, optimizes the network for the user plane and chooses IP-based protocols for all interfaces.[20] The result: a much simpler architecture with far fewer network elements. Not only does this reduce capex and opex for 4G networks relative to 3G, but it also means reduced network latencies; see Exhibit 4-F. The performance of TCP/IP, the Internet data transport protocol, is directly impacted by latency,[21] so that reduced latencies translate directly into improved user experiences.

BOX 4-A

Wireless Multiple Access 101

In any wireless network with multiple users, those users must share the wireless communication channel. Different technologies use different schemes for sharing the channel; these schemes are commonly referred to as multiple access schemes. One such scheme is Time Division Multiple Access, or TDMA, which divides the channel into multiple time slots, allocating each to one of many users. The users then communicate with the base station by transmitting and receiving on their respective time slots. TDMA is used in GSM/GPRS/EDGE as well as the eponymous TDMA IS-54 standard.

Another scheme is Code Division Multiple Access or CDMA. It uses *spread-spectrum* technology for sharing the physical communication channel between the users. More precisely, in CDMA, the signal to and from each user is modulated using a uniquely assigned code. This modulated signal on the assigned code is spread across far more bandwidth than the bandwidth of the data being transmitted. This allows multiple users to simultaneously transmit or receive communication signals on the channel, which are then separated at the base station using the codes. CDMA allows for greater spectral efficiency than TDMA where communication to each user takes place in a uniquely assigned time slot. All 3G technologies, EV-DO and UMTS/HSPA, use CDMA, as does IS-95 and CDMA 1xRTT.

Finally, in Orthogonal Frequency Division Multiplex Access or OFDMA, data transmission occurs on a set of orthogonal *sub-carriers* assigned to each user; the sub-carriers are then modulated and transmitted using conventional modulation techniques. OFDMA has emerged as the multiple access technique for 4G technologies.[15]

Exhibit 4-D:
Different Wireless Technology Families Have Evolved Over Time [22]

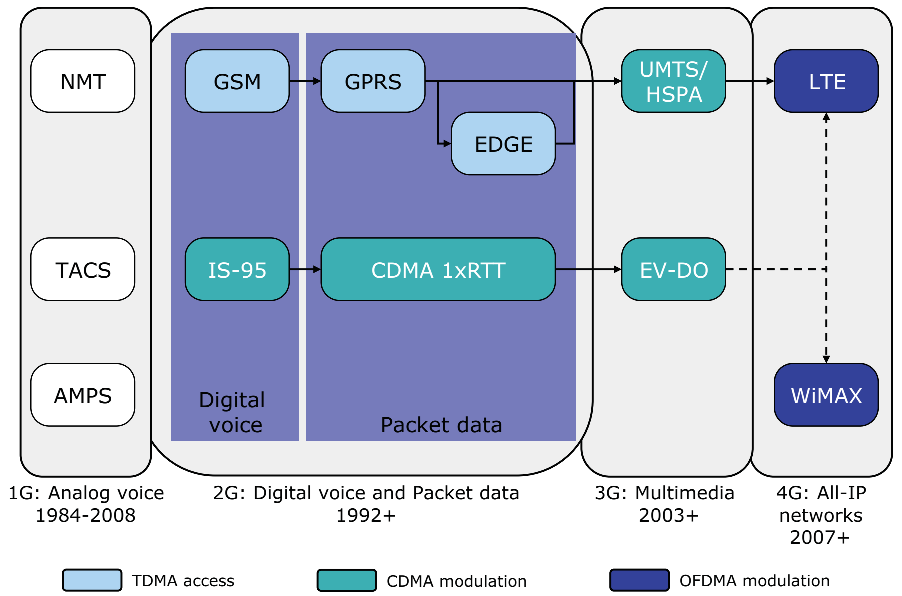
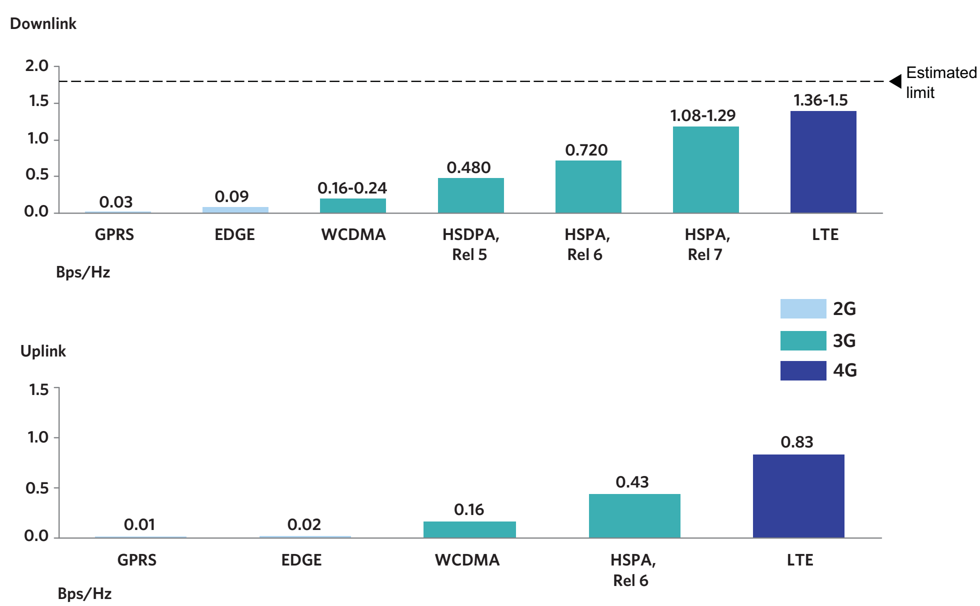


Exhibit 4-E:
Downlink and Uplink Spectral Efficiencies by Technology [23]



4G Deployment Plans

Exhibit 4-G shows projected 4G deployment plans for major carriers in the United States based on public announcements.[24] Verizon Wireless has the most aggressive deployment schedule for LTE. It plans to build out to 20 to 30 markets in 2010, extending to its entire EV-DO footprint by 2013—thus reaching more than 93% of the U.S. population.[25] AT&T has announced that it will be trialing LTE in 2010, then rolling it out commercially in 2011. Sprint plans to deploy WiMAX through its partnership with Clearwire. WiMAX has been rolled out in a few markets already and Clearwire announced plans to cover 120 million people by the end of 2010. With carriers in the United States and around the world making these commitments to deploy 4G, we expect it to have significant benefits of scale: a robust ecosystem, strong innovation and substantive cost savings.

Given the superior performance of 4G and the likely extensive 4G coverage by 2013, we shall limit our wireless analysis to 4G technologies in the rest of this document. Our goal is certainly not to pick technology winners, and we recognize that other wireless technologies, such as WiFi mesh, cognitive radios and even 3G, will be important parts of the broadband solution. However, these technologies are unlikely to deliver a cost-effective and reliable wide-area broadband experience consistent with the National Broadband Availability Target in unserved communities. To the extent these technologies offer appropriate service at comparable or lower prices, they will certainly play a role.

Fixed Wireless Access (FWA) Networks

By FWA networks, we refer to wireless networks that use fixed CPEs in addition to (or, possibly, even instead of) mobile portable devices. FWA solutions have been deployed as a substitute for wired access technologies. For example, FWA networks are being used commercially in the U.S. by Clearwire with WiMAX and Stelera with HSPA, and globally by Telstra

Exhibit 4-F:
Evolution of Round-Trip Latencies in Wireless Networks, in Milliseconds [26 27]

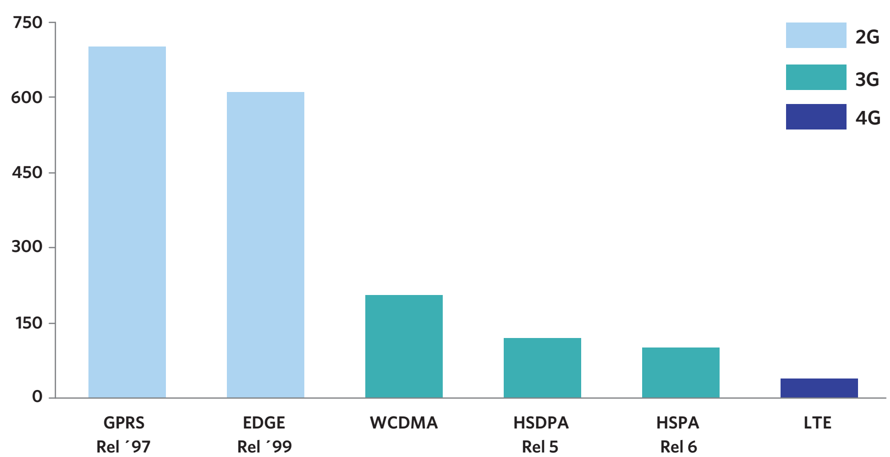


Exhibit 4-G:
Publicly Announced 4G Wireless Deployments

Technology	Companies	2009	2010	2011	By 2013
LTE	• Verizon • AT&T • MetroPCS • Cox		• Verizon (100MM) • AT&T (Trials)	• AT&T (start deployment) • Cox (start deployment) • MetroPCS (start deployment)	• Verizon (entire network)
WiMAX	• Clearwire/Sprint • Open Range • Small WISPs	• Clearwire (30MM) • WISPs (2MM)	• Clearwire (120MM)		• Open Range (6MM)

with HSPA. In addition to the larger providers, there are hundreds of entrepreneurial and independent Wireless Internet Service Providers (WISPs) who provide fixed wireless services to at least 2 million customers in rural areas, including many areas not covered by the national wireless companies.[28] Such deployments are particularly attractive in areas where wired competitors do not exist or have inadequate capabilities.

Fundamentally, FWA uses fixed CPE to deliver better performance by improving end-user signal quality. Examples of techniques that allow fixed wireless to provide superior performance compared to mobile broadband include:

- CPE techniques:
  - Using a higher power transmitter than would be possible with a battery-powered end-user device in order to improve the upstream data rate and/or increase the coverage area
  - Using large high-gain antennas along with external mounting to decrease building loss and further improve both upstream and downstream data rate and/or increase the coverage area
  - Placing the antenna in a favorable location to achieve line-of-sight or near line-of-sight to reduce path loss
- Base Station techniques: using stronger power amplifiers and multiple antenna techniques in order to increase the coverage area and/or capacity

These techniques are broadly applicable to most spectrum bands and to both 3G and 4G technologies. As such, generally speaking, FWA networks can support both fixed and mobile traffic, with fixed CPEs improving the performance of fixed service relative to mobile.

Our objective is to provide fixed broadband service to homes; so, we have used the performance characteristics of a FWA network in our network model. *In what is to follow, unless otherwise mentioned, the term wireless network will refer to a FWA network.*

Complexity of Analyzing Wireless Networks

It is important to recognize that a wireless network has several layers of complexity that are not found in wireline networks, each of which affect the user experience and, therefore, network buildout costs and the investment gap. For example, the location of the user relative to the cell site has a significant impact on data rates. More precisely, those at the cell edge, i.e., farthest from the cell site, will have much lower signal quality than those closer to it. And as signal quality drops, throughput drops as well; thus, at the cell edge a user may experience more than 60% degradation in data rates relative to the average experience within the cell.[29]

Another factor affecting user experience is the fact that wireless spectrum is shared by all the users in the cell. As a result, a user can experience significant variations at the same position in the cell depending on temporal changes in capacity demand (or loading).

There are other factors that lead to a heterogeneity of user experience. For example, the wireless signal itself undergoes different levels of degradation depending on terrain, user mobility and location (indoors vs. outdoors vs. in-car). Further, there is a wide range of end-user device types, which vary in their peak bandwidth capabilities, have different types of antennas, form factors, etc. Each of these factors can lead to a different user experience under otherwise identical conditions.

Consequently, analysis of the performance of wireless networks requires a statistical approach under a well-defined set of assumptions. We shall describe the assumptions behind the parameters we used in our wireless network model. However, it is possible that the parameters in an actual network deployment are different from those that we estimated. Improving the accuracy of our estimates would require a RF propagation analysis in the field—an extremely time-consuming and expensive proposition that is usually undertaken only at the time of an actual buildout. And even that approach will not always capture some effects, such as seasonal foliage.

Approach

Exhibit 4-H is a schematic that lays out our approach to analyzing the cost of the network buildout. The cost of the network, as shown, is driven by the number of cell sites required to deliver broadband service and the cost of building, operating and maintaining each cell site.

The number of cell sites required to serve an area is fundamentally dependent on capability of the technology. Using the performance of LTE networks, we dimension cell sites to deliver downlink and uplink speeds of 4 Mbps and 1 Mbps, respectively, in two steps:

- First, we ensure that the cell sizes are dimensioned to provide *adequate signal coverage*; i.e., absent any capacity limitations, the propagation losses within the coverage area are constrained and, therefore, the received signal strengths are adequate for delivering the target data rates. Our analysis indicates that the uplink requirement is the driver of coverage limitations.
- Next, once we have ensured adequate signal coverage, we ensure that each cell site has sufficient *capacity* to meet the traffic demand. We achieve this by constraining the maximum number of subscribers per cell site. As mentioned in Network Dimensioning, we only consider the downlink capacity requirements—and not the uplink—for our analysis.

Following that, we present the economics of a wireless network. In particular, we analyze the influence of factors like spectrum, terrain and downlink capacity on wireless economics. We also discuss in detail the factors that influence the cost of building and operating a cell site, namely tower lease/construction and backhaul for cell sites.

Dimensioning the Network for Coverage

The method of determining the maximum cell radius to ensure sufficient coverage in the modeled network is driven by three key factors (see Exhibit 4-I):

- ➤ Broadband rate targets and the corresponding link budgets: Link budgets allow us to calculate the Maximum Acceptable Propagation Loss (MAPL) of the transmitted signal such that the received signal quality is adequate for achieving the target data rates.
- ➤ Spectrum bands: The propagation characteristics of spectrum bands are different, thereby impacting cell radius.
- ➤ Terrain: It plays an important role in radio propagation. Simply put, mountains and hills block wireless signals; so areas with rougher terrain require smaller cell radii than areas with flat terrain.

Link Budgets

In order to deliver uplink speeds of 1 Mbps within 90% of the cell coverage area in a FWA network, the maximum acceptable propagation loss (MAPL) is 142 to 161 dB; see highlighted text in Exhibit 4-J. By contrast, the MAPL in a mobile environment is 120 to 132 dB. In other words, higher power CPEs with directional antennas placed in favorable locations in a FWA network yield gains of more than 20 dB over mobile devices.[30]

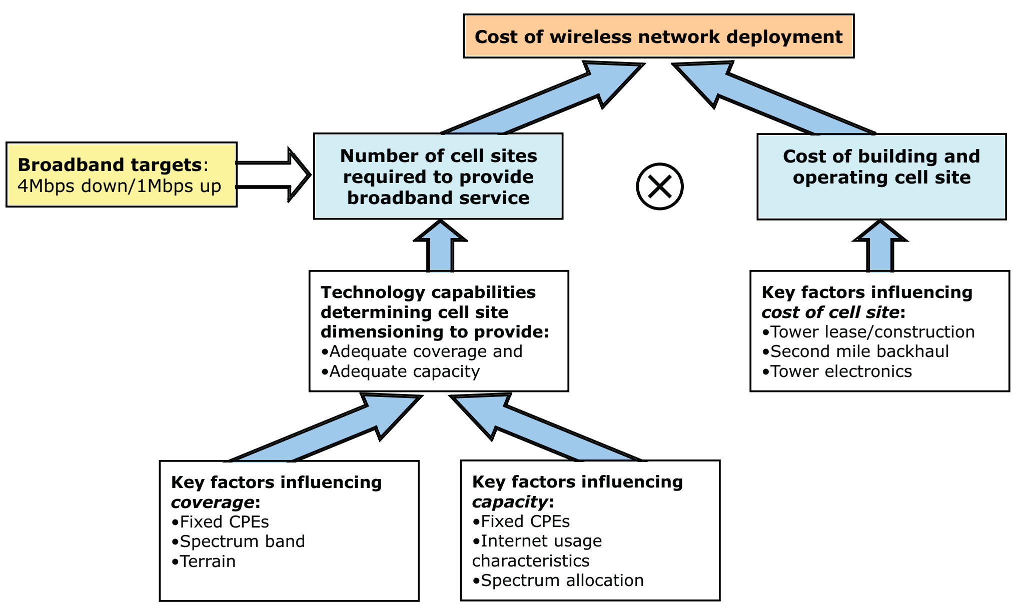
For our target data rates, it is the uplink that drives coverage limitations; i.e., the cell radius limits imposed by the uplink link budget calculation are smaller than the radii required to ensure adequate downlink received signal strengths. A cell radius small enough for a 200 mW handheld device or a 500 mW FWA device to deliver adequate signal strength to the base station is also small enough for a 40 W (macro) base station to deliver more than adequate downlink signal strengths.

Loosely speaking, unless the downlink and uplink requirements are more asymmetric than the power differential, the significantly higher power at the base station implies that adequate uplink coverage should result in adequate downlink coverage.[31]

Impact of spectrum bands

Cellular service today typically operates in one of several bands: from 700 to 900 MHz; from 1.7 to 2.1 GHz; and from 2.5 to 2.7GHz (see Chapter 5 of National Broadband Plan for details). Generally speaking, in this range of frequencies lower frequency signals suffer lower propagation losses and therefore travel farther, allowing larger cell sizes. Lower frequency signals also penetrate into buildings more effectively. Thus, for example, the Okumura-Hata model[32] predicts that the radius of rural cells in the 700MHz band can be as much as 82% greater

Exhibit 4-H: Approach for Analyzing Cost of FWA Network



than in the PCS band for comparable coverage. In suburban areas this benefit is 105%, while in urban areas the improvement is greater than 140%. That makes lower frequency bands better suited for coverage and deployments in rural areas.

Terrain classification and maximum cell size

Terrain plays an important role in radio propagation, an effect that cannot be captured using propagation loss models such as the Okumura-Hata model.[33] Since mountains and hills block wireless signals, areas with rougher terrain require smaller cell radii than areas with flat terrain.

To account for this effect of terrain, we classified terrain into each of the four categories shown in Exhibit 4-K. More precisely, we used GIS data to classify each Census Tract (CT),[34] based on elevation variations across one square Km grids, into one of the four categories.

Exhibit 4-I: Methodology for Determining Maximum Cell Radius for Coverage

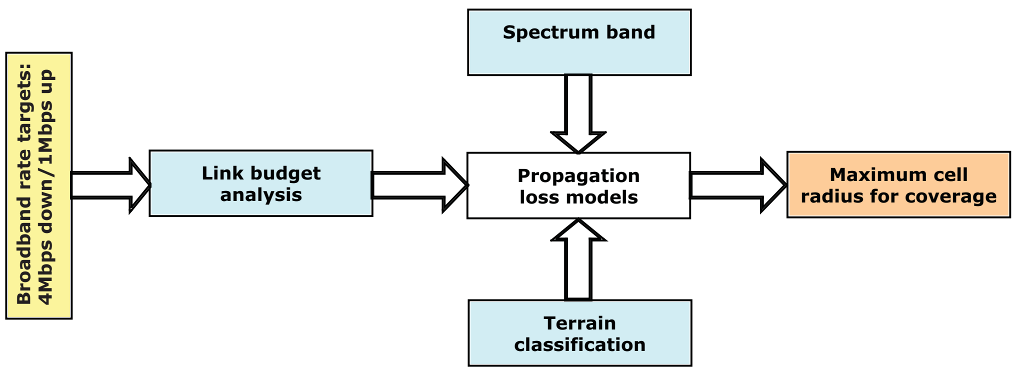
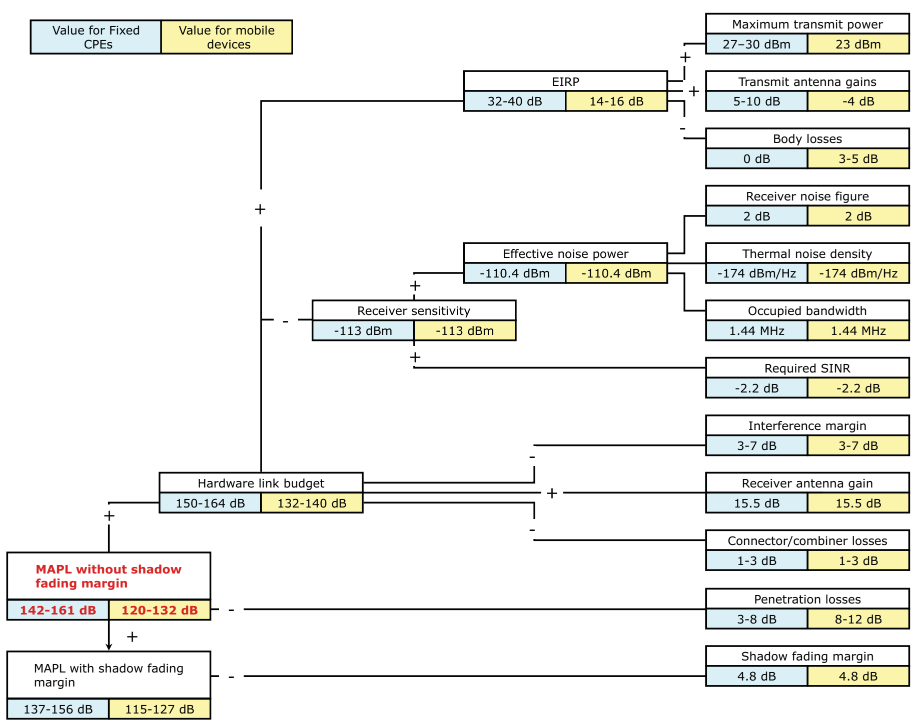


Exhibit 4-J: Link Budget for Delivering 1.26 Mbps Uplink Speeds at 700MHz[35][36]



Recall from the discussion of link budgets that the Maximum Allowable Propagation Loss (MAPL) for achieving our target broadband speeds is 142—161 dB. We use RF planning tools[37] (see Exhibit 4-M) to estimate the cell radius for each terrain type that will keep propagation losses within bounds.[38] More specifically, we choose the MAPL to be 140 dB, allowing for possible propagation losses due to foliage.[39] Areas in green in Exhibit 4-M correspond to areas with adequate signal coverage. The results of this analysis are shown in Exhibit 4-L for the 700MHz band.

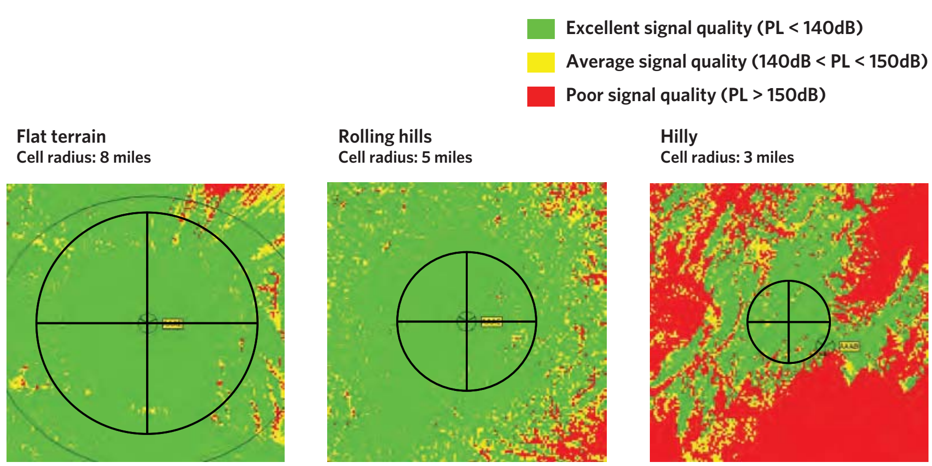
Exhibit 4-K:
Classification of Terrain of Census Tracts

Terrain type	Standard deviation (SD) of elevation (meters)	Examples
Flat	≤ 20	Topeka, Kan.; SD = 12 King City, Mo.; SD = 19
Rolling hills	20 to 125	Manassas, Va.; SD = 41 Lancaster, Pa.; SD = 45
Hilly	125 to 350	Lewisburg, W.V.; SD = 167 Burlington, Vt.; SD = 172
Mountainous	≥ 350	Redwood Valley, Calif.; SD = 350

Exhibit 4-L:
Maximum Cell Radius for Adequate Coverage in the 700MHz Band

Terrain type	Examples	Maximum cell radius (miles)
Flat	Topeka, Kan. King City, Mo.	8
Rolling hills	Manassas, Va. Lancaster, Pa.	5
Hilly	Lewisburg, W.V. Burlington, Vt.	3
Mountainous	Redwood Valley, Calif.	2

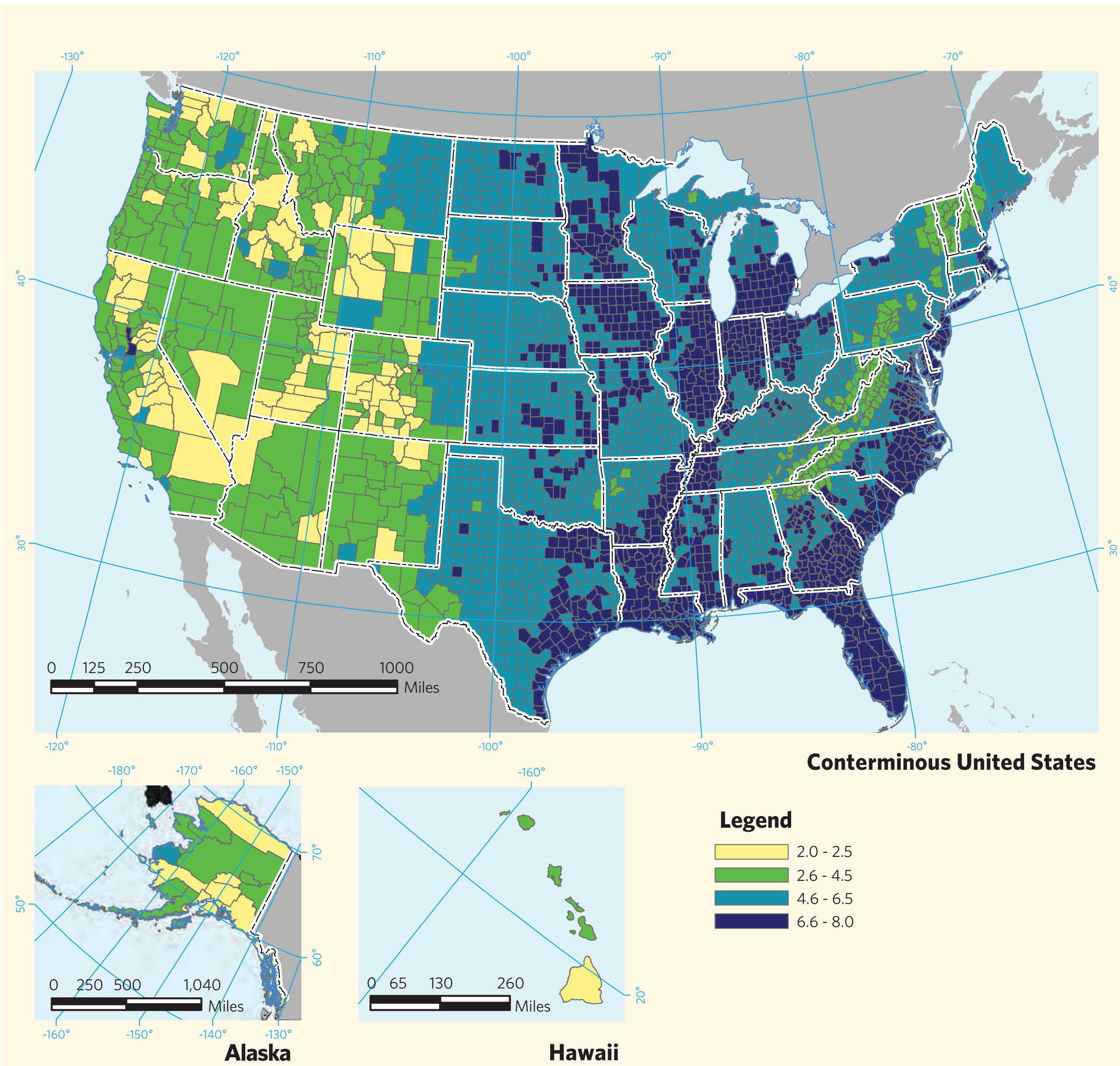
Exhibit 4-M:
Propagation Loss for Different Terrain Types at 700MHz[40]



We show a terrain map of the continental United States in Exhibit 3-X; average cell radii for each county based on the classification in Exhibit 4-L for the 700MHz band are shown in Exhibit 4-N. Finally, Exhibit 4-O quantifies the number of households by the cell sizes required to provide adequate coverage to them. Note that only around 13% of housing units (HUs) are in hilly or mountainous areas.

Finally, the propagation characteristics of the spectrum band clearly impact coverage. But, spectrum availability does not play an explicit role in our analysis. Certainly the

Exhibit 4-N:
Average Cell Size in Each County (in miles)



aggregated uplink *capacity* at a cell site improves with spectrum, but the only way to increase the maximum achievable data rate for a *specific user* is to reduce cell size. In other words, site counts will increase if we increase the uplink data rate requirement; adding more spectrum will not alleviate the problem.

Dimensioning the Network for Capacity

Exhibit 4-P shows that subscriber capacity of the wireless network depends primarily on the following:

- Broadband requirements and traffic characteristics. The first represents the National Broadband Availability Target of 4 Mbps downlink while the latter is a characterization of the demand for network capacity, generated by the subscribers on the network (see also Network Dimensioning section).
- Spectrum allocation. Loosely speaking, if spectral efficiency of the air interface remains unchanged, capacity of the wireless network grows proportionately with spectrum allocation.
- Fixed CPE with directional antennas. Specifically, the improvement in signal quality and data rates resulting from using directional antennas at CPE.

We then use the performance of LTE networks to determine the maximum subscriber capacity of the FWA network.

Importantly, signal quality or Signal to Interference and Noise Ratio (SINR)[41] in the downlink is not significantly impacted by increasing the transmission power in cells that are not coverage (i.e., signal strength) limited. This is because signal attenuation depends on the distance from the transmitter, so that SINR depends on the distance of the user from the *serving*[42] cell site relative to the other interfering cell sites. So, if we increase transmission power of all cells similarly, both received signal power and interference power increase proportionately and the net improvement in SINR is small. Correspondingly, reducing the radius of all cell sites proportionately also has a relatively small impact on SINR distribution.

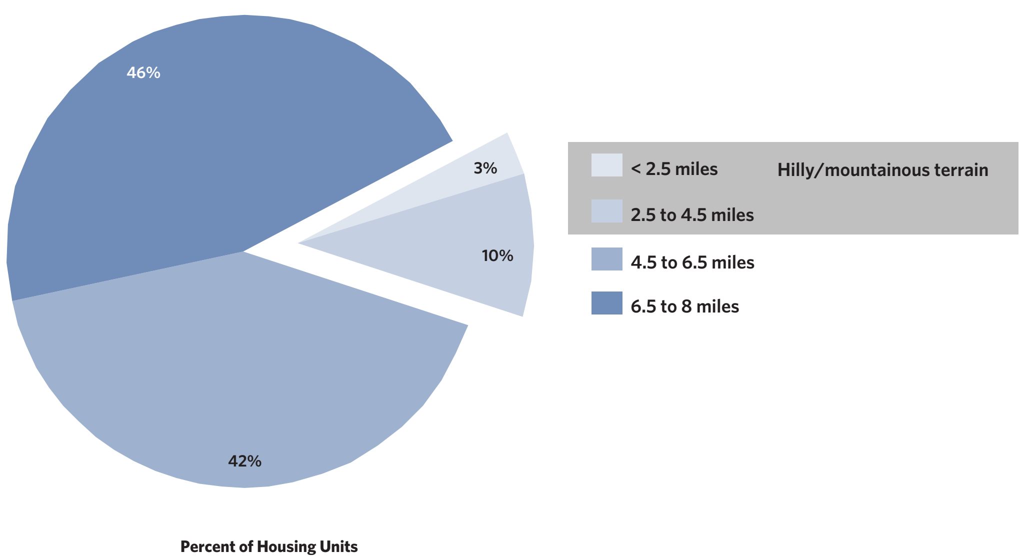
Requirements and Traffic Characteristics

Exhibit 4-Q shows our estimate of the maximum number of subscribers in a FWA cell site for different spectrum allocations.[43] This estimate includes the impact of directional antennas in fixed CPE as discussed below.

As noted in the section on coverage, cell radii are chosen to ensure that the signal quality is adequate for delivering 4 Mbps downlink and 1 Mbps uplink. However, since spectrum is a shared resource, we must ensure that the network is also capable of providing sufficient capacity to deliver these speeds. The approach to sizing the number of subscribers therefore is to first characterize network usage using the Busy Hour Offered Load (BHOL) metric; see Network Dimensioning for details. We assume the BHOL per subscriber is 160 kbps. Then, we use the performance of LTE networks to determine the maximum number of subscribers per cell site for different spectrum allocations such that users achieve the broadband-speed target 95% of the time when the BHOL is 160 kbps.[44]

Note that we achieve our target downlink data rate by limiting the maximum subscribers per cell site, which can be

Exhibit 4-O: Coverage of Unserved Housing Units by Cell Radius



interpreted to be a limit on cell size. But we remarked earlier that we cannot increase data rates by reducing cell size—a seeming contradiction. The resolution is that reducing cell size does not improve signal quality unless it results in a reduction in the number of subscribers per cell site. For example, the user-experience in two cells with 100 subscribers each will not be materially impacted if the cell radius of each is 1/2 km instead of 1 km. Since the load on the network will not change in either case, the utilization is unchanged as well. If we now introduce two additional cells into this hypothetical network, such that each cell has 50 subscribers, then we will see an improved user experience because fewer subscribers in each cell will imply reduced load in each cell. That, in turn, will reduce each cell's utilization and, thereby, improve signal quality and end-user data rates.

So, we cannot prescribe a maximum cell radius to achieve a target downlink data rate (because population density across geographies is not uniform). But we can limit subscribers per cell to achieve target speeds.

Fixed CPE with directional antennas

Using fixed CPE with directional antennas can result in more than a 75% improvement in spectral efficiency over CPE with omni-directional antennas.[45] More significant is the gain in data rates at the cell edge. We illustrate this in Exhibit 4-R. Specifically, the chart on the left shows the improvement in SINR distribution in the cell site when the network has CPE with directional antennas instead of omni antennas. For

Exhibit 4-P: Methodology for Dimensioning Wireless Networks to Provide Adequate Capacity

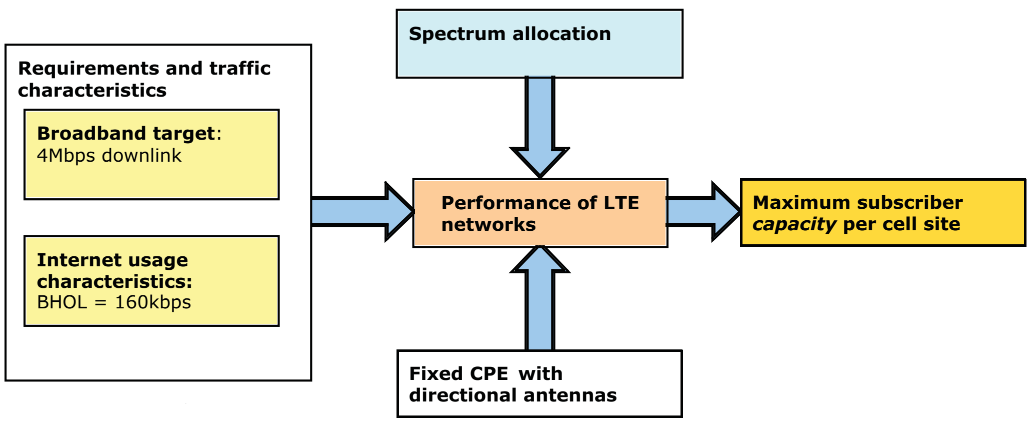
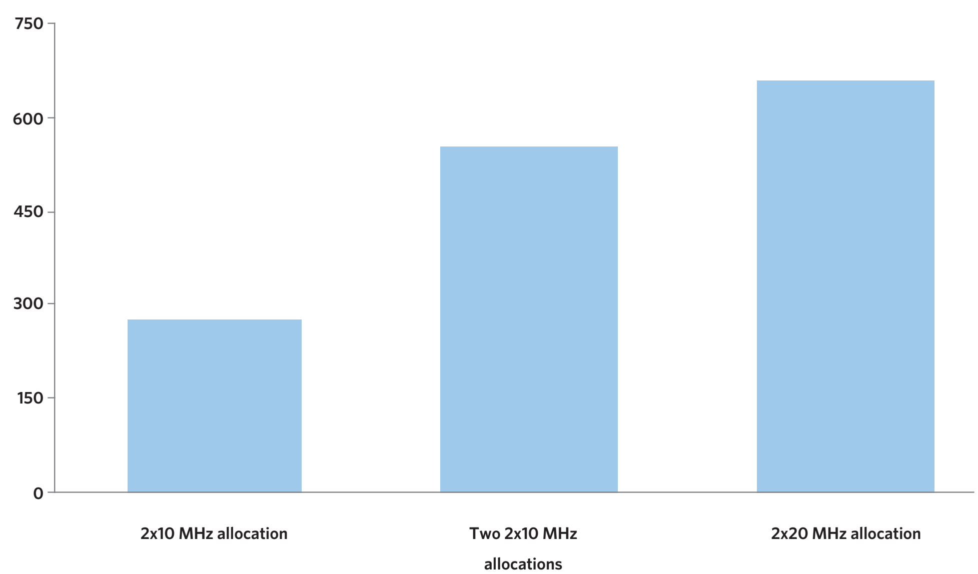


Exhibit 4-Q: Maximum Number of Subscribers Per Cell Site in an FWA Network with Directional Antennas at the CPE[46]



example, nearly 35% of users in a network with omni antennas have a SINR of 0 dB[47] or worse. By contrast, less than 1% of the users in a network with directional antennas have a SINR of 0 dB or worse. The significant boost in signal quality is a result of (a) improved signal reception with the higher antenna gain of a directional antenna and (b) reduced interference due to the increased interference rejection possible with such antennas.

This improvement in SINR directly translates to better data rates. For example, if a CPE with an omnidirectional antenna experiences a data rate of ~3 Mbps, then a CPE with a directional antenna will experience an average of ~9 Mbps under otherwise identical conditions.

Spectrum allocation

We mentioned above that lower spectrum bands are better suited for coverage. Higher frequency spectrum, on the other hand, is better suited for capacity by deploying Multiple Input and Multiple Output, commonly referred to as MIMO,[48] solutions. This is because smaller antennas can be used at higher frequencies and multiple antennas can be more easily integrated into handsets constrained by form factor. As such, deployments in these bands can have higher spectral efficiency. That is not to say that MIMO cannot be deployed in the lower frequency bands; rather, MIMO solutions are more practical and cheaper in the higher bands.

In our model, we assume 2x2 MIMO,[49] which is easily implemented in the 700MHz band in a FWA network.

The importance of spectrum towards ensuring a robust mobile broadband future has been discussed at length in the Chapter 5 of the NBP. In this section, we discuss how spectrum availability impacts subscriber capacity. For convenience, we shall assume the propagation characteristics of the 700MHz band for this discussion.

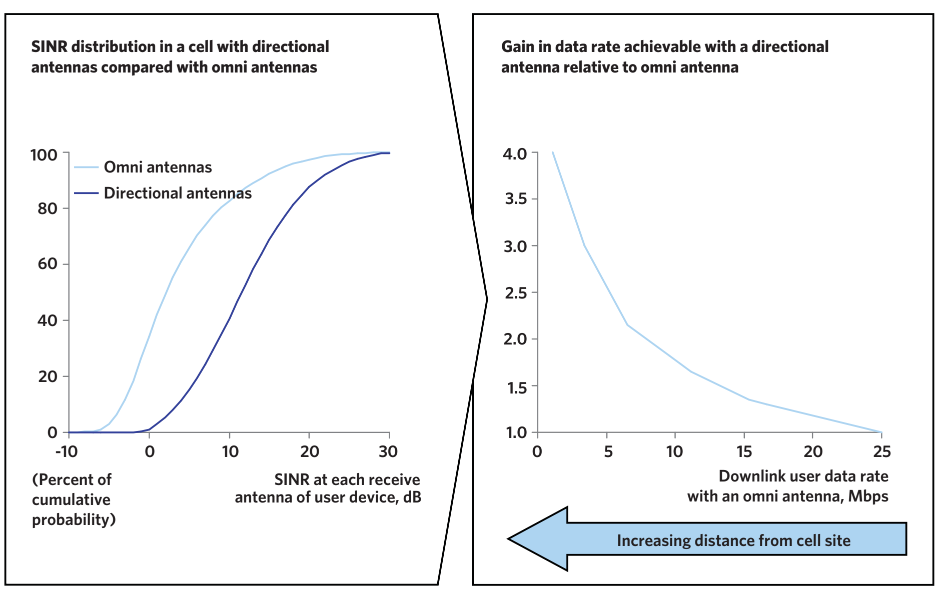
In Exhibit 4-Q, we saw that the capacity of a network with two paired 2x10MHz carriers[50] is twice that of a single 2x10MHz carrier. That should not be surprising. Interestingly, however, the capacity with a single 2x20MHz carrier is 20% higher than with two 2x10MHz carriers.[51] This is, in part, due to the better statistical multiplexing possible with the first option (using the wider carrier). Most of these gains will also be achievable with the second option once carrier/spectrum aggregation is introduced in the LTE standard.

Exhibit 4-S shows the spectrum needs in 2020 and 2030 for *coverage* cell sites in the unserved regions of the United States. Recall that coverage cell sites provide adequate downlink and uplink coverage (i.e., 4 Mbps/1 Mbps downlink/uplink speeds at the cell edge); however, depending on the number of households within the cell site, it may not have enough capacity to meet the traffic needs.

For our baseline model, we assume that 2x20MHz of spectrum is available per cell site. So, as the figure shows, in 2020, 94% of the *coverage* cell sites will also have adequate capacity. The remaining cells need techniques such as cell-splitting or 6-sector cell sites to increase capacity.[52] As the uptake continues to increase, the spectrum needs will also increase, as shown by the chart on the right.

This analysis is based on an average BHOL per subscriber of 160 kbps. Higher data usage than that will indeed increase spectrum needs. Still, the analysis shows that spectrum needs are

Exhibit 4-R: Impact of Directional Antennas at CPE on SINR [53,54]



relatively modest, due to three reasons. First, we used a FWA network, which has higher capacity than a mobile one. Second, the population density in the unserved regions is very low—less than 10 HUs per square mile. Consequently, the number of subscribers per cell site and the traffic demand per cell site are also relatively modest. Finally, the uplink coverage requirement of 1 Mbps resulted in a much higher cell site density than would otherwise be necessary, which further reduced the number of subscribers per cell site.

We end this discussion on spectrum availability by contrasting the difference in impact spectrum has on uplink and downlink dimensioning:

➤ In order to achieve a target *uplink* user data rate, we limit the maximum cell radius to ensure sufficient *coverage*. And while propagation characteristics of the spectrum band are important for our calculation of maximum cell radius, spectrum availability has little impact—the uplink signal received at the cell tower, not the availability of spectrum, is the limiting factor.

➤ In the *downlink*, on the other hand, we are limited by cell site *capacity*. We can either reduce the cell size to match subscriber demand with capacity, or we can add spectrum to the cell site, because more spectrum implies more capacity. The first option is more expensive, because the incremental cost of using additional spectrum at a cell site is smaller than the construction costs associated with cell-splitting if spectrum is available.

Therefore, the overall impact of spectrum availability on network buildout depends on the evolution of downlink and uplink usage characteristics. Specifically, let us consider two extreme scenarios:

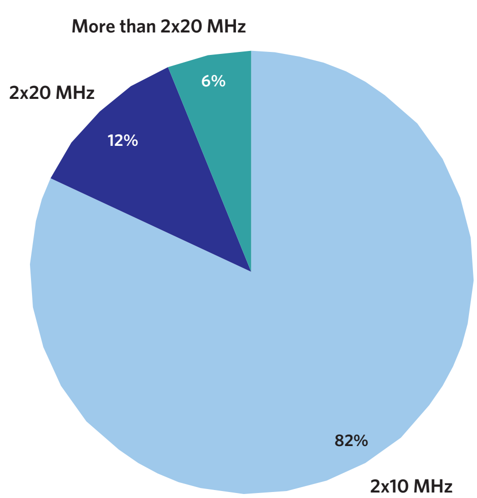
➤ **Extreme uplink usage**: If uplink usage were to evolve disproportionately faster than the downlink, then the only way to dimension the network would be to reduce the cell size. In doing so, we reduce the number of subscribers per cell site. That, in turn, automatically reduces the downlink capacity needs per cell site so that spectrum plays a less critical role in the solution.

➤ **Extreme downlink usage**: If, on the other hand, downlink usage evolves disproportionately faster than the uplink, then availability of spectrum can significantly mitigate the need for additional cell sites. That, in turn, significantly reduces the cost of network capacity expansion.

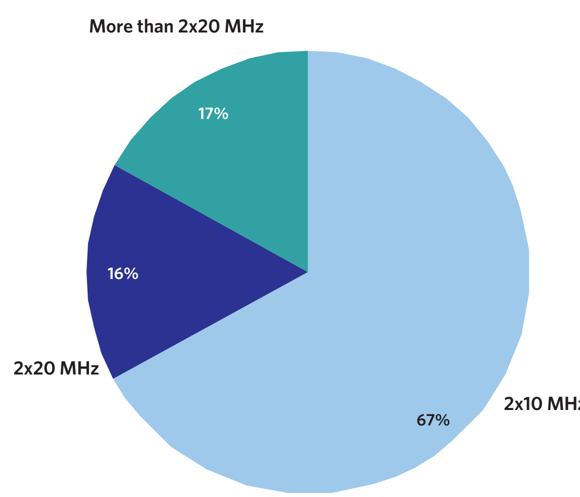
Second-Mile Backhaul

A key requirement of wireless broadband networks is high-capacity backhaul, a need that will only grow as end-user speed and effective load grow. Today, even though 97.8%[55] of the U.S. population has 3G coverage, most cell sites are still copper fed. For example, Yankee Group estimates that more than 80% of cell sites are copper fed.[56] Further, Sprint Nextel noted that in its network, "most towers carry between one and three

Exhibit 4-S: Spectrum Needs for Cell Sites in 2020 and 2030, Based on BHOL of 160 kbps



Spectrum needs for cell sites, 2020
Percent of cell sites



Spectrum needs for cell sites, 2030
Percent of cell sites

DS-1s" and that "almost no towers have more than five DS-1s."[57] This is important because copper facilities will have inadequate speeds for a well-subscribed 4G cell site; so, without adequate upgrades, backhaul can quickly become the choke point of the network (see Exhibit 4-T). Additionally, both fiber and microwave avoid some of the reliability problems often found in dealing with copper-based backhaul. Said differently, dimensioning adequate backhaul is one of the key drivers for providing wireless broadband. As shown in Exhibit 4-T, for our purposes we need backhaul capacity that can only be provided by fiber and/or microwave.

In unserved areas, microwave point-to-point backhaul is a potentially attractive alternative to fiber for providing second-mile capacity at substantial cost savings relative to fiber. We assume that microwave allows high-capacity connectivity at a lower price by bypassing the need for a direct aerial or trench-based connection. For instance, a microwave link can provide speeds of up to 500 Mbps over a distance of 20 miles[58] at a typical equipment cost of roughly $50,000.[59]

By contrast, costs of new fiber construction depend heavily on the distance to an existing fiber network and whether the area has aerial plant available for connection. Costs can range from approximately $11,000 to $24,000 per mile for aerial construction and roughly $25,000 to $165,000 per mile for buried construction.[60] Many providers may prefer fiber regardless of the cost, especially in denser areas, because of its ability to provide higher capacity per link and its inherent reliability.

Overall, when compared with new fiber construction, and even with leased Ethernet links, microwave links can have a lower total cost for link distances greater than 1-2 miles.[61]

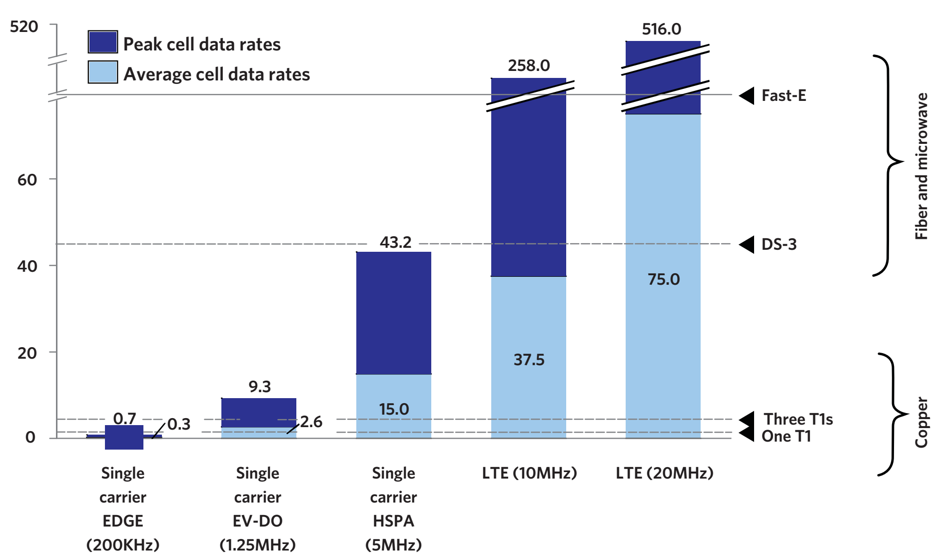
Ethernet over Copper (EoC) may also be part of the 4G-backhaul solution. We did not include EoC in our 4G-backhaul calculations for several reasons: first, as noted above, there is often a limited amount of copper available; second, the quality of that copper over the multi-mile distances in rural areas is unknown; and third, for new cell-site construction, where there are no existing backhaul facilities, carriers are likely to install fiber or rely on microwave.

Hybrid Fiber Microwave (HFM) backhaul architecture

Since microwave can be a cost-effective substitute for fiber, a Hybrid Fiber Microwave (HFM) backhaul architecture would yield significant cost savings in wireless networks relative to an all fiber network (see Exhibit 4-U). Specifically, as illustrated in the exhibit, in an HFM architecture some cell sites rely on microwave for backhaul, and only few cell sites are fiber-fed. The fiber-fed sites serve as backhaul "aggregation points" for the remaining cell sites. These remaining sites connect to the fiber-fed aggregation points using microwave links, sometimes using more than one microwave hop. For example, Cell site 3 is fiber fed, serving as an aggregation point for the backhaul needs of Cell sites 1 and 2. Further, Cell site 2 connects to Cell site 3 using one microwave hop, while Cell site 1 connects using two (via Cell site 2). Such HFM architectures are already being used by wireless service providers such as Clearwire, for example.[62]

Even though the microwave links now have reliability comparable with their wireline counterparts, an HFM network that uses a large number of hops can lead to concerns about

Exhibit 4-T:
Average and Peak Capacity of a 3-Sector Cell Site Relative to Backhaul Speeds, Mbps



reliability. To see this, observe in Exhibit 4-U that the loss of the microwave link between Cell sites 2 and 3 will also result in the loss of backhaul connectivity for Cell site 1. If each of these cell sites had a radius of 5 miles, then as much as 150 square miles would lose coverage through the loss of the single link. Clearly, then, this cascading effect can become particularly pronounced in a network that has a large number of hops. On the other hand, the more hops, the greater the potential for second-mile cost savings.

Our baseline model for FWA uses an HFM architecture with a maximum of four microwave hops.

In unserved areas, an HFM second-mile network architecture has cost advantages over a fiber-only network architecture. Microwave backhaul has two additional benefits, especially to service providers who do not already own fiber middle-mile backhaul assets. First, microwave can often be deployed faster than fiber. Second, in many territories, the owner of wired backhaul facilities could be a competitor in providing wireless service. In such cases, microwave backhaul offers an effective alternative to paying competitors for backhaul service.

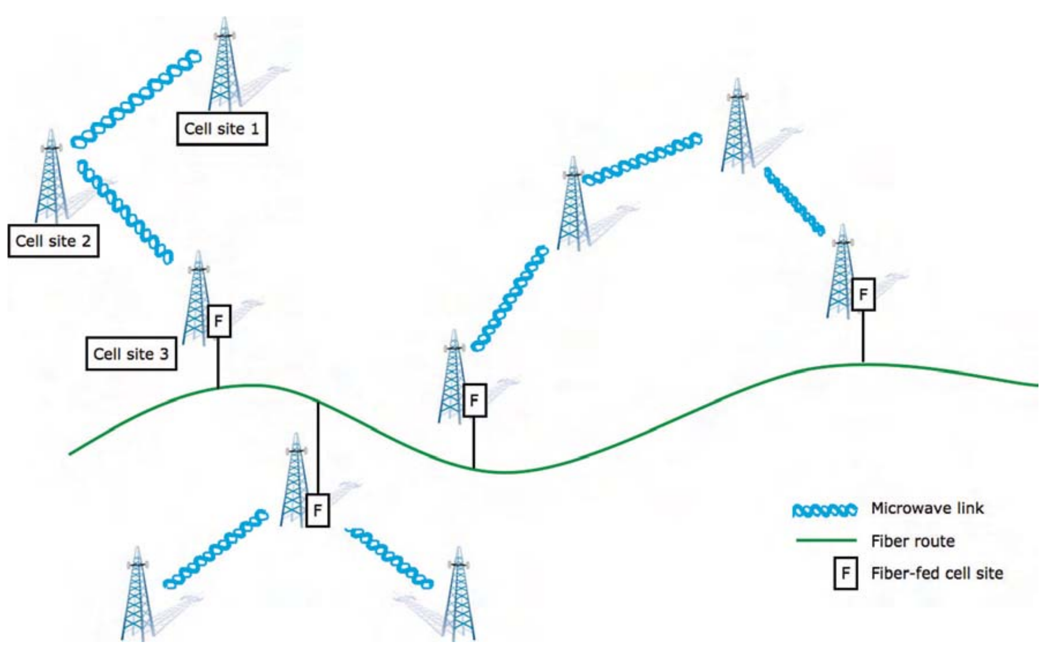
However, microwave backhaul also has two significant limitations. First, as noted earlier, microwave links have capacity limitations and cannot be used for very high-speed backhaul needs. Further, higher data rates require more spectrum. Since there is only a limited amount of spectrum available, carriers can only have a limited number of high-speed microwave links in a geographical area. Note that the NBP had a series of recommendations related to improving point-to-point backhaul solutions in Chapter 5.

The second limitation is a requirement for line of sight from one microwave tower to the next. In hilly or mountainous terrain, this may mean that a provider needs to add additional microwave relays even beyond the reduction in cell size described above, adding to costs. It may be the case that the same terrain issues drive up fiber costs as well, perhaps even more quickly, so this will not necessarily tip the balance toward fiber. But it will likely drive up backhaul costs overall. Further, in some cases the tower may need structural reinforcements to support a microwave antenna, which will drive up the cost of microwave installation.

So, even though an HFM architecture has significant cost advantages, fiber is expected to be the primary backhaul choice for service providers because it offers a scalable, future-proof backhaul solution.

Finally, a fiber-only architecture has one significant strategic advantage. As broadband needs continue to grow, fiber emerges as the only last-mile technology capable of meeting ultra high-speed needs. So, any solution that brings fiber closer to the home by pushing it deeper into the network puts into place an infrastructure that has long-term strategic benefits. On balance, therefore, we need to weigh this strategic benefit against the higher associated cost to evaluate the value of a fiber-only architecture over an HFM architecture.

Exhibit 4-U: Hybrid Fiber Microwave Backhaul Architecture for Cellular Networks



Economics of a Wireless Network

Exhibit 4-V shows the network elements that we modeled for FWA network cost analysis (see also Exhibit 4-A above). Specifically, in the last mile—the link from the cell site to the end-user—we model installation and operations costs, as appropriate, for the tower infrastructure, Radio Access Network (RAN) and other ancillary[63] equipment. We also account for the cost of the end-user CPE. In the second mile, which is the backhaul connection from the cell site to the second point of aggregation in the exhibit, we model the costs of installing microwave equipment and new fiber, as needed; see the Section on Middle Mile for details on backhaul network architecture.

Our network model, as shown in Exhibit 4-V, shows that the Investment Gap when using FWA networks in the 700MHz band for providing broadband to the unserved population in the United States is $12.9 billion (Exhibit 4-W). This funding gap is for the wireless buildout *only* and is not driven by the second least-expensive of a mix of technologies. For more details on our overall network modeling assumptions and principles, see **Creating the Base-case Scenario and Output** above.

Dependence on terrain type

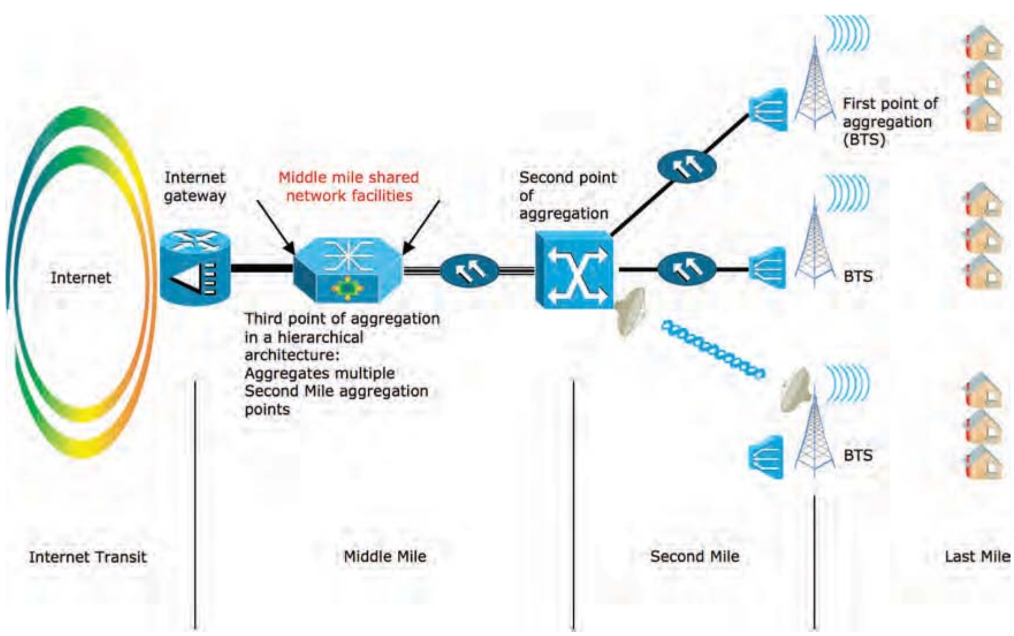
Recall that for our network model, we classify terrain into four types, choosing a different maximum cell radius for each. Exhibit 4-X shows the average investment (i.e. capex) per housing unit (HU) and Investment Gap per HU based on the underlying cell radius required. The smaller cell radii correspond to counties that are mountainous/hilly.

The exhibit shows that the cost of serving HUs in hilly terrain can be as much as 30 times higher on average than in flatter areas. This is in part due to the fact that smaller cell radii in hilly terrain mean that we need more cell sites, thereby driving up the cost; and, in part due to the fact that HU density is also lower in hilly areas. [64]

Our classification of terrain in Exhibit 4-K is based on a statistical analysis of terrain variation data. It is likely that in some instances our method will misclassify a census tract (CT). The only way to get an extremely accurate estimate of cell radius is to actually do a RF propagation analysis for each CT using tools such as those provided by EDX Wireless. That is extremely time-consuming and expensive. To range the impact of misclassification, we analyze the sensitivity of buildout costs and the investment gap to our terrain classification parameters.

Exhibit 4-Y illustrates the results from our sensitivity analysis. In addition to the FWA buildout costs and the FWA investment gap, we also show the overall investment gap for bringing broadband to the unserved using a mix of technologies. Note that the impact on the overall investment gap is less than 10%. This is because the overall investment gap is driven by the second least-expensive technology. More specifically, we find that the percentage of unserved HUs served by wireless drops from 89.9% in the baseline to 89.1% with the "very mountainous" classification in parameter C, thus explaining the relatively small impact terrain classification has on the overall investment gap.

Exhibit 4-V: Illustrative Wireless Network Architecture



Dependence on downlink capacity
Since LTE is not commercially deployed yet, it is conceivable that actual downlink spectral efficiency and, consequently, subscriber capacity differ from that simulated. So, we analyze the dependence of wireless buildout costs and the investment gap to our subscriber capacity estimates as shown in Exhibit 4-Z. We note that the impact on costs as well as Investment Gap is negligible. Consequently, the impact on the overall Investment Gap—as determined by the cost of the second least-expensive network—is also small (not shown in chart).

Dependence on spectrum
Our baseline model assumes a network deployment in the 700 MHz band. If, instead, we deploy the network in the PCS band, the

Exhibit 4-W:
Investment Gap for Wireless Networks

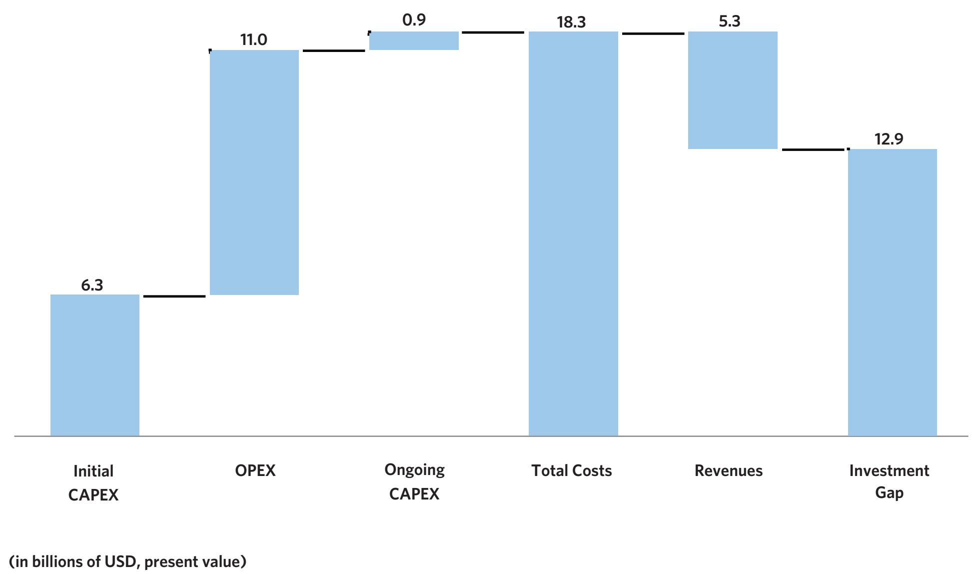
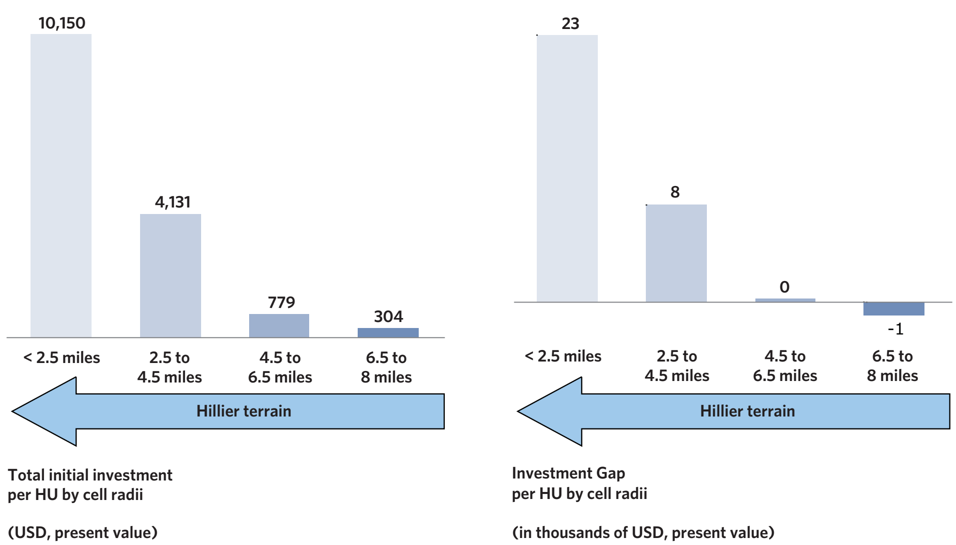


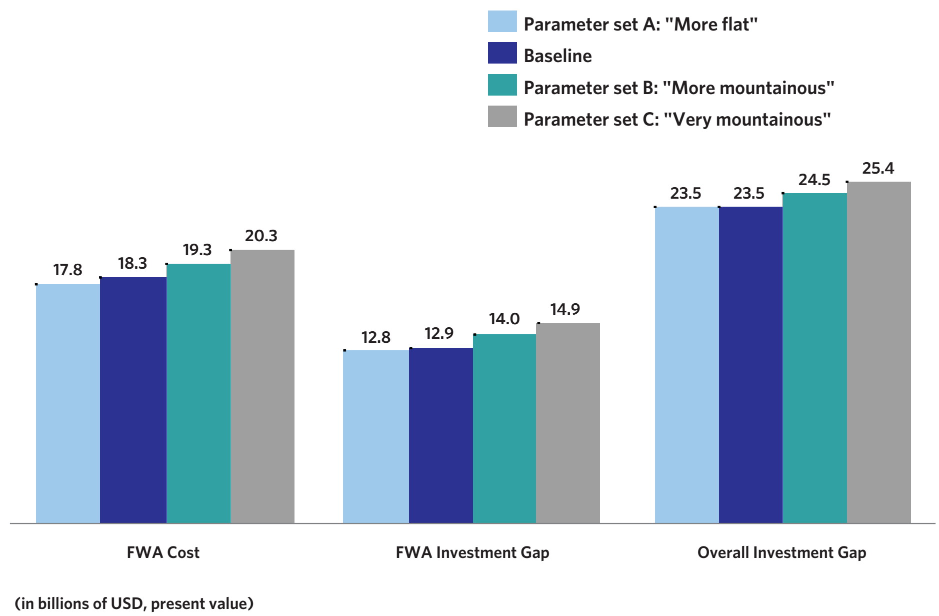
Exhibit 4-X:
Total Investment per Housing Unit (HU) and Investment Gap per HU by Cell Size



total cost of the FW deployment in counties with negative NPV is 96% greater. Further, the FW investment gap is 90% more. Note that this is a comparison of the FW investment gap only and not that of the overall investment gap. For this analysis, we use the following maximum cell radius for each of the four terrain types.[65]

Terrain classification	Maximum cell radius (miles)
Flat	5
Rolling hills	3
Hilly and Mountainous	2

Exhibit 4-Y:
Sensitivity of Investment Gap to Terrain Classification—Change in Costs and Investment Gap by Changing Terrain Classification[66]



Terrain type	Classification parameters based on Standard Deviation of elevation of CTs			
	Baseline	Parameter set A	Parameter set B	Parameter set C
Flat	≤ 20	≤ 25	≤ 20	≤ 20
Rolling hills	20 to 125	25 to 125	20 to 125	20 to 125
Hilly	125 to 350	125 to 350	125 to 300	125 to 250
Mountainous	≥ 350	≥ 350	≥ 300	≥ 250

Cost and gap shown for counties that have a negative NPV. The baseline classification is based on parameters in Exhibit 4-K. The remaining parameter sets alter the classification of flat and hilly terrains, as shown below. We highlight the changes in the parameters from the baseline for convenience.

Our baseline also assumes 2x20 MHz of spectrum availability. Exhibit 4-AA shows the economic impact of spectrum availability assumptions. Note that the lack of spectrum increases the cost of the buildout in unserved areas by nearly 5%. The cost impact is relatively small because 2x10 MHz of spectrum is sufficient for 82% of the cell sites (see Exhibit 4-S). The cost impact in areas with negative NPV is even smaller (less than 3%). This is because the cell sites in these areas are typically smaller, so that they also have fewer HUs in them (see Exhibit 4-X for the impact of cell radius on the Investment Gap), which reduces the spectrum needs for the cell sites. Consequently, the impact on the Investment Gap in these areas is also small.

We have not yet addressed the fact that no U.S. service provider currently has more than 2x10MHz of contiguous spectrum in the 700MHz band. But both Verizon Wireless and AT&T Wireless do have noncontiguous spectrum holdings of over 2x20MHz of spectrum across different bands. However, these bands will not all have similar propagation characteristics.

A common deployment strategy used in such situations is to use the lower frequency bands with superior propagation characteristics to serve households further away from the cell site. The higher frequency bands, which can have superior capacity through the use of MIMO techniques, are then reserved for serving those closer to the cell site. This ensures that each available spectrum band is efficiently used.

Cost per cell site

Exhibit 4-AB shows a cost breakdown of a wireless network for all unserved areas. Note that the cost of the network is dominated by last-mile and second-mile costs, which we shall refer

Exhibit 4-Z:
Sensitivity of Costs and Investment Gap to Subscriber Capacity Assumptions—Change in Costs and Investment Gap Under Different Downlink Capacity Assumptions

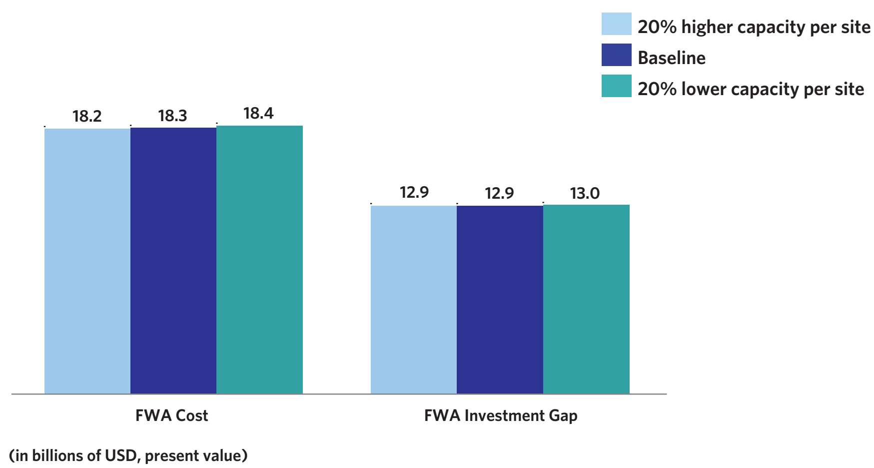
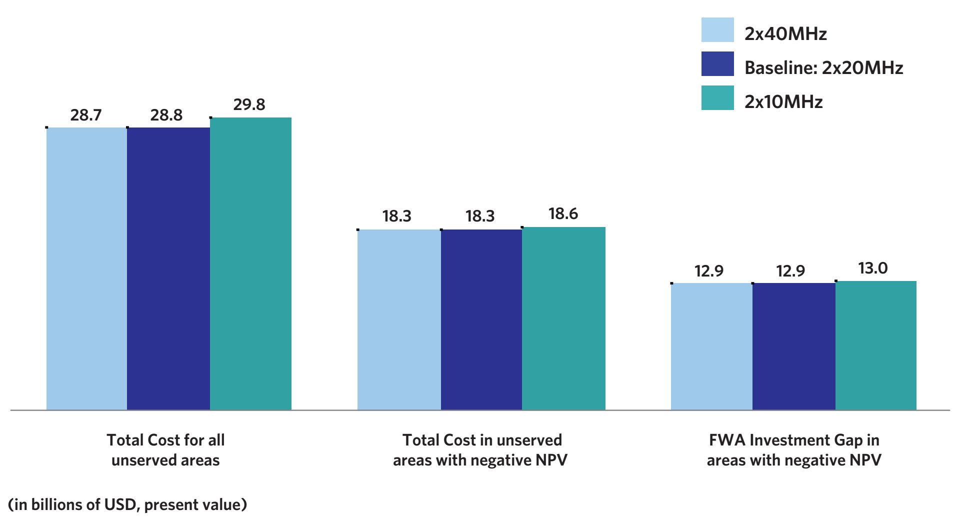


Exhibit 4-AA:
Impact of Spectrum Availability on FWA Economics—Change in FWA Costs and Investment Gap Under Different Spectrum Availability Assumptions



to as simply *site costs*; these account for more than 67% of the total costs. Exhibit 4-AC shows that tower construction/lease and second-mile backhaul costs constitute 68% of the cost of deploying, operating and maintaining a cell site.

Tower construction/lease costs comprise 34% of site costs. To model site costs appropriately, we create one set of hexagonal cells that cover the entire country for each analyzed cell-size (2, 3, 5 and 8 miles). These hexagonal cells represent the wireless cells. Each cell needs to contain at least one tower. To account for the fact that existing services imply existing towers, we turn to several data sources. First, we used the Tower Maps data set of tower locations.[67] For cells that do not include a tower site in that data set, we used 2G and 3G coverage as a likely indicator of cell site availability. Specifically, we assumed that the likelihood of a tower's presence is half the 2G/3G coverage in the hexagonal cell area. For example, a cell that is fully covered by 2G/3G service has only a 50% chance of having a tower site. In areas without a tower, we assume that a new tower needs to be constructed 52.5% of the time;[68] the remainder of the time we assume a cell site can be located on an existing structure (e.g., a grain silo or a church steeple).

In practice, the cost of deploying a wireless network in an area without any wireless coverage today should be higher because of the likely absence of any existing wireless network infrastructure that the provider can leverage. And, with our assumptions above, we capture that effect.

Our cost assumptions in the model indicate that the total 20-year cost of constructing and maintaining a tower is \$350K to \$450K. By comparison, the total cost of co-locating on an existing structure is only \$165K to \$250K. Further, our model

Exhibit 4-AB:
Cost Breakdown of Wireless Network Over 20 Years [69]

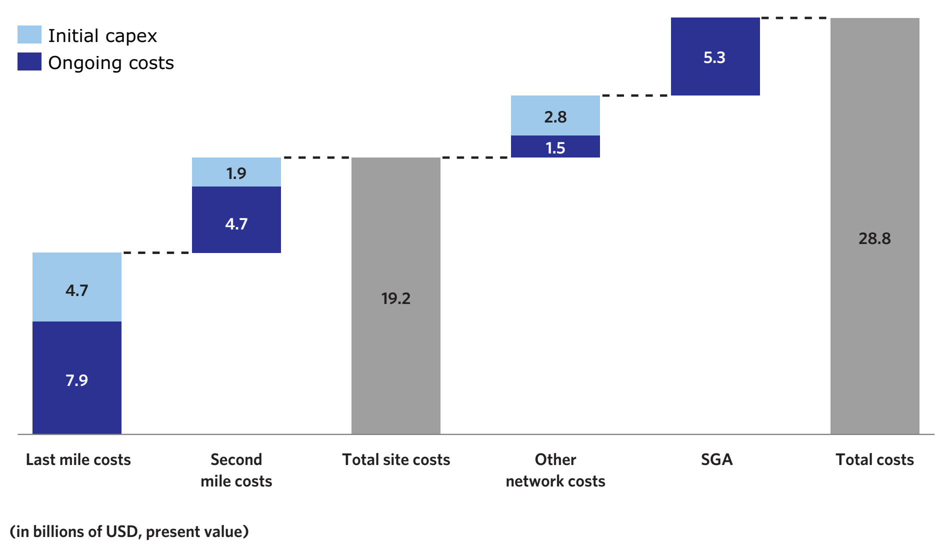
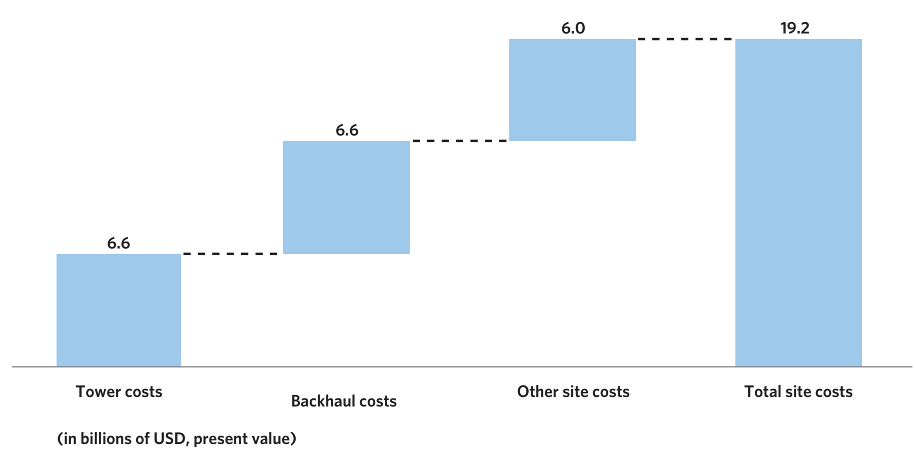


Exhibit 4-AC:
Breakdown of Total Site Costs for Wireless Network in Unserved Areas



shows that new tower construction is necessary around 15% of the time.

Second-mile backhaul

Our baseline model for the FWA network uses a Hybrid Fiber Microwave (HFM) backhaul architecture with limited microwave penetration. Specifically, we allow a maximum of four hops. Recall that a network architecture that allows a deeper microwave penetration will reduce network costs at the expense of a possible reduction in reliability. Recognizing this trade-off between reliability and cost, we analyze how a restriction on the number of hops affects the cost of the FW buildout and the investment gap. Specifically, we analyze two HFM architectures and compare them with a fiber-only network: (1) Very limited microwave penetration: an HFM network where we allow a maximum of four hops; and (2) Moderate microwave penetration: an HFM network where we allow a maximum of four hops.

In each scenario, we constrained the capacity of the microwave link to 300 Mbps. That limits our ability to daisy-chain microwave links, because the cumulative backhaul needs of all cell sites upstream of a link in the chain cannot exceed the capacity of that link. For example, returning to Exhibit 4-U, the capacity of the link between Cell sites 2 and 3 must be greater than the cumulative backhaul needs of Cell sites 1 and 2; otherwise, one of Cell sites 1 or 2 will require a fiber connection.

Exhibit 4-AD compares the initial investment for the three scenarios. We note that the cost of limiting the number of hops is small—less than 5% when we limit it to two instead of four. This is because most of the unserved regions do not constitute large contiguous areas and can, therefore, be served using a small cluster of cell sites. As a result, the limitation does not severely impact cost. In fact, in the scenario where we allow deep microwave penetration, more than 85% of the cell sites using microwave backhaul connect to a fiber-fed cell site in two or fewer hops.

Exhibit 4-AD: Cost of an HFM Second-Mile Backhaul Architecture—Initial Investment with Different Second-Mile Backhaul Network Architectures

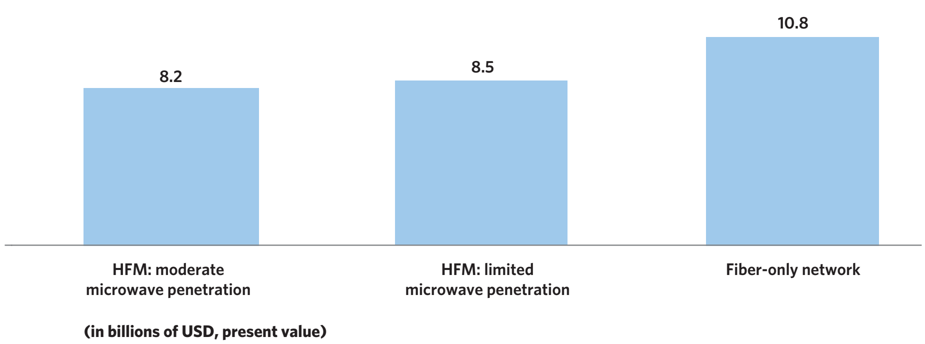


Exhibit 4-AE: Cost Assumptions and Data Sources for Wireless Modeling

Parameter	Source and comments
Tower construction	Mobile Satellite Ventures filing under Protective Order
BTS	Mobile Satellite Ventures filing under Protective Order
Ancillary Radio Access Network	Mobile Satellite Ventures filing under Protective Order
Core network equipment	Mobile Satellite Ventures filing under Protective Order
Site operations	Mobile Satellite Ventures filing under Protective Order
Land Cover	http://www.landcover.org/data/landcover/ (last accessed Feb. 2010) Summary File 1, US Census 2000
Elevation	NOAA GLOBE system http://www.ngdc.noaa.gov/mgg/topo/gltiles.html (last accessed Feb. 2010)
Microwave radio	Dragonwave
Microwave operations	Level-(3) filing under Protective Order
Fiber installation, equipment, operations and maintenance	See cost assumptions for FTTP
Wireless CPE	Based on online price information available for different manufacturers

Conclusions

In order to engineer a wireless network to provide a service consistent with the National Broadband Availability Target, we use the uplink speed target and supplement it with terrain data to compute a maximum cell radius for four different terrain types. In the downlink, we calculate a maximum subscriber capacity per cell site.

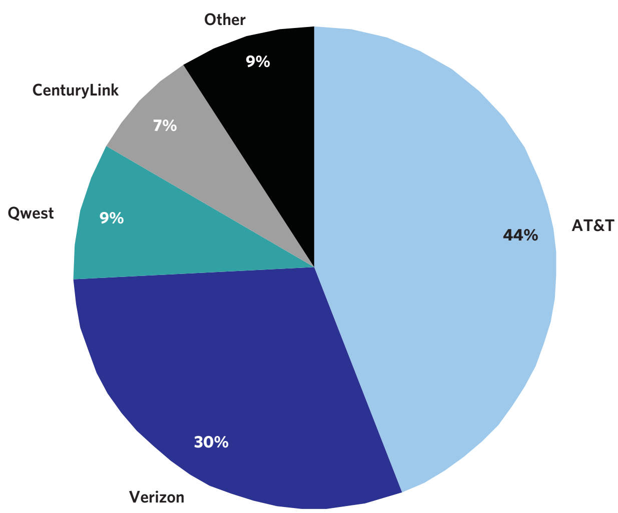
A significant driver of variation in per site costs is tower availability and backhaul costs. For backhaul, a Hybrid Fiber Microwave (HFM) architecture results in a lower cost; but a fiber-only network does have the benefit of deeper fiber penetration.

Next, we conduct a sensitivity analysis of our model parameters and assumptions. Not surprisingly, spectrum availability and spectrum bands can have a significant impact on the cost the FWA network as well as the investment gap.

12,000-foot-loop DSL (Digital Subscriber Line)
Telephone networks have traditionally been two-way (or duplex) networks, arranged in a hub-and-spoke architecture and designed to let users make and receive telephone calls. Telephone networks are ubiquitous in rural areas, in part because local carriers have had the obligation to serve all households in their geographic area; this is known as the carrier-of-last-resort obligation. In addition, some telephone companies have historically relied upon implicit subsidies at both the federal and state levels to provide phone service. More recently, they have received explicit financial support through the federal Universal Service Fund (USF). The USF was designed to ensure that all households have access to telephone service at rates that are reasonably comparable to urban rates.

Thousands of independent telephone companies provided service in local markets. But when the telephone network was originally constructed, a single operator, AT&T, dominated it. In 1984, AT&T divested its access network into seven Regional Bell Operating Companies (RBOCs). Over time, the original seven RBOCs have consolidated into three: AT&T (formerly Southwestern Bell, Pacific Telesis, Ameritech, BellSouth and non-RBOC SNET), Verizon (formerly NYNEX, Bell Atlantic and non-RBOC GTE) and Qwest (formerly US WEST).

Exhibit 4-AF:
Breakout of Voice Line Ownership — Telco Consumer Telephone Access Lines Market Share (3Q 2009)[70]



Percent of United States lines

Numbers do not sum to 100% due to rounding.

Consolidation has occurred among smaller Incumbent Local Exchange Carriers (ILECs) as well, with many of them consolidating into CenturyLink, Windstream, Frontier and Fairpoint. Yet well over a thousand small ILECs remain. Today, there are more than 1,311 Telco operators,[71] but the three RBOCs own 83% of voice lines.[72] See Exhibit 4-AF.

The evolution of modern telephone company networks has required significant investments in network capabilities in order to offer broadband access. In the late 19th and early 20th centuries, these networks were built for plain old telephone service (POTS), which provides basic voice service between users over twisted-pair copper wires. These wires, or "loops," were installed between the home and the telephone exchange office via an underground conduit or telephone poles. The basic telephone network architecture and service, originally designed for two-way, low frequency (~4 kilohertz, or kHz), all-analog transmissions with just enough capacity to carry a single voice conversation, are still used today by most homes and businesses. In fact, this network is the basis for the high-speed broadband service known as Digital Subscriber Line (DSL) offered by telecommunications companies.

With the advent of the modem, telephone networks were the first networks to provide Internet access. After all, millions of homes were already "wired" with twisted-pair copper lines that provided POTS. Initially, dial-up Internet used the same analog network designed for voice to deliver Internet access at speeds of up to 56 kilobits-per-second (kbps). To offer high-speed access, the network needed to be reengineered to handle digital communications signals and upgraded to handle the tremendous capacity needed for broadband data and broadcast transmissions. Although twisted-pair copper cables are capable of carrying high-capacity digital signals, the network was not optimized to do so. The large distance between a typical home and telephone exchange offices, as well as the lack of high-speed digital electronics, stood in the way of broadband deployments.

Steps to upgrade telephone networks for broadband:

- Invest in fiber optic cable and optic/electronics to replace and upgrade large portions of the copper facilities for capacity purposes
- Replace and redesign copper distribution architecture within communities to "shorten" the copper loops between homes and telephone exchanges
- Deploy new equipment in the exchanges as well as the homes (DSL equipment) to support the high capacity demands of DSL and broadband
- Develop the technology and equipment necessary for sophisticated network management and control systems

- Implement back-office, billing and customer service platforms necessary to provide the services common among telephone operators today

DSL provided over loops of 12,000 feet (12 kft) is a cost-effective solution for providing broadband services in low-density areas. In fact, it is the lowest cost solution for 10% of the unserved housing units. DSL over 12 kft loops meets the broadband target of a minimum speed threshold of 4 Mbps downstream and 1 Mbps upstream, and the backhaul can easily be dimensioned to meet the BHOL per user of 160 kbps.[73] Since DSL is deployed over the same existing twisted-pair copper network used to deliver telephone service, it benefits from sunk costs incurred when first deploying the telephone network.

Capabilities

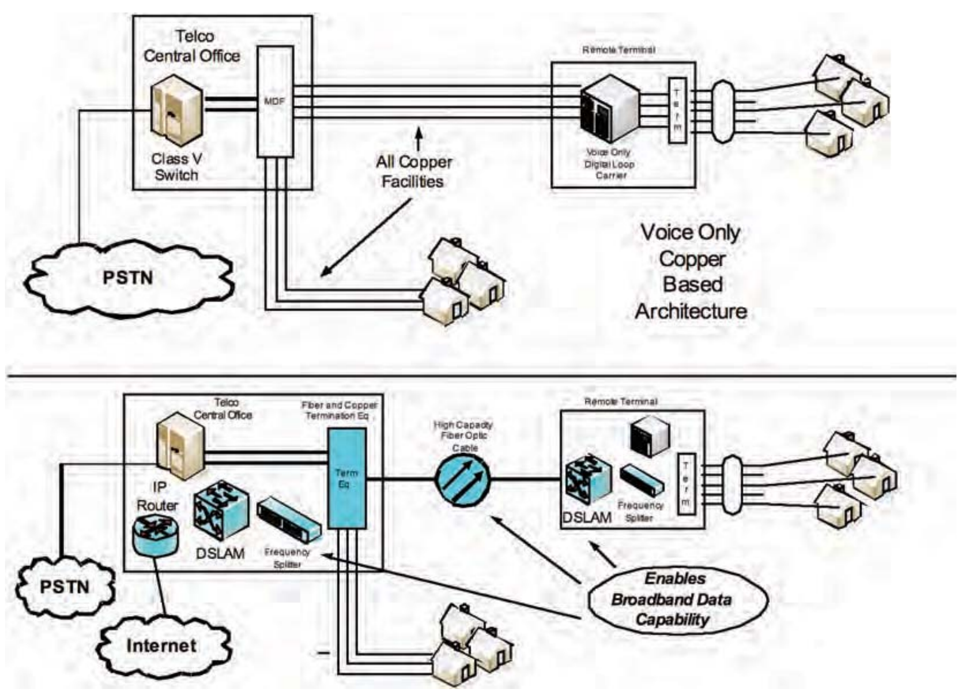
DSL over loops of 12,000 feet typically uses ADSL2/ADSL2+ technology, which was first standardized in 2005 and which uses frequencies up to 2.2 MHz. As ADSL2+ over 24AWG gauge wire provides rates of 6 Mbps downstream and 1 Mbps upstream, the technology meets the speed requirements for broadband service of 4 Mbps down and 1 Mbps up. Figure 4-AH illustrates how loop length affects speed for ADSL2+.

The technology can perform 1 Mbps upstream on 12 kft of 24 AWG twisted-pair copper loops.[74] In this case, 24 AWG wire is assumed with no bridged taps. Performance with 22 AWG wire, which is often used in rural areas, would yield higher bitrates, while use of 26 AWG wire would yield lower rates.

In order to provide faster speeds than those listed above, DSL operators can bond loops and continue to shorten loop lengths. The bonding of loops can be used to multiply the speeds by the number of loops to deliver rates over 30 Mbps if sufficient numbers of copper loops are available.[75] The performance improvements that can be achieved by shortening loops from 12 kft to 5,000 feet or 3,000 feet and replacing existing technology with VDSL2 are discussed in the DSL 3-5 kft section below. Shortening loops requires driving fiber closer to the end-user; while costly, it could provide much faster speeds that could serve as an interim step for future fiber-to-the-premises (FTTP) deployments. Investment in 12 kft DSL ,therefore, provides a path to future upgrades, whether the upgrade is to 5 kft or 3 kft loops or FTTP.

For the small-to-medium enterprise business community, copper remains a critical component in the delivery of broadband. Ethernet over Copper (EoC), often based on the G.SHDL standard, is a technology that makes use of existing copper facilities by bonding multiple copper pairs electronically. EoC can provide speeds between 5.7 Mbps on a single copper pair

Exhibit 4-AG:
Telco-Plant Upgrades to Support Broadband



and scale up to 45 Mbps, or potentially higher, by bonding multiple copper pairs. Though middle and second mile connectivity of 100 Mbps is likely necessary, bonded EoC technology can serve as a useful and cost-effective bridge in many areas. Moreover, the embedded base of copper plant is vast—one market study shows that more than 86% of businesses today are still served by copper.[76] Although service providers may prefer to deploy fiber for new builds, existing copper likely will be part of the overall broadband solution, particularly for last- and second-mile applications, for the next several years.

In addition to bonding and loop shortening, marginal speed improvements and increased stability of service levels with ADSL2+ can be achieved through the use of Level 1 dynamic spectrum management (DSM-1).[77] DSM-1 is physical layer network management software that enables reliable fault diagnosis on DSL service. This advancement is available today and may increase bit-rates by up to 10% on ADSL2+.[78] Additionally, DSM-1 helps to ensure stability and consistency of service such that carriers can reach the theoretical 4 Mbps even at high take rates within a copper-wire binder.

We model a 12 kft DSL network that meets the speed and capacity requirements defined in the discussion of 4Mbps downstream requirement in Chapter 3. As outlined in the network design considerations below, we note network sharing in DSL networks does not start until the second mile. The modeled ADSL2+ technology exceeds the speed requirement and includes costs associated with loop conditioning when appropriate. In addition, the modeled build ensures that second and middle-mile aggregation points are connected to the Internet backbone with fiber that can support capacity requirements.

A fundamental operational principle for DSL is that all of the bandwidth provisioned on the last-mile connection for a given end-user is dedicated to that end-user. Unlike HFC, Fixed Wireless, and PON, where the RF spectrum is shared among multiple users of that spectrum and thus subject to contention among them, the last-mile DSL frequency modulated onto the dedicated copper loop and associated bandwidth are dedicated. Sharing or contention with other users on the network does not occur until closer toward the core of the network, in the second and middle mile, where traffic is aggregated (see Exhibit 4-AI). This second- and middle-mile network sharing still occurs in all other access network technologies as well. The "sharing" concept is introduced in detail in the capacity planning discussion in the Network Dimensioning section below.

The ADSL 2+ standard is widely deployed today in telco DSL networks and is assumed to be the minimum required to achieve 4 Mbps downstream and 1 Mbps upstream. The last mile access network ADSL2+ is defined in ITU-T Recommendation G.992.5[11]. The technology provides rates of 6 Mbps downstream and 1 Mbps upstream on the longest loops of a Carrier Serving Area (CSA) (3.7 km or 12 kft of 24 AWG twisted-pair copper loop), with much higher rates attainable on shorter loops.[79]

We perform our analysis and cost calculations based upon a maximum 12 kft properly conditioned copper loop. Loop conditioning costs are applied to those loops that have never been conditioned to offer DSL. For example, if the statistical model showed any DSL speeds for a given census block, we do not apply the loop-conditioning cost since we assume it had already occurred. We believe that only about 1 million homes nationwide have DSL available at a speed below the 4 Mbps

Exhibit 4-AH: Downstream Speed of a Single ADSL2+ Line as a Function of Loop Length[80] (24 AWG)

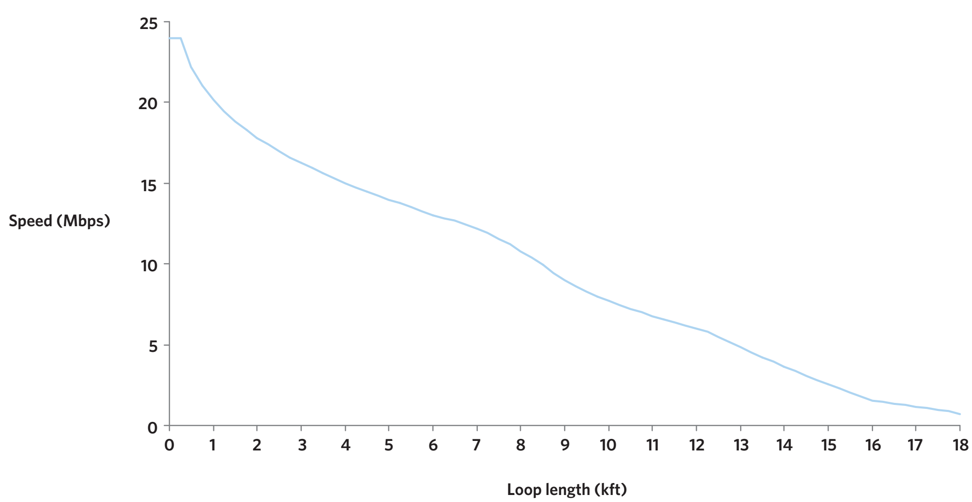


Exhibit 4-AI:
DSL Network Diagram

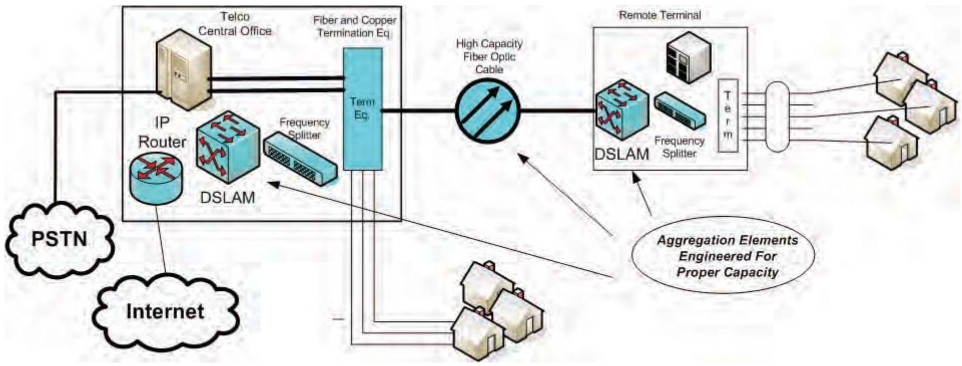


Exhibit 4-AJ:
Capacity of a DSL Network—Simultaneous Streams of Video in a DSL Network[81 82]

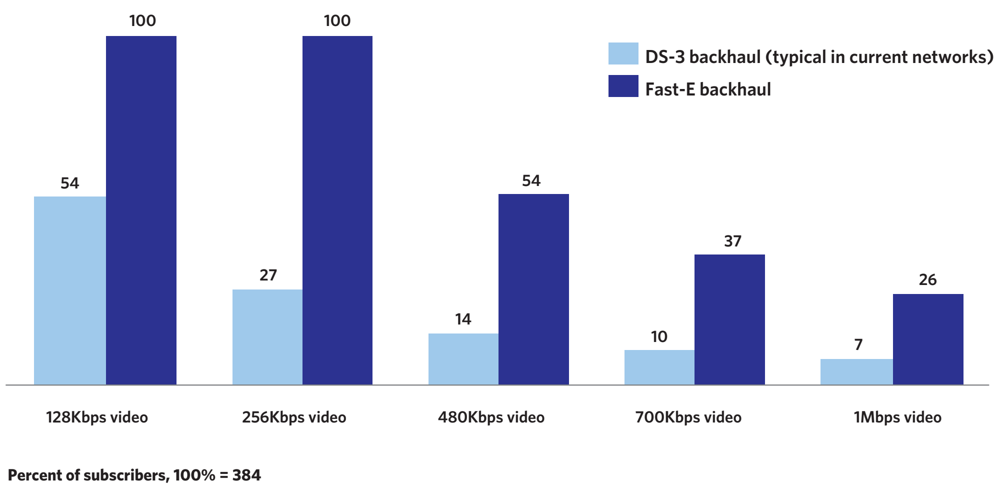
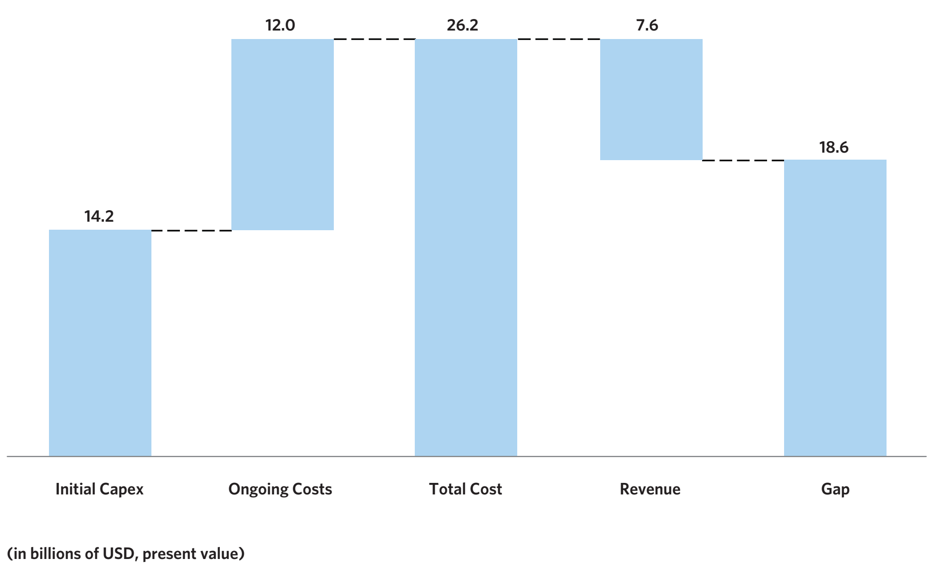


Exhibit 4-AK:
Economic Breakdown of 12,000-foot DSL



target speed. In the remaining areas, comprising about 6 million housing units, the model includes loop-conditioning costs.

We model the ADSL2+ access network such that DSLAMs are connected to the central office and other middle- and second-mile aggregation points using fiber optic-based Ethernet technology that provides backhaul capacities more than sufficient to meet a 4 Mbps down and 1 Mbps up end-user requirement. Moreover, we calculate the estimated average BHOL per user to be 160 kbps. A typical DSLAM serves between 24-384 subscribers. Since Ethernet-based backhaul provides a minimum of 100 Mbps (a.k.a. Fast-E) bandwidth, scaling to as much as 1 Gbps (a.k.a. Gig-E), the middle- or second-mile aggregation point has sufficient backhaul capacity required to support 4 Mbps down and 1 Mbps up. The resulting capacity of such a DSL network dimensioned with a Fast-E backhaul is shown in Exhibit 4-AJ.

In a DSL network with fewer subscribers, as will be the case in rural areas with low population density, the fraction of users who could simultaneously enjoy video streams of a given data rate would go up proportionately. The dimensioning discussed above is in contrast to the capacity of the network with conventional backhaul provisioning of ~1 Mbps in the shared portions of the network for every 14.5 users.[83]

Economics

The economics of the DSL network depend on revenues, operating costs and capital expenditures. Using granular cost data from DSL operators and vendors, the model calculates the gap to deploy 12 kft DSL to unserved markets as $18.6 billion. Exhibit 4-AK shows the breakout among initial capital expenditure, ongoing costs and revenue.

Initial Capex

Initial capital expenditures include material and installation costs for the following: telco modem, NID, protection, aerial or buried copper drop, DSLAM, cabinet, ADSL2+ line card,

Exhibit 4-AL: Data Sources for DSL Modeling

Material Costs	Source
Telco Modem	Windstream filing under Protective Order
For port sizes of 24 - 1,008:	
DSLAM Unit	Windstream filing under Protective Order
Cabinet	Windstream filing under Protective Order
Allocated Aggregation Cost (CO Ear)	Windstream filing under Protective Order
ADSL2+ line cards	Windstream filing under Protective Order
Fiber optic cabling	FTTH Council
Aerial Drop	Windstream filing under Protective Order
Buried Drop	Windstream filing under Protective Order
NID	Windstream filing under Protective Order
Protection	Windstream filing under Protective Order
Copper cable (24 and 22 AWG)	Windstream filing under Protective Order
Drop terminal/ building terminal (DTBT)	Windstream filing under Protective Order
Feeder distribution interface (FDI)	Windstream filing under Protective Order
Material Labor Costs	
FDI Splicing and Placing labor cost	Windstream filing under Protective Order
DTBT Splicing and Placing labor cost	Windstream filing under Protective Order
Telco Drop and NID labor cost	Windstream filing under Protective Order
Structure Labor Costs	
Duct, Innerduct and Manhole labor cost	Windstream filing under Protective Order
Loop Conditioning cost	Windstream filing under Protective Order
Poles. Anchor and Guy labor cost	Windstream filing under Protective Order
Buried Excavation labor cost under various types of terrain- normal, hardrock and softrock	Windstream filing under Protective Order

allocated aggregation cost, fiber cable up to 12 kft from the end-user, feeder distribution interface and drop terminal/building terminal, as well as the engineering costs for planning the network and the conditioning required on loops (i.e., the removal of load coils[84] and bridged taps[85]). For a detailed list of inputs into our model and the source for each, please refer to Exhibit 4-AL.

Ongoing Costs
Ongoing costs include: replacement capital expenditures required to replace network components at the end of their useful lives, network administration, network operations center support, service provisioning, field support, marketing and SG&A.

Revenues
Revenues are calculated by taking the Average Revenue Per User (ARPU)—which varies according to the level of broadband service/speed provided as well as whether the bundle of services provided includes voice, data and video—and multiplying it by the average number of users. For 12 kft DSL, only data ARPUs are used as incremental to voice, which is assumed present due to the fact that DSL technology utilizes twisted-pair copper wires originally installed and used for POTS.

Satellite
Broadband-over-satellite is a cost-effective solution for providing broadband services in low-density areas. In fact, it could reduce by $14 billion the gap to deploy to the unserved if the 250,000 most-expensive-to-reach housing units were served by satellite broadband. Satellite broadband, as provided by next generation satellites that will be launched as early as 2011, meets our Broadband Availability Target requirements by offering a minimum speed threshold of 4 Mbps downstream and 1 Mbps upstream and BHOL per user of 160 kbps.

Capabilities
Satellite operators are in the midst of building high capacity satellites that will dramatically augment the capacity available for subscribers in the next two years. ViaSat and Hughes, for example, plan to launch high-throughput satellites in 2011 and 2012, and offer 2-10 Mbps and 5-25 Mbps download-speed services, respectively. Upload speeds will likely be greater than the 256 kbps offered today, but no specific upload speeds have been announced. Since satellites are technically constrained by the total capacity of the satellite (>100Gbps), operators could change plans to offer customers at least 1 Mbps upstream even if it is not currently planned. Since the next-generation satellites will be able to offer 4 Mbps downstream and 1 Mbps upstream, satellite broadband meets the technological requirements for inclusion in the National Broadband Plan.

Technical limitations
Over the last decade, satellite technology has advanced to overcome some of the common drawbacks previously associated with it. Due to the properties of the spectrum band used for this service (Ku band downlink 11.7-12.7 GHz, uplink 14-14.5 GHz; Ka band downlink 18.3- 20.2 GHz; uplink 27.5-31 GHz), inclement weather can have an effect on service. However, the ability to dynamically adjust signal power, modulation techniques and forward error correction have all reduced degradation of service except in the most severe of weather conditions.

Since the satellites are in geosynchronous orbit nearly 22,300 miles above the earth, there is a round-trip propagation delay of 560 milliseconds associated with a typical PING (user to ISP and back to user). Recently, integrated application acceleration techniques, including TCP acceleration, fast-start and pre-fetch, have helped mitigate satellite latency for some Web-browsing experiences.[86]

Despite these technological advancements to improve the Web-browsing experience, the latency associated with satellite would affect the perceived performance of applications requiring real-time user input, such as VoIP and interactive gaming. Not only does this delay have a potentially noticeable effect on applications like VoIP, but it would also be doubled in cases where both users were using satellite broadband (e.g., if two neighbors, both served by satellite VOIP, talked on the telephone). Given that most voice calls are local, this could become a significant issue for rural areas if all calls must be completed over satellite broadband.

Spot beams
Broadband satellites use multiple spot beams to provide nationwide coverage. Spot beams use the same spectrum over and over in different geographies, providing more total throughput for a given amount of spectrum. The multiple re-use of frequencies across the coverage area for a satellite provider is similar to a cellular system that reuses frequencies in a "cell." Furthermore, because a spot beam focuses all its energy on a very specific area, it makes more efficient use of the available satellite power.

Nevertheless, a satellite's bandwidth to an end user is provided by and limited to the bandwidth of the spot beam covering that geographic area as well as the total satellite capacity. Therefore, potential network chokepoints for a satellite broadband network include total satellite capacity and spot beam bandwidth.[87] Each spot beam is designated over a section of the United States; once a spot beam is assigned to a certain geographic area, it generally cannot be re-allocated, shifted or moved to cover another area.

With its first leased satellite in 2005 and again with its own satellite in 2007, WildBlue found itself running out of capacity in high-demand regions.[88] In fact, ViaSat plans to aim bandwidth at exactly the same regions where WildBlue's capacity has run out.[89] Many unserved do not live in high-demand areas. These are among the factors that play a role in the capacity assumed available for broadband as discussed below.

Capacity

Providing sufficient capacity for a large number of broadband subscribers, e.g. all of the unserved, may prove challenging with satellite broadband. ViaSat and Hughes believe these next generation satellites have the capacity to serve as many as 2 million homes each;[90] ViaSat has stated on the record that its ViaSat-1 satellite will be capable of providing approximately 1 million households with Internet access service at download speeds of 4 Mbps and upload speeds of 1 Mbps.[91]

Treating satellite as a substitute for terrestrial service, however, requires that satellite be able to deliver service comparable to terrestrial options. Practically speaking, that means that satellite needs to support an equivalent BHOL per user.[92] We believe that the satellite industry could support more than 1.4 million subscribers in 2011 (note that this combines existing capacity with what is planned on being launched) and a total of more than 2.0 million subscribers in 2012 (after the launch of Hughes's next generation satellite, Jupiter). The picture becomes less clear, however, as we look to 2015, when the number of subscribers that current and planned satellites can support would decrease as demand per user grows. End-user demand has been growing at rates as high as 30% annually.[93]

We make certain assumptions in quantifying the number of subscribers that the entire U.S. satellite broadband industry could support with the launch of ViaSat-1 in 2011 and Jupiter in 2012. As there have been no commitments to launch new broadband satellites after 2012, we create a five-year outlook on satellite broadband capacity based on the following assumptions (see Exhibit 4-AM):

- ViaSat will launch a 130 Gbps satellite in early 2011.[94] A comparable satellite, Jupiter, will be launched by Hughes in 2012.[95]
- "Total Downstream Capacity" is 60% of "Total Capacity."
- "Total Usable Downstream Capacity" factors in 10% loss, which includes factors such as utilization and a potential loss of capacity from geographic clustering in which a non-uniform distribution of subscribers would engender certain spot beams to not be fully utilized.

Busy hour offered load (BHOL) assumption

Busy hour offered load, or BHOL, is the average demand for network capacity across all subscribers on the network during the busiest hours of the network. Understanding BHOL is critical for dimensioning the network to reduce network congestion. A more detailed discussion on BHOL can be found later in the Network Requirements section, but the basis for our assumption in satellite is explained here.

Suppose we want to dimension a network that will continue to deliver 4 Mbps. In order to estimate the BHOL for such a network in the future, we first note that average monthly usage is doubling roughly every three years, based on historical growth.[96] There is a significant difference between average usage and the typical user's usage with average usage heavily influenced by extremely high bandwidth users. Next, it becomes crucial to pick the right starting point (i.e., today's BHOL). As the mean user on terrestrial based services is downloading roughly 10 GB of data per month, busy hour loads per user for terrestrial networks translate to 111 kbps busy hour load, assuming that 15% of traffic is downloaded during the busy hour. Terrestrial-based services like cable and DSL experiencing busy hour loads of close to 111 kbps today form the "high usage" case in Exhibit 4-AN.

If we exclude the extremely high-bandwidth users, the average user downloads about 3.5 GB/month, which under the same assumptions for the busy hour would translate to 39 kbps busy hour load. The "medium usage" case in Exhibit 4-AN takes the 39 kbps as a starting point and grows to 160 kbps in 2015; it is this case that we use for our analysis of satellite as well as other networks. The "low usage" case assumes a user downloads 1 GB/month, which translates to 11 kbps; that is roughly what level of service satellite providers offer today of 5-10 kbps.[97] Using 11 kbps as a starting point, the "low usage" case applies the same growth rate as the medium and high usage cases. Exhibit 4-AN summarizes the three usage cases.

Exhibit 4-AM: Available Satellite Capacity Through 2015

Year	2009	2010	2011	2012	2013	2014	2015
Total Capacity (Gbps)	35	35	165	295	295	295	295
Total Downstream Capacity (Gbps)	21	21	99	177	177	177	177
Total Usable Downstream Capacity (Gbps)	19	19	89	159	159	159	159

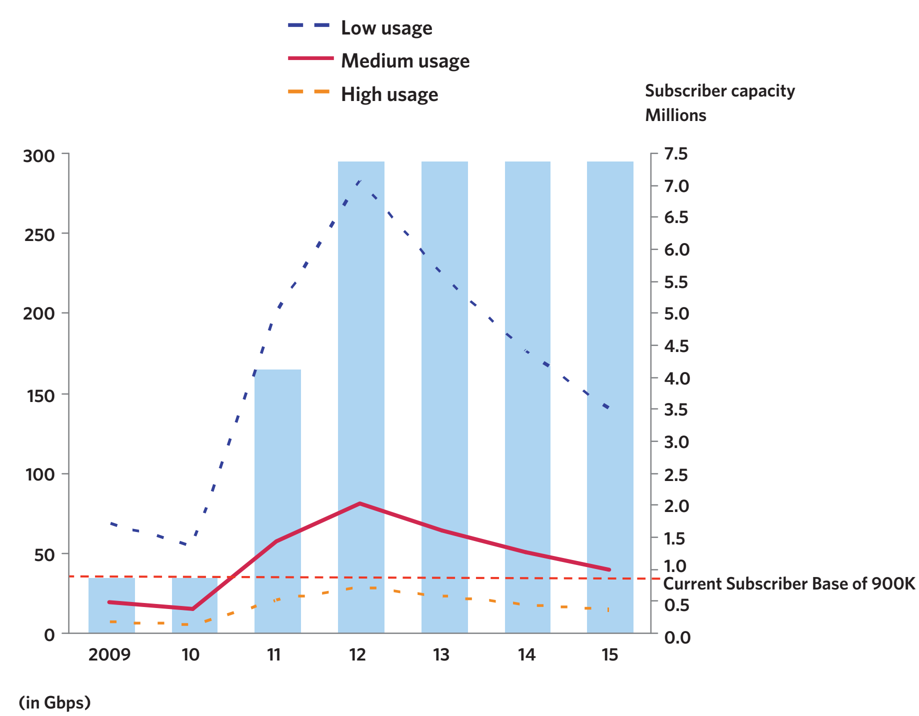
One reason why the BHOL-per-user might be lower for satellite: satellite operators' fair access policies, which are essentially usage caps, and a degree of self-selection in those who choose satellite-based broadband. However, in a world where users do not self-select into satellite, it is far from certain the extent to which these reasons will still be valid.

Using the above-mentioned assumptions under the "medium usage" case, the satellite industry could support nearly 1 million subscribers by 2015 (see Exhibit 4-AO). Note that each successive year, the satellites can support fewer subscribers due to the doubling of the BHOL every few years noted above. Each next-generation satellite can support approximately 440,000 subscribers using the usage forecast for 2015. Given that the satellite industry in the United States currently supports roughly 900,000 subscribers, this presents a potential difficulty in meeting the needs of the industry's current subscriber base, plus new net additions. If satellite broadband is offered at a level of service comparable to that of terrestrial broadband under the "medium usage" case and BHOL growth continues, satellite providers will need to devote significant incremental capacity to their existing customer base.
Since satellite providers today offer BHOL of between 5 kbps and 10 kbps,[98] our terrestrial-based BHOL assumptions would represent a marked increase in the service level of satellite providers. ViaSat has said on the record that its ViaSat-1 will support a "provisioned bandwidth" (a concept very similar to busy hour load) of 30-50 kbps.[99] However, satellite operators may not be planning for yearly growth comparable to historical terrestrial rates. Thus, despite the growth in satellite capacity between 2010 and 2012, the number of subscribers capable

Exhibit 4-AN:
Satellite Usage Scenarios[100]

Year	2009	2010	2011	2012	2013	2014	2015
Busy Hour Load (Kbps) @ 27% growth y-o-y							
Low usage	11	14	18	22	28	36	46
Medium usage	39	49	62	79	100	126	160
High usage	111	141	178	225	285	360	455

Exhibit 4-AO:
Satellite Capacity Based on Low, Medium and High Usage Scenarios



of being supported with our assumptions starts to fall quickly after 2012, absent additional satellite launches. Due to the limited capacity, we do not assume satellite in the calculation of the gap figure of $23.5 billion, but we have contemplated a case in which 250,000 of today's unserved subscribe to broadband over satellite.[101]

If satellite is used to serve the most expensive 250,000 of the unserved housing units, it will reduce the gap. Some 250,000 housing units represent 3.5% of all unserved, <0.2% of all U.S. households, and account for 57%, or $13.4 billion, of the total gap. Exhibit 4-AP shows the remaining gap if satellite is used to serve the most expensive census blocks containing a total of 250,000 subscribers.

The map in Exhibit 4-AQ identifies the location of the highest gap census blocks with a total of 250,000 housing units that we assume are served by satellite in Exhibit 4-AP.

Economics

Nearly all of the costs for satellite broadband are fixed and upfront with the development, construction and launch of the satellite. Each next-generation satellite costs approximately $400 million, which includes satellite construction, launch insurance and related gateway infrastructure.[102] Operating costs for a satellite broadband operator are typically lower than for a wired network provider. Because a single satellite can provide coverage for the entire country with the exception of homes on the north face of mountains or with dense tree cover, the cost of satellite broadband remains constant regardless of household density, which makes it a great option for remote areas.

However, due to the capacity constraints of each satellite, and the growth in use discussed above, satellite operators likely need to continue adding new satellites over time. Estimates of the initial capital expenditure to provide all 7 million of the unserved housing units using satellite broadband service are near $10 billion, including the cost of up to 16 next-generation satellites as well as the CPE and installation for each end-user, assuming the "medium usage" scenario. Timing may be an issue if satellite broadband were deployed as the only means of reaching the unserved, as a next-generation satellite takes approximately three years to build.[103]

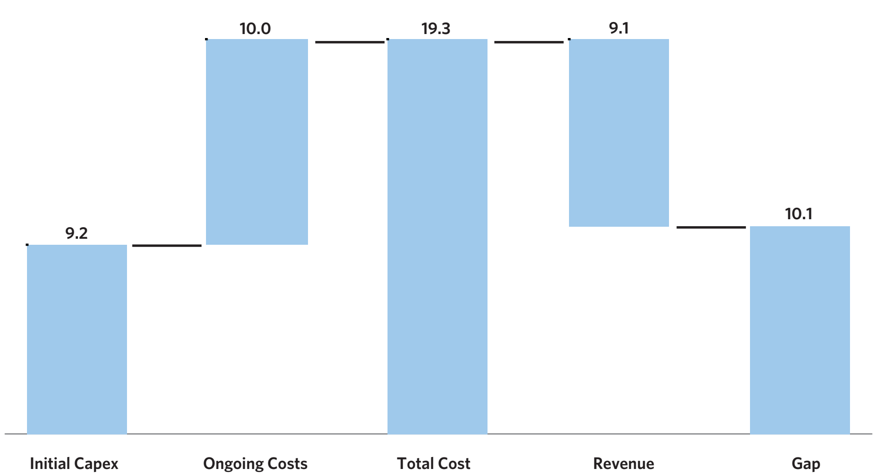
Additionally, with each satellite capable of supporting roughly 440,000 subscribers using our assumptions, satellite operators could be forced to potentially more than double their current monthly subscriber fees, which today range from $60-80 per month, in order to maintain the same return on investment as today.

The cost-per-subscriber is driven by the high up-front costs associated with building and launching a satellite. As capacity required per-subscriber increases, the number of subscribers that each satellite can support drops. That drop, in turn, means that there are fewer subscribers over whom to amortize high fixed costs. Thus the average cost-per-subscriber increases, creating less favorable economics over time or requiring higher monthly fees to be charged to the end-user as described above.

Even with greater efficiency of planned satellites like ViaSat-1 or Jupiter, which provide more capacity per launch, the average capex-per-subscriber will only grow with the increase in effective load-per-user. See Exhibit 4-AR, which shows the average capex per subscriber at various levels of monthly usage. The levels of usage correspond to the low, medium and high usage cases described above.

In Exhibit 4-AR, the capex of a satellite (including build, launch and insurance), the associated gateway infrastructure and the CPE is divided by the number of subscribers, depending on the usage characteristics. Note that the average cost calculation may in fact overstate the true cost of a given subscriber over the lifetime of the satellite.

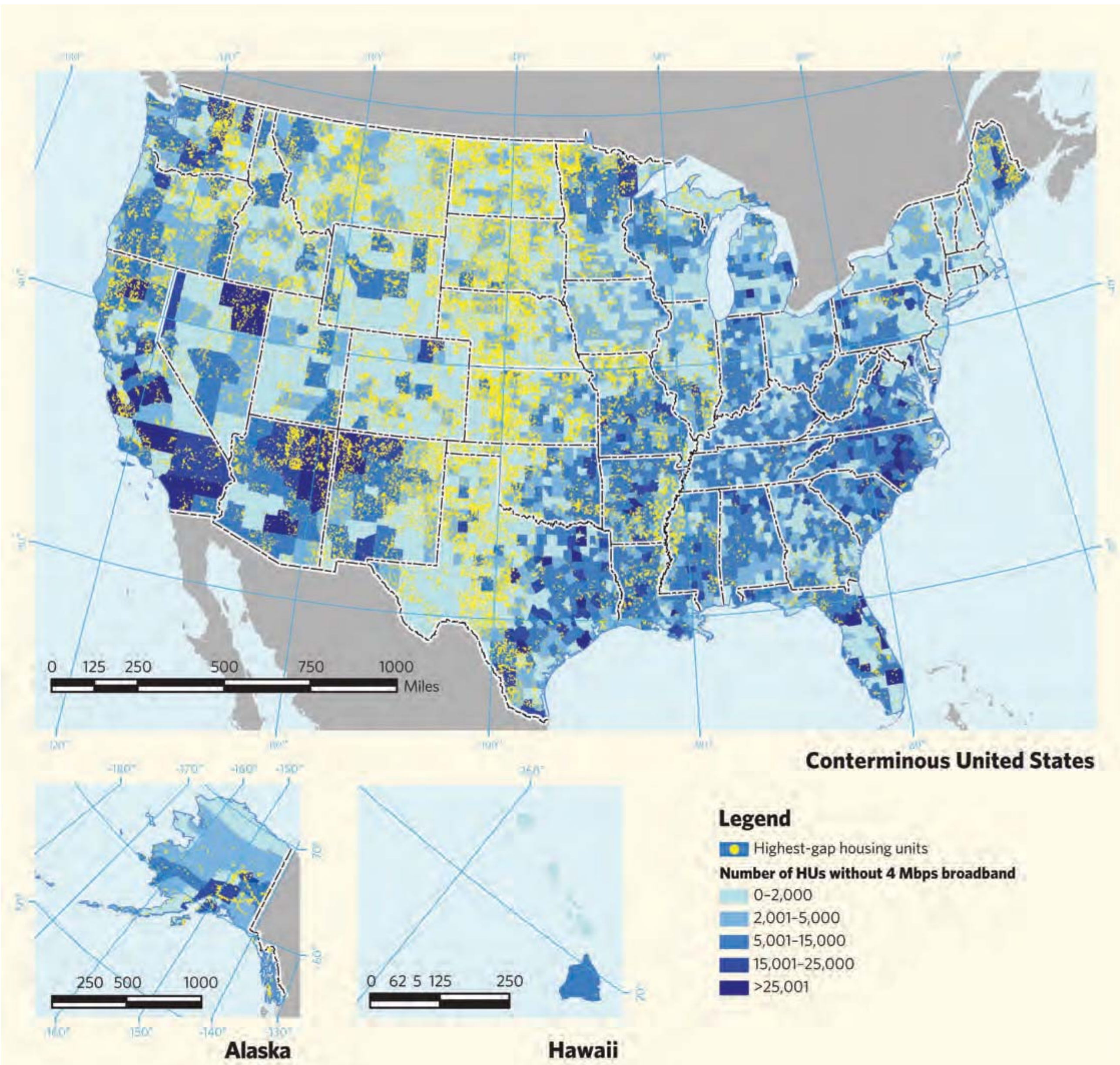
Exhibit 4-AP: Economics of Terrestrially Served if Most Expensive Housing Units are Served with Satellite[104]



Buy down

Due to the relatively high price of satellite broadband service, there may be a need for a subsidy of the monthly ARPU for those served by satellite broadband. Current ARPU for satellite broadband is generally $60-80 per month depending on speed tier, service provider and choice of whether to purchase CPE upfront or pay a monthly fee for it.[105] For illustrative purposes, assuming a starting point of $70 per month, end-user support to reduce the price to $35 monthly would cost $105 million annually (250,000 people x $35 difference in ARPU x 12 months).

Exhibit 4-AQ:
Location of Highest-Gap Housing Units

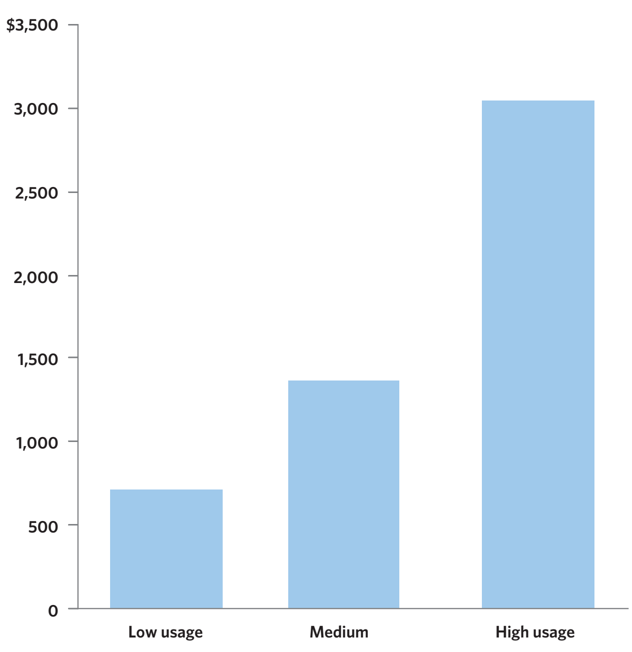


Over 20 years, discounting at 11.25% , the present value of this annual amount is over $800 million.

As discussed above, if satellite operators were to assume a higher use case to provide a level of service comparable to terrestrial providers and to double their price to ensure consistent return on investment (note that the ability to generate enough cash flow affects their ability to finance future satellites), the required subsidy would grow proportionately. Assuming a contemplated starting price of $120, the subsidy required would be $255 million annually (250,000 people x $85 difference in ARPU x 12 months) to yield an end-user price of $35. Over 20 years, the present value of this annual expenditure is roughly $2 billion.

Despite these challenges, we believe that satellite can still provide an economically attractive service for some, and that satellite providers can be an alternative to terrestrial providers, both wired and wireless. However, as we explain further in Chapter 3, uncertainty—principally about the optimal role satellite might play in the disbursement process—has led us to not explicitly include satellite in the base-case calculation.

Exhibit 4-AR:
Satellite Capex per Subscriber— Average cost/POP at Scale



TECHNOLOGIES NOT INCLUDED IN THE BASE CASE

Fiber-to-the-premises (FTTP)

Fiber-to-the-premises (FTTP) offers the greatest potential capacity of any of the technologies considered, making it the most future-proof alternative. The tradeoff for this is the additional construction cost incurred to extend fiber all the way to the premises, making FTTP the most capital-intensive solution considered. On the operational side, the extension of fiber enables the removal of all active components in the outside plant, providing FTTP with a substantial operational savings over competing technologies with active electronics in the outside plant.[106] However, in unserved areas in particular, these savings are insufficient to overcome the initial capital expenditure burden, making FTTP the solution with the highest lifetime cost and the highest investment gap.

Capabilities

There are three basic types of FTTP deployments: point-to-point (P2P) networks, active Ethernet networks and passive optical networks (PON). PON makes up more than 94% of the current residential FTTP deployments in the United States.[107] PON has the advantage of offering lower initial capital expenditure requirements and lower operating expenditures relative to P2P and Active Ethernet deployments, respectively. As such, our analysis utilized PON as the modeled FTTP network.

Exhibit 4-AS shows the capabilities of the varieties of PON currently in use in the United States.[108]

While the majority of homes currently passed by FTTP deployments in the United States are passed by BPON networks, more new deployments are utilizing GPON.[109] PON is a shared medium, meaning that a portion of the access network running between the headend and the passive optical splitter is shared among multiple end-users.

Typical PON deployments share a single fiber in the feeder portion of the access network among 32 end-users. See Exhibit 4-AT. For BPON, this yields a fully distributed downstream capacity of 19.4 Mbps and upstream capacity of 4.8 Mbps per end-user. For GPON, these capacities increase to 78 Mbps downstream and 39 Mbps upstream. As these speeds do not factor in any oversubscription, with a reasonable oversubscription of 15:1,[110] an operator with either a BPON or GPON deployment could easily offer its customers a product with download speeds exceeding 100 Mbps, far exceeding what we anticipate being required in the foreseeable future.[111] As such, FTTP clearly is a candidate from a capability standpoint for delivering broadband to the unserved.

Future PON architectures

PON architectures continue to evolve. The full standard for the next evolution of GPON is expected to be completed in June

2010, with deployments starting in 2012. It will offer download speeds of 10 Gbps and upload speeds of 2.5 Gbps and 10 Gbps, and it will be able to coexist on the same fiber as GPON. Deployments of the next evolution of EPON could even predate those of GPON, offering download speeds of 10 Gbps and upload speeds of 1 Gbps and 10 Gbps.[112] See Exhibit 4-AU.

Beyond these near-term standards, numerous long-term ideas are being presented. For example, Wave Division Multiplexing PON would replace the splitter with an arrayed wave guide and utilize a different wavelength for each end-user. This would effectively eliminate the sharing of the fiber in the second mile that takes place with existing PON varieties, enabling dedicated end-user capacities of 10 Gbps or more.

Exhibit 4-AS:
Capabilities of Passive Optical Networks (PON)

	BPON	EPON	GPON
Standard	ITU-T G.983	IEEE 802.3ah	ITU-T G.984
Bandwidth	Downstream up to 622 Mbps	Downstream up to 1.25 Gbps	Downstream up to 2.5 Gbps
	Upstream up to 155 Mbps	Upstream up to 1.25 Gbps	Upstream up to 1.25 Gbps
Downstream wavelength(s)	1490 and 1550 nm	1550 nm	1490 and 1550 nm
Upstream wavelength	1310 nm	1310 nm	1310 nm
Transmission	ATM	Ethernet	Ethernet, ATM, TDM

Exhibit 4-AT:
Passive Optical Network (PON) FTTP Deployment

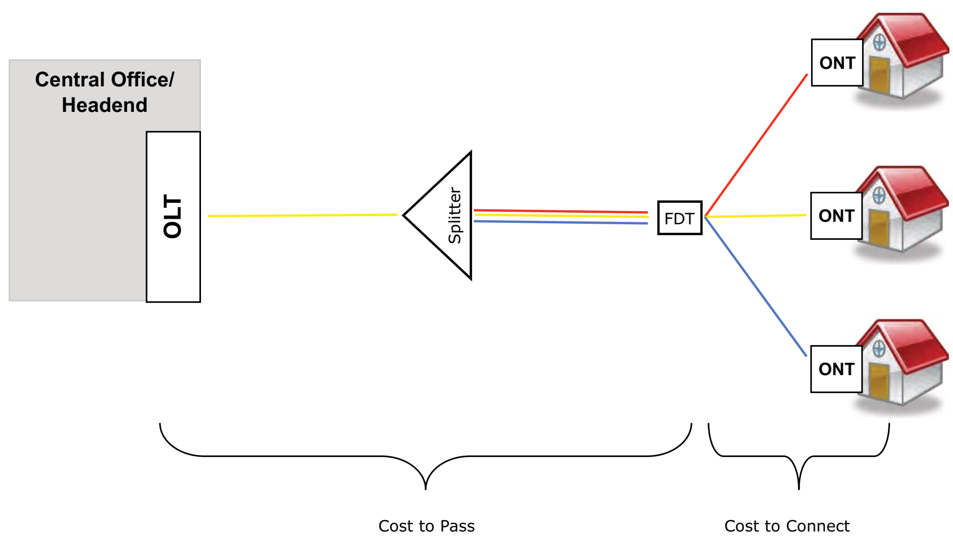


Exhibit 4-AU:
Future PON Architectures

	10G GPON	10G EPON
Bandwidth (upstream/downstream)	10/2.5 Gbps or 10/10 Gbps shared	10/1 Gbps or 10/10 Gbps shared
Positives	Compatible with existing GPON	First completed
Key challenges	10 Gbps upstream not viable for single-family units	10 Gbps upstream not viable for single-family homes; 1 Gbps upstream too little bandwidth

FTTP economics

To build FTTP to deliver broadband to the 7 million housing units that are classified as unserved (at a broadband definition of 4 Mbps download and 1 Mbps upload) would lead to an investment gap of $62.1 billion.

The initial capital expenditure averages out to be slightly more than $5,000 per premises. This initial capex value comprises two pieces: the cost to pass a premises and the cost to connect a premises. (These costs are detailed in Exhibit 4-AV.)

The cost to connect a premises is the smaller of the two charges, typically averaging about $650-$750/premises.[113] The cost to connect is entirely success-driven and consists of the installation of the fiber drop and equipment at the customer premises. Making up the bulk of the $5,000 initial capex cost of a FTTP deployment is the cost to pass a premises; this is the cost to build the fiber network distributed over the premises capable of being serviced by the network. Cost-to-pass is typically spoken of in terms of all premises passed by a FTTP deployment, but the more meaningful number is cost-to-pass per subscriber, which takes into account penetration rate. With fiber installation costs ranging between $10,000 and $150,000 per mile, depending on a variety of factors including deployment methodology, terrain and labor factors,[114] the cost to pass is highly sensitive to penetration rate and household density.

Using several data points provided by existing FTTP providers, we are able to establish the following empirical relationship between the cost-to-pass for a FTTP deployment and household density, using standard curve-fitting techniques[115] (see Exhibit 4-AW):

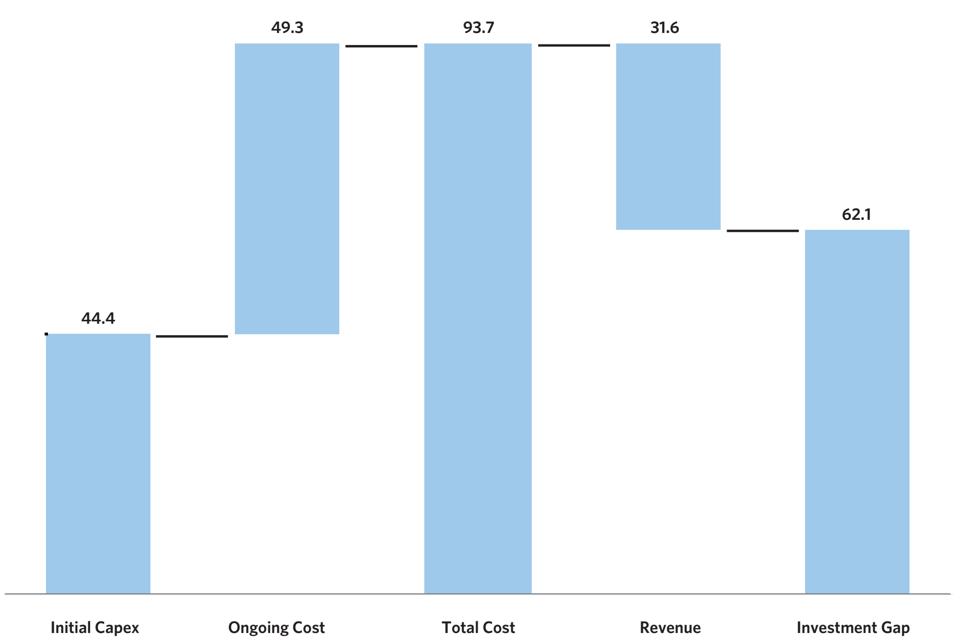
Cost per home passed = $\$701.59 * e^{(8.19/\text{Household density})}$

where Household density is in homes per square mile.

As one can see, the unserved segment starts to intersect the cost-to-pass curve just as the curve starts to steepen significantly. At about 10 households per square mile, the cost-per-premises passed is slightly less than $1,600. Halving the density to five housing units per square mile more than doubles the cost-to-pass, to more than $3,600. At this level, factoring in average broadband penetration of roughly 65% and including the cost to connect each premises yields a cost-per-subscriber in excess of $6,000. Due to the low densities of the unserved segment and given the current expectation of bandwidth demand over the coming years, even with an optimistic scenario for increasing broadband adoption, FTTP may be prohibitively expensive when alternative technologies can also meet bandwidth demands.

The final category of costs is one where FTTP holds a significant advantage: the cost-to-serve. By extending fiber all the way from the serving office or headend to the customer premises, an FTTP network eliminates the need for any active components in the outside plant. This can reduce ongoing maintenance and support expenditures by as much as 80% relative to an HFC plant.[116] However, on a monthly basis for a typical scale network deployment, this savings amounts to just a few dollars per subscriber, and as such is generally insufficient to offset the initial capital expenditure burden.

Exhibit 4-AV:
Breakout of FTTP Gap



FTTP Deployment

The cost information above can be displayed in a simple financial model that can be used to easily estimate the viability of a FTTP deployment in addition to the model that calculates the cost of the investment gap across the country. See Exhibit 4-AX.

First, consider cost per home passed. In this example, we use $850, a value that would cover roughly 80% of the United States. Factoring in a 40% penetration rate, a value taken from the high end of Verizon's publicly stated 2010 target rate for its competitive deployments,[117] we get a $2,125 cost-to-pass per subscriber. Adding in the cost-to-connect, inflated to account for churn and equipment replacement over the life of the network, we get a rough estimate of $3,225 total investment per subscriber. At this level, an operator could succeed with a monthly EBITDA of

Exhibit 4-AW:
Cost to Pass with FTTP by Density of Homes[118]

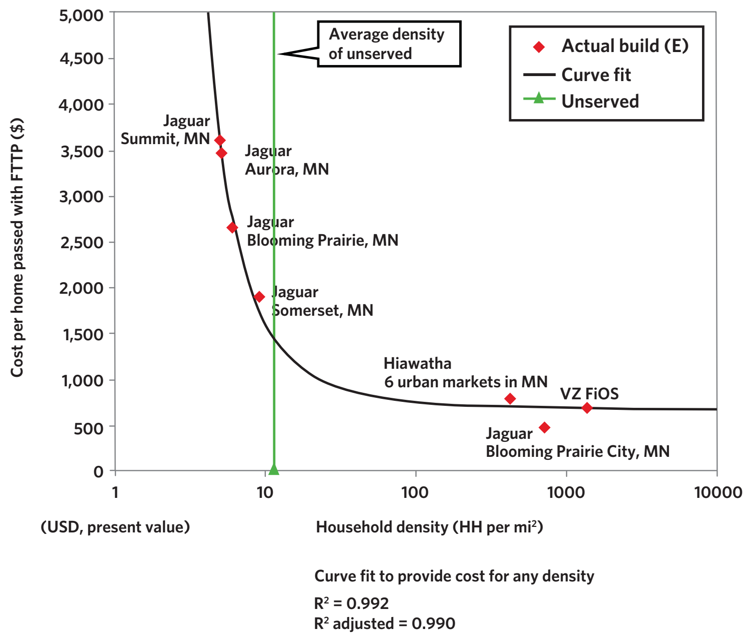


Exhibit 4-AX:
Simple Financial Model to Calculate Breakeven EBITDA for FTTP

Cost per home passed	$850
Take rate	40%
Plant cost per sub	$2,125
Cost to connect/maintain	$1100
Total capex per sub	$3,225
Profit for NPV = 0 (over 20 years)	$3,225
Taxes (@ 20% effective rate)	$806
PV of EBITDA required	$4,031
EBITDA per month (@ 10% WACC over 20 years)	$42.50

$650 initial cost to connect
$450 CPE/churn replacement

Low profit target

Ignores potentially significant interest payments and impact on required EBITDA

Assumes customer lifetime is 5 years

Key questions:
- How will EBITDA required for breakeven change as density-driven costs change?
- Is that EBITDA target reasonable?

$42.50/subscriber, a value that is roughly in line with estimates of margins for some of the largest providers in the country.

Next, we calculate the cost to deploy FTTP in each county in the country using the curve fit calculated in Exhibit 4-AW. Applying that cost to the financial model laid out in Exhibit 4-AX, one can calculate the EBITDA required for FTTP to break even in each county; the results are shown in Exhibit 4-AY. Note that a successful FTTP entrant would need to have roughly $38 in monthly EBITDA from each customer at the assumed 40% take rate to provide returns to capital in the denser half of the country.

It is important to note that for an incumbent, much of the revenue associated with a FTTP deployment cannibalizes its existing revenue. As such, an incumbent telco would only want to factor in the incremental revenue offered by a FTTP deployment, namely additional data revenue and video revenue. This has the effect of significantly reducing the viability of FTTP deployments currently for many incumbent providers.

Due largely to this cost structure, there have been few large incumbent providers overbuilding their existing footprints with FTTP. To date, the bulk of FTTP deployments have been driven by a single RBOC, Verizon, which has deployed FTTP in the denser, suburban and urban areas in its footprint, and by Tier 3 ILECs, CLECs, municipalities and other small providers. These providers have deployed FTTP in areas that are less densely populated than those of Verizon, but they have been able to largely replicate the RBOCs' cost structure by achieving an average penetration rate that is nearly double that of the RBOC (54% vs. 30 %).[119]

3,000 – 5,000 foot DSL

Despite providing faster broadband speeds than 12 kft DSL and being capable of delivering video services, DSL over loops of 3,000 (3 kft) feet or 5,000 (5 kft) feet has a higher investment gap when providing broadband services in low-density unserved areas. DSL over 3-5 kft loops delivers broadband speeds well in

Exhibit 4-AY:
Esitmated Monthly EBITDA Required to Break Even on an FTTP Build Across the Country[120]

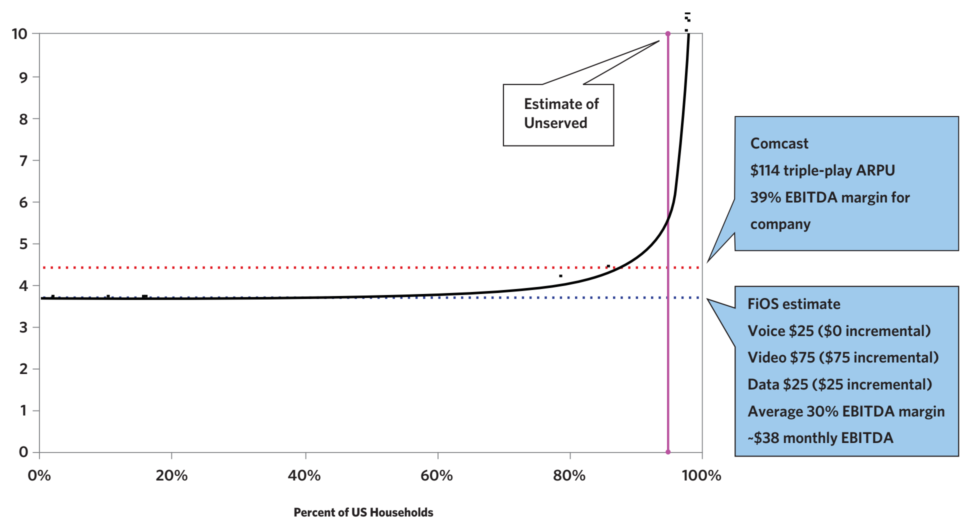


Exhibit 4-AZ:
Data Sources for FTTP Modeling

Item	Source
Optical light terminal (OLT)	Calix protective order filing
Fiber distribution hub (FDH)	FTTH Council
optical splitter	FTTH Council
Fiber drop terminal (FDT)	FTTH Council
Optical network terminal (ONT)	FTTH Council, Calix protective order filing
fiber optic cabling	FTTH Council
aerial placement	FTTH Council
buried placement	FTTH Council
operating/maintenance expenses	Hiawatha Broadband protective order

excess of the 4 Mbps downstream and 1 Mbps upstream target. However, due to the cost of driving fiber an additional 7,000 to 9,000 feet closer to the end user, 3 kft DSL and 5 kft DSL are more costly solutions than 12 kft DSL and, thus, have higher investment gaps than 12 kft DSL in all unserved markets.

Capabilities

DSL over loops of 3 kft or 5 kft typically uses VDSL2 technology, which was first standardized in 2006 and uses frequencies up to 30 MHz. While there may be some VDSL technology still being used today, many operators are replacing it with VDSL2. Therefore, we will examine the capabilities of VDSL2 technology at 3 kft and 5 kft.

VDSL2 can provide 35 Mbps downstream and 6 Mbps upstream over 3 kft loops, and it can provide 20 Mbps downstream and 2 Mbps upstream over 5 kft loops. As VDSL2 over 24 AWG wire provides rates well above 4 Mbps downstream and 1 Mbps upstream, the technology meets the speed requirements for broadband service. Exhibits 4-BA and 4-BB illustrate how loop length affects speed for VDSL2. Of course, speeds realized in the field are heavily dependent on plant quality, so

Exhibit 4-BA: Downstream Speed of a Single VDSL2 Line at Various Loop Lengths [121]

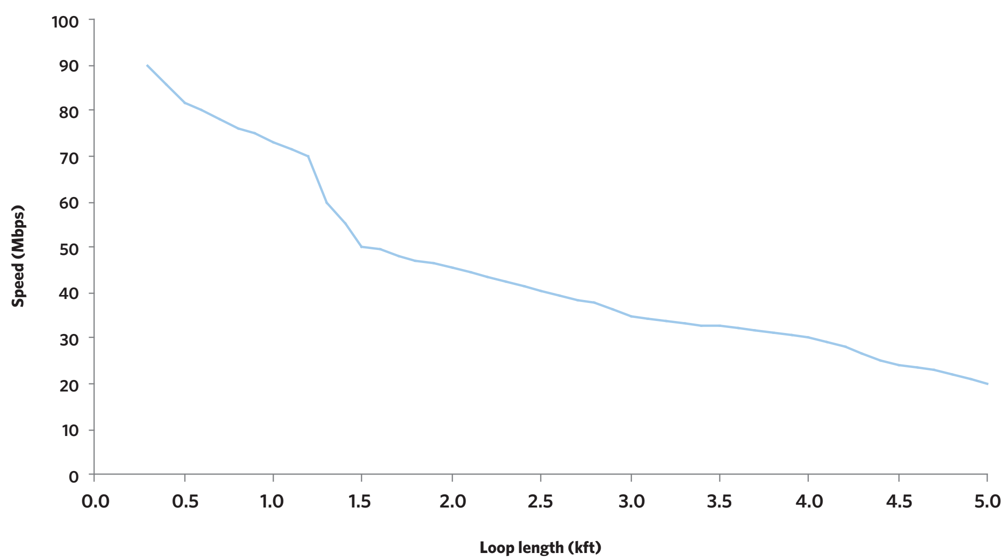
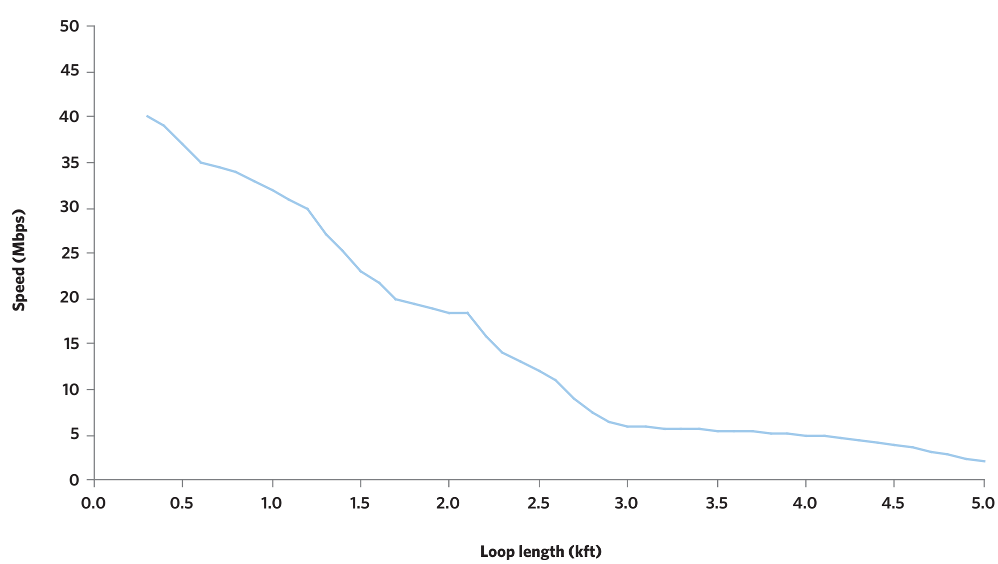


Exhibit 4-BB: Upstream Speed of a Single VDSL2 Line at Various Loop Lengths [122]



any degradation in the copper plant will lead to lower speeds for a given loop length.

In this case, 24 AWG wire is assumed with no bridged taps. Performance with 22 AWG wire, which is often used in rural areas, would yield higher bitrates, while use of 26 AWG wire would yield lower rates.

For VDSL2, performance can be improved through vectoring, bonding or a combination of the two. Vectoring, or Dynamic Spectrum Management level 3 (DSM-3), has shown improved performance in lab tests by canceling most of the crosstalk between VDSL2 lines sharing the same binder and is currently being tested in the field. The bonding of loops, assuming there are two copper pairs available, would enable the doubling of the speed achieved to the end-user. A combination of vectoring and bonding could produce downstream speeds over 300 Mbps if lab and field tests prove successful. Exhibits 4-BC and 4-BD illustrate the performance of bonded and vectored VDSL2.

Operators who have shortened loops from 12 kft to 3-5 kft and currently use VDSL2 technology have seen DSL technology offer faster speeds in the past decade.[123] Current and future

Exhibit 4-BC: Downstream Speed of VDSL2 Variants[124]

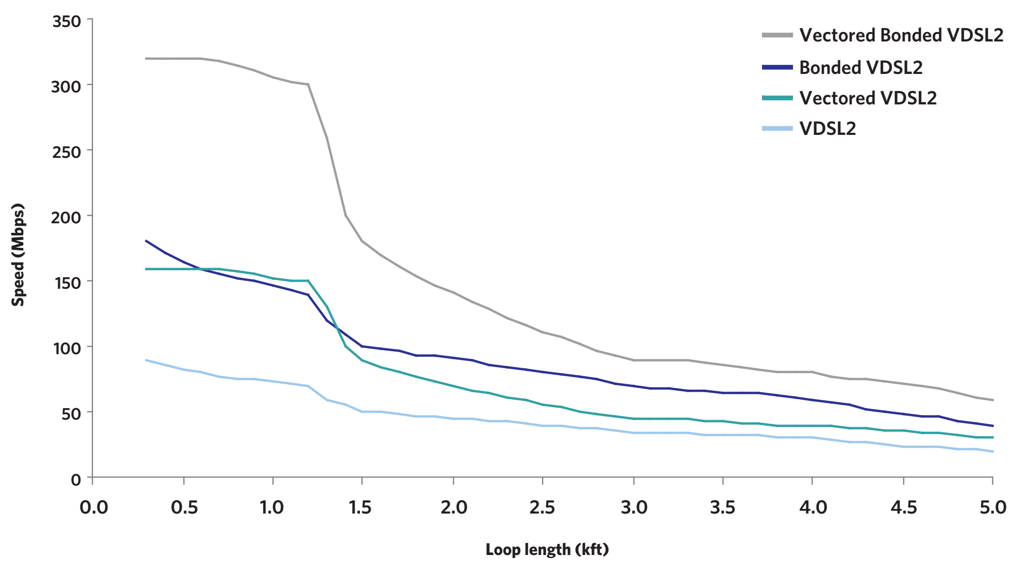
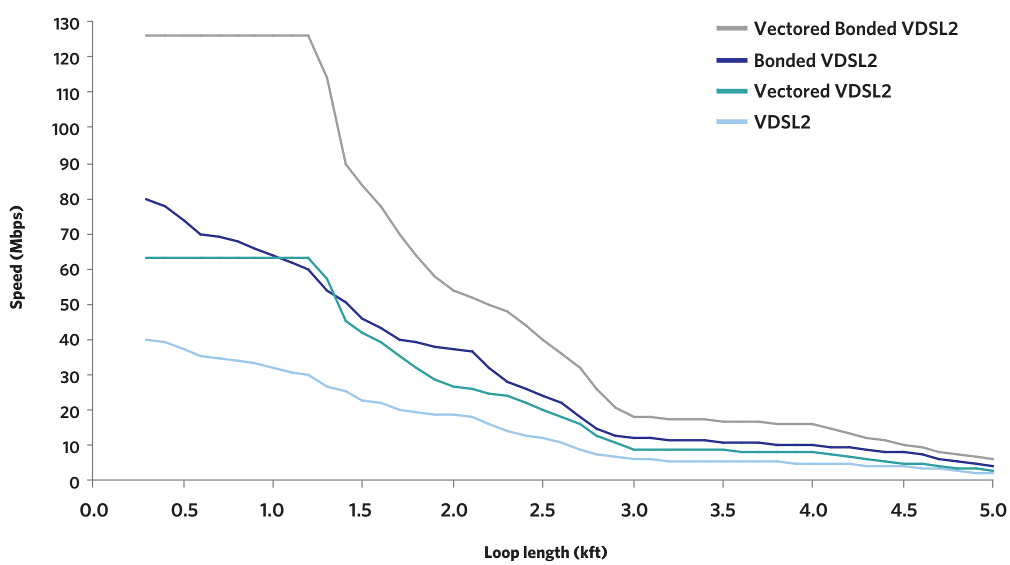


Exhibit 5-BD: Upstream Speed of VDSL2 Variants[125]



technology improvements, such as the three levels of DSM, are likely to continue to improve speeds as well as the stability of the service provided. Further development of and investment in these improvements, along with bonding, are likely due to DSL's prevalence worldwide.

We model the VDSL2 access network in a similar fashion to the ADSL2+ network described (see above for details). In essence, we assume VDSL2 DSLAMs are connected to central office and other middle- and second-mile aggregation points with fiber-optic-based Ethernet technology providing backhaul capacities that are more than sufficient to meet the end-user requirement. Costs associated with loop conditioning are included when appropriate.

Economics

Like those of the 12 kft DSL network, the economics of the 3 kft DSL and 5 kft DSL networks depend on revenues, operating costs and capital expenditure. Using granular cost data from DSL operators, the model calculates the investment gap to deploy 3 kft DSL to unserved markets as $52.7 billion and the investment gap to deploy 5 kft DSL to unserved markets as $39.2 billion. The total gaps for 3 kft and 5 kft DSL are more than twice as costly as the respective number to deploy 12 kft DSL to the unserved, despite 3-5 kft DSL earning nearly 3x the revenue of 12 kft DSL because their ARPUs include video as well as data. The cost differential is mainly driven by the high cost of driving fiber closer to the end user, less so by the higher cost of VDSL2 technology versus ADSL2+ technology. The following waterfall charts show the breakout among initial capital expenditure, ongoing costs and revenue. See Exhibits 4-BE and 4-BF.

Initial Capex

Initial capital expenditures include material costs and installation for the following: telco modem, NID, protection, aerial or buried copper drop, DSLAM, cabinet, VDSL2 line card, allocated aggregation cost, fiber cable up to 3 kft or 5 kft from the end-user (respectively), feeder distribution interface and drop terminal/building terminal, as well as the engineering costs for planning the network and the conditioning required on loops (i.e., the removal of load coils and bridged taps).

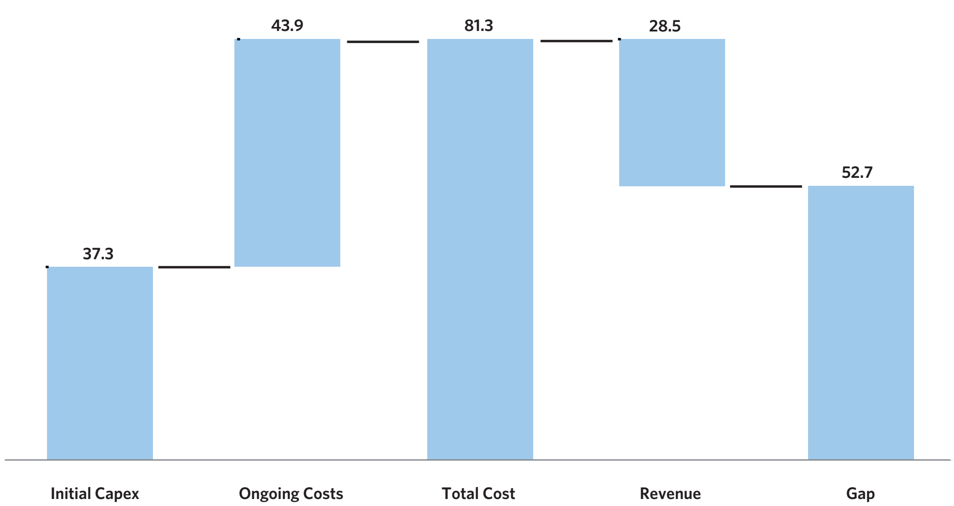
Ongoing Costs

Ongoing costs include replacement capital expenditure required to replace network components at the end of their useful lives, network administration, network operations center support, service provisioning, field support, marketing and SG&A.

Revenues

Revenues are calculated by taking the ARPU—which varies according to the level of broadband service/speed provided as well as whether the bundle of services provided includes voice, data and video—and multiplying it by the average number of users. For 3 kft and 5 kft DSL, data and video ARPUs are used as the incremental services to voice, which is assumed present due to the fact that DSL technology utilizes the twisted pair of copper wires originally installed and used for POTS. VDSL2's higher speeds at 3 kft and 5 kft could support both video and data, although not all real-world operators of VDSL2 choose to offer both services today. The addition of video revenue is not enough to compensate for the incremental investment required to drive fiber within 3 kft and 5 kft of the end user for the unserved.

Exhibit 4-BE:
Breakout of 3,000-Foot DSL Gap



Material and labor costs for 3 kft and 5 kft DSL are the same as for 12 kft DSL except for VDSL2 line cards, which are sourced from a Qwest filing under Protective Order.

15,000 foot DSL

DSL over loops of 15,000 feet (15 kft) is a very cost-effective solution for providing Internet access in low-density areas but fails to meet the Broadband Availability Target.

Capabilities

DSL over 15 kft loops typically uses ADSL2/ADSL2+ technology. ADSL2+ over 24 AWG wire provides rates of 2.5 Mbps downstream and 600 kbps upstream; therefore, the technology does not meet the speed requirements for broadband service under the Broadband Availability Target. Refer to Exhibit 4-AH in the 12 kft DSL section for a further understanding of how downstream speed varies with loop-length distance.

Hybrid Fiber-Coax Networks

The focus in this section will be on high-speed data connectivity provided by hybrid-fiber-coax (HFC), or cable, networks. We'll look first at the capabilities of HFC networks, then at the economics of these services.

Our analysis indicates that the capabilities of HFC networks far exceed end-user speed and network capacity requirements, as shown above and in the National Broadband Plan. Therefore, by

Exhibit 4-BF:
Breakout of 5,000-Foot DSL Gap

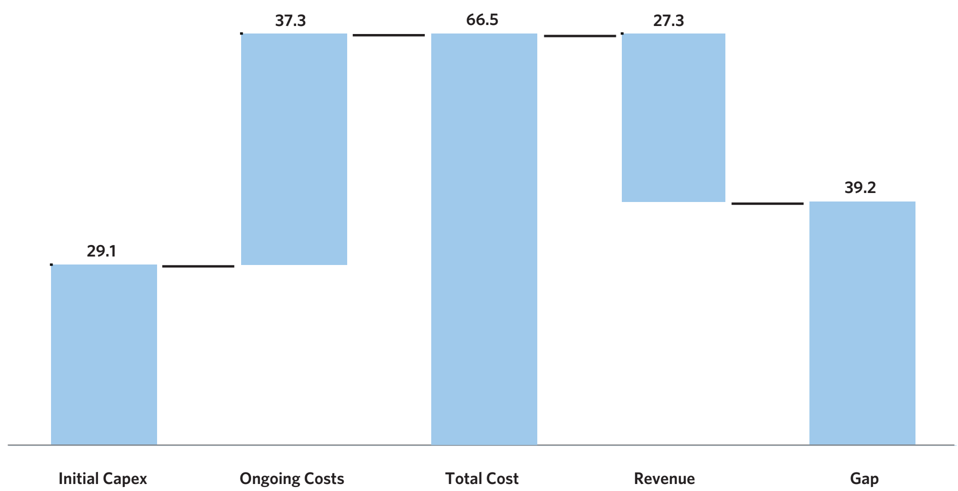
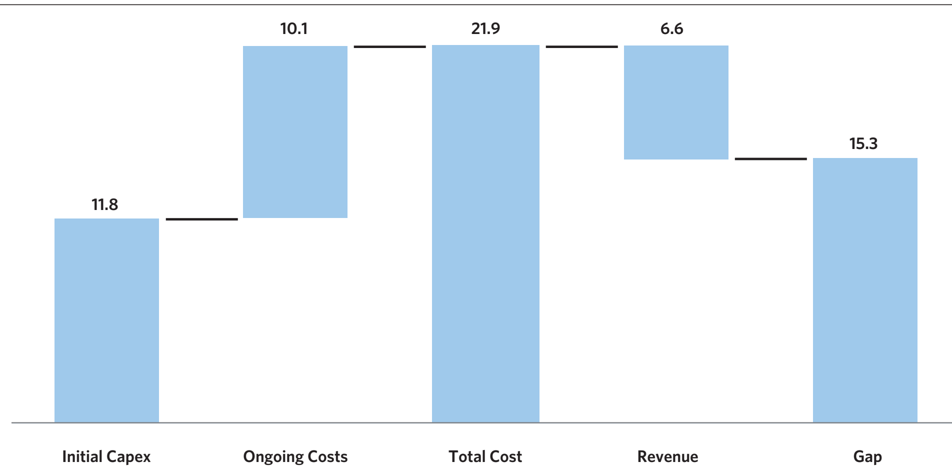


Exhibit 4-BG:
Breakout of 15,000-Foot DSL Gap



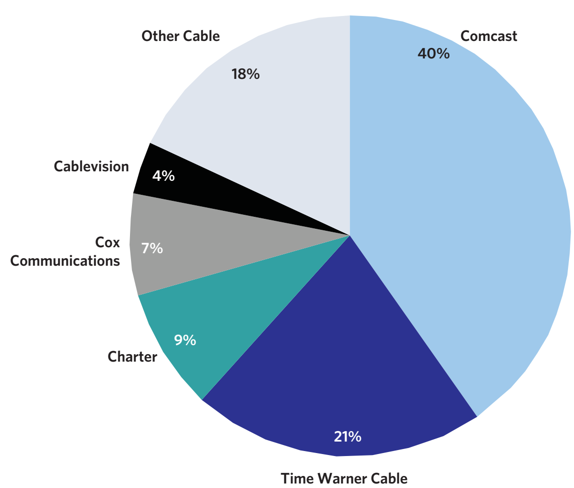
definition, homes within the HFC footprint are considered served. However, the investment gap to deploy HFC networks in unserved areas is larger than that of DSL or fixed wireless as noted above.

The near-ubiquity of HFC networks that can provide high-speed broadband access is a tremendous asset that puts the United States in a unique position among other countries. HFC networks were initially designed to deliver one-way video, but have evolved over time to allow two-way transmission of data and voice in addition to video. Today, cable systems pass roughly 90% of U.S. households with high-speed data services; in addition, more than 90% of homes are passed by cable plant, with 50% of those homes taking at least basic cable video service, thereby amounting to 63 million subscribers.[126] Some 52% of broadband subscribers in the United States subscribe to cable-based service, the second highest rate among OECD countries.[127]

History

When cable systems were initially constructed, the industry was highly fragmented, with many small firms operating networks in local markets. Today, there is very little overlap in cable networks because, in most markets, cable operators received exclusive rights to operate in their geography in the form of a franchise agreement granted by local franchising authorities. It is important to note that cable companies have not been subjected to the same network-sharing or carrier-of-last-resort obligations as the telephone companies; however, cable companies do not receive Universal Service Fund (USF) monies to offset the costs of constructing and maintaining their networks. Maintaining one network per geographic area greatly reduced the network cost-per- subscriber, which, along with having monopoly or near-monopoly control over the video market, has allowed these networks to be successful in the face of large up-front capex requirements.

Exhibit 4-BH:
Breakout of Cable Coverage— Share of Homes Passed by Cable Companies



Numbers do not sum to 100% due to rounding.

Due to the complementary nature of footprints and scale advantages in content acquisition, the cable industry has experienced significant consolidation over the years. Today, there are almost 1,200 cable system operators but, as shown in Exhibit 4-BH, the top five companies pass 82% of homes passed by cable video service.[128]

Cable MSOs have spent $161 billon from 1996-2009 on capital expenditures; in part, this was used to enable broadband capabilities.[129] Cable systems were originally constructed to provide one-way video signals, so customers initially could not send information back through the network. In the early deployment of cable (1950s-1970s), the networks were known as CATV (Community Antenna Television) and were built to provide TV and radio services. The network was designed to support all-analog, one-way transmissions from the community satellite antennas (cable headends) to end-user televisions over coaxial cable.

In the 1990s with the advent of the Internet and passage of the 1996 Telecommunications Act, cable companies began upgrading their networks to provide the two-way transmission capabilities required for Internet data traffic and telephony in addition to TV/radio signals. The network needed to be reengineered to handle two-way transmissions of digital communication signals and upgraded to handle higher capacity demands. The original "tree and branch" architecture of cable systems was ideal for transmitting TV signals from the head-end to the home television. However, video transmission over coaxial cable was still susceptible to noise and interference and required amplifiers, line extenders and other active electronics to ensure that the signal would reach end-user TV sets with acceptable quality. Unfortunately, these active electronics a) were not capable of passing signals in the upstream direction and b) were often not spaced properly within the cable plant for upstream transmission. As a result cable companies invested in HFC upgrades throughout the 1990s to overcome these problems. Such upgrades were seen as attractive since millions of homes were already "wired" with high capacity coaxial cable and the revenue potential of triple play services created a compelling business case. Exhibit 4-BI illustrates some examples of the infrastructure upgrades required for HFC networks.

Steps to upgrade cable networks for broadband:

➤ Invest in fiber optic cable and optic/electronics to replace and upgrade coaxial cable for capacity purposes

- ➤ Replace and redesign headend equipment, line transmission equipment, set top boxes to allow for two-way data transmission, and add DOCSIS modems
- ➤ Deploy telephone switching equipment and interconnection facilities to provide VoIP services
- ➤ Develop the technology and equipment necessary for more sophisticated network management and control systems
- ➤ Implement the back-office, billing and customer service platforms necessary to provide the standard triple play services common among cable operators today

Capabilities

Cable companies coupled their investments in two-way upgrades with a standardization effort. Cable-based broadband relies on Data Over Cable Service Interface Specification (DOSCIS). The first release of DOCSIS was in 1997, with DOCSIS 2.0 released in 2001 and the third-generation standard (DOCSIS 3.0) now being deployed widely. DOCSIS 2.0, currently the most widely deployed, provides up to 36 Mbps of downstream bandwidth and up to 20 Mbps upstream, while DOCSIS 3.0 provides up to 152 Mbps of downstream bandwidth and up to 108 Mbps of upstream (with four bonded channels).[130]

As noted above, cable systems provide shared bandwidth in the last mile, with multiple homes sharing a fixed amount of bandwidth at a single node. Ultimately, bandwidth-per-customer is driven both by the number of customers (and their usage) per node and the total bandwidth available per node. Given typical busy-hour usage rates (see Network Dimensioning section), users on a DOCSIS 2.0 system can receive up to 10 Mbps;[131] under DOCSIS 3.0, that number will increase substantially, to 50 Mbps.[132] Actual figures, however, depend on a large number of variables, including not only the DOCSIS specification, but also spectrum allocation and use and the number of homes per node.

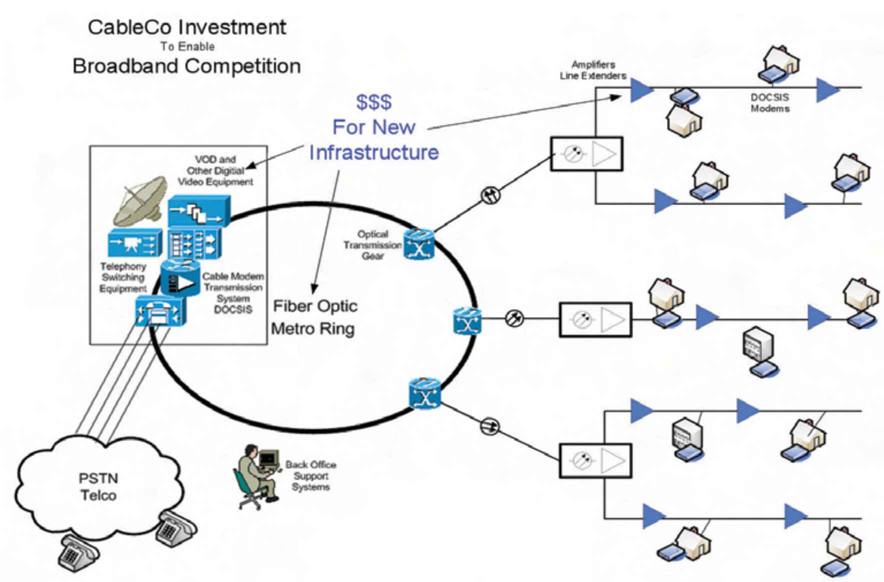
Impact of cable-system spectrum

Spectrum in cable plants, as in over-the-air broadcasting, is a measure of how much "real estate" is devoted to transmitting signals. Most two-way cable plants use 450 MHz or more of spectrum, with many having been upgraded to provide 750 MHz or more. Each analog television channel requires 6 MHz of spectrum. Exhibit 4-BJ shows the spectrum allocation for a typical 750 MHz, DOCSIS 2.0 deployment.

Note that all upstream communications take place in low-frequency spectrum, below 52 MHz. FCC rules requiring that broadcast Channel 2 be carried on Channel 2 of the analog spectrum (54 – 60 MHz) established the low end of downstream spectrum.[133] Cable companies' outside plant equipment is tuned for this: band-pass filters allow upstream traffic only below 52 MHz. In addition, band-pass filters in consumer electronics are tuned to block potentially large amplitude upstream signals only below 52 MHz.

The 52-MHz upper bound on upstream spectrum places limits on upstream bandwidth. First, because it would require

Exhibit 4-BI:
Upgrades to Enable Broadband Services



changes to cable plant and consumer electronics, adding spectrum for upstream use above the 52 MHz would be difficult and costly. In addition, interference at low frequencies (e.g., from motor noise, ham and CB radio, walkie-talkies) could reduce usable upstream spectrum significantly.[134] While DOCSIS 3.0 allows for the bonding of multiple channels to increase upstream capacity, these other spectrum issues will likely provide real-world limits to upstream capacity.

Downstream bandwidth faces fewer constraints; cable companies can devote higher-frequency 6 MHz channels to downstream capacity. In addition, DOCSIS 3.0 allows carriers to devote four or even eight channels to downstream data communications.

Cable companies use Quadrature Amplitude Modulation ("QAM") to increase the bandwidth transmitted over a given amount of spectrum (the Mbps-per-MHz), with typical deployments featuring 16, 64 or 256 QAM. In typical DOCSIS 2.0 deployments, the downstream direction is 64 or 256 QAM and the upstream is 16 QAM. As an example, consider a typical DOCSIS 2.0 deployment with one 6 MHz downstream channel at 64 QAM which delivers approximately 36 Mbps.

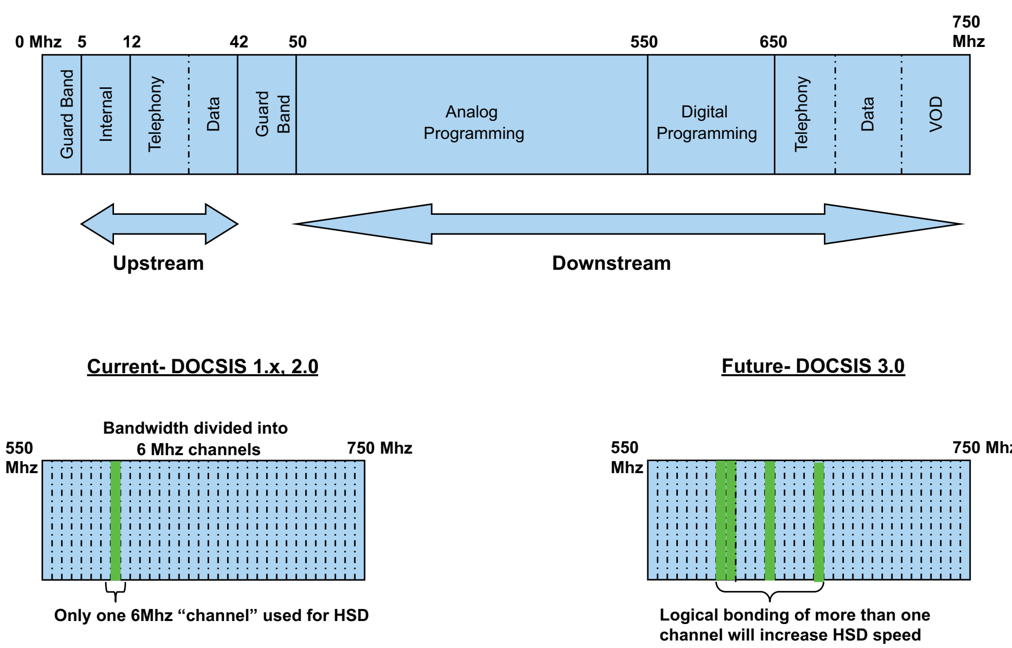
Cable companies can create additional capacity for downstream bandwidth (or for additional broadcast video channels, or other services like video-on-demand) through a number of means. The most obvious may be to increase the frequency of the cable plant, but this requires extensive upgrades in outside plant and is often very expensive.

There are a number of less expensive options available. As discussed above, going from DOCSIS 2.0 to DOCSIS 3.0 allows the cable system to devote more frequency, assuming it can be made available, to data while keeping the plant total unchanged. Cablevision estimated the cost of its DOCSIS 3.0 rollout at about $70 per home passed (there may be additional success-based expense, e.g., CPE). Scale economies may bring that number 10-20% lower for larger MSOs.[135]

Another option is Switched Digital Video (SDV). In the current HFC architecture, all video channels are sent to all subscribers with filtering of channels for different subscription services made by the set-top box. SDV transmits only those channels to a given node when those channels are in use by a subscriber. This means that the majority of channels are not transmitted most of the time, thereby using fewer channels in aggregate. SDV is therefore a relatively inexpensive technique to reclaim on the HFC network bandwidth to be used for other purposes. Cisco Systems estimates the cost of SDV at $12-$16 per home passed.[136] A number of MSOs are moving forward with SDV,[137] although concerns exist for third party providers of DVRs like TiVo.[138]

Another approach is analog reclamation. In analog reclamation, often termed "going all digital," cable companies move away from transmitting analog signals entirely. A single analog channel takes up 6 MHz (the equivalent of more than 30 Mbps as noted above); the same spectrum (or bandwidth) can carry 10 digital standard-definition channels or three high-definition channels. Analog reclamation can therefore "add" a substantial number of channels to a typical system. For example, by

Exhibit 4-BJ:
Spectrum Allocation in Cable Plant



moving a fairly typical 85 analog channels to digital, a cable company can free up over 500 MHz of spectrum, providing enough capacity to carry well over 200 digital HD channels. The cost of analog reclamation is estimated at approximately $30 per home passed.[139]

Finally, cable companies could go all-IP, moving away from the current spectrum allocation entirely. A 750-MHz system could provide 4.5 Gbps[140] of all-IP bandwidth, to be shared among all users and all applications. This would require a significant change not only in network architecture for cable companies, but also significant business-process redesign to figure out how to capture revenue from an all-IP network.

Impact of homes per shared node

As noted above, cable capacity is shared among all users on a given node. Where there are more users, bandwidth is shared more widely and individual users will, on average, have less capacity. By splitting nodes, cable companies can reduce the user-load per node and increase the capacity per user. Some cable companies have been splitting nodes aggressively, moving from 1,000 homes per node to 100 homes per node or fewer.[141] Cisco estimates the cost of splitting a node at approximately $1,500.[142] Assuming 300-400 homes per node puts the cost at approximately $50 per home passed.

As node-splitting continues, HFC networks will reach the point where the run of coaxial cable is quite short—short enough that there is no need for active electronics in the coaxial part of the network. These so-called passive nodes often have roughly 60 homes per node,[143] but the driver is the linear distance covered by the coaxial cable, not the number of homes. Removing active electronics from the field, however, will yield a network that is more robust and that requires less maintenance.

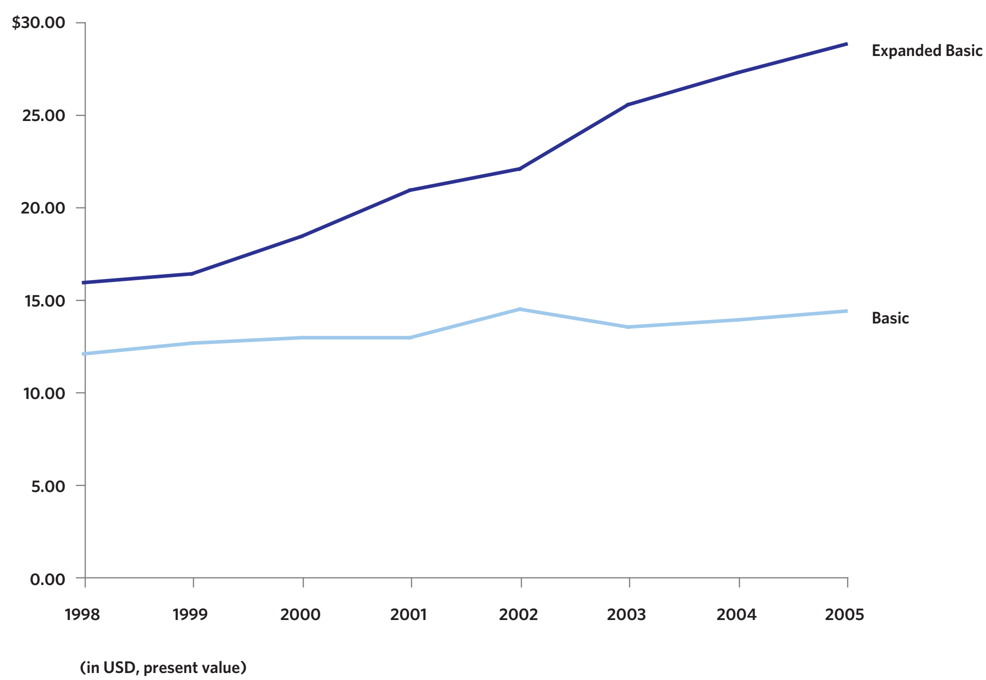
Economics

The economics of providing broadband service over cable plant are driven largely by the presence of existing network. Where networks exist, and costs are sunk, broadband economics are very attractive. In other areas, where one examines greenfield builds, the economics can be far more challenging. Since the network capabilities of an HFC network far exceed the target speed set forth in the plan, the unserved are all in greenfield areas where the investment gap of HFC is much larger than that of DSL or fixed wireless.

Existing cable deployments were funded by video

As noted earlier, cable networks were originally designed to offer video service. And, in many markets, cable companies were granted exclusive franchise agreements. As a result, the video business over

Exhibit 4-BK: Cable Video ARPU Over Time[144]—Cable Pricing



time has accounted for a large portion of cable-company revenue, providing a network on which to build the incremental broadband business. The video business, in fact, has enjoyed increasing ARPU over a long period of time (see Exhibit 4-BK), providing much of the capital for HFC investment in infrastructure. Of all subscribers who have access to these services, 88% subscribe to expanded basic and 55% subscribe to digital programming.[145]

Incremental broadband upgrades

As noted above, large investments have been made in cable systems already, principally funded by the video business. Further, as shown in Exhibit 4-BL, the incremental expense for upgrades—each aspect of which has been discussed previously—is low given the significant sunk investment already in the cable plant. As a consequence, cable systems are relatively well positioned to meet

Exhibit 4-BL: Upgrade Costs for Cable Plant

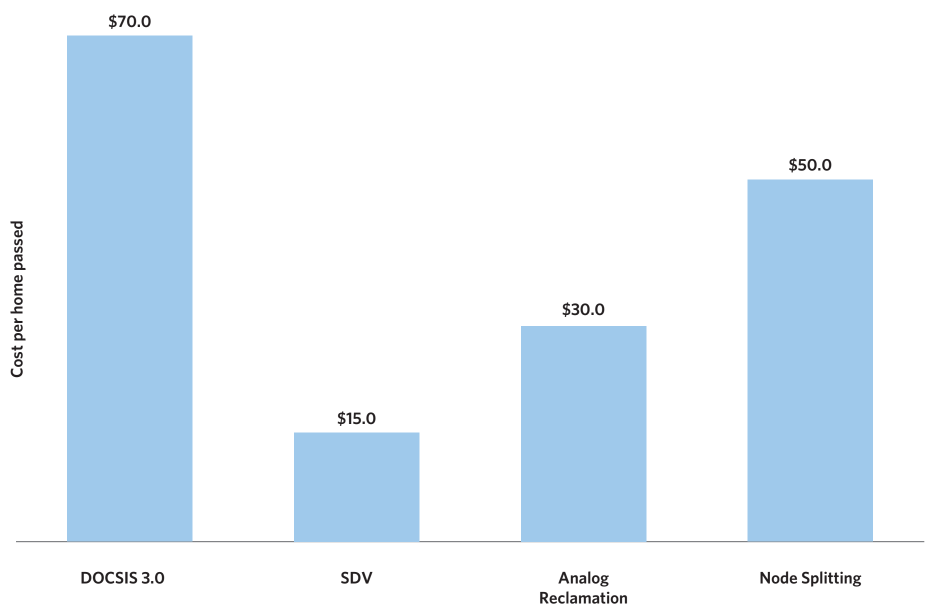
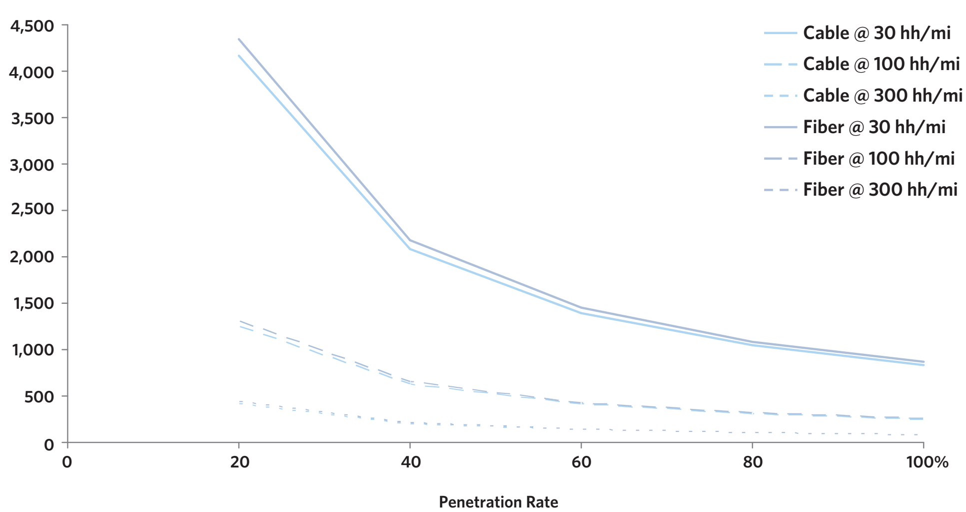


Exhibit 4-BM: Outside Plant Cost, FTTP or RFoG vs. HFC—Relative Capex Costs of Cable and Fiber, Excluding Headend Equipment[146 147]



Dollars of capex/sub/mile; penetration rate future growth in bandwidth demand.

In summary, where existing two-way cable plant exists, upgrade costs to provide high-speed service of up to 50 Mbps are low: roughly $165 per home passed.

Greenfield deployments

Building a new cable plant requires deploying a new outside plant and some form of headend to aggregate and distribute video and data content. The choice of technology for the outside plant is not an obvious one: providers can deploy a network that is a traditional hybrid fiber-coax plant, or one that is all fiber, a so-called RF over Glass (RFoG) plant.

When connecting a home for the first time—effectively adding a completely new last-mile connection—providers are likely to use the most future-proof technology possible. It would make little sense to deploy, for example, a brand-new long-loop twisted-pair network. The choice is less clear when comparing HFC and RFoG (or any other FTTP deployment). As Exhibit 4-BM shows, HFC and fiber networks have similar outside plant costs, which are mostly a function of labor costs. However, RFoG and FTTP deployments, by removing all active electronics from the outside plant, have lower ongoing expenses.

Estimates suggest these opex savings are approximately $20 per home passed per year.[148] While this may not sound large at

Exhibit 4-BN:
HFC Plant Diagram—CableCo HFC Architecture

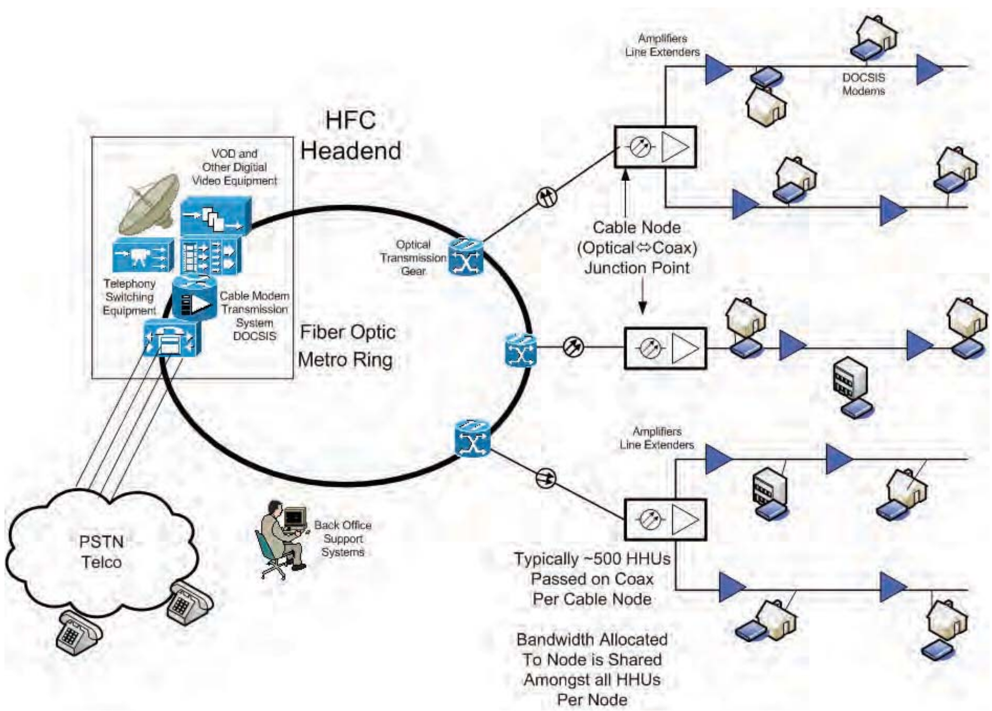


Exhibit 4-BO:
Data Sources for HFC Modeling

Material Costs	Source
Splitter	Cable ONE (filed under protective order)
Fiber Node	Cable ONE (filed under protective order)
CMTS	Hiawatha (filed under protective order)
Up Stream Reciever	Hiawatha (filed under protective order)
Cable Modem	Hiawatha (filed under protective order)
Drop	Hiawatha (filed under protective order)
Tap	Cable ONE (filed under protective order)
Coaxial Cable	Cable ONE (filed under protective order)

the outset, it adds up over the life of the network. A majority of these savings come from power required for active components, system balancing and sweeping, and reverse maintenance.

The other major expense for a new network, whether HFC or RFoG, is the cost of a drop per subscriber. RFoG drops are approximately $175 more expensive than HFC drops.[149] As a consequence, the initial cost of connecting a subscriber is higher for RFoG relative to HFC.

However, the aggregate cost of a typical HFC customer will exceed, in less than 10 years, the aggregate cost of serving the same customer using RFoG. In other words, the operational savings from having an all-passive plant outstrip the initial cost savings from deploying an HFC system. It is reasonable to expect RFoG and FTTP drop costs will decline over time as deployments become increasingly mainstream and the industry attains greater scale. Accordingly, it is likely that as RFoG and FTTP deployments become cheaper, this break-even period will become even shorter. As a consequence, a greenfield developer of wireline infrastructure is more likely to choose RFoG or FTTP over HFC going forward, given both lifecycle cost and future-proofing benefits of an all-fiber network.

Modeled cost assumptions

We modeled the incremental costs of extending HFC networks into unserved areas with a high degree of granularity. Exhibit 4-BN shows the basic network elements of an HFC network and Exhibit 4-BO lists the sources for assumptions used in the model.

NETWORK DIMENSIONING

In order to ensure that the investment gap is reflective of the full costs of deployment, it is important to dimension the network to be able to deliver target broadband speeds during times of peak network demand. In particular, we need to determine that we properly model the capacity of every shared link or aggregation point in order to ensure that the network is capable of delivering required broadband speeds.

However, data flows are far more complex to characterize than voice traffic, making relatively straightforward analytical solutions of aggregated data traffic demand very challenging; this will be discussed ahead in **Complexities of data-network dimensioning**. Our approach is to describe typical usage patterns during times of peak demand, which we then use to estimate the network capacity needed to ensure a high probability of meeting end-user demand; this is discussed at the end of this chapter in **Capacity considerations in a backhaul network**.

Complexities of data-network dimensioning

Network dimensioning will not guarantee that users will always experience the advertised data rates. Note that even traditional voice networks are designed for a certain probability of being able to originate a phone call (e.g. 99% of the time in the busy hour for wireline, 95% for cellular) and a certain average sound quality. For dimensioning IP data networks, it may be useful to point out the difficulty of applying traditional voice traffic engineering principles to IP data-traffic flow. Dimensioning IP data networks is intrinsically more complex than dimensioning voice networks.

To properly dimension a traditional circuit switched voice network, it is typical to use the Erlang B formula that allows an operator to provision the number of circuits or lines needed to carry a given quantity of voice traffic. This is a fairly straightforward process mainly because the bandwidth consumed for each call is effectively static for a given voice codec in the busy hour. In fact, technology has enabled carriers to encode speech more efficiently so a voice conversation today may actually consume much less bandwidth than a voice conversation did 20 years ago. Nonetheless, the three basic variables involved are:

- Busy Hour Traffic, which specifies the number of hours of call traffic there are during the busiest hour[150]
- Blocking, or the failure of calls due to an insufficient number of lines being available and
- The number of lines or call-bearing TDM circuits needed in a trunk group

As long as the average call hold time is known and the operator specifies the percentage of call blocks it is willing to accept in the busy hour, the number of trunks is easily calculated using the Erlang B formula.

For broadband Internet access, however, there is much more uncertainty. Unlike voice telephony, Internet traffic is quite complex, multi-dimensional, and dynamic in the minute-to-minute and even millisecond-to-millisecond changes in its characteristics. Network planning and engineering for broadband Internet are more difficult with higher degrees of uncertainty because of the following principal factors:

- Each application used during an Internet access session, such as video streaming, interactive applications, voice, Web browsing, etc., has very different traffic characteristics and bandwidth requirements.
- End-user devices and applications are evolving continuously at the rate of silicon electronics, as opposed to voice (we continue to speak at the same rate of speech).
- Broadband Internet access supports many different user applications and devices, from streaming high definition video (unidirectional, very high bandwidth), to short messaging (bidirectional, very low bandwidth).
- The scientific community has not yet developed and agreed upon the best mathematical representations for modeling Internet traffic.

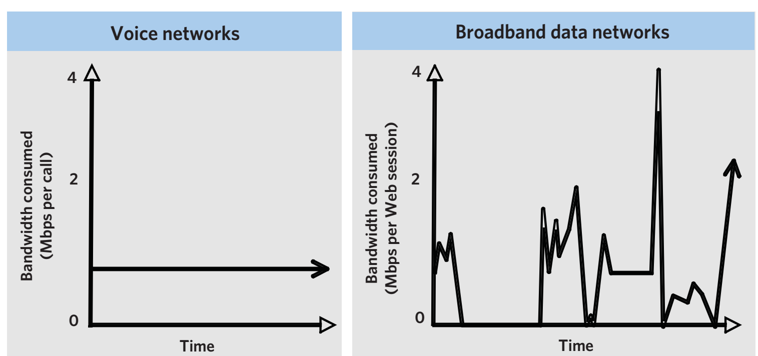
Exhibit 4-BP illustrates the additional complexities of multi-dimensional data traffic verses traditional circuit switched voice traffic. These differences introduce chaotic variables not present in the Erlang traffic model used to dimension voice networks.

Many individual Internet applications are "bursty" in nature. Consider a typical Web-surfing session, in which a user will "click" on an object, which results in a burst of information painting the computer screen followed by a lengthy period of minimal data transmission, followed by another burst of information. The instantaneous burst may occur at several Mbps to paint the screen, followed by many seconds or even many minutes with essentially no traffic, so the average transmission rate during a session may only be a small percentage of the peak rate. This type of traffic does not lend itself to modeling by the traditional mathematical models such as the Erlang formulas used for voice traffic; it can be considered fractal and chaotic in nature, as shown in Exhibit 4-BP. By contrast, the viewing of a high-definition video involves streaming content in one direction steadily at several Mbps. And a typical Skype video conference may involve a two-way continuous streaming of information but at only at around 384 kbps in each direction.[151]

Computer processing keeps improving at the rate set forth by "Moore's Law," as does the price/performance of storage. This doubling every two years enables much better performance of existing applications (e.g., very refined graphics instead of simple pictures, high definition and now even 3D-HD instead of NTSC video or standard-definition TV), as well as new applications that could not have existed several years earlier. So as long as silicon chips and electronics continue to improve, network providers may see more and more demands placed on the network by individual user applications. Moreover, behind an individual network interface, the subscriber is likely to have a local area network with several users running various applications for which traffic characteristics vary widely and with variable timescales such that the cumulative effect is a highly variable and unpredictable traffic flow into the network.

To conclude this discussion, we note that traffic engineering is based on mathematical models involving probabilities and statistics. As noted earlier, modeling voice traffic makes use of the simple inputs of average duration of call, bits-per-second used by the voice encoding scheme and number of call originations per hour. This has enabled scientists and engineers over the years to develop reliable mathematical models that correlate well with real-world experience. However, for Internet traffic, the number of variables, the magnitude of variation of these variables and the statistical nature of the variables have made it difficult for the scientific community to develop

Exhibit 4-BP:
Differences Between Voice and Data Networks



Factor	Relevance to voice network dimensioning	Relevance to data network dimensioning
Number calls/data sessions	Number of calls generated in the busy hour	Number of sessions invoked by user or users during busy hour
Average call/session duration	Average duration of each call (usually in minutes)	Duration of application session (range from hours to milliseconds)
Variation in call/session duration	**Almost all calls measured in minutes with little deviation**	**Variable session duration between applications ranging from minutes to seconds to milliseconds**
Bandwidth intensity (amplitude)	**N/A- bandwidth consumed for each call is static at 64 kbps**	**Bandwidth consumed per application session (Variable based upon active application)**
Variation in bandwidth intensity	**N/A (see previous)**	**Wide variation of bandwidth consumption for different applications**
Calls Blocked / Congestion threshold during busy hour	"blocked" calls tolerated in the busy hour (typically one call block per 100 call attempts)	Minimum bandwidth at which packets are lost

a well-accepted mathematical model that can predict network traffic based on end-user demand. In fact, the underlying behavior of the traffic is still the subject of research and debate.

Consequently, it is very difficult to statistically characterize the traffic per subscriber or the aggregated traffic at each node in the network. And without such a characterization, we cannot dimension the network, *ex ante*, with the level of precision necessary to ensure subscribers will always experience the advertised data rates.

Generally speaking, Internet traffic engineers do not drive the expansion of network capacity from end-user demand models. Rather, they measure traffic on network nodes and set thresholds to increase capacity and preempt exhaust for each critical network element. Adtran remarks in its filing: "While sustainable speed can be measured in existing networks, it is nearly impossible to predict in the planning stages due to its sensitivity to traffic demand parameters."[152]

Still, we need to engineer our network model to deliver a robust broadband experience, capable of delivering burst rates of 4 Mbps in the download and 1 Mbps in the upload even without being able to measure traffic on actual network elements. The approach to do this is to provide sufficient capacity to provide a high probability of a robust user experience (as discussed in the next section). For this, we need a metric that characterizes traffic demand. One such metric that measures traffic demand is the Busy Hour Offered Load (BHOL) per subscriber.[153]

Capacity per user: busy hour offered load (BHOL)

The data received/transmitted by a subscriber during an hour represent the network capacity demanded by the subscriber during that hour. This can be expressed as a data rate when the volume of data received/transmitted is divided by the time duration. BHOL per subscriber is the network capacity demand or offered load, averaged across all subscribers on the network, during the peak utilization hours of the network.

In general, the total BHOL at each aggregation point or node of the network must be smaller than the capacity of that node in order to prevent network congestion. Alternately, the number of subscribers per aggregation node of the network must be smaller than the ratio of the capacity of the node to the average BHOL. This is the general principle we use to dimension the maximum number of subscribers at each aggregation point of the network model.

The BHOL-per-subscriber depends on a subscriber's Internet usage pattern and, as such, is a complicated overlay of the mix of Internet applications in use, the bandwidth intensity of each application and the duration of usage. But, for practical engineering purposes, the average BHOL-per-subscriber can be derived from monthly subscriber usage. Typically, 12.5% to 15% of daily usage happens during the busy hour.[154] We recognize that very high monthly usage on the same connection speeds usually results from increased hours spent online, outside of the busy hours, rather than an increased intensity of usage during the busy hours. As such, very heavy usage may not quite lead to the same proportionate increase in BHOL. However, for the purposes of our network dimensioning, we shall make the simplifying (and conservative) assumption that the effect is proportionate.

Current usage levels and corresponding BHOLs for different speed tiers are shown in Exhibit 4-BQ. Observe that the mean usage is more than five times that of the usage by the median or typical user. In fact, a small percentage of users generate an overwhelming fraction of the network traffic as shown in Exhibit 4-BR. This phenomenon is well known and is discussed in more detail in Omnibus Broadband Initiative, Broadband Performance.[155] For example, the heaviest 10% of the users generate 65% of the network traffic. So, if we were to exclude the capacity demand of these heaviest users, the BHOL of the remaining users would be far lower. For example, by excluding the heaviest 10% of the users, the BHOL by the remaining 90% is only 36-43 kbps. In Exhibit 4-BS, we show the impact on the BHOL by excluding different fractions of the heaviest users. For comparison, we also show the BHOL for the median or typical user.

Suppose we want to dimension a network that will continue to deliver 4 Mbps to all users even after the next several years of BHOL growth. In order to estimate the future BHOL, we first note that average monthly usage is doubling roughly every three years as discussed in Omnibus Broadband Initiative, Broadband Performance.[156] Next, given the significant difference between mean usage and the typical or median user's usage, it is likely that the service provider will seek to limit the BHOL on the network using reasonable network management techniques to mitigate the impact of the heaviest users on the network. For example, an Internet service provider might limit the bandwidth available to an individual consumer who is using a substantially disproportionate share of bandwidth and causing network congestion. Exhibit 4-BS shows the BHOL for possible scenarios, ranging from dimensioning for the typical user to mean usage. For our network dimensioning purposes, we shall use a BHOL of 160 kbps to represent usage in the future. Thus, this network will not only support the traffic of the typical user, but it will also support the traffic of the overwhelming majority of all user types, including the effect of demand growth over time. It is also worth noting that the additional cost of adding capacity on shared links, as described throughout this paper, is low.

Capacity considerations in a backhaul network

Operators of IP broadband networks must provide a consistent, reliable broadband experience to consumers in the most cost-effective way that meets the consumer broadband requirements set forth in the Broadband Plan: 4 Mbps downstream and 1 Mbps upstream of actual speed.

An important consideration for an economical deployment of affordable broadband networks is proper sizing and dimensioning of the middle- and second-mile links. A fundamental element in the design of all modern packet-switched networks is "sharing" or "multiplexing" of traffic in some portions of the network to spread costs over as many users as possible.[157] In other words, network operators can take advantage of the network capacity unutilized by inactive applications and/or users by dynamically interleaving packets from active users and applications thus leading to a better shared utilization of the network. This is commonly known as statistical multiplexing.

This ability to dynamically multiplex data packets from multiple sources contributes to packet-switched networks being more

Exhibit 4-BQ:
Monthly Usage and BHOLs by Speed Tier

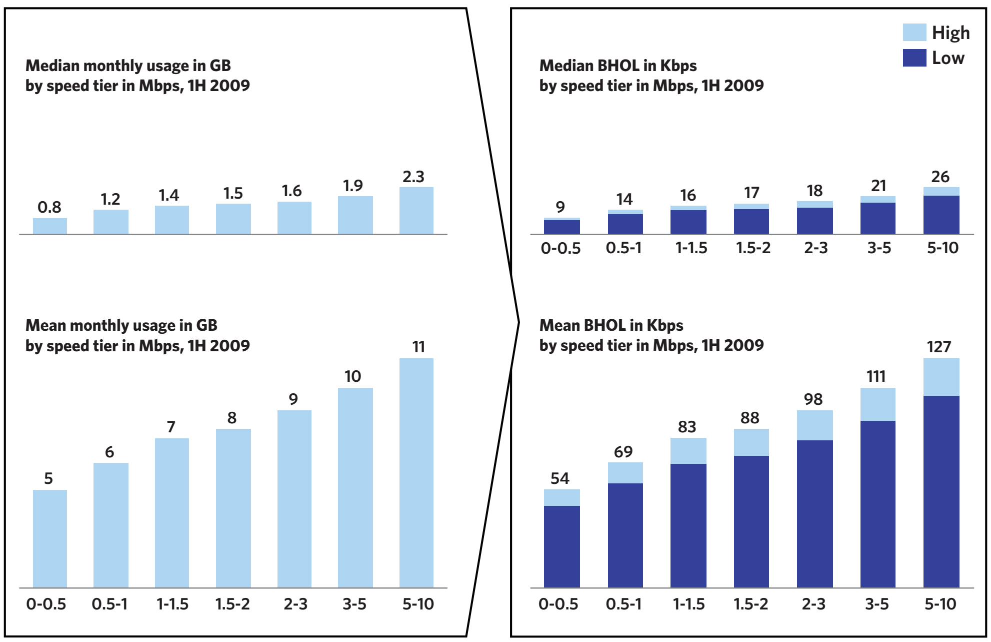
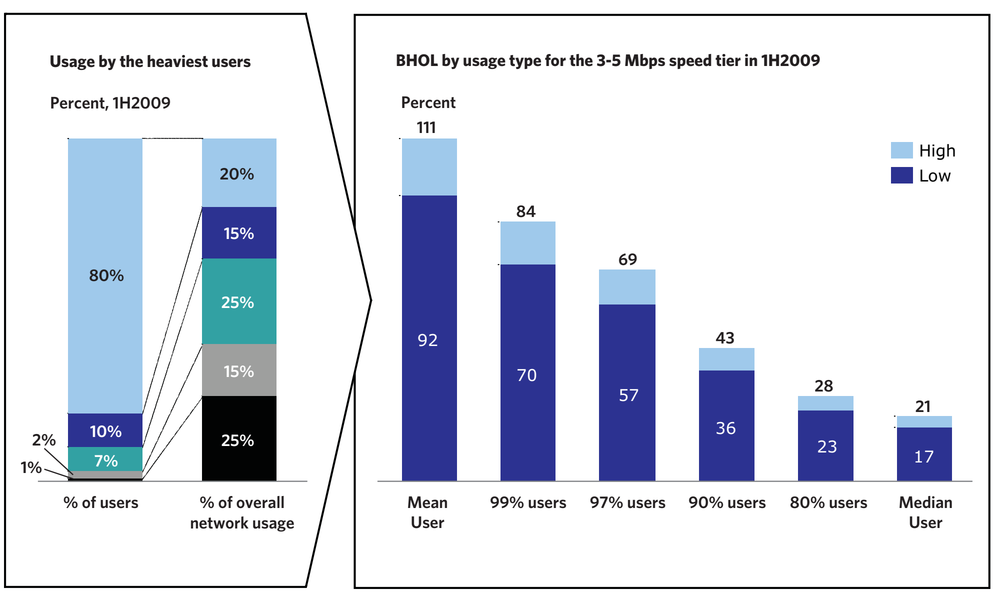


Exhibit 4-BR:
Usage by Tier and BHOL



efficient and economical than circuit-switched networks. Shared network resources are the principle of network "convergence" in practice. Voice, video and data applications like Web browsing and other applications noted above are now all packetized and transmitted using the same network transmission facilities.

Of course there is a downside to shared networks, which are typically oversubscribed in order to exploit the benefits of statistical multiplexing. Oversubscription refers to the fact that the maximum aggregate demand for capacity at a shared link or node in the network can exceed the link or node capacity. Thus, there is a risk, however small, that the total traffic presented at a given time might exceed transport resources in a way that will, in turn, result in congestion, delay and packet loss.

Even though it is challenging, *a priori*, to accurately characterize the user experience on a network because of the complexity of characterizing the traffic per subscriber, we used some available analytical tools to validate the network dimensioning assumptions in our model. Specifically, in Exhibit 4-BT,

Exhibit 4-BS:
Expected Future BHOL in Broadband Network Dimensioned to Deliver 4 Mbps—Expected BHOL in kbps for Different Usage Types in 2015

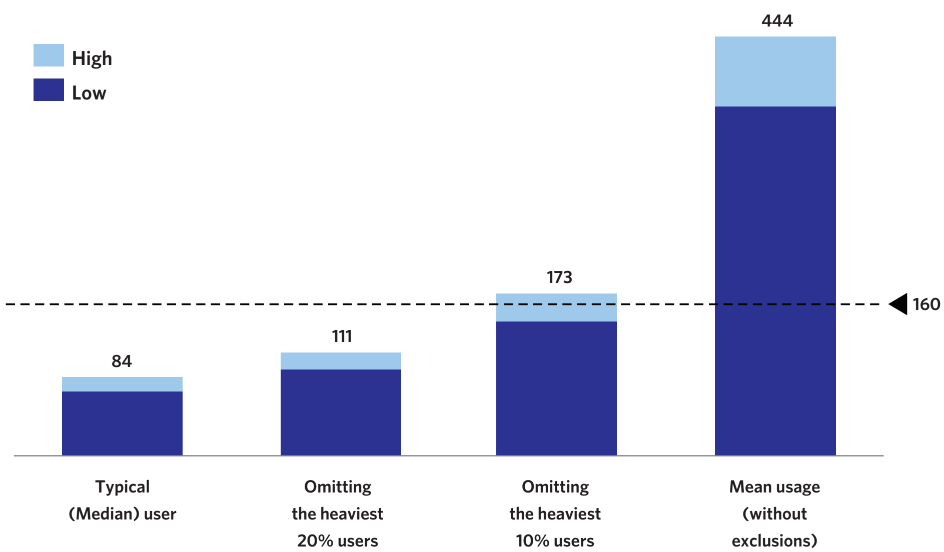
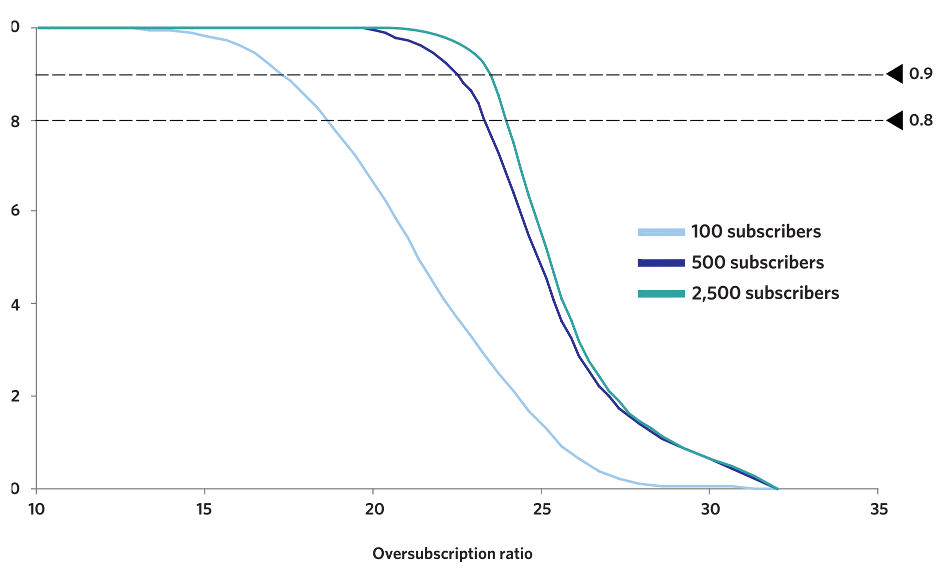


Exhibit 4-BT
Likelihood of Achieving a Burst Rate Greater Than 4 Mbps at Different Oversubscription Ratios with a Varying Number of Subscribers[158]



we show the likelihood of being able to burst at rates greater than 4 Mbps on a shared *wired* or *satellite* link at different oversubscription ratios. For convenience, we shall refer to this likelihood as simply "burst likelihood."

In Exhibit 4-BT, the case with 100 subscribers is meant to represent a typical HFC node with ~100 subscribers; the 500 and 2,500 subscriber curves, on the other hand, represent a DSLAM with ~500[159] and a satellite beam with ~2,500 subscribers, respectively.

We use this chart to validate the network dimensioning assumptions in our model. For example, the chart shows that for a burst likelihood of 90%, the maximum oversubscription ratio on a link with 100 subscribers is approximately 17. Recall that oversubscription ratio of a link of capacity C Mbps with N subscribers who have an actual data rate of R Mbps is:

$$\textit{Oversubscription ratio} = \frac{\textit{(Number of subscribers) x (Actual Speed)}}{\textit{(Link Capacity)}} = \frac{N \times R}{C}$$

That implies that the link capacity must be greater than approximately 23.5 Mbps. Since the capacity of a DOCSIS 2.0 HFC node is about 36 Mbps, we conclude that a single DOCSIS 2.0 node, which serves about 100 subscribers can deliver our target broadband speeds with high likelihood. We can use the same approach to validate the dimensioning of shared links and aggregation points in other networks like DSL, Satellite and FTTP.[160]

We recognize that the results shown in the chart are based on certain traffic demand assumptions,[161] and that these assumptions may not hold in practice. Still, given our conservative choice of parameters in our network models, these results indicate that the network will support the required broadband speeds with very high probability. In reality, network operators may monitor traffic levels at different links within their networks and engineer their respective oversubscription ratios to ensure that capacity in the shared portions of the network is available to support offered service levels; in this case, 4 Mbps download and 1 Mbps upload in the busiest hours of the network.

One very interesting implication of the traffic simulation represented in Exhibit 4-BT is that higher oversubscription rates for the larger number of subscribers mean that capacity can grow more slowly than the number of subscribers. This is due to improved statistical multiplexing with increased number of users. For example, adding five times more subscribers, moving from 100 to 500 or from 500 to 2,500 subscribers, requires adding only roughly four times as much capacity to provide the same probability of end-user service. Thus, adding capacity linearly with the number of subscribers, as we assume in our analysis, is a conservative approach that does not account for the full benefits of statistical multiplexing.

MIDDLE-MILE ANALYSIS

Middle-mile facilities are shared assets for all types of last-mile access. As such, the cost analysis is very similar regardless of last-mile infrastructure. The local aggregation point can vary based on technology (e.g., a cable headend, LEC central office or a wireless mobile switching center (MSC)) while the Internet gateway is a common asset. Middle-mile facilities are widely deployed but can be expensive in rural areas because of the difficulties of achieving local scale, thereby increasing the investment gap. On a per-unit basis, middle-mile costs are high in rural areas due to long distances and low aggregate demand when compared to middle-mile cost economics in urban areas.

While there may be a significant affordability problem with regard to middle-mile access, it is not clear that there is a middle-mile fiber *deployment* gap. The majority of telecom central offices (approximately 95%)[162 163] and nearly all cable nodes (by definition, in a true HFC network) are fed by fiber.

Please note: terms like "backhaul," "transport," "special access" and "middle-mile" are sometimes used interchangeably, but each is distinct. To avoid confusion, "middle-mile transport" refers generally to the transport and transmission of data communications from the central office, cable headend or wireless switching station to an Internet point of presence or Internet gateway as shown in Exhibit 4-BU.

Middle-Mile Costs

The middle-mile cost analysis concludes that the initial capex contribution to serve the unserved is 4.9% of the total initial capex for the base case. That is, the modeled cost for the incumbent or lowest cost provider to build these facilities incrementally is estimated at approximately $747 million.

In order to accurately model the costs of middle-mile transport, particularly in rural, unserved areas, we examined all available data about the presence of reasonably priced and efficiently provided, middle-mile transport services. However, we recognize that broadband operators who rely on leased facilities for middle-mile transport may pay more for middle-mile than broadband providers who self-provision. This is discussed further within the subsection titled **Sensitivity: Lease vs. Build**. Thus, in a hypothetical case in which leasing facilities turns out to be four times the modeled incumbent build cost, the resulting middle-mile contribution could be estimated as high as 9.8% of the total initial capex for the base case, or approximately $1.6 billion. The following discusses the analysis done to ensure our model accurately captures the appropriate costs.

Broadband networks require high-capacity backhaul, a need that will only grow as end-user speed and effective load grow. Given the total amount of data to be transmitted, optical fiber backhaul is the required middle-mile technology in most instances. Once the transport requirement reaches 155 Mbps and above, the only effective transport mode is at optical wavelengths on a fiber optic-based transmission backbone. Plus, while the initial capital requirements of fiber optic systems are substantial, the resulting infrastructure provides long-term economies relative to other options and is easily scalable.[164] Microwave and other terrestrial wireless technologies are well suited in only some situations such as relatively short middle-mile runs of 5-25 miles. However, microwave backhaul may be a critical transport component in the second mile, primarily for wireless backhaul as discussed in detail in the wireless section.

Approach to Modeling Middle-Mile

The costs associated with providing middle-mile services are heavily dependent on the physical distances between network locations. Therefore, the approach to modeling middle-mile costs revolves around calculating realistic distance-dependent costs.

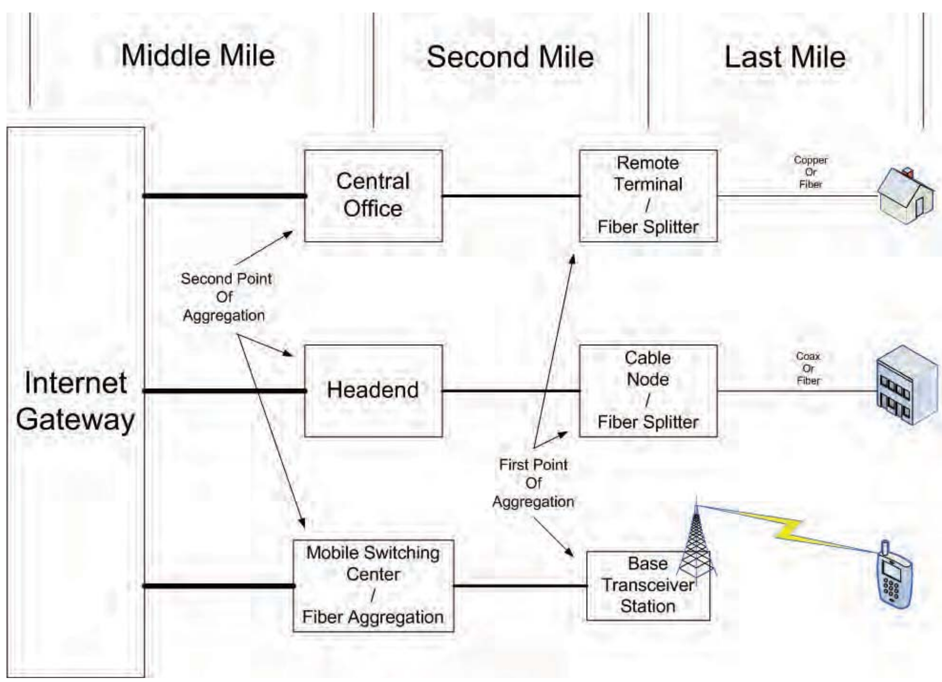
Our focus is on ILEC central offices given the availability of information on their locations. Starting with the location of ILEC central offices and the network homing topology, we estimated the distances and costs associated with providing middle-mile service. Since the cost estimate is distance-dependent, calculating the cost requires making an assumption about the routing used to connect LEC offices as will be discussed below. This same approach—mapping known fiber locations and their logical hierarchy to calculate the distances and costs for providing middle-mile service—could apply equally well to cable headends, or CAP, or IXC POPs given thorough information on their locations. However, publically available information on exact locations of cable headends, private IXC fiber POPs and other entity fiber node locations is limited; thus, the focus exclusively on ILEC fiber suggests that this analysis will significantly underestimate the presence of fiber around the country.

The following sections describe the process of collecting and processing data, along with the cost inputs and assumptions used in the model. The gap calculation assumes internal transfer pricing: i.e., the incremental cost the owner of a fiber facility would assign to the use of the fiber in order to fully cover both the cash cost and opportunity cost of capital. Importantly, as discussed below, this cost may be substantially lower than the price a competitor or other new entrant, like a wireless provider, may be charged for the same facility.

Middle-Mile Data Collection

- Identify all ILEC Central Offices (CO) and obtain each Vertical and Horizontal coordinates (analogous to latitude and longitude)

Exhibit 4-BU:
Breakout of Middle, Second & Last Mile



➤ Identify all Regional Tandems (RT) within their respective LATA locations and determine which Central Office subtends which RT

After the middle-mile anchor node locations and hierarchical relationships between the nodes are captured, the distances between these nodes must be calculated so that the distance-dependent cost elements can be applied appropriately.

Middle-Mile Processing Steps

➤ Each subtending CO is assigned to its nearest RT to create the initial relation of COs to RTs.

➤ COs are then routed to other COs that subtend the same RT using shortest distance routing back to their respective RTs (i.e., we calculate a shortest-distance route to connect the COs to their respective RTs). To achieve this route, the process starts at the CO coordinate farthest from the appropriate RT and selects the shortest CO-to-tandem distance based on airline mileage. The CO starting point is prohibited from routing back to itself and must route toward the tandem. This approach minimizes the amount of fiber needed.

➤ The RTs within a given LATA are routed together in a ring.

  ➤ The shortest ring is chosen by comparing the distances between RTs and selecting the shortest ring distance within each LATA; this distance is then used for the middle-mile feeder calculations.

  ➤ It is assumed that the Internet gateway peering point is located on the RT ring. In this manner, all COs that are connected to the RT ring have access to the Internet.

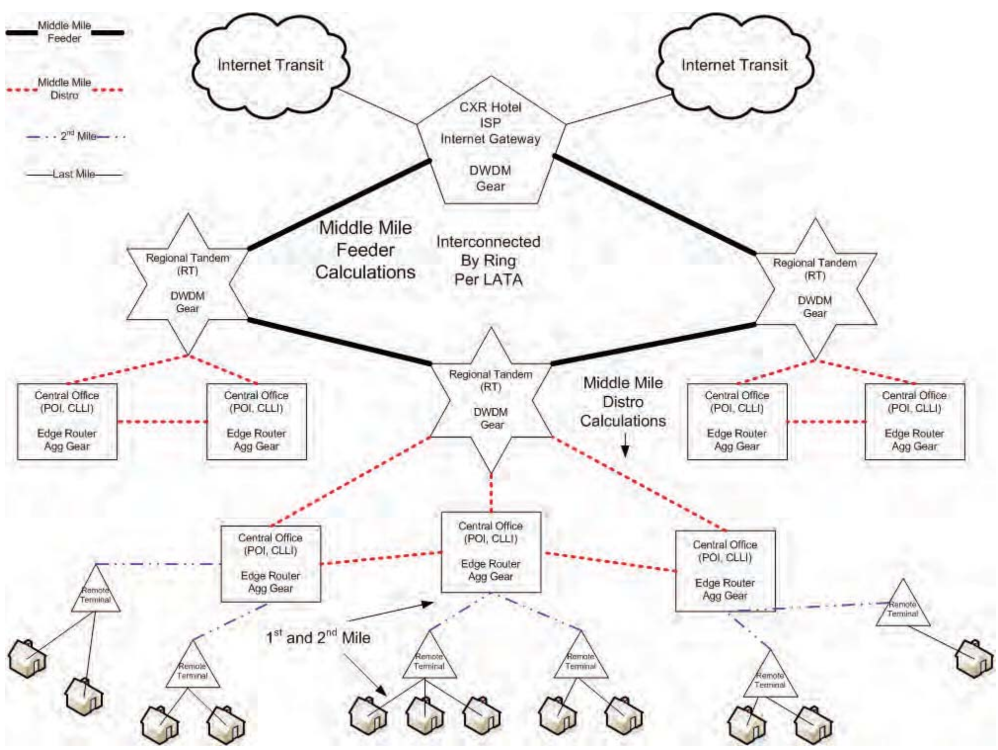
  ➤ Internet gateway sites are assumed to be located in regional carrier collocation facilities (known commonly as "carrier hotels"). We estimate there are some 200 of these located regionally throughout the United States.

➤ The middle-mile calculation is run state-by-state and stored in one central distribution and feeder table.

Tree vs. Ring architecture

➤ The design depicted in Exhibit 4-BV represents a hub-and-spoke hierarchy interconnected via closed rings. The model contemplates that a typical ILEC would likely interconnect end office, tandems and regional tandems in redundant-path "ring architecture."

Exhibit 4-BV:
Topology Used for Middle-Mile Cost Modeling



- By assumption, the fiber link and distance calculations between COs and RTs are increased by a factor of 1.8 to account for the redundant, geographically diverse, fiber spans that would be required in ring architecture as opposed to a hub-and-spoke architecture. Note that this assumption could be fairly conservative (i.e., assuming higher than necessary costs) given degree of interconnection among the COs.

Cost Allocations on Facility

These middle-mile facilities by nature and design are engineered as shared infrastructure facilities that aggregate end-user traffic and transport traffic to regional Internet gateways. The cost of a particular middle-mile facility cannot be allocated solely to the consumer broadband users of that facility. Since that facility is shared with other provider services such as residential and enterprise voice, wholesale carrier services, enterprise data services and other management services utilized by the provider, the cost needs to be allocated appropriately.

- The model assumes that the total cost of the facility is allocated thus: 1/3 for service provider voice service, 1/3 wholesale and enterprise carrier services and 1/3 consumer broadband services. This is an estimation of the allocation of traffic within a typical ILEC transport environment, but the allocation of cost to any single product or customer group is speculative at this point.
- The model only calculates the consumer broadband services portion of the facility and assumes that BHOL doubles roughly every three years.

Nationwide Middle-Mile Fiber Estimation

Data sources about fiber routes or even the presence of fiber in a given LEC office are extremely limited. Consequently, we created our best approximation of fiber facilities available for middle-mile service; detail on that process is provided below. The overwhelming majority of telecom central offices (approximately 95%)[165] [166] and nearly all cable nodes (by HFC definition) are fed by fiber.

The map shown in Exhibit 4-BW is an illustration of the paths of fiber used in our calculation to connect ILEC offices (and only ILEC offices). While it is based on as much real and calculated data as are available, we had to make a number of assumptions about the specific routes. Therefore, while we believe this map represents an accurate, if conservative, estimate of middle-mile fiber, it is not appropriate for network-planning purposes.

The diagram in Exhibit 4-BW is an estimation based on:

- Known locations of ILEC CO
- Topology based on a Gabriel Network[167] topology was considered but likely overestimated the number of links of fiber distribution. Thus, a Relative Network Neighborhood[168] distribution was chosen given the set of points representing the CO locations.
- Approximately 90% ILEC Fiber CO deployment, which is significantly lower (i.e., more conservative) than most estimates. Exhibit 4-BX, which shows the distribution of fiber-fed CO based on known services available per CO.

Exhibit 4-BW contemplates ILEC fiber only. Estimating the presence of middle-mile fiber based only on the fiber that connects LEC central offices, while excluding the fiber networks of cable companies, CAPs, CLECs and other facilities-based providers, systematically underestimates the presence of fiber. If one imagines overlaying the fiber optic facilities that have been deployed by other entities—such as Tier One IXCs/ISPs (ATT, Sprint, GX, Verizon Business, Level 3, XO, TWTC, etc.); Nationwide and regional Cable Operators (Comcast, Cox, Time Warner, Charter etc); Competitive Fiber Providers (Abovenet, Zayo, Deltacom, 360 Networks, Fiberlight, Alpheus etc.); private fiber deployments (hospitals and institutional); municipal fiber; and utility fiber—it becomes clear that the United States is generally well connected coast-to-coast.

In the limited instances where LEC fiber is not available, Windstream[169] has found that the exchanges typically have the following reasons for lack of deployment:

- The exchange is an island exchange (i.e., isolated from other exchanges in the LECs footprint) or part of a small, isolated grouping of exchanges;
- Fewer than 1,000 access lines fall within the exchange; and
- The closest point of traffic aggregation is more than 50 miles away from the CO.

The combination of a small customer base and long transport distances can make it impossible to build an economic case for fiber deployment.

However, recognizing that fiber-based middle-mile services are physically deployed does not necessarily mean that they are always economically viable in every rural area. The challenge is that access to such fiber may not be available at prices that result in affordable broadband for businesses, residents and anchor institutions, as discussed in the following section.

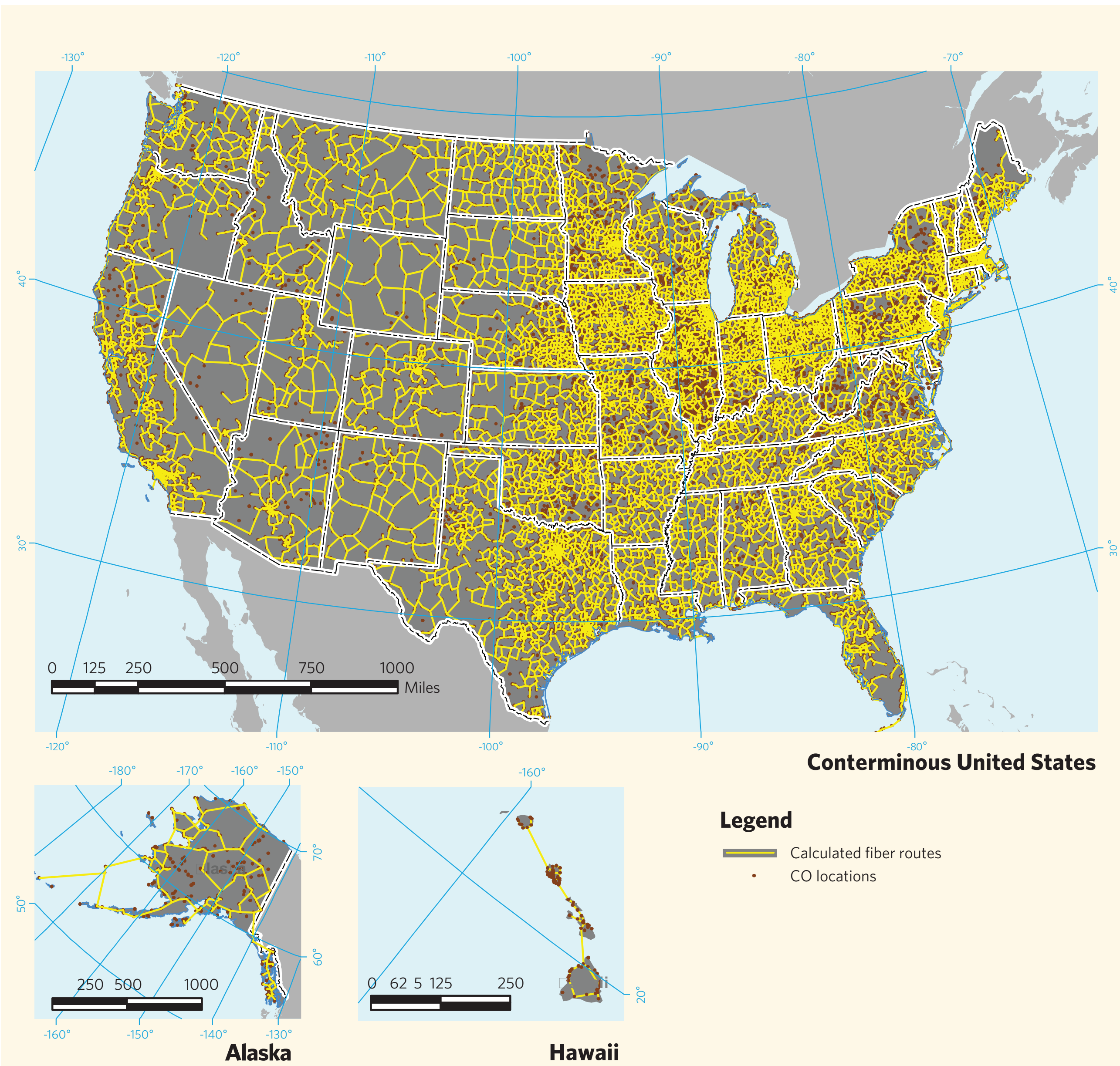
Costs Drivers for Middle-Mile Transport

Transporting data 50 miles or more from a local CO or other access point to the nearest Internet point of presence is a costly endeavor.

The costs of these facilities are proportional to their lengths. In urban or suburban areas, the cost of new fiber network construction varies widely, roughly from $4 to $35 per foot where the largest cost component is installation. The cost range depends on whether the fiber is suspended from utility poles or buried, the number of fiber strands in the cable, right-of-way costs, terrain, soil density and many other factors.[170] In the model, we assume that in rural settings, even for inter-CO transport facilities, 75% would be aerial construction. Of the 25% buried construction, the model calculates fiber burial costs that take into account local terrain, including soil composition.

Providing fiber-based service to low-density areas carries with it higher per-user costs. These costs are driven by larger distances which, even when offset by lower per-foot costs, lead

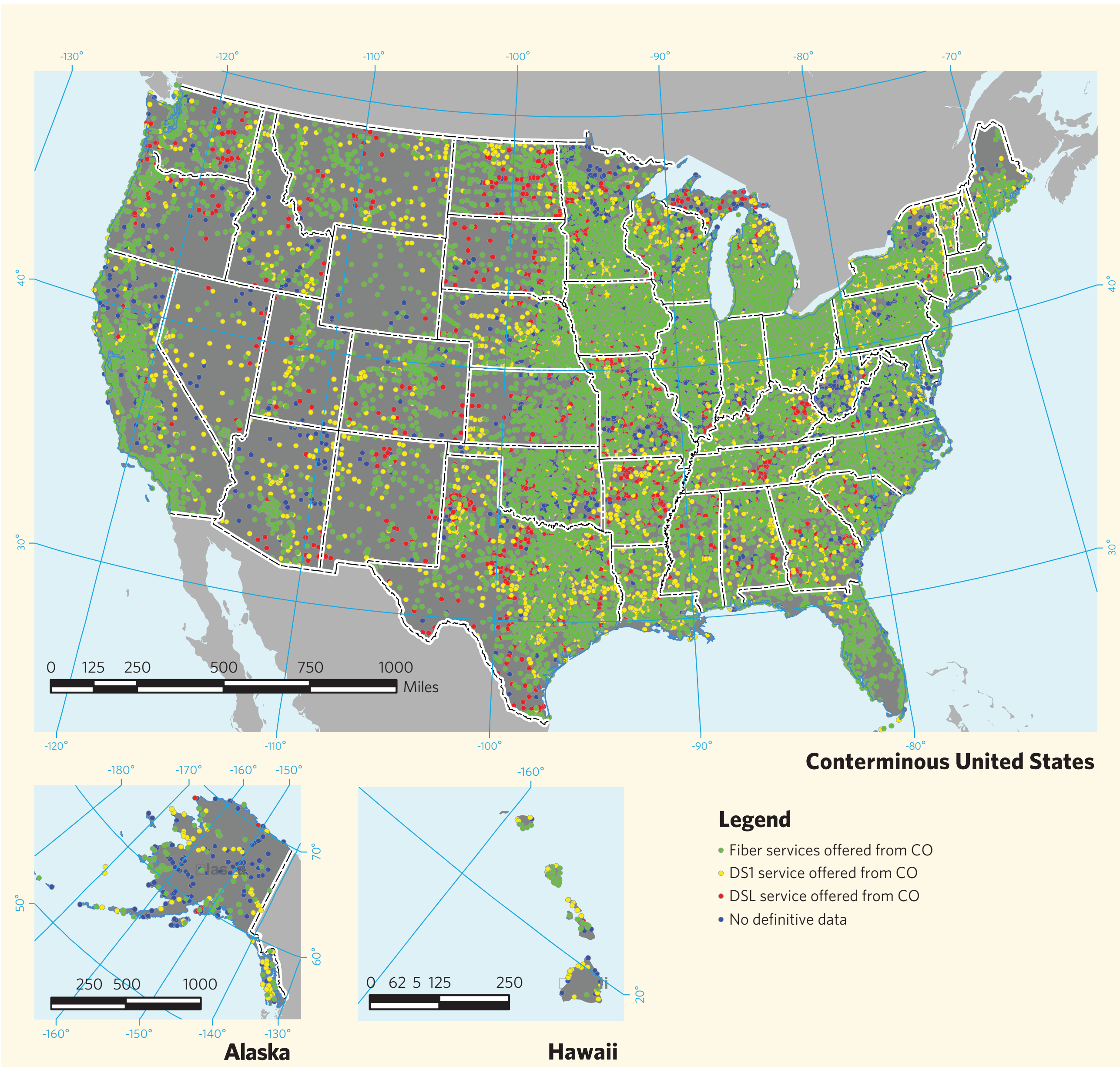
Exhibit 4-BW:
Calculated Telco Fiber Routes



to higher total cost per link. In addition, there are simply fewer users per link. Given that middle-mile links have very high fixed costs yet low costs associated with adding capacity, larger connections are more cost-effective per bit than smaller links. This is reflected in the prices shown in Exhibit 4-BY.

The low density and demand in rural areas, coupled with the volume-dependent middle-mile cost structure, mean that rural broadband operators do not benefit from the same economies of scale common among providers in denser areas. The distances at issue in unserved areas are much longer than typical

Exhibit 4-BX:
Classification of Central Offices for Creating Fiber Map



special access connections. Moreover, low population density prevents the aggregation of demand that would allow rural carriers to use lower-cost, high-capacity links.[171]

Pricing data are difficult to obtain. Tariffs are widely available but "street prices," including all contract savings and contract-term penalties, are not as readily available. Different discount structures, terms and agreements can cause great variability in middle-mile rates. As part of its COMMENTS ON NBP NOTICE #11, the NTCA provided Exhibit 4-BY that shows that while prices of middle-mile connections are indeed dependent on volume, they also vary widely across providers and geographies.[172] The highest and lowest prices vary by more than an order of magnitude for services below about 100 Mbps.

Exhibit 4-BY illustrates that on a per-unit basis, higher capacity middle-mile facilities are more economical than low-capacity facilities. According to NTCA and NECA filings, the average middle-mile cost contribution per subscriber per month is approximately $2.00 in study areas using middle-mile Ethernet connections of higher than 1,000 Mbps.[173] This can be compared to areas using middle-mile Ethernet connections of less than 10 Mbps, that resulted in monthly middle-mile costs per user of approximately $5.00 or more.[174] Again, these data are consistent with the premise that larger pipes carry lower costs per bit, suggesting the benefit for communities in smaller and less-dense areas to aggregate demand for homes and businesses as much as possible and that long-term commitments to utilize these facilities be in place.

Sensitivity: Lease vs. Build

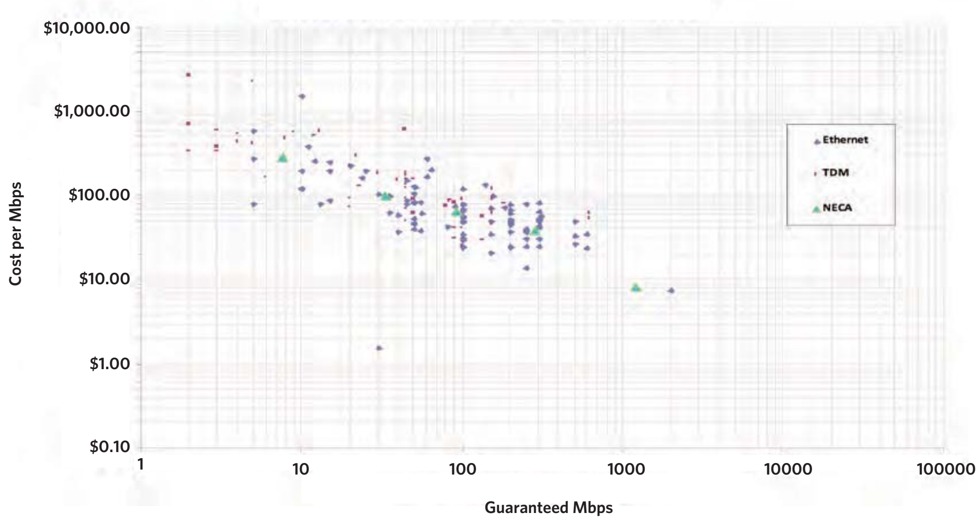
The base case assumes that operators in unserved areas have access to middle-mile transport at economic pricing—cost plus a rate of return. To the extent that middle-mile transport prices exceed this cost-plus pricing model, middle-mile costs can be higher for carriers leasing capacity. The broadband team models the cost to incrementally build middle-mile fiber facilities from scratch to a) understand the overall middle-mile cost contribution for the unserved and b) to establish a baseline middle-mile cost with which to compare to leased middle-mile costs.

The analysis in Exhibit 4-BZ compares middle-mile facility connections of different distances, connection sizes and methods to highlight the lease vs. build decision. Leasing facilities from an incumbent carrier, when properly sized for capacity demand, carries higher costs than the modeled cost for the incumbent provider to build these facilities incrementally. Thus broadband operators who rely on leased facilities for middle-mile may pay more for middle-mile costs than incumbent broadband providers.

To arrive at these estimates, we examine randomly chosen regional routes as shown in Exhibit 4-BZ. Separate "city-pair" routes were selected specifically in rural areas that are homed back to regional carrier collocation facilities (CCF) or "carrier hotels." These particular towns and CCF pairs were selected based upon known locations of CCFs to avoid Tier One MSA access points to best represent rural middle-mile connections. For each route, we calculate the applied tariff rate for the appropriate connection, applying a 30% discount rate for each connection. We recognize, however, that discount levels can range from 10-70% from "rack rates" and that a particular provider in an area may pay more or less than modeled.

NECA Tariff #5 was used as these tariffs are published, and we believe NECA carriers are likely to provide these rural

Exhibit 4-BY: Middle-Mile Cost Dependency on Capacity



Cost per Mbps by Guaranteed Mbps per Connection middle-mile connections. The towns were selected such that they are likely to be in the high-cost study group in accordance with NECA rate band blends.[175] In its comments, NECA suggests that on average, 1 Mbps is required in the shared portions of the network for every 14.5 users for a typical consumer best-effort DSL service.[176] We use this ratio in the analysis and size middle-mile capacity to provide 1 Mbps for every 14.5 users. For example, in the Exhibit 4-BZ for Flasher, ND, the middle-mile capacity required to support 351 HUs is 24 Mbps. In order to provide middle-mile support in Flasher ND, the lowest-cost facility likely available for lease large enough to carry the required 24 Mbps is a DS-3, which has a capacity of 45 Mbps. This need to "overbuy" capacity is repeated as demand requires the lease of larger facility tiers from DS3 to OC3 to OC12, etc. This illustrates the importance of demand aggregation and capacity utilization in the middle mile.

We also estimate the incremental cost that the owner of existing fiber facilities would assign to the use of these facilities in order to fully cover both the cash cost and opportunity cost of capital along these routes. The cost of the build includes the fiber deployment costs (labor, plowing, trenching, pole attachments, ROW, etc.) and the fiber optic electronics (DWDM transport nodes, regenerators, aggregation electronics, etc.). The capacity of the middle-mile network was modeled as 40 Gbps between interoffice nodes. While we believe that the modeled electronics are very high capacity and represent future scalability, it should be understood that included in this cost model is the fiber itself, which is virtually unlimited in capacity as electronics are upgraded. While we make assumptions about the allocation of cost to the modeled services as discussed in the previous section entitled "Approach to Middle-Mile Model," we also estimate the full cost of providing service along these routes as a price ceiling. The results of the analysis are summarized in Exhibit 4-BZ.

Exhibit 4-BZ suggests that on a per-unit basis, it is cheaper to build than to lease. However, that does not necessarily imply that for a given (small) user base and limited capacity demand that the lowest cost option is to build. Cost-per-unit for fiber builds is highly sensitive to scale and utilization. Consequently, it is possible that cost-per-unit for a build is actually higher than lease when demand and utilization are subscale. There is still a question regarding the extent to which leased facility pricing in rural areas is reflective of high deployment costs—long distances driving high-cost deployments that can be amortized over only a small base of end users—or of rent-seeking by facilities owners. The Federal Communications Commission is currently undertaking a proceeding to address special access pricing generally, not only with regard to interoffice transport in rural areas.[177] That proceeding will delve in greater depth into the question of costs and pricing.

In order to connect some rural areas, providers must deploy

Exhibit 4-BZ: Middle-Mile Build vs. Lease Comparison

From City	To City	# of unserved HU	Airline miles between	Circuit size	Build cost per HU per month	Lease cost per HU per month	Lease Premium
Nenana, Alaska	Juneau, Alaska	315	648.96	DS3	$26.99	$302.44	1020%
Bagdad, Ariz.	Phoenix, Ariz.	206	100.32	DS3	$36.49	$93.34	156%
Irwinton, Ga.	Macon, Ga.	934	26.95	OC3	$3.46	$10.10	192%
Libby, Mont.	Missoula, Mont.	2,372	127.95	OC12	$10.89	$12.93	19%
Fort Sumner, N.M.	Ruidoso, N.M.	701	113.87	OC3	$28.22	$31.86	13%
Flasher, N.D.	Bismark, N.D.	351	32.66	DS3	$16.73	$28.06	68%
Lindsay, Okla.	New Castle, Okla.	834	29.46	OC3	$4.87	$11.76	141%
Glide, Ore.	Eugene, Ore.	759	51.76	OC3	$11.19	$17.28	54%
Denver City, Texas	Brownfield, Texas	455	35.24	DS3	$17.98	$22.44	25%
Eureka, Utah	Provo, Utah	578	31.02	DS3	$3.61	$16.65	361%
Rock River, Wyo.	Cheyenne, Wyo.	30	73.32	DS3	$155.63	$516.23	232%
Sheffield, Ala.	Huntsville, Ala.	3,570	58.88	OC12	$1.93	$5.00	159%
Hope, Ark.	Fouke, Ark.	3,465	32.65	OC12	$2.40	$3.75	56%
Buena Vista, Colo.	Colorado Springs, Colo.	2,592	70.96	OC12	$5.29	$7.75	47%
Ketchum, Idaho	Boise, Idaho	1,532	92.00	OC3	$2.92	$12.46	326%
Monticello, Miss.	Hattiesburg, Miss.	2,746	50.59	OC12	$2.09	$5.94	184%
Winchester, Tenn.	Chattanooga, Tenn.	5,145	46.77	OC12	$1.46	$3.03	107%
Pomeroy, Wash.	Walla Walla, Wash.	893	45.15	OC3	$9.99	$13.59	36%
Fayetteville, W. Va.	Beckley, W. Va.	2,780	24.30	OC12	$0.86	$4.11	381%

middle-mile facilities over considerable distances at significant cost. These challenges are further compounded by the fact that these areas often do not have the population density necessary to generate the type of demand that justifies the large investment needed to construct these facilities.[178] The list below summarizes the basic conclusions based upon the middle-mile analysis:

- ➤ The distances at issue in unserved areas are much longer than typical special access connections and the low housing-unit or population density results in demand that is insufficient for lower cost high-capacity links.[179]
- ➤ As Internet demand increases, the total middle-mile cost for all providers will rise.
- ➤ Rural broadband operators do not benefit from the economies of scale on middle-mile facility cost in comparison to urban providers.

CHAPTER 4 ENDNOTES

1 *See* Section 5, Wireless Technology, for a discussion of wireless second mile backhaul.

2 While we realize that a typical fully configured DSLAM would likely support no more than ~350 subscribers, we used 550 to show maximum subscribers that can be achieved at a DSLAM aggregation point (RT or CO) using Fast Ethernet backhaul.

3 Note that the number of simultaneous video streams is driven by capacity of the cell site, not the coverage which is limited by upstream signal strength as discussed below.

4 Simultaneous streams assume non-real-time streams/videos with sufficient buffers at the receiver. Capacity with real-time traffic requirements, such as is required with video-conferencing applications, will be lower. The 480Kbps and 700Kbps video streams here are typical Hulu video streams. *See* Hulu typical video streaming requirements, http://www.hulu.com/support/technical_faq, February 2010. The 1Mbps video stream corresponds to a high-def Skype video conference.

5 UBS Investment Research, "US Wireless 411," August 14, 2009.

6 A paired 2x20MHz of spectrum refers to a spectrum allocation where downlink and uplink transmissions occur on two separate 20MHz bands.

7 Enhanced technologies, such as multiple antenna technologies (aka MIMO), can also help. *See* Wireless Technology section below for more detail.

8 In the bands below 3.7GHz, 547MHz is currently licensed as flexible use spectrum that can be used for mobile broadband. The NBP recommends an additional 300MHz be made available within the next five years.

9 Yankee Group, "North America Mobile Carrier Monitor," December, 2009.

10 Theoretical peak rate inside a cell, does not take into account many real world deployment issues or cell-edge average rate.

11 The CDMA family of standards has its own 4G evolution called UMB. However, UMB is no longer in development and most worldwide CDMA operators have already announced plans to adopt either WiMAX or LTE for when they upgrade to 4G. In the United States, for example, Verizon has chosen LTE while Sprint is planning to deploy WiMAX.

12 Includes total cost of network plus success based capital for subscribers.

13 Based on American Roamer mobile coverage data, August 2009.

14 In 2G systems, by contrast, the signals were transmitted over 200kHz and 1.25MHz.

15 For a more detailed exposition on these multiple access techniques, *see*, for example, "Fundamentals of Wireless Communication," David Tse and Pramod Viswanath, as well as references therein.

16 Letter from Dean R. Brenner, Vice Pres., Gov't Aff., Qualcomm Inc., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 09-51 (Dec. 9, 2009) Attach. A at 2. Figure shows downlink capacities calculated for 2x10MHz spectrum availability. Estimates of spectral efficiency calculated for each technology with the following antenna configuration: WCDMA, 1x1 and 1x2; HSPDA, Rel.5, 1x1; HSPA Rel. 6, 1x2; HSPA, Rel. 7, 1x1 and 1x2; LTE, 1x1 and 1x2.

17 *See*, for example, "Fundamentals of Wireless Communications," David Tse and Pramod Viswanath, for details on Shannon theory as well as multi-user scheduling.

18 Our estimate of the limit is based on a simplified evaluation of the "single-user" Shannon capacity of a cell site using the signal quality distribution for a cell site provided in Alcatel Lucent's Ex Parte Presentation, GN Docket 09-51, February 23, 2010, and then adjusting for multi-user scheduling gains. Our analysis also assumes 43% loss in capacity due to overhead; *see*, for example, "*LTE for UMTS - OFDMA and SC-FDMA Based Radio Access*," Harri Holma and Antti Toskala (Eds). *See*, for example, "*Fundamentals of Wireless Communications*." *See*, for example, Section 7.7 in "*The Mobile Broadband Evolution: 3G Release 8 and Beyond, HSPA+, SAE/LTE and LTE-Advanced*," 3G Americas.

19 *See*, for example, Section 7.7 in "The Mobile Broadband Evolution: 3G Release 8 and Beyond, HSPA+, SAE/LTE and LTE-Advanced," 3G Americas.

20 *See*, for example, "LTE for UMTS - OFDMA and SC-FDMA Based Radio Access," Harri Holma and Antti Toskala (Eds).

21 *See*, for example, "The performance of TCP/IP for networks with high bandwidth-delay products and random loss," T. V. Lakshman and U. Madhow, IEEE/ACM Transactions on Networking, June 1997.

22 CDMA operators can choose either LTE or WiMAX for their 4G evolution. LTE currently supports handoffs from CDMA systems.

23 Spectral efficiencies calculated for a (paired) 2x10MHz spectrum allocation for all technologies. Downlink spectral efficiency for WCDMA performance based on 1x1 and 1x2 antenna configurations; HSDPA Rel 5 and HSPA Rel 6 results based on 1x1 and 1x2 configurations, respectively; HSPA Rel 7 performance assumes 1x2 and 2x2 configurations while LTE result assumes 2x2. Uplink spectral efficiencies for WCDMA, HSPA and LTE capacities evaluated for 1x2 antenna configurations. Performance of (3G) EV-DO, which is not shown in the chart, is comparable to (3G) HSPA.

24 CITI BROADBAND REPORT AT 25-28.

25 CITI BROADBAND REPORT AT 8.

26 "HSPA to LTE-Advanced: 3GPP Broadband Evolution to IMT-Advanced (4G)," Rysavy Research/3G Americas, September 2009.

27 Round-trip latencies do not include public Internet latencies. Illustrative latencies for 2G/3G/4G networks; latencies for two networks using the same technology can vary depending on network configuration, infrastructure vendor optimizations, etc.

28 CITI BROADBAND REPORT AT 8.

29 *See*, for example, Figure 9.12 in "LTE for UMTS - OFDMA and SC-FDMA Based Radio Access," Harri Holma and Antti Toskala (Eds); and "LS on LTE performance verification work" at http://www.3gpp.org/FTP/tsg_ran/WG1_RL1/TSGR1_49/Docs/ R1-072580.zip.

30 In terms of cell radius, this gain translates to nearly a three-fold improvement in coverage.

31 *See* also Clearwire Ex-Parte filing, "Mobile broadband link budget example – for FCC", GN Docket No. 09-51 (Nov. 13, 2009) and link budget templates in http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_45/Documents/RP-090740.zip. Both documents perform downlink and uplink link budget analyses for a number of data rates and show that the limiting link budget in each scenario is the uplink.

32 Okumura-Hata is a RF propagation model. *See*, for example, "*Introduction to RF propagation*," by John Seybold.

33 Using the Okumura-Hata model, we obtain the maximum cell-size at 700MHz to be 12 miles or higher.

34 We chose to classify CTs instead of counties or Census Block Groups (CBG) because counties can be very large and CBGs too small—especially when compared with a typical cell size. Studying the variation over too large an area can lead to picking up terrain effects that are well outside of the cell-coverage area. On the other hand, looking at variations over an area that is too small compared with the desired cell size can lead us to overlooking significant terrain variations that are within the cell coverage area.

35 Based on data provided in Qualcomm Ex-Parte filing, "Mobile broadband Coverage by Technology," GN Docket No. 09-51 (Feb. 22, 2010); Clearwire Ex-Parte filing, "Mobile broadband link budget example – for FCC," GN Docket No. 09-51 (Nov. 13, 2009); "LTE for UMTS - OFDMA and SC-FDMA Based Radio Access," Harri Holma and Antti Toskala (Eds); and link budget templates in http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_45/Documents/RP-090740.zip.

36 Maximum transmit power: fixed CPEs can have higher transmit powers and higher antenna gains through the use of directional antennas and can avoid body losses. Receiver noise figure assumes the use of low-noise amplifiers. Effective noise power is calculated as: Total noise density + 10log10 (Occupied bandwidth), where total noise density = thermal noise density +receiver noise figure = -172dBm/Hz. Required SINR assumes the use of two receive antennas at the base station. Penetration losses can be reduced by fixed CPEs by placing the antennas in ideal locations within the house or outside. MAPL without shadow fading margin is appropriate when using RF planning tools because these tools enable shadowing and diffraction losses due to terrain. Shadow fading margin is required for 90% coverage reliability. MAPL with shadow fading margin is appropriate when using propagation loss models, such as the Okumura-Hata model.

37 RF planning tools by EDX Wireless; see http://www.edx.com/index.html.

38 Propagation loss analysis using RF planning tools takes into account shadowing and diffraction effects due to terrain. So, it is not necessary to include a shadowing margin in the MAPL.

39 Propagation losses due to foliage are ~2-7dB at 700MHz.

40 "PL" denotes propagation loss.

41 Signal quality is the ratio of the received signal strength to the sum of the aggregated interference from other cell sites and thermal noise. This ratio is often called SINR or Signal to Interference and Noise Ratio.

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42 A *serving* cell site is the cell site that is transmitting the desired data to the end-user. All other cell sites are, then, interfering cell sites.

43 Based on data and analysis provided in: Alcatel Lucent in Ex Parte Presentation, GN Docket 09-51, February 23, 2010; Ericsson in Ex Parte filing, GN Docket 09-51, February 17, 2010; "*The LTE Radio Interface - Key Characteristics and Performance*," Anders Furuskar, Tomas Jonsson, and Magnus Lundevall, Ericsson Research; "LTE-Advanced – Evolving LTE towards IMT-Advanced," Stefan Parkvall, et al, Ericsson Research; "LTE and HSPA+: Revolutionary and Evolutionary Solutions for Global Mobile Broadband," Anil Rao, et al, in Bell Labs Technical Journal 13(4), (2009); "LS on LTE performance verification work," at http://www.3gpp.org/FTP/tsg_ran/WG1_RL1/TSGR1_49/Docs/ R1-072580.zip; 3GPP RAN-1 submission by QUALCOMM Europe, Ericsson, Nokia and Nokia Siemens Networks in 3GPP TSG-RAN WG1 in "Text proposal for TR on system simulation results," http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_53/Docs/R1-082141.zip.

44 *See*, for example: Ericsson in Ex Parte filing, GN Docket 09-51, February 17, 2010; 3GPP RAN-1 submission by QUALCOMM Europe, Ericsson, Nokia and Nokia Siemens Networks in 3GPP TSG-RAN WG1 in "Text proposal for TR on system simulation results," http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_53/Docs/R1-082141.zip; "The LTE Radio Interface - Key Characteristics and Performance," Anders Furuskar, Tomas Jonsson, and Magnus Lundevall, Ericsson Research; "LTE-Advanced – Evolving LTE towards IMT-Advanced," Stefan Parkvall, et al, Ericsson Research; "LS on LTE performance verification work," at http://www.3gpp.org/FTP/tsg_ran/WG1_RL1/TSGR1_49/Docs/ R1-072580.zip.

45 Based on signal quality distribution data provided by Alcatel Lucent in Ex Parte Presentation, GN Docket 09-51, February 23, 2010. We then determine spectral efficiency for mobile and FWA networks by mapping signal quality to data rates using the method and results published in "LTE Capacity compared to the Shannon Bound," by *Morgensen, et al*, in IEEE 65th Vehicular Technology Conference, 2007.

46 A paired 2x20MHz of spectrum refers to a spectrum allocation where downlink and uplink transmissions occur on two separate 20MHz bands. This is also referred to as Frequency Division Duplex, or FDD, allocation. Note that the total spectrum allocation in this example is 40MHz. Similarly, the total allocation in a paired 2x10MHz of spectrum is 20MHz.

47 When SINR is 0 dB, the power of the signal is equal to the sum of the powers of the interfering signals and noise.

48 MIMO techniques use multiple antennas at the transmitter and receiver to improve spectral efficiency of communication. *See*, for example, "Fundamentals of Wireless Communications," David Tse and Pramod Viswanath, for a detailed exposition.

49 In a system with 2x2 MIMO downlink, both the transmitter (base station) and the receiver (CPE) are equipped with two antennas.

50 For the rest of this section, we shall refer to a "paired 2x10MHz" carrier as simply a 2x10MHz carrier. Thus, for example, a 2x20MHz carrier will imply a "paired 2x20MHz" carrier.

51 Based on results published by QUALCOMM Europe, Ericsson, Nokia and Nokia Siemens Networks in 3GPP TSG-RAN WG1 in "*Text proposal for TR on system simulation results*," http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_53/Docs/R1-082141.zip.

52 *See* "WCDMA 6-sector Deployment - Case Study of a Real Installed UMTS-FDD Network," by Ericsson Research and Vodafone Group R&D, in IEEE Vehicular Technology Conference, Spring 2006; "LTE for UMTS - OFDMA and SC-FDMA Based Radio Access," Harri Holma and Antti Toskala (Eds); "Higher Capacity through Multiple Beams using Asymmetric Azimuth Array," by TenXc wireless, April 2006. The last two references show that 6-sector cells result in an 80% to 90% capacity improvement per cell site.

53 Based on signal quality distribution data provided by Alcatel Lucent in Ex Parte Presentation, GN Docket 09-51, February 23, 2010, and "LTE Capacity compared to the Shannon Bound," by *Morgensen, et al*, in IEEE 65th Vehicular Technology Conference, 2007.

54 "Downlink user data rate" refers to burst rate in a fully utilized network.

55 *See* American Roamer Advanced Services database (accessed Aug. 2009) (aggregating service coverage boundaries provided by mobile network operators) (on file with the FCC) (American Roamer database); see also Geolytics Block Estimates and Block Estimates Professional databases (2009) (accessed Nov. 2009) (projecting census populations by year to 2014 by census block) (on file with the FCC) (Geolytics databases).

56 "Mobile Backhaul: Will the Levees Hold?", Yankee Group, June 2009.

57 Sprint Nextel in Ex Parte Presentation, GN Docket 09-51, January 13, 2010.

58 Level(3) Communications, Notice of Ex Parte Presentation, GN Docket 09-51, November 19, 2009; the filing notes that gigabit links are also available, albeit with limited range; see also "Microwave, Leased Lines, and Fiber Backhaul Deployments: Business Case Analysis."

59 Dragonwave, "Achieving the Lowest Total Cost of Ownership for 4G Backhaul," and "Microwave, Leased Lines, and Fiber Backhaul Deployments: Business Case Analysis."

60 Fiber-to-the-Home Council (FTTH Council), Notice of Ex Parte Presentation, GN Docket 09-51,October 14, 2009, Response to September 22, 2009, FCC Inquiry regarding Broadband Deployment Costs.

61 Dragonwave, "Achieving the Lowest Total Cost of Ownership for 4G Backhaul."

62 Clearwire Ex Parte Presentation, GN Docket 09-51, November 12, 2009 at 12.

63 Ancillary equipment here refers to communication cables, antennas, etc.

64 Average HU density in mountainous and hilly areas is 3 POPs/square mile and 7.4 POPs/square mile, respectively, while in flat areas it is 308 POPs/square mile.

65 Cost and gap shown for counties that have a negative NPV. Recall that the rural cell radius in the 700MHz band can be as much as 57% greater than that at 1900MHz. We chose the cell radius in mountainous areas to be 2 miles as well. In these areas, terrain rather than propagation losses dominate the determination of cell radius; so, it is unlikely that cell sizes will get much smaller than 2 miles.

66 This exhibit supports information and conclusions found in Exhibit 4-Z: Sensitivity of Buildout Cost and Investment Gap to Terrain Classifications.

67 *See* Tower Maps database (Accessed August, 2009) (on file with the Commission).

68 Mobile Satellite Ventures Subsidiary, LLC, Comments, in PS Docket 06-229 at 50 (June 20, 2008). They show that 30% of the sites required to cover 95th percentile of the population in the rural United States are "greenfield;" that number grows to 75% for the 99th percentile. We assume in our model that the number of greenfield sites required is 52.5%, which is the average of those two numbers.

69 Other network costs include those incurred in the Core (Node-0) network as well as on CPE (Node-4) subsidies

70 IDC, United States Consumer Communications Services QView Update, 3Q09, pg. 5, December 2009.

71 United States Telecom Association, Telecom statistics, http://www.ustelecom.org/Learn/TelecomStatistics.html (last visited Feb. 3, 2010). It should be noted that these 1,311 operating companies comprise fewer than 850 holding companies.

72 IDC, United States Consumer Communications Services QView Update, 3Q09, pg. 5, December 2009.

73 *See* Network Dimensioning section below.

74 Adtran -"Defining Broadband Speeds: Estimating Capacity in Access Network Architectures." Submissions for the Record -- GN Docket No. 09-51, (January 4, 2010) at 8.

75 Adtran -"Defining Broadband Speeds: Estimating Capacity in Access Network Architectures." Submissions for the Record -- GN Docket No. 09-51, (January 4, 2010) at 8.

76 Zhone Applications, http://www.zhone.com/solutions/ethernet/, (last visited Nov. 17, 2009).

77 Level 2 Dynamic Spectrum Management (DSM-2) is currently available and aids in the management of power and begins to cancel some crosstalk. Level 3 Dynamic Spectrum Management (DSM-3), also known as vectoring, is currently being tested in the laboratory and in field trials. Vectoring is discussed in greater detail in the 3-5 kft section of the appendix because, although possible on ADSL2+, the technique is most beneficial on line lengths below 4,000 feet; Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum at 5.

78 Letter from Robin Mersh, Chief Operating Officer, Broadband Forum, to Marlene H. Dortch, Secretary, FCC (Jan. 19, 2010) ("Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum") at 4.

79 Adtran -"Defining Broadband Speeds: Estimating Capacity in Access Network Architectures." Submissions for the Record -- GN Docket No. 09-51 (January 4, 2010).

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80 Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum at 10.

81 Comments of National Exchange Carrier Association (NECA) at Table 1, Impact of Middle and Second Mile Access on Broadband Availability and Deployment, GN Docket #s 09-47,09-51,09-137 (filed November 4, 2009).

82 "Current backhaul dimensioning" is based on comments from NECA that on average ~1Mbps is required in the shared portions of the network for every 14.5 users.

83 Comments of National Exchange Carrier Association (NECA) at Table 1, Impact of Middle and Second Mile Access on Broadband Availability and Deployment, GN Docket #s 09-47,09-51,09-137 (filed November 4, 2009).

84 Load coils, which are in-line inductors used as low-pass filters to balance response for voice frequency transmission, effectively block xDSL signals. Load coils generally exist on loops exceeding 18,000 feet.

85 Bridged taps, lengths of unterminated wire typically formed when changes are made to the loop and unneeded cable is left attached to the loop, can cause some service degradation, especially for data services.

86 TCP acceleration is the consolidation of requests for and acknowledgement of data to minimize the number of serial transmissions over communications links. TCP fast-start is the disabling of slow-start, which entails error checking before the link is brought to full speed, in order to provide full link bandwidth from the outset of the session. TCP pre-fetch is the use of the predictive caching of Web content and DNS look-ups.

87 Letter from John P. Janka on behalf of ViaSat, Inc. to Marlene H. Dortch, Secretary, FCC (Jun. 24, 2009) ("ViaSat Jun 24, 2009 *Ex Parte*") at 6.

88 Max Engel, Satellite Today, http://www.satellitetoday.com/via/satellitegetspersonal/Why-ViaSat-Acquired-WildBlue-and-Why-WildBlue-Needed-It_32911.html (last visited Jan. 12, 2010).

89 Peter B. de Selding, Space News, http://www.spacenews.com/satellite_telecom/with-wildblue-acquisition-via-sat-doubles-bet-satellite-broadband.html (last visited Jan.12, 2010).

90 CITI BROADBAND REPORT AT 57.

91 ViaSat Comments at 3.

92 BHOL is the average demand for network capacity across all subscribers on the network during the busiest hours of the network. BHOL is discussed later in the Network Dimensioning section.

93 *See* OBI, Broadband Performance.

94 ViaSat Jan. 5, 2010 *Ex Parte* at 2.

95 Hughes Oct. 26, 2009 *Ex Parte* at 6.

96 See OBI, Broadband Performance.

97 ViaSat Comments in re A National Broadband Plan for Our Future, GN Docket No. 09-51, Notice of Inquiry, 24 FCC Rcd 4342, (2009) at 13.

98 ViaSat Comments in re National Broadband Plan NOI, at 13.

99 ViaSat Comments in re National Broadband Plan NOI, at 3.

100 We assume a growth rate that doubles exactly every three years, i.e. 26.5%, for this analysis.

101 It is unclear what the effect of the Plan will be for satellite broadband providers' subscriber churn due to the buildouts in areas that are currently served only by satellite.

102 ViaSat 2009 Annual Report at 17.

103 ViaSat 2009 Annual Report at 4.

104 Note that the investment gap calculation does *not* exclude NPV-positive counties as the base case does, which explains why the revenue number differs from the $8.9 billion in the base case.

105 Hughes, High-speed Internet Service Plans and Pricing, http://consumer.hughesnet.com/plans.cfm (last visited Mar. 8, 2010).

106 Operational savings are offered by the Point to Point (P2P) and Passive Optical Network (PON) varieties of FTTP, not by the Active Ethernet variety.

107 RVA LLC, FIBER TO THE HOME: NORTH AMERICAN HISTORY (2001-2008) AND FIVE YEAR FORECAST (2009-2013), 7 (2009), *available* at http://www.rvallc.com/FTTP_subpage7.aspx.

108 CISCO SYSTEMS, FIBER TO THE HOME ARCHITECTURES, 4 (2007), *available* at http://www.ist-bread.org/pdf/FTTP%20Architectures.pdf.

109 Dave Russell, Solutions Marketing Director, CALIX, Remarks at FCC Future Fiber Architectures and Local Deployment Choices Workshop 31 (Nov. 19, 2009).

110 National Exchange Carrier Association Comments in re PN#11 filed (Nov. 4, 2009) at 10.

111 See OBI, Broadband Performance.

112 Dave Russell, Solutions Marketing Director, CALIX, Remarks at FCC Future Fiber Architectures and Local Deployment Choices Workshop 31 (Nov. 19, 2009).

113 Letter from Thomas Cohen, Counsel for Hiawatha Broadband Communications, to Marlene H. Dortch, Secretary, FCC (November 10, 2009) ("Hiawatha Broadband November 10, 2009 *Ex Parte*") at 7.

114 Letter from Thomas Cohen, Counsel for the Fiber to the Home Council, to Marlene H. Dortch, Secretary, FCC (October 14, 2009) ("Fiber to the Home Council October 14, 2009 *Ex Parte*") at 9-10.

115 This equation was derived from fitting a curve to the data, and as such averages over the type of outside plant (aerial or buried). This curve fit may underestimate costs in very high-density areas or other areas with a greater mix of buried infrastructure. The r2 for the curve fit is 0.992 and the R2 adjusted is 0.990.

116 JOHN A. BROUSE, JR., FIBER ACCESS NETWORK A CABLE OPERATOR'S PERSPECTIVE, 3 (2006), http://www.itu.int/ITU-T/worksem/asna/presentations/Session_2/asna_0604_whitepaper_brouse.doc.

117 DOREEN TOBEN, FIBER ECONOMICS AND DELIVERING VALUE, 34 (2006) *available* at http://investor.verizon.com/news/20060927/20060927.pdf.

118 Letter from Thomas J. Navin, Counsel for Corning, to Marlene H. Dortch, Secretary, FCC (October 13, 2009) ("Corning October 13, 2009 *Ex Parte*") at 17.

119 RVA LLC, FIBER TO THE HOME: NORTH AMERICAN HISTORY (2001-2008) AND FIVE YEAR FORECAST (2009-2013), 7 (2009), http://www.rvallc.com/FTTP_subpage7.aspx.

120 Data obtained from Comcast SEC Form 10Q dated 11/4/09, Verizon SEC Form 10Q dated 10/29/09, and Verizon Communications, FIOS Briefing Session, 37-41, 2006.

121 Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum") at 7.

122 Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum") at 8.

123 Qwest, Wireline Network News, http://news.qwest.com/VDSL2 (last visited Jan. 20, 2010).

124 Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum") at 7.

125 Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum") at 8.

126 NCTA, Industry Data, http://www.ncta.com/Statistics.aspx, (last visited Jan. 13, 2010).

127 OECD, OECD Broadband subscribers per 100 inhabitants, by technology, June 2009, http://www.oecd.org/sti/ict/broadband; (last visited Feb. 10, 2010).

128 National Cable & Telecommunications Association, Industry Data, http://www.ncta.com/StatsGroup/Availability.aspx (last visited Feb. 3, 2009) and ROBERT C. ATKINSON & IVY E. SCHULTZ, COLUMBIA INSTITUTE FOR TELE-INFORMATION, BROADBAND IN AMERICA: WHERE IT IS AND WHERE IT IS GOING (ACCORDING TO BROADBAND SERVICE PROVIDERS) at 20 (2009) ("CITI BROADBAND REPORT"), *available* at http://www4.gsb.columbia.edu/citi/.

129 National Cable & Telecommunications Association, Industry Data, http://www.ncta.com/StatsGroup/Investments.aspx (last visited Feb. 3, 2009).

130 David Reed, Chief Strategy Officer, CableLabs, Remarks at FCC Future Fiber Architectures and Local Deployment Choices Workshop 31 (Nov. 19, 2009).

131 Adtran, Defining Broadband Speeds: Deriving Required Capacity in Access Networks, at 24, GN Docket No. 09-51, January 4, 2010. Assumes 40% penetration of 350 person node so that capacity = 36 Mbps/(40% x 350) = 250 kbps of capacity per subscriber, well in excess of the 160 kbps average usage forecast.

132 This does not mean that every cable operator will offer packages at these speeds, nor that every subscriber will have service at these speeds; instead this is a comment on the capability of the access network for typical user loads. Localized heavy use, e.g., from heavy use of peer-to-peer programs could load the network more than is typical and lead to lower realized speeds.

133 FCC, US spectrum allocation (http://www.fcc.gov/mb/engineering/usallochrt.pdf), (last visited Feb. 19, 2010).

134 ADRIANA COLMENARES et al., DETERMINATION OF THE CAPACITY OF THE UPSTREAM CHANNEL IN CABLE NETWORKS, 3-4, https://drachma.colorado.edu/dspace/bitstream/123456789/74/1/NCS_Spec_031299.pdf, (last visited Feb. 9, 2010).

135 Stacey Higginbotham, DOCSIS 3.0: Coming Soon to a Cableco Near You, http://gigaom.com/2009/04/30/docsis-30-coming-soon-to-an-isp-near-you/, (last visited Feb. 9, 2010).

136 Cisco Systems, The Economics of Switched Digital Video, http://www.lanpbx.net/en/US/solutions/collateral/ns341/ns522/ns457/ns797/white_paper_G1701A.pdf, (last visited Feb. 9, 2010).

137 Zacks Equity Research, Switched Digital Video Thriving, http://www.zacks.com/stock/news/30346/Switched+Digital+Video+Thriving+-+Analyst+Blog,

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(last visited Feb. 25, 2010).

138 TiVo Comments in re NBP PN#27 (Video Device Innovation – NBP PN#27, GN Docket Nos. 09-47, 09-51, 09-137; CS Docket No. 97-80, Public Notice, DA 09-2519, rel. Dec. 3, 2009), filed Feb. 17, 2010, at 1.

139 Lightreading, Comcast's 30-to-1 Odds, http://www.lightreading.com/document.asp?doc_id=152873, (last visited Feb. 9, 2010).

140 Assumes 50% of the spectrum operates at 256-QAM and the other 50% at 64-QAM.

141 Cisco Systems, Understanding Data Throughput in a DOCSIS World, https://www.cisco.com/en/US/tech/tk86/tk168/technologies_tech_note09186a0080094545.shtml, (last visited Feb. 9, 2010).

142 Cisco Systems, Unicast Video Without Breaking the Bank: Economics, Strategies, and Architecture, https://www.cisco.com/en/US/solutions/collateral/ns341/ns522/ns457/unicast_video_white_paper.pdf, (last visited Feb. 9, 2010).

143 Cisco Systems, Understanding Data Throughput in a DOCSIS World, https://www.cisco.com/en/US/tech/tk86/tk168/technologies_tech_note09186a0080094545.shtml, (last visited Feb. 9, 2010).

144 Report on Cable Industry Prices, MM Docket No. 92-266, ATTACHMENT 4 (2009).

145 Report on Cable Industry Prices, MM Docket No. 92-266, ATTACHMENT 3-b (2009).

146 Charter Communications, Fiber Access Network: A Cable Operators Perspective, http://www.itu.int/ITU-T/worksem/asna/presentations/Session_2/asna_0604_s2_p4_jb.ppt, (last visited Feb. 19, 2010).

147 Penetration rate denotes attach rate of homes passed for digital TV, high-speed data and voice; cost does not include CPE cost.

148 Charter Communications, Fiber Access Network: A Cable Operators Perspective, http://www.itu.int/ITU-T/worksem/asna/presentations/Session_2/asna_0604_s2_p4_jb.ppt, (last visited Feb. 19, 2010). Assumes 50% penetration of homes passed.

149 Letter from Thomas Cohen, Kelley Drye & Warren LLP, to Marlene H. Dortch, Secretary, FCC (Nov. 10, 2009) at 1.

150 Westbay Engineers - http://www.erlang.com/whatis.htm; February 2010.

151 *See* https://support.skype.com/faq/FA1417/How-do-I-know-if-I-have-sufficient-bandwidth?: For Skype-to-Skype video (both normal and high quality) we recommend: 384 kbps.

152 Adtran, *Defining Broadband Speeds: Deriving Required Capacity in Access Networks*, at 22, GN Docket No. 09-51, January 4, 2010.

153 IEEE: Similarities between voice and high speed Internet traffic provisioning, IEEE CNSR'04, 25 October 2004.

154 "LTE for UMTS - OFDMA and SC-FDMA Based Radio Access", *Harri Holma and Antti Toskala* (Eds).

155 *See* OBI, Broadband Performance.

156 *See* OBI, Broadband Performance.

157 Consumer-oriented broadband today is provided as a best-effort service whereby the transport network elements are shared among many users. However, business-oriented broadband networks often are sold with service level guarantees that provide performance assurances. As such, last mile as well as the backhaul network elements must be engineered with higher capacity to assure that bandwidth is always available to the subscribers at all times, regardless of network conditions. This adds cost to the transport portions of the networks, which are reflected in much higher prices to the end-users. Business class "dedicated" Internet services have a pricing structure that can be many times more expensive on a cost-per-bit basis.

158 Adtran Ex-Parte Filing; *A National Broadband Plan for Our Future*, GN Docket No. 09-51, (FCC filed 23 February, 2010).

159 While we realize that a typical fully configured DSLAM would likely support no more than ~350 subscribers, we used 500 per the availability of the simulation tool. Assuming that fast Ethernet backhaul is still used for a ~350 subscriber DSLAM would result in an even better oversubscription ratio and even greater probability performance.

160 The results of this analysis do not easily apply to wireless networks. Unlike in other networks, the signal quality or data rate in a wireless network is strongly dependent on the location of the user relative to the cell site. We need to account for this non-uniformity in signal quality to dimension the wireless network [See Wireless Section above.] Still, we note that the spectral efficiency of a Fixed Wireless Access (FWA) network is ~2.35—2.7 b/s/Hz. So, the oversubscription ratio of a 3-sector cell site with 2x20 MHz spectrum allocation and 650 subscribers is ~16—18.5. Therefore, at first blush, this figure indicates that a FWA network should be able to deliver 4 Mbps in the download with high likelihood. And, as we show in more detail in the Wireless Section above, the FWA network can indeed support this subscriber capacity.

161 The analysis is based on a simulation of N subscribers on a link with capacity C. Specifically, the simulation determines the burst likelihood for the Nth subscriber on the link when the remaining subscribers generate traffic according to a Pareto distribution of mean 160 kbps. Note that the mean of this distribution corresponds to our BHOL assumption of 160 kbps. For more details, *see* Adtran, *Defining Broadband Speeds: Deriving Required Capacity in Access Networks*, at 22, GN Docket No. 09-51, January 4, 2010.

162 Centurylink Ex-Parte filing; *A National Broadband Plan for Our Future*, GN Docket No. 09-51; *International Comparison and Consumer Survey Requirements in the Broadband Data Improvement Act*, GN Docket No. 09-47; *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 09-137(FCC filed January 22, 2010).

163 Windstream Ex-Parte Filing; *A National Broadband Plan for Our Future*, GN Docket No. 09-51; *International Comparison and Consumer Survey Requirements in the Broadband Data Improvement Act*, GN Docket No. 09-47; *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 09-137 (FCC filed January 13, 2010).

164 Comments of Kodiak-Kenai Cable Company, LLC. at 5, *A National Broadband Plan for Our Future*, GN Docket # 09-51, PN #11 (FCC filed November 4, 2009).

165 Centurylink Ex-Parte filing; *A National Broadband Plan for Our Future*, GN Docket No. 09-51; *International Comparison and Consumer Survey Requirements in the Broadband Data Improvement Act*, GN Docket No. 09-47; *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 09-137(FCC filed January 22, 2010).

166 Windstream Ex-Parte Filing; *A National Broadband Plan for Our Future*, GN Docket No. 09-51; *International Comparison and Consumer Survey Requirements in the Broadband Data Improvement Act*, GN Docket No. 09-47; *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 09-137 (FCC filed January 13, 2010).

167 The Gabriel network for a point set is created by adding edges between pairs of points in the source set if there are no other points from the set contained within a circle whose diameter passes through the two points, introduced as one means of uniquely defining contiguity for a point set such that no other point could be regarded as lying 'between' connected pairs; *available* at: http://www.spatialanalysisonline.com/output/html/Gabrielnetwork.html.

168 A subset of the Gabriel network in which the additional constraint is applied that no other points may lie within the area of intersection defined by circles placed at each Gabriel network node with radius equal to the inter-node separation: *available* at: http:*//www.spatialanalysisonline.com/output/html/Gabrielnetwork.html.*

169 Comments of Windstream at16 1, *A National Broadband Plan for Our Future*, GN Docket # 09-51, PN #11 (FCC filed November 4, 2009).

170 Comments of XO Communications at 10, *A National Broadband Plan for Our Future*, GN Docket # 09-51, PN #11 (FCC filed November 4, 2009).

171 Comments of Verizon at 3, *A National Broadband Plan for Our Future*, GN Docket # 09-51, PN #11 (FCC filed November 4, 2009).

172 Comments of National Telecommunications Cooperative Association (NTCA) at 10, *Comment Sought on Impact of Middle and Second Mile Access on Broadband Availability and Deployment*, GN Docket #s 09-47,09-

CHAPTER 4 ENDNOTES

51,09-137 (filed November 19, 2009).

173 Comments of National Telecommunications Cooperative Association (NTCA) at 8, *Comment Sought on Impact of Middle and Second Mile Access on Broadband Availability and Deployment*, GN Docket #s 09-47,09-51,09-137 (filed November 19, 2009).

174 Comments of National Exchange Carrier Association (NECA) at 3, *Impact of Middle and Second Mile Access on Broadband Availability and Deployment*, GN Docket #s 09-47,09-51,09-137 (filed November 4, 2009).

175 High Cost group is the average of special access rate bands 8, 9, 10; Middle Cost group is the average of special access rate bands 4, 5, 6 and 7; Low Cost group is the average of special access rate bands 3 or lower Comments of National Exchange Carrier Association (NECA) at Table 3, *Impact of Middle and Second Mile Access on Broadband Availability and Deployment*, GN Docket #s 09-47,09-51,09-137 (filed November 4, 2009).

176 Comments of National Exchange Carrier Association (NECA) at Table 1, Impact of Middle and Second Mile Access on Broadband Availability and Deployment, GN Docket #s 09-47,09-51,09-137 (filed November 4, 2009).

177 See Parties Asked to Comment on Analytical Framework Necessary to Resolve Issues in the Special Access NPRM, WC Docket No. 05-25, Public Notice, 24 FCC Rcd 13638 (WCB 2009).

178 Comments of Verizon at 1, *A National Broadband Plan for Our Future*, GN Docket # 09-51, PN #11 (FCC filed November 4, 2009).

179 Comments of Verizon at 1, *A National Broadband Plan for Our Future*, GN Docket # 09-51, PN #11 (FCC filed November 4, 2009).

LIST OF COMMON ABBREVIATIONS

3G .... Third generation

4G .... Fourth generation

ADSL................ Asymmetric Digital Subscriber Line

AMPS............... Advanced Mobile Phone Service

ARPU .... Average Revenue per User

AWG .... American Wire Gauge

BHOL............... Busy Hour Offered Load

BPON............... Broadband Passive Optical Network

CAP .... Competitive Access Provider

Capex .... Capital Expenditures

CDMA.............. Code-Division Multiple Access

CLEC .... Competitive Local Exchange Carrier

CO..................... Central Office

CPE .... Customer Premises Equipment

DOCSIS........... Data Over Cable Service Interface Specification

DSL .... Digital Subscriber Line

DSLAM............ Digital Subscriber Line Access Multiplexer

EBITDA........... Earnings Before Interest, Taxes, Depreciation and Amortization

EPON............... Ethernet Passive Optical Network

EV-DO .... Evolution-Data Optimized

FTTN .... Fiber to the Node or Fiber to the Neighborhood

FTTP................ Fiber-to-the-Premise

FW.................... Fixed Wireless

Gbps .... Gigabits per second

GHz .... Gigahertz (1 billion Hertz)

GPON............... Gigabit Passive Optical Network

GSM .... Global System for Mobile communication

HFC.................. Hybrid Fiber Coaxial

HFM................. Hybrid Fiber Microwave

HSDPA .... High Speed Downlink Packet Access

HSUPA .... High Speed Uplink Packet Access

HSPA................ High Speed Packet Access

HU .... Housing Units

Hz .... Hertz

iDEN .... Integrated Digital Enhanced Network

ISP .... Internet Service Provider

kft .... Kilo-feet (1,000 feet)

ILEC .... Incumbent Local Exchange Carrier

IXC .... Interexchange Carrier

kbps .... Kilobits per second

kHz .... Kilohertz (1 thousand Hertz)

LATA................ Local Access and Transport Area

LTE................... Long-Term Evolution

Mbps .... Megabits per second (1 million bits per second)

MHz .... Megahertz (1 million Hertz)

MIMO............. Multiple Input, Multiple Output

MSC .... Mobile Switching Center

MSO .... Multiple System Operator

NBP .... National Broadband Plan

NIU .... Network Interface Unit

NPV.................. Net Present Value

OECD.............. Organization for Economic Co-operation and Development

Opex .... Operating Expenses

OTT .... Over-the-top

POP .... Point of Presence

PON.................. Passive Optical Network

POTS................ Plain Old Telephone Service

PSTN................ Public Switched Telephone Network

PV .... Present Value

QAM................. Quadrature Amplitude Modulation

QOS .... Quality of Service

RBOC................ Regional Bell Operation Company

RFoG .... Radio Frequency Over Glass

RT .... Regional Tandem

SG&A .... Selling, General and Administrative expenses

SINR .... Signal to Interference plus Noise Ratio

TDMA .... Time Division Multiple Access

UMTS .... Universal Mobile Telecommunications System

VDSL................ Very high bit rate Digital Subscriber Line

VOIP .... Voice Over Internet Protocol

WCDMA........... Wideband Code Division Multiple Access

WISP................ Wireless ISP

GLOSSARY

4G—Abbreviation for fourth-generation wireless, the stage of broadband mobile communications that will supersede the third generation (3G). Specifies a mobile broadband standard offering both mobility and very high bandwidth. Usually refers to LTE and WiMax technology. For the purposes of analysis in this paper, areas where carriers have announced plans to deliver 4G service are treated as 4G areas; all other areas are treated as non-4G areas.

Access Network—Combination of Last and Second Mile portions of a broadband network. See Last Mile and Second Mile.

Actual Speed—Refers to the data throughput delivered between the network interface unit (NIU) located at the end-user's premises and the service provider Internet gateway that is the shortest administrative distance from that NIU. In the future, the technical definition of "actual speed" should be crafted by the FCC, with input from consumer groups, industry and other technical experts, as is proposed in Chapter 4 of the National Broadband Plan. The technical definition should include precisely defined metrics to promote clarity and shared understanding among stakeholders. For example, "actual download speeds of at least 4 Mbps" may require certain achievable download speeds over a given time period. Acceptable quality of service should be defined by the FCC.

Advanced Mobile Phone Service (AMPS)—A standard system for analog signal cellular telephone service in the United States and elsewhere. It is based on the initial electromagnetic radiation spectrum allocation for cellular service by the FCC in 1970 and first introduced by AT&T in 1983.

American Wire Gauge (AWG)—A U.S. measurement standard of the diameter of non-ferrous wire, which includes copper and aluminum—the smaller the number, the thicker the wire. In general, the thicker the wire, the greater the current-carrying capacity and the longer the distance it can span.

Analog reclamation—In a cable system, refers to repurposing spectrum previously used to carry analog channels for other uses, either digital channels or high-speed data.

[1] The authors provide this glossary as a reader aid. These definitions do not necessarily represent the views of the FCC or the United States Government on past, present or future technology, policy or law and thus have no interpretive or precedential value.

Asymmetric Digital Subscriber Line (ADSL)—A technology that transmits a data signal over twisted-pair copper, often over facilities deployed originally to provide voice telephony. Downstream rates are higher than upstream rates—i.e., are asymmetric. ADSL technology enables data transmission over existing copper wiring at data rates several hundred times faster than analog modems using an ANSI standard.

Average Revenue Per User (ARPU)—A metric used by investors and financial analysts to measure the financial performance of telecommunications service providers. ARPU is the average amount of revenue a company collects from each user per month.

Availability Gap—See Broadband Availability Gap and Investment Gap.

Base Case—The basic set of assumptions that leads to the $23.5 billion Investment Gap. The base case in the model compares the most economical technologies: 12,000-foot-loop DSL and Fixed Wireless. For the 12k-foot-loop DSL, the main assumption is that there is one competing provider in areas that are assumed to receive 4G service, and zero competing technologies in non-4G areas. For Fixed Wireless, costs are allocated to mobile infrastructure in 4G areas; in non-4G areas, all costs are allocated to fixed service, but the carrier is assumed to earn incremental revenue from mobile operations.

Broadband—For the purposes of determining the Investment Gap, 4 Mbps actual download and 1 Mbps actual upload; see also the National Broadband Availability Target.

Broadband Availability Gap—The amount of funding necessary to upgrade or extend existing infrastructure up to the level necessary to support the National Broadband Availability Target. Because this is a financial metric, and to avoid confusion with measures of whether local networks are capable of supporting a given level of broadband service, the Broadband Availability Gap is referred to as the *Investment Gap* throughout this paper.

Broadband Passive Optical Network (BPON)—A type of PON standardized by the ITU-T, offering downstream capacities of up to 622 Mbps and upstream capacities of up to 155 Mbps, shared among a limited number of end users.

Brownfield—A network in which a carrier already has infrastructure in the area that can be used to deliver service going forward.

Burst Rate—The maximum rate or "speed" which a network is capable of delivering within a short timeframe, typically seconds or minutes. This is usually expressed as a rate in Mbps.

Busy Hour Offered Load (BHOL)—BHOL (per subscriber) is the network capacity required by each user, averaged across all subscribers on the network, during the peak utilization hours of the network. Network capacity required is the data received/transmitted by a subscriber during an hour; this can be expressed as a data rate (like kbps) when the volume of data received/transmitted is divided by the time duration.

Capacity—Ability of telecommunications infrastructure to carry information. The measurement unit depends on the facility. A data line's capacity might be measured in bits per second, while the capacity of a piece of equipment might be measured in numbers of ports.

Capital Expenditures (Capex)—Business expense to acquire or upgrade physical assets such as buildings, machinery and in this case telecommunications equipment; also called capital spending or capital expense.

Census Block—The smallest level of geography designated by the U.S. Census Bureau, which may approximate actual city street blocks in urban areas. In rural districts, census blocks may span larger geographical areas to cover a more dispersed population.

Central Office (CO)—A telephone company facility in a locality to which subscriber home and business lines are connected on what is called a local loop. The central office has switching equipment that can switch calls locally or to long-distance carrier phone offices. In other countries, the term *public exchange* is often used.

Churn—The number of subscribers who leave a service provider over a given period of time, usually expressed as a percentage of total customers.

Code-Division Multiple Access (CDMA)—Any of several protocols used in so-called second-generation (2G) and third-generation (3G) wireless communications. As the term implies, CDMA is a form of multiplexing, which allows numerous signals to occupy a single transmission channel, optimizing the use of available bandwidth. The technology is used in ultra-high-frequency (UHF) cellular telephone systems in the 800-MHz and 1.9-GHz bands.

Competitive Access Provider (CAP)—Facilities-based competitive local exchange carriers (CLECs).

Competitive Local Exchange Carrier (CLEC)—The term and concept coined by the Telecommunications Act of 1996 for any new local phone company that was formed to compete with the ILEC (Incumbent Local Exchange Carrier).

Coverage—In wireless communications, refers to the geographic area in which one can obtain service.

Customer Premises Equipment (CPE)—Equipment which resides on the customer's premise. Examples include set top boxes, cable modems, wireless routers, optical network terminals, integrated access devices, etc.

Data Over Cable Service Interface Specification (DOCSIS)—A cable modem standard from the CableLabs research consortium (www.cablelabs.com), which provides equipment certification for interoperability. DOCSIS supports IP traffic (Internet traffic) over digital cable TV channels, and most cable modems are DOCSIS compliant. Some cable companies are currently deploying third-generation (DOCSIS 3.0) equipment. Originally formed by four major cable operators and managed by Multimedia Cable Network System, the project was later turned over to CableLabs.

Digital signal 1 (DS-1)—Also known as T1; a T-carrier signaling scheme devised by Bell Labs. DS-1 is a widely used standard in telecommunications in North America and Japan to transmit voice and data between devices. DS-1 is the logical bit pattern used over a physical T1 line; however, the terms DS-1 and T1 are often used interchangeably. Carries approximately 1.544 Mbps.

Digital Subscriber Line (DSL)—A generic name for a group of enhanced speed digital services generally provided by telephone service providers. DSL services run on twisted-pair copper wires, which can carry both voice and data signals.

Digital Subscriber Line Access Multiplexer (DSLAM)—Technology that concentrates or aggregates traffic in DSL networks. Located in the central office or in a remote terminal.

Discount Rate—The annual percentage rate used to determine the current value of future cash flows.

Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA)—An approximate measure of a company's operating cash flow based on data from the company's income statement. Calculated by looking at earnings, which are calculated by subtracting opex and SG&A from net revenues, before the deduction of interest expenses, taxes, depreciation and amortization. This earnings measure is of particular interest in cases where companies have large amounts of fixed assets which are subject to large depreciation.

Ethernet Passive Optical Network (EPON)—A type of PON standardized by the IEEE, offering downstream capacities of up to 1.25 Gbps and upstream capacities of up to 1.25 Gbps, shared among a limited number of end users.

Evolution-Data Optimized (EV-DO)—A 3G wireless radio broadband data standard that enables faster speeds than are available in existing CDMA networks or other 2G services, such as GPRS or EDGE.

Fast Ethernet (Fast-E)—A network transmission standard that provides a data rate of 100 Mbps.

Fiber—Shorthand for "fiber-optic cable." Fiber-optic cable is the medium associated with the transmission of information as light impulses along a strand of glass.

Fiber to the Node (FTTN)—A high-capacity bandwidth approach that uses both fiber and copper wires. Optical fiber is used from the core of the telco or CATV network to an intelligent node in the neighborhood where copper wire is used for the connection to the end-user, with one node serving perhaps many residences or small businesses. The few 100 meters or so of the local loop from the node to the premises generally is either unshielded twisted pair (UTP) in a telco application or coaxial cable (coax) in an HFC application, although some form of wireless technology is also possible. Known as Fiber to the Neighborhood, or Fiber to the Cabinet (FTTCab), as well.

Fiber-to-the-Premise (FTTP)—A fiber-deployment architecture in which optical fiber extends all the way to the customer's premise. Also known as Fiber to the Home (FTTH) or Fiber to the Building (FTTB). Typically using PON for residential deployments.

Fisher-Pry Model—A mathematical model used to forecast technology adoption when substitution is driven by superior technology where the new product or service presents some technological advantage over the old one.

Fixed Wireless (FW)—Wireless service that uses fixed CPE in addition to (or, possibly, even instead of) mobile portable devices to deliver data services. FW solutions have been deployed as a substitute for wired access technologies. For example, it is being used commercially in the U.S. by Clearwire with WiMAX and Stelera with HSPA, and globally by Telstra with HSPA.

Gabriel Network Topology—An approach to modeling efficient (shortest-route) connections between known network nodes, where the links are determined by making a pairwise comparison of points in the context of the points around them. In a classic Gabriel network, the set of points should not include any co-incident points, that is two points that lie exactly at the same location.

Gigabit Ethernet (Gig-E)—A network transmission standard that provides a data rate of 1,000 megabits per second.

Gigabit Passive Optical Network (GPON)—A type of PON standardized by the ITU-T, offering downstream capacities of up to 2.5 Gbps and upstream capacities of up to 1.25 Gbps, shared among a limited number of end users.

Global System for Mobile communication (GSM)—A second-generation digital mobile cellular technology using a combination of frequency division multiple access (FDMA) and time division multiple access (TDMA). GSM operates in several frequency bands: 400MHz, 900MHz and 1800MHz. On the TDMA side, there are eight timeslots or channels carrying calls, which operate on the same frequency. The standard was jointly developed between European administrations under Groupe Speciale Mobile in the 1980s and introduced commercially in 1991. Unlike other cellular systems, GSM provides a high degree of security by using subscriber identity module (SIM) cards and GSM encryption.

Gompertz Model—A mathematical model used to forecast technology adoption when substitution is driven by superior technology, but purchase depends on consumer choice.

Greenfield—A network in which a carrier has no infrastructure currently (of that technology), and it needs to be built from scratch.

High Speed Packet Access (HSPA)—A family of high-speed 3G digital data services provided by cellular carriers worldwide that uses the GSM technology. HSPA service works with HSPA cell phones as well as laptops and portable devices with HSPA modems. The two established standards of HSPA are HSDPA (Downlink) and HSUPA (Uplink).

Housing Units (HU)—Includes a house, an apartment, a mobile home, a group of rooms or a single room that is occupied (or if vacant, is intended for occupancy) as separate living quarters.

Hybrid Fiber Microwave (HFM)—A network (usually wireless) whereby the backhaul transport elements of the network are a mixture or combination of fiber-optic facilities and wireless microwave transport.

Hybrid Fiber Coaxial (HFC)—Another term for cable systems, which are a combination of fiber (Middle and Second Mile) and coaxial cable (Last Mile).

Incumbent Local Exchange Carrier (ILEC)—The dominant local phone carrier within a geographical area. Section 252 of the Telecommunications Act of 1996 defines Incumbent Local Exchange Carrier as a carrier that, as of the date of enactment of the Act, provided local exchange service to a specific area; for example, Verizon, Windstream and Frontier. In contrast, Competitive Access Providers (CAPs) and competitive local exchange carriers (CLECs) are companies that compete against the ILECs in local service areas.

Integrated Digital Enhanced Network (iDEN)—A wireless technology from Motorola combining the capabilities of a digital cellular telephone, two-way radio, alphanumeric pager and data/fax modem in a single network. iDEN operates in the 800 MHz, 900MHz and 1.5 GHz bands and is based on time division multiple access (TDMA) and GSM architecture. It uses Motorola's Vector Sum Excited Linear Predictors (VSELP) voice encoder for voice compression and QAM modulation to deliver 64 kbps over a 25 KHz channel.

Interexchange Carrier (IXC)—A telecommunications service provider authorized by the FCC to provide interstate, long distance communications services and authorized by the state to provide long distance intrastate communications services. An Interexchange Carrier provides, directly or indirectly, interLATA or intraLATA telephone toll services. May be an individual, partnership, association, joint-stock company, trust, governmental entity or corporation engaged for hire in interstate or foreign communication by wire or radio, and between two or more exchanges. Also known as an Interexchange Common Carrier.

Internet Service Provider (ISP)—A company that provides a connection to the public Internet, often owning and operating the Last-Mile connection to end-user locations.

Investment Gap—The amount of funding necessary to upgrade or extend existing infrastructure up to the level necessary to support the National Broadband Availability Target, which is referred to in the National Broadband Plan as the Broadband Availability Gap.

Last Mile—Refers generally to the transport and transmission of data communications from the demarcation point between the end user's internal network and the carrier's network at the customer premise to the first point of aggregation in the carrier's network (such as a remote terminal, wireless tower location, or HFC node).

Levelized–A method, often used in regulatory proceedings, to calculate the annuitized equivalent—i.e., the effective annual value of cash flows—of the costs and revenues associated with building and operating a network. A "levelized" calculation provides a steady cash-flow stream, rather than trying to model or guess the timing of largely unpredictable yet sizable real-world payouts like those for upgrading and repairing equipment. The (net) present value of a levelized cash flow is equal to the (net) present value of actual cash flows.

Link Budget—A calculation involving the gain and loss factors associated with the antennas, transmitters, transmission lines and propagation environment used to determine the maximum distance at which a transmitter and receiver can successfully operate.

Local Access and Transport Area (LATA)—One of 196 local geographical areas in the U.S. created by the Modified Final Judgment in which a divested Regional Bell operating company (RBOC) was permitted to offer exchange telecommunications and exchange access services.

Long-Term Evolution (LTE)—A high performance air interface for cellular mobile communication systems. LTE technology increases the capacity and speed of wireless networks relative to current 3G deployments.

Microwave—Microwave transmission refers to the technique of transmitting information over microwave frequencies, using various integrated wireless technologies. Microwaves are short-wavelength, high-frequency signals that occupy the electromagnetic spectrum 1 GHz to roughly 300 GHz, (typically within ITU Radio Band Signal EHF) though definitions vary. This is above the radio frequency range and below the infrared range.

Middle Mile—Refers generally to the transport and transmission of data communications from the central office, cable headend or wireless switching station to an Internet point of presence.

Mobile Switching Center (MSC)—The mobile switching center (MSC) connects the landline public switched telephone network (PSTN) system to the wireless communication system. The mobile switching center is typically split into a mobile switching center server and a media gateway, and incorporates the bearer independent call control (BICC). The MSC routes the communications to another subscribing wireless unit via a BSC/base station path or via the PSTN/Internet/other network to terminating destination.

Multiple Input Multiple Output (MIMO)—An antenna technology for wireless communications in which multiple antennas are used at both the source (transmitter) and the destination (receiver). The antennas at each end of the communications circuit are combined to minimize errors and optimize data speed. MIMO is one of several forms of smart antenna technology, the others being MISO (multiple input, single output) and SIMO (single input, multiple output).

Multiple System Operator (MSO)—Typically refers to a firm that owns more than one cable system, but may refer also to an operator of only one system.

National Broadband Availability Target—The level of service set in the National Broadband Plan that should be available to every household and business location in the U.S. The initial target is an actual download speed of at least 4 Mbps and an upload speed of at least 1 Mbps, with a proposed review and update every four years.

Net Present Value (NPV)—A technique used to assess the current worth of future cash flows by discounting those future cash flows at today's cost of capital. The Net Present Value (NPV) of a project is the total discounted value of all revenues and costs; NPVs greater than zero generate value for a company.

Node—An active or passive element in a cable system where Second-Mile fiber connects with coaxial cable.

Node splitting—In a cable system, adding infrastructure so that subscribers previously served by a single node are moved to multiple nodes, reducing the number of subscribers per node.

Operating Expenses (Opex)—An expense a business incurs over the course of its normal operations. Examples include product overhead, employee salaries and electric bill payments. Importantly, operating expenses on a balance sheet reflect only ordinary expenses rather than unexpected, one-time expenses. One subtracts the operating expense from operating revenue to determine the operating profit.

Organization for Economic Co-operation and Development (OECD)—The 30 member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

Over-the-top (OTT)—Carried over an Internet connection. For example, OTT video would include video delivered by YouTube, Hulu and TV Everywhere.

Passive Optical Network (PON)—A type of Fiber To The Premise (FTTP) network in which unpowered optical splitters are utilized to enable a single fiber to be shared by multiple end users. There are several varieties of PON currently in use in the U.S., including BPON, EPON and GPON, each of which has its own set of standards and capabilities.

Plain Old Telephone Service (POTS)—The basic single line switched access service offered by local exchange carriers to residential and business end users, using loop-start signaling.

Point of Presence (POP)—An access point to the Internet. A point of presence is a physical location that houses servers, routers, switches and aggregation equipment.

Point to point (P2P)—A type of fiber to the premise network in which each endpoint is connected to its serving office via a dedicated fiber optic strand.

Present Value (PV)—The value today of a future payment, or stream of payments, discounted at some appropriate compound discount rate. For example, the present value of $100 to be received 10 years from now using a discount rate equal to 10% interest compounded annually is about $38.55.

Public Switched Telephone Network (PSTN)—The worldwide collection of interconnected public telephone networks that was designed primarily for voice traffic. The PSTN is a circuit-switched network, in which a dedicated circuit (also referred to as a channel) is established for the duration of a transmission, such as a telephone call. This contrasts with packet switching networks, in which messages are divided into small segments called packets and each packet is sent individually. Packet switching networks were initially designed primarily for data traffic.

Quadrature Amplitude Modulation (QAM)—A system of modulation in which data is transferred by modulating the amplitude of two separate carrier waves, mostly sinusoidal, which are out of phase by 90 degrees (sine and cosine). Due to their phase difference, they are called quadrature carriers. Used extensively in cable systems.

Quality of Service (QoS)—The ability to provide different priority to different applications, users or data flows, or to guarantee a certain level of performance to a data flow in a broadband network.

Radio Frequency over Glass (RFoG)—An evolutionary technology that allows cable companies to offer an all-fiber architecture (not hybrid-fiber coax) without changing modulation schemes. RFoG is an SCTE Interface Practices Subcomittee standard in development for Point to Multipoint (P2MP) operations that has a proposed wavelength plan compatible with data PON solutions including EPON and 10G-EPON.

Regional Bell Operation Company (RBOC)—Local exchange carriers formed after the breakup of AT&T in 1984. The seven regional holding companies (RHCs) of roughly equal size were formed as a result of the 1982 Consent Decree AT&T signed with the U.S. Department of Justice, stipulating that it would divest itself of its 22 wholly owned telephone operating companies. The seven RHCs were Ameritech, Bell Atlantic, BellSouth, NYNEX, Pacific Telesis, Southwestern Bell and US West. After a series of acquisitions, mergers and name changes (including one in which a combination of several RHCs reclaimed the original AT&T name), only three of the original seven remain. They are AT&T, Qwest and Verizon. The RBOCs are the incumbent local exchange carriers (ILECs) in their local markets.

Regional Tandem (RT)—A tandem switch is an intermediate switch or connection between an originating telephone call or location and the final destination of the call. These are hub facilities that interconnect telephone central office exchanges and are deployed by geographical region within a telco LATA or exchange.

Remote Terminal—Telephone communications equipment that is installed within the service area or “neighborhood” that traditionally aggregates and multiplexes telephone local loops and transmits the aggregated signals from the service area back to the telephone central office switch. This has evolved to become the “Node” within a service area in a fiber-to-the-node architecture.

Second Mile—Refers generally to the transport and transmission of data communications from the first point of aggregation (such as a remote terminal, wireless tower location, or HFC node) to the point of connection with the Middle Mile transport.

Selling, General and Administrative expenses (SG&A)—Corporate overhead costs, including expenses such as marketing, advertising, salaries and rent. SG&A is found on a corporate income statement as a deduction from revenues in calculating operating income.

Signal to Interference plus Noise Ratio (SINR)—For a wireless communications device, the ratio of the received strength of the desired signal to the received strength of undesired signals (noise and interference).

Spectrum Allocation—The amount of spectrum dedicated (or allocated) to a specific use; in wireless, spectrum allocation is typically made in paired bands, with one band for upstream and the other for downstream.

Spectrum Band—The frequency of the carrier wave in wireless communications. Radios can transmit on different frequencies in the same area at the same time without interfering; frequency marks the division of different parts of spectrum for different uses. Frequency is measured in Hertz (Hz); the range of frequency typically used for radio communications is between 10,000 (10 kHZ) and 30,000,000,000 Hz (30 GHz). Different frequencies have different natural properties: Lower frequencies travel farther and penetrate solids better, while higher frequencies can carry more information (faster data rates, etc.) The best balance of these properties for the purpose of cell phones is in the range of roughly 700-2,500 MHz. A specific range of frequencies allocated for a specific purpose is called a "band."

Switched Digital Video (SDV)—A network scheme for distributing digital video via a cable more efficiently to free up bandwidth for other uses. Only channels being watched by end-users in a given node are transmitted to that node.

Take rate—The ratio of the number of premises that elect to take a service divided by the total number of premises in a market area; effectively a penetration rate of homes passed.

Time Division Multiple Access (TDMA)—Technology used in digital cellular telephone communication that divides each cellular channel into three time slots in order to increase the amount of data that can be carried. TDMA is used by Digital-American Mobile Phone Service (D-AMPS), Global System for Mobile communications (GSM), and Personal Digital Cellular (PDC). Each of these systems implements TDMA in somewhat different and potentially incompatible ways. An alternative multiplexing scheme to FDMA with TDMA is CDMA (code division multiple access), which takes the entire allocated frequency range for a given service and multiplexes information for all users across the spectrum range at the same time.

Universal Mobile Telecommunications System (UMTS)—Third-generation (3G) broadband, packet-based transmission of text, digitized voice, video and multimedia at data rates up to and possibly higher than 2 Mbps, offering a consistent set of services to mobile computer and phone users. Based on the Global System for Mobile (GSM) communication standard.

Unserved—Those housing units without access to a broadband network capable of offering service that meets the National Broadband Availability Target.

Very high bit rate Digital Subscriber Line (VDSL)—A form of DSL similar to ADSL but providing higher speeds at shorter loop lengths.

Voice Over Internet Protocol (VOIP)—A family of transmission technologies for delivery of voice communications over IP networks such as the Internet or other packet-switched networks. Other terms frequently encountered and synonymous with VoIP are *IP telephony*, *Internet telephony*, *voice over broadband* (VoBB), *broadband telephony* and *broadband phone*.

Wideband Code Division Multiple Access (WCDMA)—Another name for UMTS. Also see Universal Mobile Telecommunications System.

Wireless ISP (WISP)—An Internet service provider that provides fixed or mobile wireless services to its customers. Using Wi-Fi or proprietary wireless methods, WISPs provide last mile access, often in rural areas and areas in and around smaller cities and towns. The largest provider of wireless broadband in the U.S. is currently Clearwire Corporation, a WISP that uses an early version of WiMAX to deliver the Internet to customers in the U.S., Ireland, Belgium and Denmark (see WiMAX).

WiMax—Worldwide Interoperability for Microwave Access (WiMAX) is a telecommunications technology that uses radio spectrum to transmit bandwidth between digital devices. Similar to WiFi, WiMAX brings with it the ability to transmit over far greater distances and to handle much more data.

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STATEMENT OF
CHAIRMAN JULIUS GENACHOWSKI

Re: *Connect America Fund*, WC Docket No. 10-90, *A National Broadband Plan for Our Future*, GN Docket No. 09-51, *High-Cost Universal Service Support*, WC Docket No. 05-337

This item is an important milestone in our deeply important effort to ensure that every American, no matter where they live or what they earn, has access to affordable, high-quality broadband communications service. It will not be easy. But that is what we are committed to do. It is necessary that we do so to promote economic growth, job creation and broad opportunity in the 21st Century.

Last month, the Commission delivered to Congress a plan to promote world-leading communications infrastructure in the United States – to match, and surpass, broadband deployment in other countries with which we compete. One of the key components of the plan – and the Commission Joint Statement on Broadband – was comprehensive reform of the universal service program. Today's item is the first in a series of proceedings to implement that vision.

This proceeding will lay the groundwork for a system that provides universal service support for broadband and voice services in an efficient and targeted manner. Today's Notices suggest common-sense reforms to cap growth and cut inefficient funding of voice networks. And they seek comment on the use of a model to assist with determining levels of universal service support for broadband communications. That support must be sufficient to ensure that providers can offer quality broadband service to high cost areas, without unfairly burdening those who ultimately bear the costs of universal service.

The comprehensive universal service reform that the National Broadband Plan envisions will take time, but cannot take too long. We do not want flash cuts. We want a reasonably paced and certain approach to converting universal service to broadband communications. That is why the Plan sets out a step-by-step approach, suggesting that the Commission begin with action, and act steadily and consistently as we work with all stakeholders to get the job done. This item begins that process by seeking the best way to create an accelerated process to fund deployment of broadband networks in unserved areas, while the Commission works on fully implementing the new Connect America Fund.

I thank the staff for their hard work on this item, and I look forward to working with my colleagues to make affordable, high-quality broadband available to all Americans.

STATEMENT OF
COMMISSIONER MICHAEL J. COPPS

Re: *Connect America Fund*, WC Docket No. 10-90, *A National Broadband Plan for Our Future*, GN Docket No. 09-51, *High-Cost Universal Service Support*, WC Docket No. 05-337

I approve both the NOI and the NPRM before us as the Commission makes good on its pledge to be fast-off-the-mark in implementing the National Broadband Plan. The comprehensive reform of the Universal Service Fund is, as we've all known for a long time, integral to getting broadband ubiquitously deployed and adopted. Today we begin to move in earnest toward a Twenty-first century Universal Service program that delivers for broadband what Twentieth century Universal Service delivered for voice service—and more.

Comprehensive reform is never painless and when it comes to building a new Universal Service system, shared sacrifice will be required from just about every stakeholder. Maybe, probably, this is why the Commission has never successfully tackled comprehensive Universal Service reform before. Previous Commissions undertook partial fixes and adjustments to existing USF programs to address discrete problems or contain costs. Sometimes real problems were solved, but at other times this approach had the unfortunate consequence of pushing interested parties apart rather than bringing them to the table to pursue workable, long-term solutions.

Today parts of the country have only legacy voice services—sometimes not even that—under the current high-cost Universal Service program, while others have access to truly amazing broadband-capable networks funded indirectly through that same high-cost program. While we often rightly complain about the lapses, we should also recognize the achievements. Regardless of where the funding comes from, I commend those providers who have made broadband deployment a priority. For example, a lot of small rural telcos often went where others feared to tread and brought broadband to some pretty remote places. Their efforts should be not only recognized, but applauded. Now our challenge is to retool the Universal Service system to provide the efficient and targeted support needed to bring high speed, value-laden broadband to all our citizens. The National Broadband Plan commits to such action and today this Commission takes important steps with the NOI and the NPRM.

While I am supportive of most of what we do today, the record will show that I have expressed concerns in the past about some of the suggestions put forward here. In particular, as it seeks to develop a detailed analytic foundation for the distribution of Universal Service support, the NOI places strong emphasis on the use of reverse auctions. When I supported the previous Commission's decision to seek comment on the merits of reverse auctions for distributing Universal Service support, I cautioned that the prospect of using such a mechanism raised many questions that still remain unanswered. For instance, how do we ensure that the winning bidder provides the services for which support is received? What happens if the auction winner decides to discontinue its operation in the supported area? Who will pick up the pieces and how will that be decided? What will be the rules of the road and how will they be established? And enforced? I'm not saying these questions are unanswerable and I am hopeful we will develop an extensive record on these issues, but I do emphasize that answering all these—and I'm sure other—questions and allaying all doubts are the necessary predicates of my support.

The NPRM proposes several options for containing the growth of the high-cost Universal Service program. I have been wary of some of the earlier makeshift attempts by the Commission to curtail the overall size of the Universal Service Fund because these efforts have too often served as delay tactics to avoid the tougher challenge of comprehensive reform. Clearly, the situation has changed with this new Commission, and I recognize that the proposals in the NPRM seek to phase out legacy support while we ramp up direct funding for broadband through the Connect America Fund. We need to do this, no question about it. But let's recognize that many of the proposals in the NPRM—which may very well be necessary and overdue—require major actions that will be burdensome for some, perhaps most, Universal

Service participants. Here, too, compiling a full and viable record is the key to success. And let's also emphasize that while we are shifting Universal Service to support broadband, at the same time we must make sure that voice service is available nationwide. Go to Indian Country to see how much remains to be done on this score.

I commend the Chairman for initiating this very important proceeding in the first month following the birth of the National Broadband Plan. And I thank the staff of the Wireline Competition Bureau for drafting an item that parses out a very complex issue, with, I am sure, more to come. This is the time, more so than any time in the nearly nine years I have been around this place, to truly and comprehensively reform Universal Service. We have the commitment, we have the Plan, and now we begin to implement. This item makes a great start. We begin to glimpse the prize at the end of the road—a first-rate broadband network covering the length and breadth of the nation.

STATEMENT OF
COMMISSIONER ROBERT M. McDOWELL

Re: *Connect America Fund*, WC Docket No. 10-90, *A National Broadband Plan for Our Future*, GN Docket No. 09-51, *High-Cost Universal Service Support*, WC Docket No. 05-337

Today we take an important first step on our journey toward badly needed Universal Service reform. USF is America's largest telecommunications subsidy program, which redistributes nearly $9 billion per year. If we have been able to agree on only one thing at the FCC, it is that the Universal Service subsidy system is antiquated, arcane, inefficient and just downright broken. For instance, since 1998 the contribution factor has increased from 5.53 percent to more than 15 percent today. Positive and constructive change must happen as soon as possible.

In November of 2008, the Commission came close to a bi-partisan, groundbreaking agreement to resolve many of the most vexing challenges facing not only Universal Service but intercarrier compensation as well. Unfortunately, needless roadblocks were thrown in our way. But today we have an opportunity to regain our momentum and pursue honest, constructive and comprehensive reform for the benefit of American consumers.

I therefore support the Notice of Proposed Rulemaking ("NPRM") and Notice of Inquiry ("NOI") regarding Universal Service reform now before us. First, the NOI seeks comments as to whether the Commission should use a cost model for a new support mechanism for broadband. And, if so, the NOI seeks comments on how a model should be structured. Second, the NPRM seeks comments on potential ways to contain the growth of the fund through cuts in the existing system, putting out for comment the cuts that were outlined in the Broadband Plan and also soliciting additional ideas. I am encouraged and pleased that we are <u>seriously</u> examining the possible benefits of employing reverse auctions.

As I have mentioned over the years, comprehensive Universal Service reform must adhere to five basic principles. The Commission should:

(1) contain the growth of the Fund;
(2) in a limited and fiscally sound manner, explore the possibility of broadening the base of contributors;
(3) reduce the contribution burden;
(4) ensure competitive neutrality; and
(5) eliminate waste, fraud and other abuses of the system.

To achieve effective and meaningful Universal Service reform, the Commission will need to engage in a complex analysis of potential costs surrounding any changes to the fund. Today's NPRM and NOI start that process.

I thank the Chairman for his leadership in this area. I also thank Sharon Gillett and the diligent team in the Wireline Bureau for your tireless work on these issues. I look forward to working with you and my colleagues on an expeditious, transparent and fair process in pursuit of sensible reforms.

STATEMENT OF
COMMISSIONER MIGNON L. CLYBURN

Re: *Connect America Fund*, WC Docket No. 10-90, *A National Broadband Plan for Our Future*, GN Docket No. 09-51, *High-Cost Universal Service Support*, WC Docket No. 05-337

With this item we embark upon an ambitious and long-overdue mission: the comprehensive reform of our universal service system to support broadband in geographic areas where there is no business case to deploy or operate broadband. In order for us to successfully accomplish this mission, we must begin with a good road map. The item before us identifies the issues to consider when devising our map. I thank the staff for their hard work in identifying these issues in the National Broadband Plan and for their effort on this item.

While the start of any journey can be very exciting, it also can be fraught with anxiety. I recognize there are many reasons for industry to be apprehensive. However, I hope as we begin the discussion of how to design a new support system and realize cost savings in our current system that we remain focused on our essential goal of fully connecting all Americans to voice and broadband services.

STATEMENT OF
COMMISSIONER MEREDITH A. BAKER

Re: *Connect America Fund*, WC Docket No. 10-90, *A National Broadband Plan for Our Future*, GN Docket No. 09-51, *High-Cost Universal Service Support*, WC Docket No. 05-337

As I have said many times, I believe that it is critical that we move toward comprehensive reform of the Universal Service Fund, targeted to broadband investment. As a nation, we need to transition to a support mechanism that is effective, efficient, and sustainable for areas where market forces are not sufficient to drive broadband services to America's consumers. The Notice before us is an important first step down that road. Universal service reform will be a challenging—and perhaps sometimes frustrating—endeavor. I have expressed concerns about the ballooning size of the Fund and I am convinced that some hard choices will have to be made to keep it under control. But I am convinced that we have a window of opportunity to finally make the changes that this program desperately needs. I also strongly support seeking comment on the possible implications of using a cost model in a new support mechanism for broadband and I hope to see active participation from all sectors of industry and the public. Building a strong record to be the foundation for reform is always important—but never more so than when we consider whether to adopt, and if so, how to structure a cost model. I look forward to working with the Chairman and my fellow commissioners to tackle universal service reform, and I would like to thank the staff for their thoughtful work on this item.