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Subject: Peer Review of Connect America Phase II Cost Model

Executive Summary

In response to your request, we have reviewed the Connect America Cost Model (CACM) for Phase II. The CACM estimates the forward-looking deployment and operations cost of a modern voice and broadband-capable network.

The CACM does a reasonable job of providing an *estimate* of the cost of deploying a broadband network across a wide number of deployment scenarios found throughout the nation. But this review also suggests there is room for improvement to the model, most importantly through better documentation that would invite more effective review of the methodology and assumptions employed in order to more easily verify the accuracy of the results. Such improved transparency would also spur further review and more rapid improvement of the model.

Other key points of the review include:

- *Network Technologies*. Even for telephone companies, accepted engineering practices of the network technologies considered today for deployment of broadband services in a "green field" includes Hybrid Fiber Coax networks. The CACM should include this as an option.
- *Voice Assumptions*. The per subscriber or variable cost estimation methodology applied for the cost of voice-specific network components is not consistent with the access network costing approach which includes fixed costs.
- *Network Sizing*. The description of the methodology or engineering practices applied for driving the network sizing in CACM deserve further attention as it has significant implications for future costs of the network to meet growing demand.
- *Service Scope*. The scope of CACM includes voice and broadband services, but not video services. Given that video is rapidly emerging as an application in the broadband space, this distinction is not logically consistent with current technical and market trends in broadband. The implications of this omission are that economies of scale and scope between broadband and video services may not be realized or properly reflected in the results of the CACM.
- *Cost and Support Model Interactions*. Determining consistent model results between the assumed take rates and the level of universal service support requires an iterative process that may not be obvious to most model users.

Introduction

The purpose of this document is to provide a peer review that addresses the primary question of "whether the Connect American Cost Model (CACM) can reasonably be used to estimate the forward-looking cost of deploying and operating a modern voice and broadband-capable network." Specifically, the instructions for this peer review request advice on the following:

1. "Whether the methodology and assumptions employed are reasonable and technically correct
2. Whether the methodology and assumptions are consistent with accepted practices in the fields of economics, engineering, GIS, and costing
3. Whether the model is logically consistent."

A full review of the CACM to address these questions is a massive undertaking. It requires in depth review of the overall model structure, all model assumptions, confirmation of model calculations, and verification of the accuracy of the cost reports against actual deployment and operating costs in the field.

Such an undertaking exceeds the effort and accompanying review provided here. To begin, as will be discussed below, the current state of model documentation is still being developed, making such a complete review difficult at this moment in time.[1] Instead, this review provides feedback and comments organized under the three focus areas listed above based on incomplete information, limited both by our ability to find the information in the time frame set for this review and the ability to access the information from the model itself.

The overarching goal of the CACM, of course, is to provide estimates of the forward-looking cost to deploy networks capable of delivering voice and broadband services in a variety of circumstances set by the different housing density and geographic terrain found throughout the nation. The current CACM version is a reasonable start in meeting this goal. It implements a reasonable methodology for generating cost estimates for the deployment and operations of modern voice and broadband-capable networks. The key word here is estimation, as we must recognize that reasonable limitations of accuracy exist to any costing methodology attempting to estimate network deployment and operating costs on a nationwide basis.

This review is organized to describe our reactions and comments to the three areas that were requested for us to focus our review: 1) Model Methodology and Assumptions, 2) Accepted Practices, and 3) Model Consistency.

Unfortunately the significant scope of the CACM, and fragmented nature of the documentation, also means that we might have simply missed or failed to identify

[1] For example, the System Evaluator data package, which provides access to review the model code to verify calculations, is not available at this date for third parties to review.

key information that would address the concern raised. With this caveat in mind, we proceed to provide our review of the CACM.

I. Model Methodology and Assumptions

The methodology of CACM, as reported in a presentation to an FCC workshop last year, appears reasonable to generate cost estimates that are representative of actual costs in a wide variety of scenarios.[2] There do remain, however, areas of improvement

Documentation

Documentation of how to use the CACM model, as well as descriptions of the assumptions inherent within each calculation, is key to minimizing errors or incorrect cost estimates. Like any software package, the need for clear documentation of model software, assumptions, and results reports is necessary to understand and reproduce the model results. The need for clear documentation is heightened by the fact that the CACM will be used as an important quantitative tool to implement FCC universal service policies. The more transparency and clarity provided by documentation of the model, the better it will serve this role.

Unfortunately, at the current time, model documentation is not sufficient such that all model calculations can be reproduced and verified in a straightforward manner. To be sure this is a complicated model that requires expert users to navigate and operate; yet there is nonetheless room for better documentation.

This statement does not mean that the model calculations are incorrect. Instead, our experience with model documentation in conducting this review was that it was insufficient to allow one to operate or understand in straightforward fashion the key assumptions in each model calculation and report of results. For example, it is the rare exception, rather than the rule, that the specific units of the numeric model inputs are documented in the input models.

Another problem is that the model documentation is fragmented across different documents and sources. These include:

- Two lengthy PowerPoint presentations based on Universal Service workshops held by the FCC to discuss cost model issues.[3] These two documents are the best documentation describing the cost estimation algorithms employed in CACM. The slides describe the approach taken in the

[2] See Slides 34 and 91, http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part1.pdf

[3] See http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part1.pdf and http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part2.pdf for ~300 slides describing the CostQuest Broadband Analysis Tool, which is the precursor to the CACM.

CostQuest Broadband Analysis Tool (CQBAT). This model, however, is different than the v2.0 model version in CACM.

- The web site for CACM operated by the Universal Service Administrative Company (USAC).[4] The changes in each version of the CostQuest model are contained in notes on this site, as well as documents such as "Background Information on CACMv2.0", "User Guide" and "Report Types & Toggle Field Definitions Reference". CostQuest Associates operates a support line that will answer questions by email regarding "issues relating to access, administration and output generation" to the CACM as well.
- Comments on CACM posed by the Wireline Competition Bureau (WCB) on the FCC web site.[5] These are third-party comments on issues pertaining to CACM posed by the WCB, and responses from WCB staff. They provide another source of documentation that is focused CACM-related issues.

The bottom line here is that the model documentation, while appreciated in each one of these forums, is fragmented and not located in one location that makes it straightforward for a model user to quickly pull together the latest and most accurate information available at any given time.

In addition, FCC policy requires that "*All underlying data should be verifiable, engineering assumptions reasonable, and outputs plausible… The cost study or model must include the capability to examine and modify the critical assumptions and engineering principles."*[6] Adequate documentation within the model, obviously, is critical to meeting these requirements. CACM clearly offers the capability to conduct a parametric analysis through the modification of critical assumptions, though it is made more difficult by the current state of documentation. The workshop presentations, for example, cover the topics of discussion at the workshop, which is a far different organization of information than one typically finds in a well-written user manual with a comprehensive table of contents, key word index, and description of how to utilize a software product.

To address these shortcomings, at a minimum links between essential documentation that already exists need to be established as a first step. Subsequently, a clear strategy for implementing the documentation should be established and executed. This strategy should include the development of a comprehensive user manual, one that describes the capabilities of the model, network configurations considered, and other key assumptions.

Another important issue revolves around the lack of information made available to model users that describes the justification for a particular cost estimate used in the

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[4] See https://cacm.usac.org/
[5] See http://www.fcc.gov/blog/wcb-cost-model-virtual-workshop-2012
[6] See Slide 19, http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part1.pdf

model. While the model provides the ability for users to change the estimates or values of many model parameters, as well as a list of model values for many of the model parameters, it would be useful for the base case parameters if the model documentation would provide an explanation for the value.[7] A derivation or rationale for each cost component estimate would be useful to raise the transparency and ability to verify model results.[8] This includes documentation of the derivation of the values of input assumptions as well.[9]

The importance of better documentation cannot be overstated. Improved documentation will reduce the "black box" effect of the model (i.e., cost estimates that magically appear to provide quantitative answers to questions without adequate understanding of whether the set of assumptions that drive the estimates are appropriate). Left unaddressed, this situation is at best inefficient and likely to cause more errors due to poor information flow and at worst leading to inefficient allocation outcomes due to the inability to easily verify cost estimates generated by CACM.

Network Layout

The methodology to develop and estimate the cost of the network topology implemented in CACM show that reasonable assumptions are being made to simulate actual network deployment costs to the best ability of current estimation methods.[10]

The only observation here is that the lack of documentation and/or generation of network maps in the model itself make the "math" difficult or impossible to check. With the distances calculated in the model, and the amount of network equipment required to serve the particular topology dimensioned according to a scorched node approach using a road-based minimum spanning tree algorithm, it is not readily apparent how to verify the accuracy or optimum nature of the model calculations.

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[7] Through a color-coding system of spreadsheet entries, the input models do provide a way to track the source of the parameter value (e.g., Coalition, CostQuest).

[8] Note that model users have signed non-disclosure agreements protecting the output of the model from disclosure to the public if there are concerns that additional disclosure of proprietary information could occur through more thorough model documentation.

[9] The documentation of the input models is inconsistent as well. To pick just one example for illustration purposes, under the CAPEX model "CO and Middle Mile Material" tab, the Materials Cost column includes notes for some of the components explaining how they are derived, but not for the derivation of the materials cost for the Ethernet Edge Router. Best practices for cost modeling would require a consistent documentation for all calculations in the model. This transparency is critical to straightforward debugging and understanding of the model methodology.

[10] See slides 16 -50, http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part2.pdf

This is particularly true given the highly stylized nature of each network topology generated for the actual census block areas loaded into the model.

Voice capability

A new capability in CACM V.2 estimates the cost of a network capable of providing voice service using IP Multimedia Subsystem (IMS) technology. This cost is calculated on a per subscriber basis and takes into account the cost of hardware, software, services, and customer premises equipment to provide carrier-grade Voice over Internet Protocol (VoIP) service. This methodology for cost estimation removes any fixed cost component to deployment of the VoIP system and makes it entirely a variable cost component of the model. For the IMS software required for service, this is reasonable as software licenses on a per subscriber basis are common. For the hardware equipment in the form of servers and communications links, however, this is not a reasonable estimate. We do not know how significant the percentage of hardware costs for IMS-based voice is relative to total costs (the base case CACM estimates this percentage to be roughly 30%, which is not insignificant). At a minimum, this per subscriber cost estimation methodology is not consistent with the access network costing approach by replacing these fixed costs with variable costs.[11] Moreover, the "Switching" input of the CAPEX model assumes the same cost across all company sizes, which would not be a good assumption if 30% of total costs were fixed.

II. Accepted Practices

This section reviews some selected topics associated with accepted practice – network technologies corresponding to engineering practices, and network sizing assumptions of the broadband service.

Network Technologies Approach

The network technology modeled in the CACM must be "*the least-cost, most-efficient, and reasonable technology for providing the supported services that is currently being deployed*".[12] To meet this goal, the CACM can calculate the costs for two network technologies: "fiber to the DSLAM" (FTTD) and "fiber to the premises" (FTTP). These are the two predominate network platforms deployed and used by telephone companies today to serve their customers and should be included in the model.

The CACM does not calculate the cost of one network technology, however, that is widely deployed throughout the nation: the hybrid-fiber coax (HFC) network platform generally deployed by cable companies. Telephone companies have deployed HFC networks on occasion in the past in order to deliver voice and

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[11] The one scenario where this per subscriber approach would reflect actual costs is the case where the network provider purchases an IMS-based VoIP service from a third-party provider based on a monthly per subscriber price.

[12] See Slide 17, http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part1.pdf

broadband services, along with other advanced services (typically video). A true "green field" calculation would consider HFC approach since it can be deployed from the existing wire centers of the ILECs as required by the "scorched node" assumption of the model.

Whether or not to include an HFC option in the model depends upon the advanced services to be delivered by the network and the likelihood of a "brown field" deployment. HFC networks have proven to be economical platforms for the delivery of voice, broadband, and video services, even in rural environments. If the services to be delivered by the network are only voice and lower-speed broadband (<4 Mbps), then it may not be a viable option.[13] Likewise, HFC likely will not be viable in comparison to brown field deployments of FTTD that reuse large portions of the existing copper wire networks already deployed in the field. Other considerations would also include the costs to interconnect HFC with the existing legacy back-office systems of the telephone companies to provision and manage telephone and broadband services.

Under this logic, to the extent the CACM is to include only "forward-looking costs", the inclusion of HFC is consistent with most accepted definitions of this concept to include the lowest, potentially disruptive technical strategies available in the market. It would also be consistent with accepted engineering practices of the network technologies that are considered today for deployment of broadband services.

Network Sizing

One of the most difficult issues confronting broadband service providers is planning for adequate network capacity to satisfy the rapidly growing demand of broadband customers. Cumulative average growth rates (CAGRs) in excess of 50% for broadband usage have been commonly reported over the past decade. This strong growth places significant demands on capacity planning efforts to insure that the broadband service quality meets the expectations of customers. In meeting this demand, network engineers face a tradeoff in the cost of additional broadband capacity versus the network allocation provided per user.[14]

It appears that network sizing within CACM occurs as follows:

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[13] The question in part is how broadly to interpret the requirement that "the loop design incorporated into a forward-looking economic cost study or model should not impede the provision of advanced services." (Slide 17, *ibid*) Generally speaking, HFC networks might provide telephone companies a "mid-range" broadband speed option between DSL and FTTP network technology.

[14] The network allocation per user reflects the amount of capacity designed into the network for each user during the peak usage period, adjusted by an "oversubscription" or shared usage factor that reflects the fact that not all users are active at their maximum rate during the peak period.

1. The take rate for residential and business customers is taken as an input into the model based upon census block figures for each area.
2. A "speed value" is assigned per user based upon broadband definitions set by the FCC (e.g., 4 Mbps downstream and 768 Kbps upstream) to determine bandwidth per user required for the census block.
3. Using bandwidth estimates "supplied by the Coalition and consistent with the National Broadband Plan", CACM sizes the network for the peak usage period.[15]
4. Under the generally reasonable rubric to "keep it simple," the effects of this sizing rule on network equipment are as follows:[16]
    - "Size the OSP network (e.g., fiber, copper, terminal locations) to serve all potential customers
    - Size the Hardwired/Common equipment to serve the maximum expected demand, along with some engineering fill factor
    - Size success-based capital (e.g., line cards, modems, etc.…) to the levelized demand (along with some spare capacity)"

There is not a further explanation provided describing the amount of capacity and accompanying equipment assumed in the network within CACM. As this is an important parameter for both the cost and viability of the broadband network in the future, there are several important questions that should be more clearly addressed and answered to better understand how this is captured in the model:

- *How much of the network is initially installed?* CACM cost estimates presume the network runs past all the households in a specific area even if not all households are presumed to subscribe to the services over the network. As noted in the workshop discussion, further clarification is needed on what network components are sized only to working lines,[17] as well as how "maximum expected demand, along with some engineering fill factor" is defined, and whether additional network equipment and cabling is pre-installed to accommodate future growth (i.e., is a similar engineering fill factor assumed for OSD components as well). How would these differ for the copper pairs used in FTTD versus fiber lines used in FTTP?
- *How much working capacity is deployed for each user in the near term?* What is the core set of assumptions regarding the amount of shared capacity on the network? Is the same amount of core network capacity assumed for the

[15] See slide 135, http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part1.pdf. The slide provides a value of 0.44 to describe the "datalowbandwidth" parameter, though no explanation of the meaning of this value is provided.
[16] See slide 32, http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part1.pdf.
[17] See slide 20, http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part2.pdf

FTTD and FTTP models, despite the capability to accommodate higher speed service with FTTP?

- *What investment is made in the plant upfront to support the FCC goal that most locations receive a 6 Mbps/1.5 Mbps or faster service at the end of 5 years?*
- *How does the model incorporate the annual projected increases in broadband traffic per user?* Studies by Cisco and others project annual growth rates in traffic per broadband user averaging 29% or more.[18] With such growth rates in traffic, a system with adequate capacity in 2015 may have inadequate capacity in 2022, well within the expected lifetime of a network deployment. Proper network design requires appropriate pre-provisioning of costly-to-reinforce capital such as feeder fibers, or second mile rings. One approach would be to adjust model parameters such as "fill factors" to reflect differing traffic growth rate forecasts. However, it would be more intuitive if the model allowed for direct input of a projected traffic growth rate, and generated reasonable fill factors to be used in order to minimize costly future reinforcement.

Another observation is that the level of granularity or sensitivity of the CACM to broadband speeds appears coarse (i.e., either FTTD for 4 Mbps or FTTP for above 40 Mbps), which is different then the real world where service providers strive to supply a "best fit" network that optimizes the amount of cost-efficient bandwidth provided to customers. The CACM also does not differentiate in the bandwidth input assumptions for residential and business users even though these two sets of customers typically purchase different broadband service tiers (and the model explicitly assumes a 90% take rate for business services). This set of model assumptions should be reviewed and adjusted accordingly to reflect more accurate estimates for bandwidth input to the model. Further, an important business consumer of fiber trunking—wireless backhaul—is not specified.[19]

In sum, the description of the methodology or engineering practices applied for driving the network sizing appears vague, and deserves further attention as it has significant implications for the future costs of the network to meet growing demand.

III. Logical Consistency

This section addresses two topics regarding the logical consistency of the model: 1) the scope of services assumed to be delivered by the broadband network, and 2) the

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[18] Cisco, *Cisco Visual Networking Index: Forecast and Methodology, 2011-2016*, available at http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360_ns827_Networking_Solutions_White_Paper.html

[19] See slide 114, http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part1.pdf.

interaction of the cost model and the support model.

Scope of Services Included in the Model

The service scope of CACM is limited to broadband services, or as stated by the FCC:

"The cost study or model must estimate ***the cost of providing service for all businesses and households within a geographic region****. This includes the provision of multi-line business services, special access, private lines, and multiple residential lines. Such inclusion of multi-line business services and multiple residential lines will permit the cost study or model to reflect the economies of scale associated with the provision of these services."*[20]

The inclusion of business services along with residential broadband not only allows the cost model to reflect the economies of scale between these services, but the economies of scope as well. A similar statement may be applicable with regard to video services. By not including video services as part of the broadband platform, there may be significant economies of scale and scope that are not realized and reflected in the model results.[21] This omission may have the following implications:

- The network sizing, particularly for the FTTD option, is insufficient. The trend to IP video services is well documented elsewhere, but characteristics of video services require significant capacity planning to accommodate the bandwidth requirements of these services. Anecdotally, deployment of FTTD and FTTP broadband platforms with significant capacity are almost always accompanied by the provision of a "triple play" service bundle that includes video services.
- Costs for the broadband service component of the network could be overstated due to an absence of contribution by video service to the shared and common costs of the network. This raises the (policy) question of whether a company using Universal Service funds to deploy and operate its network platform would be allowed to deploy video services over the network?
- As IP video proliferates and expands, the definition of broadband will evolve to include the transport of widely utilized video services. Under this view forward-looking costs would necessarily have to change to reflect the growth of video applications delivered by broadband service as they are forecast to be the most significant consumer of broadband capacity[22]. Another way to view this evolution in the broadband application space is that eventually video services will evolve, just like voice services did, to become yet another

[20] See slide 18, http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part1.pdf.

[21] Consistent with model documentation we assume video is not included in the model despite the presence of an input table labeled "BundleBreakdown" in the base case set of input tables. This input file appears to establish a 45% allocation to video.

[22] Cisco, *op.cit.*, footnote 18, *infra*.

application on the broadband platform. The definition of broadband, and the networks required to provide broadband service, will need to keep pace with this evolution by including sufficient capacity to support use of broadband for video applications such as conferencing, online education, and surveillance, as well as for entertainment.

Interaction of Cost Model and Support Model

The current approach separates two issues: network design and universal support. In a first step, the "Cost Model" calculates the cost of provisioning a network based on a hypothetical take rate, and estimates the cost for providing service to customers. The "Support Model" takes the costs as input, and then using other information such as the support benchmark or total funds available, determines what customers would be eligible for subsidies and to what extent.[23] The separation of these two models creates a problem: the hypothetical take rate implicitly assumes a level of affordability, such as the benchmark price. If the support model shows that not all customers can be subsidized so as to be able to purchase service at the benchmark price, then the take rate will almost certainly be less than initially assumed in the cost model. Arriving at consistent results between the assumed take rates and the level of universal service support requires a time consuming iteration process of running first the cost model at a lower take rate, and then the support model to see if that level of take rate can be satisfied within the universal service budget cap in order to end up with consistent results for both the cost and support models. The Commission has recognized the inherent difficulties caused by take rates that vary with price or over time.[24] While they have directed for the present that cost model results be based on a standard assumed take rate, this is ultimately not sufficient for evaluating policy options, and the Commission would benefit from a model which made convergence on consistent numbers easier to achieve.

IV. Summary

In closing, we have reviewed the latest version of the CACM and provided comments on the set of requested topics. In our opinion, the model provides reasonable estimates of the forward-looking deployment and operations cost of a modern voice and broadband-capable network, but there is room for improvement in the ways described above by our peer review.

If you have any further questions, please feel free to contact us for further discussion.

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[23] Slide 22, http://transition.fcc.gov/wcb/tapd/universal_service/caf/CAF2-Part1.pdf.

[24] FCC, "WCB Cost Model Workshop 2012: Calculating Average Per-Unit Costs/Take Rate," Available at http://www.fcc.gov/blog/calculating-average-per-unit-costs-take-rate

Sincerely,

David Reed and Marvin Sirbu