

**REMARKS OF
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Thank you to The Marconi Society for inviting me to join you today. The Society is marking its 50th anniversary this year, so I consider the chance to be here a tremendous honor. Right upfront, let me also offer my congratulations to Stanford University Professor Arogyaswami Paulraj for winning this year's Marconi Prize. His remarkable insight that using arrays rather than a single antenna can increase data rates while also improving coverage led to the development of multiple-input, multiple-output—MIMO—technology. Of course, The Marconi Society has been celebrating leading lights in communications, like Professor Paulraj, for decades. So taking a page from your work, I thought I would start by mentioning a few visionaries that have revolutionized how we communicate.

Let's begin, appropriately, with your namesake. Guglielmo Marconi was toiling away in obscurity in his workshop in Italy in the 1890's. But one day he emerged with the wireless telegraph, the world's first working radio. That radio eventually sent the first signals across the Atlantic—and worldwide communications has never been the same.

Fast forward to the 1940's, at the height of World War II. Torpedoes were state-of-the-art weaponry. But they were controlled by radios operating on only one channel. So their systems were vulnerable to signal jamming by our enemies. But one creative thinker patented a method to have a transmission hop from frequency to frequency, avoiding jamming or other interference. This spread spectrum technology is now the foundation for so many of our modern wireless technologies—from CDMA to Wi-Fi to Bluetooth. The clever mind that came up with this idea? Not some strapping young student in a university or researcher in a military institution. It was a brilliant young woman named Hedwig Kiesler. But you probably know her as the actress Hedy Lamarr.

Thirty years later we are in the thick of the 1970's. The Sting and American Graffiti are in theaters. Tony Orlando and Dawn and Jim Croce are on the radio. Our friend Marty Cooper, however, is on the street in New York. He holds a clunky, 10-inch bricklike device that cost a whopping \$4,000. But the device was the first handheld mobile phone and he did something big—he made a call. That call went through and the rest is history.

Four decades later we have more than 7 billion mobile devices around the world. By any measure, that's a lot. But we are only getting started. Because mobile data traffic is projected to increase by 11 times in the next five years. By the end of the decade we will be deep in the Internet of Things, with 50 billion machine-to-machine devices communicating wirelessly worldwide.

Look what Marty's one call wrought. The world has gone wireless.

So I have some ideas I want to share with you today about the wireless future. They are not on par with the ideas of your namesake, the mother of Wi-Fi, or the father of the wireless phone. But they are some ideas for the future of wireless communications policy that could have big impact. So here are five ideas for the next five years, five ideas for the road to 5G.

First Idea: Spectrum use will become more efficient if we challenge ourselves.

Spectrum is the consummate scarce resource. We are not making more. So if we continue to cram more wireless devices into our pockets and purses and more wireless services into our skies, we are going to need to find new ways to promote spectrum efficiency. That means supporting technologies—from dynamic spectrum access to frequency agile radios to smart antenna systems—that make this possible.

Easier said than done. So I want to offer an idea building on thoughts I first heard from Marty Cooper himself. It goes like this: What if we issued a challenge in Washington? Think of it as Race to the Top, the Spectrum Edition. Imagine that we decided to reward the first person who finds a way to make spectrum use below 5 GHz 50 or 100 times more efficient over the next decade. The reward could be something simple—say 10 megahertz of spectrum suitable for mobile broadband.

This is no small prize. Because if the winner can find a way to use spectrum 50 or 100 times more efficiently, that 10 megahertz of spectrum could do the work of 500 to 1000 megahertz of spectrum using today's technology.

Think of the power of this kind of prize. We would all benefit from the winning idea when it is introduced at scale. But for that one winner, there will be any number of near misses. And we could see across the board, throughout the wireless economy, the multiplied benefit of all of these efforts together.

This contest could generate some real interest. Maybe some of you in this room might be interested. And maybe some of you saw the editorial Marty Cooper and I had in the *San Jose Mercury News* discussing this idea last week. It is not something that the Federal Communications Commission can do on its own. But I think it is one of those big, bold, and strange ideas that is worth a look.

Second Idea: Clearing more federal spectrum will be slow going unless we provide federal authorities with incentives to relocate.

In the United States federal authorities have substantial spectrum assignments. That's because critical missions throughout the government are dependent on access to our airwaves. Federal authorities use their spectrum assignments to protect us from attack, with tools like precision guided munitions and early missile warning systems. They use them to manage our air traffic, enhance our crop productivity, and monitor our water supplies. They use them to protect against forest fires, predict weather patterns, and warn us of climate events. These activities are essential to our economic security and national well-being.

But we cannot be blind to the great increases in commercial wireless demand. Commercial wireless activity has been a powerful force our economy and we need to find spectrum for it to grow.

So we are on a hunt for new opportunities to fill the spectrum pipeline. We are looking for ways to take federal airwaves and repurpose them for commercial use. But our traditional process for doing so is growing creaky. It's based on sticks. We take a stick and knock on the door of federal authorities with spectrum assignments. We then urge, coax, and cajole them to provide us with some airwaves for the commercial sector. It takes time but after pressing and prodding they offer us a bit. Then we relocate the federal users and eventually get around to auctioning their old airwaves for new mobile use. This is a slow way to go when the wireless world is moving fast. It is not the steady spectrum pipeline our mobile economy needs.

That is why it is time for a federal spectrum policy that is based on carrots, not sticks. We need to develop a series of incentives to serve as the catalyst for freeing more federal spectrum for commercial use. We need to find ways to reward federal authorities for efficient use of their spectrum so that they see benefit in commercial reallocation rather than just loss. As part of this effort, we should consider a valuation of all spectrum used by federal authorities to provide a consistent way to reward efficiency.

In addition, we should look at existing laws to see what other adjustments can make this process smoother. For instance, let's look at the Miscellaneous Receipts Act. That sounds random. But this little law can prevent negotiations between federal agencies and winning bidders in wireless auctions. That means it is up to the FCC to clear spectrum for the lowest common denominator. But if we made some changes to this law, we could speed transition to commercial use allowing winning bidders to negotiate directly with federal authorities being relocated. That could speed repurposing of our airwaves and also provide commercial opportunities to update federal systems past their prime.

Third Idea: We will need to look low and look high to find spectrum for next generation wireless networks.

Today the bulk of our wireless networks are built on spectrum ranging from 600 MHz to 3 GHz. Call it the sweet spot for mobile communications.

But the sweet spot in the future could look different—very different. We are moving from networks designed for analog voice to networks designed for high-speed data. To keep up with escalating data demand, our next generation networks are going to have to do some heavy lifting. They will need to accommodate more traffic coming from more devices at higher data rates. At the same time, they will need to lower latency and conserve battery power to extend battery life. Well, that sounds easy, right?

So how do we meet these demands? We need to think differently. We can no longer limit ourselves to frequencies in the traditional range. We need to look elsewhere. The only question is where.

First, we need to look low. We should explore if spectrum in the 400 MHz range can be repurposed for mobile broadband use. This will not come overnight because this band is segmented into many small parts. But we should explore.

Second, I think we need to look high. Very, very high. Let's bust through our old 3 GHz ceiling. Let's take a look at millimeter wave spectrum all the way up in the 60 GHz range—and maybe all the way up to 90 GHz. At these ranges, we can aggregate spectrum and allow data intensive applications to ride across hundreds of megahertz at a time. And Professor Paulraj's MIMO antenna arrays might juice the system to deliver even more. Pretty cool.

Of course, these stratospheric frequencies mean more than just wide channels. The physics here are different. That means propagation challenges, but also new opportunities to think about 5G network topology. Because if you mix those wide channels with small cells packed close together, you can densify networks at low cost. Combine this with networks using lower-band spectrum and you can deliver service further into buildings and offer faster speeds than ever before, especially in areas with the greatest traffic demands.

To look low and look high like this will require thinking through some novel technical and policy issues. But if we get them right, we will have more resources to play with as we move to next generation networks.

Fourth Idea: We need more Wi-Fi.

We talk a lot in Washington about the growing demands on our airwaves. Most of this talk is centered on licensed spectrum. But it is time to give unlicensed spectrum its due. That's because the spectrum that powers Wi-Fi and a slew of our daily activities is also getting more crowded. But it's more than that. Let's recognize that unlicensed spectrum contributes more than \$140 billion dollars to our economy annually. That's a lot. On top of that, roughly one half of data connections in this country are now offloaded from licensed spectrum to unlicensed spectrum. It may not be intuitive, but that means unlicensed spectrum helps support the value of licensed spectrum.

So I think it's time to leave behind the tired notion that we face a choice between licensed and unlicensed airwaves. Good spectrum policy requires both.

That is why we need a game plan for unlicensed spectrum. Unlicensed spectrum can no longer be an afterthought, cobbled together from junk bands and stray scraps of spectrum. It deserves attention upfront and in policy primetime.

Let me sketch out what an unlicensed game plan looks like. It takes high-band, mid-band, and low-band spectrum. High-band spectrum provides the large channels for high-definition video at short distances—think streaming video from your laptop to your television. Mid-band spectrum sacrifices some of that throughput, but gives you further reach. Low-band spectrum can go far and wide, and as a result is ideal for larger-scale Wi-Fi deployments and machine-to-machine communications. And just this week, the FCC asked for comment on

proposed technical rules for low-band Wi-Fi—specifically in the 600 MHz band. So I hope you can take a look and help us get this right.

If we do, I think we can do big things. Because it is time to move beyond the old dichotomies that pit licensed versus unlicensed spectrum. Because across the board we need to choose efficiency over inefficiency and speed over congestion—and we need to look at how more Wi-Fi can help us do it.

Fifth Idea: The next mobile evolution needs a battery revolution.

We are looking forward to a world with more mobile devices than people on earth. Imagine smartphones multiplying, processing more data, with bigger and brighter screens, and carrying many more features. But it's a lot more than these devices. Because sensors that send information wirelessly will soon be appended to countless common devices and many of our machines. What we drive, where we live, and what we wear will be capable of communicating wirelessly—keeping us in contact, improving efficiency, reducing cost, and organizing so much of our daily lives.

But this brave new world of ubiquitous connection depends on a revolution—a revolution in battery technology. Because I don't know about you, but I am already struggling with keeping it all plugged in, living a life where you are always charging. It takes planning, cords, and a non-stop search for sockets.

If we don't fix this, battery life will be the new bottleneck slowing our data flows. Still, it won't be easy. That's because developments in battery performance will never move as fast as Moore's Law. They will trail developments in spectral efficiency. Chemical science is different—and we may have reached the limit of what we can drag out of the lithium-ion batteries that power most of our devices today.

Still, research is being done. New chemical avenues are under investigation. Novel ways to charge without outlets are being developed. Researchers are looking at network design and antennas to determine if minimal changes can help maximize existing battery life. For my part, I want to issue an invitation. If you see any way that the FCC can use its policies or position to help spur new developments in battery science, let us know. Because the mobile economy is moving fast and we want to find new ways to power it along.

So there you have it. Five ideas for the wireless road ahead. Five ideas to keep the communications conversation moving. I think it's important to generate new ideas not just in research laboratories, but here in Washington. Because if icons like those honored by The Marconi Society teach us anything, it's that coming up with what is new can be hard—but the payoff can be huge. Better communications policies and better communications technologies can make us all more connected, grow our economy, and enhance our commercial and civic lives. That is good stuff—and I think it's worth fighting for. Thank you.