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NATIONAL BROADBAND PLAN WORKSHOP

SPECTRUM

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ANDERSON COURT REPORTING
706 Duke Street, Suite 100
Alexandria, VA 22314
Phone (703) 519-7180 Fax (703) 519-7190

PARTICIPANTS:

Panel 1: 4G Supply and Demand

Moderator:

JOHN LEIBOVITZ
Deputy Bureau Chief, Wireless Telecommunications Bureau

Panelists:

TARUN GUPTA, Ph.D
Vice President of Strategic Development, FiberTower

RAJIV LAROIA, Ph.D
Senior Vice President of Technology, Qualcomm

GAVIN R. LEACH
Vice-President for Finance and Administration, Northern Michigan University

KRIS RINNE
Senior Vice President, Architecture and Planning, AT&T, Inc.

JOHN SAW, Ph.D
Senior Vice President and Chief Technology Officer, Clearwire

BILL STONE
Executive Director, Network Strategy, Verizon Wireless

Panel 2: Sources of Spectrum--Opportunities and Mechanisms

Moderator:

RUTH MILKMAN
Bureau Chief, Wireless Telecommunications Bureau

PARTICIPANTS (CONT'D):

Panelists:

COLEMAN BAZELON, Ph.D
Principal, The Brattle Group Michael Calabrese,
Vice President, New America Foundation

KATHLEEN O'BRIEN HAM
Vice President, Federal Regulatory Affairs,
T-Mobile USA, Inc.

DARRIN M. MYLET
Co-Founder/Advisory Boards, Spectru-
Station/WINS/Full Spectrum/Adaptrum

WILLIAM WEBB, Ph.D
Head of Research and Development and Senior
Technologist, Ofcom

Panel 3: Innovating in Spectrum Access-Technological Advances and Other Approaches to Facilitate More Productive Spectrum Use.

Moderator:

COMMISSIONER MEREDITH ATTWELL BAKER

Panelists:

RANVEER CHANDRA, Ph.D
Researcher, Networking Research Group, Microsoft

BRUCE FETTE, Ph.D
Program Manager, Strategic Technology Office,
DARPA XG Project

PAUL KOLODZY, Ph.D
Independent Telecommunications Consultant, Kolodzy
Consulting, LLC

PARTICIPANTS (CONT'D):

PAUL MANKIEWICH, Ph.D
Chief Technology Officer of the Wireless Networks Product Division, Alcatel Lucent

DR. JOSEPH MITOLA III
Distinguished Professor and Vice President for the Research Enterprise, Stevens Institute of Technology

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P R O C E E D I N G S

MR. MATHIAS: Hello. My name is Charles Mathias with the Wireless Bureau, and I wanted to welcome you all today to our FCC National Broadband Plan Workshop on Spectrum.

I wanted to extend a special thank you to all of our panelists, some of whom have come great distances to be with us today. Thank you for that special effort. Thank you to everybody in the room and on the web who's participating and a special thank you to the many, many people who helped make this workshop today possible.

Electromagnetic spectrum is one of our nation's most treasured resources. It's also one of the keys to unlocking the power of the Internet and to making broadband accessible to all types of people on the go and wherever they may be. Our workshop today is intended to deepen the Commission's understanding of how we use our nation's spectrum and to further inform the development of the National Broadband Plan.

We have three panels. The first panel

-- everybody's here today, right now -- seeks to understand the delicate balance that must be struck between the supply and demand for spectrum and the interplay with technological developments. The second panel will look at the opportunities and mechanisms that can be used to make more spectrum available for commercial use. And the final panel, which will be, I'm happy to say, moderated by Commissioner Baker, will be worth the wait. It will explore the technological advantages that can be used to facilitate more productive spectrum use.

I'm sure we're going to have a very, very interesting afternoon. As time allows, we'll be taking questions from the audience here in Washington and from the web. We will have colleagues in the room who have cards for you to write your questions down and we have people who are also monitoring the web. We hope you won't be bashful.

So, with that, I'd like to turn the floor over to our moderator for the first panel, John Leibovitz, deputy chief of the Wireless Bureau.

MR. LEIBOVITZ: Hi. Thanks everyone for coming and for people who are streaming online. Welcome to the first panel of the day, which is going to focus on supply and demand of spectrum for 4G networks.

After years of preparation, it's pretty clear that wireless broadband is in full swing now. Tens of millions of people use wireless access for broadband on a daily basis using handsets, laptops, netbooks and other devices to access the Internet, and that number is really ramping up very quickly.

Broadband, by most accounts, consumes way more network bandwidth than traditional voice telephone and other applications. And so, you know, we're looking at a potential squeeze in terms of network capacity as -- looking out a few years as the consumer behaviors change and devices get more and more capable.

Fortunately, we're also on the verge of

a transition to a new generation of network technology. We've got more efficient 3G networks and 4G networks deploying soon. The big question we want to ask in this panel is, even with these advances in technology, will we have enough spectrum? And so, fortunately, we have a terrific, terrific panel of industry leaders who work on these problems every day and we're thrilled to be able to engage with them in this setting.

So, let me introduce them very quickly. I'm probably not going to go in the order of the name cards. Dr. Tarun Gupta is vice president of strategic development at FiberTower. He is responsible for identifying new initiatives and growth opportunities for FiberTower, which focuses on the backhaul segment of the marketplace.

Dr. Rajiv Laroia is senior vice president of technology for Qualcomm. He is an expert in cellular multiple access technologies and Next Generation Wireless standards. He was a founder of Flarion, which was a company that was acquired by Qualcomm.

Gavin Leach is vice president for finance and administration for Northern Michigan University. He oversees planning and implementation of various operations at NMU and is overseeing a WiMAX network deployment using UBS spectrum.

Kris Rinne is senior vice president for architecture and planning at AT&T, and we welcome her back. She was here on an earlier panel. She oversees all of AT&T's network planning and architecture, including wireless networks.

John Saw is senior vice president and CTO for Clearwire, which, as most of you know, is rolling out a 4G network right now. He's the chief architect of the company's advanced wireless network and structure technology.

And finally, we have Bill Stone from Verizon Wireless, where he's the executive director of network strategy and he is responsible for Verizon Wireless' advanced network planning.

So, thank you all for coming. We have

several panelists from the FCC. We've got Nese Guendelsberger, who is the acting chief of the Spectrum and Competition Policy Division. We have Blaise Scinto, who is chief of the Broadband Division of the Wireless Bureau. Carlos Kirjner will be joining us, I hope. He is the senior advisor to the chairman for Broadband and is helping to lead the broadband initiative here at the Commission. And David Goldman, on the other side of the room, is an acting legal advisor for Wireless in the Office of the Chairman, and he is part of the Chairman's team thinking about wireless issues.

So, let me just talk quickly about the format we're going to do. In lieu of the usual side presentations, we decided to pose a set of questions to each of the panelists, a different question for each panelist in advance.

Each panelist will have a few minutes -- three minutes, specifically -- to respond to the question. I think what we'll do is just go through panelist by panelist so we can cover all the bases. And then once that round of questioning is up, we'll open things up and have a more interactive discussion with the panelists, the questioners, and the audience.

So, why don't we start with question number one -- or I'll start with question number one for Kris. According to press reports, iPhone owners download applications, stream music and videos, and browse the web at higher rates than average smart phone users and at times they use as much as 10 times the network capacity as the average -- versus the average smart phone user, and this -- in response, AT&T has been upgrading network capacity. I think that's been in the news as well. The question we want to ask is, not everyone has an iPhone today, but the day is coming soon when every mobile user is going to have an iPhone or an iPhone-like device with a similar usage profile. How does this impact your spectrum needs as you look forward?

MS. RINNE: So, AT&T, over the last 3 years, has seen a 5,000 percent increase in our wireless data usage and, at the same time, our voice usage continues to rise as well.

So if you look at that, we would anticipate that as devices have faster processers, connectivity, that's high speed and reliable, lower latency, et cetera, we would continue to expect to see that continue to rise in terms of the demand similar to what we see in our IP backbone networks. In our IP backbone networks we're seeing about a 40 percent increase year over year in terms of the overall throughput. And if you subdivide those categories further, about 35 percent of that traffic right now is video and that's growing at a rate of 70 percent per year. And so those, extending to endpoints, including wireless devices, we would anticipate that would continue to be the case.

Obviously, that has driven us to purchase the AWS spectrum as well as 700 spectrum. It's driving our business case in terms of implementing the Next Generation of technologies, LTE in our roadmap, continuing to drive more spectral efficiency through enhancements that we provide to our HSPA networks as well as that drive towards the LTE networks. And so we would anticipate that over time, that there will be a challenge for this scarce national resource that we manage, that being the spectrum demand for our customers.

I think it's important as we think about this policy that we look at scenarios like global harmonization, having some predictability in terms of how that spectrum could be utilized by the operator. And so looking at those kinds of challenges are things that we will need to take into account, also ensuring that we're looking at it from band plans, et cetera, from a very efficient standpoint in terms of the spectral efficiency improves as you're able to have larger blocks of contiguous spectrum and are able to manage that from an end-to-end perspective as well.

So, I think those are all key aspects. Obviously, we are seeing significant growth on our networks today. That's what's driving us to continuously upgrade the capabilities of our network, reposition our spectrum for the most efficient capabilities, and deploy the Next Generation of technologies. So I look forward to the questions.

MR. LEIBOVITZ: Thank you. So, I think Blaise will ask the next question.

MS. SCINTO: The next question is for Bill Stone of Verizon Wireless. Verizon has been aggressively pushing its wireless data services, but it still has tens of millions of customers who are significant consumers of voice services. So, the question is, what are your options to evolve the Verizon network given your current spectrum holdings as more and more of these customers move to broadband? And in doing so, how are you going to ensure the most effective and efficient use of the spectrum?

MR. STONE: Thank you. Let me start off by echoing what Kris said. We've been experiencing very substantial data growth here in the very recent history. And if you turn the clock back a few years, or actually several years ago, of course we hit the shaft and the hockey stick with voice as well. And I want to emphasize an important concept and that is that the device that we have in the market today is both a broadband data device and a voice device, so this shift to broadband really isn't a shift, per se. It's incremental usage being created either by the same device, you know, of a typical voice user or a complementary data device, such as a MiFi device or an air card, things of that nature. So, we're dealing with incremental growth, not a shift of voice to broadband.

Now, what options do I have? The first is technology evolution. Kris touched on that. Just want to add a little more to that discussion with a historical perspective on voice. You know, when I started in this industry 20-some years ago, it was all based on analogue. And since then we've evolved to CDMA technology, we've started with IS95, continue to evolve and improve the technology. And over that period of time, we've increased the calling capacity of a cell site or spectral efficiency by greater than a 10 times factor. So, we're pushing the envelope already and using the spectrum very efficiently. And, in fact, if you look at Shannon's limit, we're right up against that already.

So, I would contend that there's little opportunity left with the actual technology evolution as we move forward with data. Data technology has been pacing right along with voice. For the most part what you hear about is speed increase, which, of course, is true. Back not that long ago we were, you know, in the kilobits per second range and now we're talking megabits per second for average data rates and peak data rates.

So, what other options do I have? We can continue to optimize network design -- cell splitting, use of picocells, femtocells -- put the spectrum to use in the hottest parts of the network. And there are some promising opportunities there. I'm sure others will talk about heterogeneous networks and some of what we can do to enhance capacity as we go forward by optimizing the network design. But even that is somewhat limited by several practical constraints. There's only so much real estate out there, so what we did with voice and what we'll have to do going forward with data, as Kris previously said, is grow into more spectrum. We were actually not able to keep up with voice entirely within the cellular spectrum and we had to use PCS.

And going forward for data, we're going to have to use AWS and 700 megahertz to keep up with the data growth.

Thank you.

MS. GUENDELSBERGER: Actually, I would like to ask Gavin a question. At Northern Michigan University we heard at the introduction that you actually started deploying WiMAX networks, but you also had a Wi-Fi network. I was wondering whether -- why the university decided to have two separate networks: One based for an unlicensed use of the spectrum the other actual licensed spectrum? And in terms of -- because you've already deployed those, and you have some experience on the ground, what can we learn from your experience about the demand for 4G spectrum?

MR. LEACH: Well, on our campus we've had a Wi-Fi network that's pretty robust. It covers all of our buildings and then probably with inside the campus walls, in a sense, is you had wireless access. We have 802.11n deployed throughout our campus, and that met the needs of our students when they were on campus and the students that lived in the residence house.

We're a town -- we're a population of about 9,500 students and of the 9,500, only about 3,000 lived on campus, so we'd have 6,000 students that left the campus at night. And we live in Marquette, which is a rural area in the Upper Peninsula of Michigan on the south shore of Lake Superior, so many of those students either couldn't afford broadband or didn't have access to broadband in their homes. And so we had started a program about 10 years ago where we provided all our students with notebook computers on a 2-year replacement cycle, and a lot of our courses and materials that they use are online. So when they went home they needed to have that access. And so we looked at -- that goal of that program was equal access to equal technology.

And so we have -- the other piece I'd like to say is we have about 40 percent of our students that are need- based students and receive PELL. And so we provided them with the technology through tuition and fees, and we wanted to expand that off campus for them. On campus they could get it; when they left campus, they didn't.

So, we tried some hotspots throughout the city and that reached a few of the students, but it really couldn't reach the mass of students, the 6,000. So when we researched the technology that was available out there, we believed that WiMAX was the best technology to fit our needs and so we moved forward with acquiring an ABS license. And we went out and we deployed that this fall to our students and right now that is in production. It's being used pretty heavily already and we're going to research that over the next year as to fine-tuning the system.

And what we'll do is next fall -- we have 3,000 students that receive WiMAX computers this year because (inaudible) included WiMAX cards in them. And next fall, the remaining 6,000 students will receive notebook computers with WiMAX cards in it, so then we'll have basically 9,500 students, you know, on our WiMAX network. We encourage them on campus to continue to do the Wi-Fi. And then when they're off campus, it expands their access and then they can communicate, you know, right from their homes with other students. They set up group chat discussions, video links. It really expands their opportunities to access to education as well as communication outside the classroom with each other.

MR. LEIBOVITZ: Gavin, how much spectrum are you using?

MR. LEACH: Thirty megahertz.

MR. GOLDMAN: I have a question for Mr. Saw. We can tell from publicly available records that Clearwire has a substantial spectrum holdings, up to 150 megahertz even in some areas. Obviously, this can lead to very high data rates, but what else can you do with big blocks of spectrum like this from a network perspective?

MR. SAW: It's true that Clearwire has a strong spectrum position, but, as we all know, not all spectrum is created equal. You know, we do have to work through different licensing rules and encumbrances and that actually, in many cases, limits our use of spectrum especially the midband channels. As we know in the EBS BRS band is reserved for high-power services. And, you know, having said that, what we're trying to do at Clearwire is to couple 4G services with mobility. And you mentioned the obvious leverage for spectrum is for high data rates and to get enough capacity, but that takes a lot of spectrum.

What we're trying to do is to deliver to our customers an average of 3 to 6 megabit per second wherever they are in our coverage area, indoors as well, and that takes a lot of spectrum. The ITU themselves have recommended that in order to do this, you know, in order to offer true broadband services, you need at least a minimum of 40 megahertz of spectrum, ideally 100 megahertz of spectrum, just for us to be able to offer it to our customers, the experience that mimics, as close as possible, to the broadband experience at home.

So, if you take all of this into account, you know, how we design our network -- you know, I'm an engineer, so I could use all the spectrum that I could get to make sure that my customers have the best experience possible; there's not much spectrum left for other applications. We are looking at where we have other spectrum opportunities, solutions like in band backhaul for picocells. As we know with 4G, you know, you need solutions besides macro cells to deliver, again, high bandwidth to where your customers are -- indoors or in the offices -- and picocells is a good solution.

You know, the big challenge with picocells is that trying to find backhaul is often the cost constraint. If you're not careful, the backhaul could cost more than the access itself. So in band backhaul sounds like an opportunity that we could leverage with the spectrum that we have, but then we have to be sure that you have enough spectrum to deliver the capacity that your backhaul network would require.

MS. MILKMAN: I don't know how to pronounce Mr. Laroia's name because I wasn't here at the very beginning.

MR. LAROIA: That's right.

MS. MILKMAN: Was that right? Good. You helped pioneer the OFDM technology that's foundational for 4G networks. How should we think about the spectral efficiency of this technology going forward? And what are the practical limits of this technology in the future?

MR. LAROIA: I love OFDM and I'd love to

tell you that, you know, it'll solve all your spectrum problems, but, unfortunately, that isn't true. OFDM is a really good technology. You know, it does offer advantages, but, you know, we heard -- we were all -- we have networks that do voice, right? Voice is 4 to 8 kilobits per second. Now, we just heard doing data of 3 to 6 megabits per second. That's three order of magnitude higher toward bits being spent in doing data.

We also heard from Kris 5,000 percent increase in network usage and 70 percent increase year over year in video. You know, technology doesn't offer year-over-year gains. You know, going to OFDM will not give you year-over- year gains. Maybe a small gain one time, but it's not going to solve any of these problems, the ones we are staring at.

So, technology has its role and I think, you know, the world's already -- 4G is already going OFDM, but I don't think, you know, that technology itself is going to be the solution to all the spectrum needs. Spectrum is going to be the solution to spectrum needs.

And so there's one more thing which I think you mentioned that we can do in the meantime is, currently, in sort of getting gains from technology, it's actually much better to get gains from system design. Currently, you know, all our cellular networks are designed towards, you know, cells that have a mile or two of radius, which means all the available spectrum is used once in that footprint of that cell. If we could reduce the footprint of cells and go to smaller cells and maybe go to femtocells, then what you're doing is you're reusing the entire available spectrum much more often in the geography and you're creating, effectively, more spectrum. So, you can do this where it is feasible to do this easily.

The other problem this solves is actually the link budget problem, the uplink, because mobile devices have inherent power limitations. If they're talking to a cell site a few miles away, they can only get certain data rates, but if they're talking to something a few meters away, they can get much higher throughputs in the uplink and in the downlink. It also solves the reliability of coverage for voice.

So, this is one approach to creating more spectrum, but this should go hand-in-hand with just allocating more spectrum because the needs are obvious from what's being described here. So, I think I would love to tell you that OFDM will solve all your problems, but I have to tell you that it wouldn't.

MS. SCINTO: I think the next question is for Mr. Gupta. We've heard from some of the other operator representatives about the explosion in needs for data in the wireless last mile. How should the FCC consider the implications of this data surge for backhaul spectrum? And what are the drivers of spectrum scarcity for wireless backhaul?

MR. GUPTA: So, thank you. So, what you find is that it's -- just listening to everybody on the panel so far, it's fantastic, because

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you're seeing tremendous growth side from the consumer and from corporations, anybody and everybody using not just voice, but also data, whether it's video, whether it's surfing the web, whether it's checking e-mail or whatnot, but the applications are getting there and the demand is getting there.

What needs to happen from -- what I believe is we need to set aside specific spectrum for backhaul because just allocating spectrum, as Rajiv was saying, is part of the solution. But if that's being used for other applications, again, like access technologies, it doesn't really help. As John was mentioning earlier, you know, you're seeing this 3 to 6 megabits per subscriber being out there. If you see, you know, 10 to 100 users in any cell, you'll need at least that kind of capacity coming through the backhaul link because the backhaul link tends to end up being the critical path to bottleneck in the whole entire, I would say, spectrum food chain.

And so, what needs to happen is as you

allocate spectrum specifically for backhaul, then I think, you know, the industry can mobilize around creating solutions, creating equipment, creating low-cost installations, creating standards that will solve this problem and not be distracted with, you know, handset issues or not be distracted with device issues or anything that goes with the access side of the technology.

The other item I see that comes with the spectrum is the spectrum that needs to be allocated, once again, is sort of compounded by the access spectrum and just allocating more to provide for that large PIPE, but also needs to be usable. And so -- but when I say usable is it needs to be low enough where you can shoot long distances, where you don't -- you're not limited to a couple hundred meters or a mile or so because you're seeing the cell densities shrink to a mile or even smaller than that. But you run out of line of sight challenges, so if you can bring in non-line of sight opportunities or bring in the opportunities for you to do something creative, like a multipoint scenario or something like that, what you'll get is more flexibility and more use of that spectrum to solve these types of problems.

MR. LEIBOVITZ: Thank you. Okay, so now we'll open up the discussion.

MS. GUENDELSBERGER: Actually, I have a follow-up question. I was -- I mean, can you explain to me if you actually are asking the FCC to set aside or somehow allocate the spectrum for backhaul, how would that approach -- sort of help in giving that today. Actually, spectrum out there, we are not necessarily saying people have to use this for access. It's -- some of them is allocated either fixed or mobile, but it is what you provide over it. It's licensees has flexibility. How would changing that approach will help the backhaul or the last mile issues that we are discussing here?

MR. GUPTA: That's a great question because in some of the large block spectrums that have been allocated, whether it's the PCS band or the cellular band or BRS or whatever it ends up being, people can absolutely use that for in-band backhaul as you're describing.

What you find, though, or at least what I believe is happening, is companies are making the decision of, well, do we want to allocate this to backhaul, which is a cost- reduction effort, or do we want to allocate this towards the consumer, which will enhance their experience and enhance their handsets and market share and whatnot?

At the same time, what you're finding is a lot of those -- a lot of that initial type of block mobile spectrum was auctioned. And so a lot of these companies are trying to figure out, well, I auctioned or I spent 2 to 5 to $7 billion for this spectrum. How do I want to use it? Once again, is it sort of saving my 10 to 15 T1s or T1 equivalents that are there today? Or do I want to take it out there for the consumer?

What you're also finding is the -- I think the backhaul bottleneck is just really now being understood. I mean, I think people have always thought about it in the past and you could say I could order another T1 or I could order -- put another link or I can do some creative sharing of bandwidth or whatnot, but now that you're getting this 1 megabit-plus to 10 megabits, and as John was mentioning 3 to 6 megabits per user as a desire, you're finding that the backhaul just isn't going to cut it. So, reusing or optimizing what's in place and already existing and been in the ground for 10 to, you know, 70 to 100 years, probably isn't going to work anymore. So I think by allocating the spectrum in this regard and using processes that the FCC is already aware of, like Part 101 rules and how you license this spectrum and how it's allocated and who gets access to it and the fees associated with it, this, I think, it's just -- by doing this, we're able to create a lot of impact without creating a lot of burden.

MR. LEIBOVITZ: Thank you. I want to just ask a broad question of the panel, which is about analytics. So, we have, you know -- there's hundreds of megahertz of allocated spectrum, we have 270 million mobile users today, tens of millions of mobile broadband users, maybe eventually they will -- mobile broadband will fully penetrate the 270 million. You've got devices that can go from kilobits per second to megabits per second. What's the right way for us to quantify, what's the math we should use, to understand how much spectrum we need?

I can't think of a better group of people to give us some pointers on how to think about the math.

MS. RINNE: In preparation for the World Radio Conference in '07, the ITU did develop some documents that focused on that specific issue and that recommendation was that we needed to find about 1,280 megahertz of spectrum for the 2020 timeline. And if you read through those ITU documents it's focused on a lot of the same products and services we're talking about here. We haven't raised machine-to-machine much, but also talking about those in addition to video services, et cetera. And even in that conference they found maybe 400 megahertz of spectrum. And if you look at that 400 megahertz of spectrum in the U.S., some of that's already occupied. Then you take into account how we might compare where we have a larger number than competitors in other places and the law of large numbers also impacts that overall efficiency, et cetera. So, I don't think there's a magic number, but it's a big number, whatever the magic number is.

MR. LEIBOVITZ: Are you saying -- are you suggesting that the ITU recommendation for 2020 is, I don't know, 10 years too late or something? I mean, we're approaching the use case that they described in their document much faster than --

MS. RINNE: I'm not suggesting that it's coming sooner than that, but if you're trying to look from a spectrum management standpoint, look at how long from the time you made the forethought -- you had the foresight in terms of how to focus that 700 megahertz, when that decision was made to when we'll start seeing traffic on that spectrum.

Our planning needs to begin now was the main point.

MR. LEIBOVITZ: All right. Bill, do you have any thoughts on that?

MR. STONE: About all I can add to that is the government needs to be looking about five-plus years. As we've talked about, you know, the spectral efficiency gains, the opportunity there is minimal. You're at 1 to 2 bits per hertz per second today, and it's not going to get a whole lot better. And you can quantify, to some extent, as you lead with, John, the number of potential users, but the real variable here and the big variable that drives the wide swing and potential spectrum need is the usage per customer. There's this wide range of bandwidth-hungry applications that are currently emerging. Video is a classic example. The more users that adopt those applications and use them frequently, the more spectrum we're going to need and I couldn't agree more, we've got to start now and look out five-plus years and plan for the future.

MR. SAW: Just to build on Bill's point is that it's the end user that is using up a lot of the new applications and they are driving tonnage that, you know, is growing year by year. I think Kris mentioned that it's grown more than 70 percent for video. And I think what we're seeing right now is for a mobile user, you're using about 1 gigabyte of tonnage a month and we expect it to grow to 15 gigabytes or even higher as you look at more streaming, real- time services.

It's a double-edged sword. As you build a more capable network what we learn is that the customers will learn the bandwidth and the developers will find new apps to run on those bandwidths and we need the spectrum. And I think not only do you need to have a lot of spectrum, I think that's what some of us are saying here, but you also need to have contiguous blocks of spectrum to really be able to deliver the true bandwidth -- the broadband experience.

You know, John, you asked for some

simple math and at the risk of making it too simple, you know the ITU advance are looking at the 4G standards. You know, the (inaudible) really stands in a WiMAX 16M. They are talking about two 20 megahertz channelization, right. If you want it to have a decent reuse, you need 16 megahertz on a tower for a 3-sector site. Correct?

Now, somebody has to pay for all this because the only way for us to actually make money then is to still have enough customers. So you need to assume that you need two carriers on every sector, which is a very decent assumption assuming that you're going to see this tremendous growth in broadband. You're looking at 120 megahertz right there of spectrum to really deliver true broadband services to your customers wherever they are and they are no longer tied to their landlines. But those are the numbers that I'm looking at.

MR. STONE: Just one other comment as well. In addition to contiguous blocks of spectrum, I think it's also important to note that the spectrum needs to be free of encumbrances, things like complex rules or potential sources of interference. These things drive complexity in the device, which drives up cost, which makes it very difficult to bring the product to market or bring new technology and new services to market in such an environment. And also it limits the ability -- or, I guess, going back to the technology, it limits what you can do with the technology in terms of the actual spectral efficiency. So, in addition to the contiguous blocks, I think it's also very important to consider that it needs to be free of any encumbrances as well.

MR. GUPTA: One additional data point to add there is as we look at -- as FiberTower looks at sort of their backhaul, the cell backhaul line of our business, and understands and tries to understand and predict what type of network we need to build to service our customers, we've done some analysis and it tends to show that in some of the rural markets a cell site can cover as many as

1,000 subs whereas in some of the denser markets you can get a -- it comes down to about 660 subs or so. And so if you look at those sort of numbers and try to put an estimate as to how much bandwidth they will use, whether it's 1 to 3 to 5 megabits per second, that's, I think, using that plus the bit per hertz or 2 bit per hertz as you're looking -- you can sort of work backwards and understand the type of spectrum that we're looking for.

MS. SCINTO: I just wanted to ask maybe for a little bit of unpacking about contiguous spectrum blocks because I think several of you have alluded to the fact that sort of the spectrum portfolio that you're working with includes cellular, PCS, AWAS, you know, and other bands, and obviously there is non-contiguity between those blocks. If you could sort of unpack for me what it is in terms of contiguity, what sort of a minimum amount. And then how are you using the uncontiguous sort of different bands that you're using together to develop the 4G services?

MS. RINNE: I think just a general rule would be the larger the block, particularly in OFDM technologies, the larger the block, the more efficient you are on a megabits per hertz standpoint. So, if you would take, even with an OFDM technology, if you would take a five up and five down, it's not tremendously more spectral efficient than the CDMA technologies that we're using today in HSPA and EVDO. But if you are able to expand that to larger contiguous blocks, 2-by-10, and ultimately 2-by-15, 2-by-20, you get more bits per hertz.

MR. STONE: Just to build on that a little, when we move forward with LTE, we are starting with 2-by-10 and, you know, I'm thinking that is the minimum that we would want to implement on a go-forward basis. If we could do 2-by-20, we would, but, you know, we have to work within the portfolio we have today, so 2-by-10 is the best we could do and certainly going forward, at least 2-by-10, preferably 2-by-20 or more.

MR. LEIBOVITZ: Let's say there was no

new spectrum put on the market. Where would you get that 2-by- 20?

MR. STONE: I couldn't --

MR. LEIBOVITZ: This is a question about refarming, so, I mean, you have a bunch of voice --

MR. STONE: Today, you know, we're using our existing PCS and cellular spectrum for voice and data with 1X and DOrevA technology. I just mentioned, we're going to build out 2-by-10 of LTE for GOFDM technology in the 700 megahertz spectrum initially.

Now, over time, you know, as you move into the future, I do anticipate that we'll eventually move voice over to data or over on to the broadband access technology using VOIP on LTE. However, as it stands right now, I don't anticipate that we're going to see any major -- or any material spectral efficiency gain. In other words, the amount of spectrum that's consumed today on 1X will be the same as we move into the future. But what that does enable me to do is to, over time, to free up cellular and PCS spectral. So, when I say we're going to grow in 2-by-10 chunks, we will grow, eventually, back into the cellular and PCS spectrum as well.

MR. LEIBOVITZ: Thank you.

MR. GOLDMAN: I have a question for Mr. Leach, actually. From a practical perspective, because I know you've been working with this now, I know you have both a WiMAX and a Wi-Fi network on your campus. Have any spectrum concerns led you to encourage the users to use one network over the other? And how do you manage that?

MR. LEACH: Well, we encourage them, I think I had mentioned earlier, is to use on campus, us the Wi-Fi, because I mean, it's faster, you know. We have better connections with that as far as speed and the broadband. But as they move off campus, that's when we prefer that they use the WiMAX because they can get what they need as far as education resources, they can get to the research. That's the encouragement.

It's really -- we use WiMAX to expand

our network into the community and where that's going to go is there's a lot of applications that we're going to start to look at using. You know, you get into home health and nursing and those types of things. I think, you know, you look down the road is there's going to be applications where you can, you know, from a broad distance, especially in rural communities, is it's a way to start servicing people out in the community through home health. You have -- you get people out doing research, they can get in contact with -- back with the resources that they need out in the field by having access.

The communication aspect, we live in an area where we get 300 inches of snow a year, so a lot of times people are homebound for a few days and they don't lose that access.

They still have the connectivity back to the resources that they need, they still can conduct their research, they still can communicate with their classmates, with their professors.

The capabilities just broaden the

experience for the students and allow them to have the access that they need out in the field.

But there's many services. I mean, the services, you know, you look at governmental services, those will expand. You know, one thing we did right away is in security, is most of our buildings have surveillance systems in them. So we put WiMAX computers in our public safety vehicles, so if there were an incident in a building, they could arrive and they could see what's going on in the building right from their car before they ever get out and see the action happen.

So, it's a -- the capabilities are there. It's really just, you know, on campus we use the Wi-Fi and promote the expansion of our network and access off campus for a multitude of applications, and I think it'll just continue to grow.

You had mentioned earlier about how much spectrum is going to be needed. I think, being part of a university, from where we were 10 years ago to how much students use today on our network, whether it be our Wi-Fi or our WiMAX, it grows exponentially every year.

MR. LEIBOVITZ: Do you think there are any lessons from the student behaviors since students tend to be ahead of the curve sometimes with some of these things, that some of the commercial operators might -- any numbers or statistics or anything that you can share?

MR. LEACH: Yeah, you know, I don't have any numbers off the top of my head, but I can just tell you is every year is we're constantly expanding our network and our resources. There's new applications that come out all the time and it's just a continuous exponential growth in the need for broadband on campus and off campus.

MS. GUENDELSBERGER: Is this just open to your students or anyone in the local area could actually use your networks?

MR. LEACH: What we've done is we've just provided access to our students and faculty and staff. However, we also -- because of where we're located, we're a primary resource for the region. And so what we've been also doing is within our license helping out the K-12 schools in the area, providing connectivity to them and their teachers. We also work with the city and township governments in connecting their buildings for them because they didn't have the abilities to do that. So that's part of what we do is trying to help our area and help the community and so that's, you know, just part of our overall goal.

MR. LEIBOVITZ: All right. We have an online question from Craig Chatterton. "During 30 years of cell phone technology, we have increased coverage areas and bandwidth. However, reliability has not significantly improved. Calls drop, are occasionally not understandable, and there are many areas without coverage. We tolerate this in return for the convenience mobile technologies offer. The question is, aren't we kidding ourselves to think that this technology and Next Generation WiMAX LTE can provide the reliable broadband required by critical real-time applications such as telepresence, collaborative health care, particularly for in-home users in difficult line of sight areas that contain large buildings, hills, trees, et cetera?"

And I guess I would -- just to bring it back to the central topic, what does this question -- how does this relate to our spectrum needs?

MR. LEACH: I'll start out with for us, it is a technology that works in different types of terrains, especially in a rural area. Marquette is -- we sort of have two valleys in the city and a lot of trees and a lot of different minerals in the area that can affect things and the weather and the snow. And we find that this type of technology, at least WiMAX for us and our solution, is -- works pretty effectively in meeting the needs.

MS. RINNE: And if you look at the accessibility and retainability over time, that's continuously improved. And the spectrum has an impact from a standpoint of the -- how often you have to reuse it in order to use the same capacity impacts, number one, the availability for a handoff when that's -- whether you may have a restriction and cause a dropped call because there just wasn't anything to hand into because of a spectrum limitation, and also from an interference standpoint. So it does impact the quality.

MR. LEIBOVITZ: So just to follow up on that, I mean, someone had raised earlier the point that -- I think it was Dr. Laroia, that there is this tradeoff. I mean, if you think about multiple dimensions of adding capacity to a network, one is technology upgrades. I guess we're hearing from Bill that we're reaching a limit on that just in terms of at least the (inaudible) interface, the pure bits per hertz. The second is more spectrum, which is, of course, the topic of the day. And the third would be greater reuse, spatial reuse. You buy shrinking cells or otherwise.

And so I guess am I hearing from you that there are limitations to how from a technical network performance perspective you can reuse spectrum based on cell splitting or picocells or --

MS. RINNE: And we have done a lot of overlay/underlay scenarios to where, historically, cell-splitting increases that frequency when you think about it from a horizontal standpoint. So we're also doing that from a vertical standpoint in terms of picocells and, ultimately, femtocells in terms of being able to reuse that spectrum in smaller and smaller pieces. But you still manage -- if you're not able to dedicate to that, to those underlying bands, then you still have a reuse interference potential, which you have to manage your way through.

MR. STONE: And John, I completely concur. The only thing I would add to is that the process of cell- splitting, adding macrocells, picocells, femtocells, is also a lengthy process. It takes time, you know, often 12 to 18 months or more to construct a macro site and, you know, to get, as we talked about before or one of the other panelists mentioned, to get backhaul to a femto or a pico location. So, yeah, there's opportunity here for more of that, but it's not, you know, going to get you 1,000 percent a year. It just doesn't move that quickly.

MR. LAROIA: Also, if I may add, when you deploy femtocells, you create a lot of capacity for somebody whose home it is, but not for somebody who's just walking by. In fact, you probably create a hole in coverage for somebody that's walking by the house, so it doesn't solve all problems. And unless backhaul problems saw that every femtocell can be provided backhaul not dependent on the backhaul that the user, the house owner brings, you know, you wouldn't have capacity for everybody using femtocells. But by adding more bandwidth, you create capacity in the macro network for everybody.

MR. LEIBOVITZ: So, how do we think about -- again, bringing it back to the math/analytics question because there are some people in this room who are doing that late at night, how do we think about the limitations? You know, is there a minimum size that you can make a cell site or are there any rules of thumb that you can share with us that would be useful? Maybe too complicated to have a rule of thumb, but I just thought I'd throw that out there.

MR. STONE: I mean, it really varies widely across the geography. You know, in the most dense, urban markets, you know, the cell site radiuses are down to a few city blocks, so we are pushing the envelope in terms of just how far you can go with a macro system. You know, I think most of the opportunity in those areas lies with pico and femto and that really comes back to the availability of backhaul. So I -- I'm not giving you an exact answer, but it really varies widely based on the geography and whether you're using macro, pico or femto. A femto, as we just pointed out, can just cover a few rooms in a house. You can get that small.

MR. LEIBOVITZ: And by the way, I forgot to welcome Ruth, Wireless Bureau chief at the FCC.

MS. MILKMAN: Ruth's filling in. I am

not Carlos Kirjner.

Following up on the backhaul point because backhaul keeps coming up, what we haven't really talked about today is the tradeoffs between wireless and wireline backhaul. How do you make the decisions? Maybe this is a question first addressed to Mr. Gupta. How do you think about the tradeoffs? You mentioned more spectrum that was dedicated to backhaul, which suggests that the market alone isn't going to drive carriers or licensees to decide to use the spectrum for backhaul in most cases because they perceive a greater value in using it for customer access. Does that then drive you to wireline? How should we be thinking about this?

MR. GUPTA: I think too, when you look at backhaul, it should be viewed as a business problem, not a technological problem. And so backhaul can be solved and is mostly, in the United States, solved with wireline solutions and will continue to be so for the next several years. And so, I think it'll end up being, you know, what problem are you trying to solve at that specific site? So, if you're trying to solve a femtocell problem, you know, maybe DSL or the cable modem will work. If you're trying to solve a problem that is, let's say, downtown Manhattan or downtown Washington, D.C., where there's a cell site every couple blocks, maybe the 80 gigahertz wireless solution will work or a fiber-based solution will work. If you're trying to solve a cell site that's in a suburban area, maybe the FiOS U-verse or cable plant will work, or wireless will work on top of it.

So, I think it ends up being a solution where it's part of the tools in the toolkit and basically the specific site economics and the specific area in a site you're trying to solve for, that solution will rise to the top.

Now, I think there's a value of redundancy and diversity in there as well associated with that, but that's part of the business case evaluated.

MS. RINNE: And the focus on forward

technologies, I mean, the implementation to fiber, particularly in the urban areas where you've got collocated sites, AT&T is being very aggressive in the fiber implementation and then the migration to Ethernet technology there as well.

MR. SAW: I think the other point to that is, you know, for a smaller company like Clearwire, our experience has been -- I agree with Kris, you do need to look ahead at what you're trying to deploy and what a customer is going to use. I mean, for 4G broadband mobile services you're looking at a minimum of 30 megabits per second per tower and any growth from there.

So, you know, if you look at what options we have to get a viable backhaul solution, we'll look at using a lot of microwaves, and we do. Ninety percent of our cell sites actually uses microwave point-to-point links. We use the common carrier frequencies, 18 and 23 gigahertz, that gives us a lot of bandwidth at those frequencies and the radius are fairly reasonably priced these days.

But we sort of look at it as a hybrid solution as well because at the aggregation points for all these microwave links, we bring them back to fiber hubs, where you could take advantage of the metro (inaudible) and the metro fiber solutions. So, that solution works for us and we view that for a company like Clearwire that may not have all the fiber assets that AT&T has. That works well for us in terms of our total cost of ownership.

You know, we have some lease line sites and, as we know, a lot of cell sites in the U.S. still has copper running to them. It's hard to look at an Opex case because you need so much lease lines. You need to start thinking will DS3 actually start offering 4G services? So we do have a limited number of those, but we found out that the lowest cost option is just to use a combination of microwaves and fiber at the hub sites.

MR. LEIBOVITZ: David, did you have a question? Okay, I just wanted -- so we've been talking a lot about quantity of spectrum, I want to turn a little bit to quality of spectrum. So, we've already touched on the contiguity/encumbrance issue. What about frequency band? Obviously lower spectrum propagates farther, but I was wondering if you could maybe touch a little bit on the tradeoffs. How high do you think we can go practically these days for a mobile system? How low can we go for a mobile system?

MS. SCINTO: And if I could just add on to that, sort of bringing the backhaul point in, I think some of the things that Mr. Gupta was saying about sort of dedicated backhaul, how do you make the tradeoff between -- you know, if you're arguing that you need to have spectrum available that's dedicated for backhaul, how do you make the tradeoff between backhaul and non?

MR. LAROIA: So, I guess use of spectrum for mobile services will be somewhere between 300 megahertz and 3 gigahertz. About 3 gigahertz, you know, microwave don't really bend around corners, so coverage is harder to get. Doppler shifts are much higher with mobility. I guess, below 300 megahertz the (inaudible) size probably increases to where it doesn't fit very well with mobile devices, but this is a very useful range. And the lower you are in this range, in general, the better off you are from a coverage point, link (inaudible) standpoint, and Doppler standpoint.

MS. RINNE: It does vary with the use cases as well. I would generally agree with that, but if you -- again, since I raised the global amortization standpoint, what WRC07 was looking at were in those ranges plus some at 3.5 and 3.6. And in some of the technologies that we were talking about from a picocell, femtocell standpoint, there are applications for that as well. So, I think you have to look at what is the total use case and what are we trying to solve for? Is it capacity or is it coverage? And those answers can be different depending on the demand.

MR. LAROIA: And I should qualify, these are not hard limits, of course. If other things dictate, you can go higher, but that's just a general guideline.

MR. GUPTA: I think from the backhaul standpoint, it's interesting because we're seeing cell sites. If we just look at cellular backhaul, you see cell sites continue to get closer and closer to the ground, to sort of maximize throughput and not really have the umbrella cells that they used to have in the past, you know, 20, 20-some years ago. And so because of that, that's making, from a microwave backhaul standpoint, at least in wireless technology, it's making line of sight that much more difficult. And so, there are opportunities to do that, to put in microwave, like Clearwire is doing, or even internationally where there's quite a bit of microwave. But once again, as the cell sites begin to come down and move towards the limit of femtos, you're not going to have that occur. And so, therefore, sort of you need that lower frequency band, you know, the sub-3 gigahertz frequencies, as much as possible to be able to get the range, to be able to utilize a non-line of sight type of technology, and to leverage a fixed application where you can do some high data rate throughputs.

MS. GUENDELSBERGER: I actually want to understand better capacity versus coverage relationship and also how that interacts wherever you are, whether you are in the urban areas versus you're in the rural areas, both capacity, if you want to have larger capacity versus more coverage, how that relates to the spectrum needs.

MS. RINNE: So --

MS. GUENDELSBERGER: It's a general question, it's not just --

MS. RINNE: The capacity, as you look at what we're doing today with what we've re-farmed technologies by implementing HSPA in the 850, that gives us some coverage, deeper penetration, yet we're still utilizing those 1,900 HSPA carriers for handling that overall capacity. And if you take that further and you think about it from a vertical standpoint and you move towards pico or femto solutions, some of those higher frequencies, when your goal is to provide greater capacity in a smaller radius, there are opportunities there versus if you're trying to address rural area, significant coverage areas, not so much capacity restrictions, but coverage areas, then moving into the 400 megahertz would be beneficial from that standpoint. So it's modeling those different use cases in terms of what we're trying to solve for.

MS. GUENDELSBERGER: And the spectrum needs for rural versus urban are same? Different? Or if they are different, how they are different?

MS. RINNE: The demand is different and -- but again, it depends on the household densities, that coverage having contiguous spectrum bands in order to improve the propagation standpoint leveraging that capability as well. So the demands, from a capacity standpoint, are apt to be different, but you have to look at every situation uniquely.

MR. LEIBOVITZ: Just extending that point, how does having more spectrum potentially affect your ability to -- so typically divide the two categories -- capacity, but as I understand, there's a relationship. If you have more spectrum, you can tolerate more noise at the edge or you can have -- so, how does having more spectrum affect your ability to serve rural areas irrespective of the frequency that you're at?

MS. RINNE: Assuming there's a certain level of household density, having a 2-by-10 would enable you to serve more households with that one cell site, so your common costs are spread across a broader amount of users. So, it's very similar to the mobility environment.

MR. LEIBOVITZ: Okay. And we have another question from online, from out there in the Internet, from Chris Regan. "Are white spaces a potential solution to efficient spectral use?"

MR. GUPTA: So, let me start with that. So white space is absolutely the answer, yes. I mean, there's many unused white space channels today that are out there in different parts of the country. It varies to how many are being unused. But from a backhaul perspective, you can put in links that are anywhere from 50 to 100 miles long and you can get anywhere from 20 to 50-plus megabits of throughput. And so, if you think about what can be used from a backhaul standpoint, you can put in a single 100-mile link to cover a significant area as opposed to, you know, 5 or 7 20-mile links in a row where you have line of sight challenges and your costs are extremely higher than a single link. So the answer is absolutely yes.

MS. RINNE: When you look at mobility, however, when one of those endpoints is moving, that spectral efficiency is impacted by knowing where your interferers are.

And so that end-to-end system management is an important aspect. So, I agree with what you're saying, particularly in point-to-point, but when you're looking at sharing that with something that is mobile, you can actually negatively impact the spectral efficiency.

MR. STONE: That spectrum is heavily encumbered with the issues that I was referring to previously and that's what Kris is pointing out, is that it will definitely weigh heavily both on the end user device in terms of the complexity and cost, as well as the spectral efficiency of any technology that would be used in that band for mobile. I agree with point-to-point.

MR. LAROIA: And with respect to your point-to- point and hundred-mile links, in my view, hundred-mile links are only possible over licensed spectrum. Over unlicensed, anybody else can radiate in the middle and then you thought you had a hundred-mile link, but you only have half a mile link.

MR. LEIBOVITZ: So, extending that topic to include -- this is another question that was asked online -- unlicensed spectrum for backhaul, does it -- in general, do the points you're making about the white spaces apply to unlicensed spectrum? I mean, is unlicensed sort of an adequate substitute for wisps or other small providers that might not have access to the licensed backhaul spectrum?

MR. GUPTA: I think for backhaul it has to be licensed just because the amount of throughput you're trying to maintain through that link, the quality you're trying to maintain, as well as understanding that at least for some of the mobile environment, you're finding a lot more 911 calls go through that network that previously just weren't there and it's going up. And so, from a public safety perspective and just from a reliability perspective, the backhaul link needs to be licensed.

MR. SAW: Just to -- I agree with Tarun, I think for your macro sites where you have a lot of customers, I think you need licensed backhaul for wireless backhaul. But in the Clearwire experience, we have used and we are using the unlicensed, the 5.8 gigahertz band, for some of the spur sites that doesn't pull other sites back with it through your backhaul network.

MS. RINNE: Or special events.

MR. SAW: Special events, yeah, and spur sites, that works well. I mean, 5.8 is an easier line of sight radio to align to. In fact, you can actually use quasi non- line of sight and the cost of those radios are much lower cost, so that's why we're attracted to them. So, we have used a few 5.8 gigahertz slings for backhaul, for single sites, and opportunities like that.

MR. LAROIA: Actually, in higher frequencies it's easier to use because it's more line of sight and you can direct it and get high gain Internet. In lower frequencies, a street, it's not line of sight and any interferer in the middle would just destroy everything.

MR. SAW: I agree. You need to be careful in the sense that you need to make sure that there is no other operators nearby using that -- those spectrums.

MR. GUPTA: You know, it's interesting, for backhaul, for unlicensed backhaul, you're basically a victim of your own success. It's a sense of what it ends up being that you end up putting up so much --

MS. RINNE: If you're first, you're

okay.

MR. GUPTA: Yeah, first. Exactly.

MR. LEIBOVITZ: So, I wanted to go back to the international question. So, you raised, Kris, harmonization as an important goal. I was also just wondering -- and you mentioned the 3-5, 3-6 band. I was wondering if there are other bands internationally that are allocated that are sort of, I don't know, models for the U.S. I know that -- and then just from a purely, you know, deployment standpoint, I know Flarion had done some work in the 450 band and I was wondering if you could talk a little bit about sort of the characteristics of that band and how it affected, you know, the deployment, you know, overseas and if there are any lessons we can learn here.

MR. LAROIA: Well, 450 band, obviously from a propagation standpoint, coverage standpoint, for rural areas, if you want to start a new network and cover a whole geography, you use the fewest number of cell sites and your business case is a lot better. If you start at 450, then starting at (inaudible), for instance, or up there. So, in addition, if you're providing mobile services, Doppler shifts are a lot smaller with 450, so it's a lot easier to support, you know, 100 miles an hour (inaudible) mobility. I mean, I shouldn't say -- I mean, 100 mile an hour (inaudible) mobility is also supportable by a 3 gigahertz spectrum. It's just your degradation is greater when you have a 3 gigahertz spectrum because you have to tolerate higher Doppler shifts than if you have 450 megahertz of spectrum. So, you don't effectively degrade -- the (inaudible) doesn't degrade very much and you can handle, you know, 100 miles an hour mobility very, very easily for 50 megahertz of spectrum.

MR. LEIBOVITZ: Parallel experience. I know you obviously have 800 spectrum and PCS and --

MR. STONE: Well, I agree with everything that was really just said. In terms of finding global alignment, you know, there's some opportunity in 850, some opportunity in 700, and then as we move higher in frequency, it's hard to say exactly what's going to develop. I really don't have a lot to add to what's already been said on that category.

MR. LEIBOVITZ: Okay, and this is a slightly off- topic question, but one of the audience members had this question. How do you -- how does -- I'm trying to contextualize it, but what are your plans to train people to help deploy your networks and how does that kind of affect your network deployment plans? Job training?

So, how does that affect -- this is a slightly different topic, but how does that affect your -- you know, when you think about the cost of deploying your network and so forth, do you run into -- is there a training gap? Is there something that you -- programs that you guys have that facilitates that?

MR. STONE: I know from a Verizon perspective we put a very heavy emphasis on training our field network engineers on, you know, the ins and outs of the technology, how to go out and optimize the systems. We take great pride -- in fact, you know, I would say it's in our DNA to manage these tradeoffs we've been talking about all day between, you know, technology and, you know, quality of service. And we place a very heavy emphasis on making sure our employees are well-trained and well-equipped with the proper test equipment and whatever knowledge they need to gain from the vendors to go out and optimize system performance. So we're pushing as hard as we can to achieve maximum efficiency and bring the cost of providing service down for our customers as well as maintaining the highest quality possible. So, it's paramount.

MS. RINNE: Two areas of focus: The interoperability between the device and the infrastructure is an area that is a significant focus above what you might do on our wireline portion of our business in terms of all of those different combinations, how to optimize that RF. And then the whole migration from TDM to technologies to IP technologies is another major area of focus.

MS. GUENDELSBERGER: I actually have a follow-up question. When you are planning your network to deploy -- for example, Verizon is doing some testing on the LTE and we talk about supply and demand, all those things -- when you are planning -- from a network planning perspective, you have some models for voice network. It's developed over the years. What do you do for Next Generation, 4G, and how do you anticipate what the supply or demand will be for that network? And do you have any -- I mean, I'm not sure whether you had developed a model, but what are the things you take into consideration for that?

MR. STONE: Let me start off by saying as we move forward with new technology, especially in this new world of data, it's probably more of an art than a science at this point. I'll concede that up front.

But with that being said, I mean, we have very elaborate, extensive modeling that we run sensitivities around that are primarily based on just numbers of users, usage per customer, which is heavily based on the, you know, the assumptions we make around applications and the bandwidth that will be required for these various applications. And, you know, we basically generate models that take us into the future with our -- you know, that forecast our traffic, our capacity needs, and, you know, based on everything we've been talking about today in terms of how we optimize the network, also consider how much spectrum we'll need.

So, we do very extensive modeling, but it's -- I have to say with data, we're all over the place. There's a wide range on the forecasts. You know, generally speaking, I would say we feel comfortable for the next three to five years. But there's quite a bit of risk there with the potential uptake of these bandwidth-hungry applications, such as video, plus the more users that gravitate off of PCs and onto laptops and things of that nature, you know, the sooner we could potentially exhaust spectrum and the greater our capacity needs.

So, it's just a very -- you know, it's a modeling exercise with a lot of different sensitivities and assumptions driving it.

MS. RINNE: The end-to-end management of that, though, is a key aspect. I would think you'd agree that having some sort of ability to have the end device have certain antenna qualities, what the MiMo expectations are, et cetera, to the extent that there is some level of compliance with a set of specification that the operator lays out, that impacts the overall efficiency of the network as a whole.

MR. LEIBOVITZ: Just to follow up on the modeling question and then we have a few audience questions. Do you have some -- can you share with us any rule of thumb numbers from your experience of different types of devices and what kind of traffic they generate? So, on a monthly basis or on a busy hour peak basis.

So, you know, we know that of voice -- we've heard that voice -- someone mentioned earlier voice calls, 10 kilobits per second or less. Some earlier panelist, I think, and then news reports have suggested that some of these smart phones are generating 400, 300, 500 megabytes per month of usage. How should we think about the case you just mentioned -- laptop usage or netbook usage -- and are there any other cases we should be thinking about?

MR. STONE: I think laptops -- that general category of MiFi devices and laptops is the important one, and, you know, that's up north of 1 gigabyte a month, you know. Our current data plans allow for up to 5 gigabytes of usage and that's not uncommon. So it's in that few gigabytes of usage per month is the current usage for laptops. But also keep in mind as we move forward and these newer applications emerge and adoption increases, there is certainly potential for that to increase dramatically. And when we run these models with the various sensitivities, that's exactly what we're doing is increasing that over time and looking at what the impact is to spectrum need.

MR. LEIBOVITZ: Okay. Thanks. So, a few more audience questions. One is from Tom Peters at the FCC. With an OFDM technology such as LTE or WiMAX, is it necessary to deploy separate carriers with each sector of the site -- N = 3 reuse, which is, I think, the example that Dr. Saw used -- or can an operator use one- third of the spectrum by deploying the same carrier in each sector? Which is more spectral efficient? How should we think about the tradeoffs and how should that factor into our thinking about total aggregate spectrum needs?

MR. STONE: Well, with LTE, we've, as previously mentioned, already done extensive field tests and we've determined that the optimum configuration is a reuse of 1. So we're going to go forward with reusing all of the spectrum in every sector. Now, certainly there are tradeoffs in terms of some compromise in performance rate along the sector boundaries, but we've found that that degradation doesn't offset the benefit. The benefits are greater than that degradation. You know, we obviously had to work through the 3GPP standards process to make sure that LTE was optimized as best as possible to address that potential limitation, but we're satisfied with the results and we're going forward with n = 1.

MR. SAW: So, you know, I would like to agree with Bill, but based on what we have seen, and because, one, I think Bill alluded to at your cell (inaudible), you know, you will see a degradation in throughput if you're not careful about it. So, what you end up doing is looking at this like sub fractional reuse, which essentially means you're degrading your customer's experience and you're really using n = 3, but in a sort of sub fraction sort of way. That's one way to do that.

What we've found that, you know, in order to deliver the capacity that a customer needs for the (inaudible) applications, you need to try to minimize the interference, and there's ways to do that in technology. And over time, you know, I'm sure that's going to improve, but for now, based on what we're seeing in our markets, a reuse of 3 is what we need to do. And hopefully, the more spectrum we can free up for capacity, the better it is. But right now we are looking at n = 3.

MR. LAROIA: So, let me just add to this. Given where technology is going and the way things are evolving, the distinction we're in, n = 1 and 3, is actually getting way blurred. What Bill refers to as n = 1, and somebody else might refer to as n = 1, may actually be the same things in some sense.

When we talk of n = 1 systems, the systems are actually pretty sophisticated. They're actually not n = 1 for everybody. For the guy at the edge of the cell, they actually behave like n = 3 systems, but the guy that's not at the edge of the cell should not be penalized by just using one-third of the spectrum of the cell. So you use the entire thing for the guy that's not interfering with anybody, but you use some fraction of the (inaudible), if you will, for the guy at the edge of the cell.

So, these systems are getting more sophisticated that they're actually blurring the distinction between what used to be clean n = 1 and clean n = 3 systems.

MR. LEIBOVITZ: Thank you. We've got a few questions from the audience on the question of alternative architectures, mesh architectures for mobile. Have any of you trialed or experimented with ways to use peer-to-peer radio connections between devices to increase capacity on the network and, if so, how does that affect your -- what would be the spectrum requirements of that?

MR. LAROIA: At Qualcomm we've been developing technology that -- it's peer-to-peer technology. It allows devices to directly communicate with each other within a certain reasonable distance, about a mile, not tens of miles, and devices discover other devices.

So, one of the things in communication is lack of the knowledge that there are other devices you communicate with. So, my device, my cell phone, for instance, is my primary communication. It has no idea what other cell phones are around it or what other devices are around it that it could potentially communicate with. So we are developing technology that helps devices discover what's in your limited vicinity. And then once you discover those devices, you can actually directly connect with them rather than go through an infrastructure-based network.

Now this we are doing to complement conventional infrastructure-based communication, which, of course, everybody knows what that is. So, all the proximate communication gets handed over in a direct device-to-device communication, happening over managed or licensed spectrum, of course, because if you have unlicensed spectrum then the interference in between, then all bets are off.

MR. LEIBOVITZ: Does it require separate spectrum from the macro cell network?

MR. LAROIA: It could use separate

spectrum from the macro cell -- so we're developing that technology currently and basically somebody else mentioned this could be potentially very useful for public safety applications as well (inaudible).

MS. RINNE: I think it's important to look at the different use cases in the mesh networks that we've utilized for backhaul that can actually have the impact of increasing latency gives you some efficiencies, gives you some reliability redundancy, but could impact your latency, so you've got to think about your different use cases to answer that question. There's not a -- it depends.

MR. LEIBOVITZ: Another question from the audience: Can some of the operators on the panel tell us about the usage characteristics of their networks today from a subscriber standpoint? So, how is relative usage changing in the uplink versus the downlink? Are there any rules of thumb you can provide on sort of number of subs per square mile or cellular mile? Any other thoughts that would inform our thinking on the subject of spectrum use?

MS. RINNE: Specifically, as an uplink/downlink ratio, as devices have more large a camera size, video capabilities, plus the fact that we've introduced HSUPA into our networks, which gives you higher throughput speeds from the device back to the network, we are seeing that ratio shift just in the wireless data space. And I would say the usage characteristics of the devices are very dependent on what the operating system capabilities are, what kind of applications it has access to, customer profiles, many, many variables.

MR. LEIBOVITZ: Bill or John, do you have any --

MR. SAW: I think the range that Bill gave earlier, 1 to 5 gigabyte per month, is what we're seeing with data cards and embedded devices. One interesting fact that we have noticed is that Clearwire is also in the midst of converting a lot of pre-WiMAX networks that we have to WiMAX.

And when we converted the customers, and giving them the same type of device, we found that, you know, usage actually has gone up, which makes the point if you have a more capable network with a higher bandwidth capabilities, they will use the bandwidth. So, we do see a lot of growth just within even the same household or the same users when you give them a 4G type of experience.

MR. STONE: The only thing I think I would add is that in addition to seeing the shift, which we're also seeing as well, more data in the uplink, the uplink is a bigger challenge from a technology perspective. So we're not able to achieve the same throughput and capacity in the uplink to limitations associated with device battery life and things of that nature. So, even though we're seeing that shift, we still have that technology challenge to overcome, so there's going to be a need for as much if not more spectrum in the uplink longer term is the way we see it.

MR. LEIBOVITZ: Are there any rules of thumb on how to think of the average user ratio for a smart device?

MS. RINNE: It's going up every month.

MR. LEIBOVITZ: Presumably the maximum is 50-50 in an FTD system or is that --

MR. STONE: 50-50 for usage.

MR. LEIBOVITZ: Uplink versus downlink.

MS. RINNE: For data, less.

MR. STONE: It's less than --

MS. RINNE: Yeah.

MR. STONE: It's more like 70-30.

MS. RINNE: And to Bill's point, the capability of the uplink is different than the downlink as well.

MR. STONE: Exactly.

MR. LEIBOVITZ: Another question from online. In a future with high levels of mobile video usage and if there is a severe shortage of spectrum, what type of business models do you envision to handle the supply and demand asymmetry? Is it caps? Megabyte? Pricing? Banning mobile video?

MR. STONE: Yes. All of the above.

MR. LEIBOVITZ: That was a very technical answer.

MR. STONE: All of the above are possible. There will have to be shifts.

MR. SAW: I think what we're trying to do at Clearwire is the concept of open network where our customers can bring in different types of devices and applications and we anticipate that with our spectrum position that we would have enough to supply all the needs and all the applications that they would need to use. But to Bill's point, you know, to be realistic and pragmatic, there will be instances where there will be congestion that we need to manage, too. But otherwise, you know, we see a growth in mobile video and we intend to support our customers and all the new applications that they want to use on that.

MS. RINNE: When you -- that last mile is shared and so you also have to sort of analyze the fair use. If you've got 10 percent of your customers using 50 to 60 percent of the network, then is that appropriate in terms of the experience you're providing those other 90 percent?

MR. LEIBOVITZ: Okay, another online question for Gavin. Can you tell us a little more about your network? How many sites do you have? What's your peak capacity?

MR. LEACH: We have -- as far as the WiMAX network we have six bay stations throughout the city and that covers -- I'm trying to think -- about five square miles of city space. And through that we feel we can fit, not concurrent, but at any given time, the amount of uses that we have online. Right now we have 400 to 600 users concurrently on the system at any time. That will multiply significantly over the next year.

But some of what we do is potentially put, you know, rate limiters on it to control it such as I think we were mentioning here, and those are some of the things you need to look at as the network goes up. And the number of applications and type of applications are going to grow so that would be another factor in it.

MR. LEIBOVITZ: Great. Any other questions from the panelists before we go to a closing (inaudible).

MR. GOLDMAN: I actually just had one more question about the open network that you were talking about.

And do you find that because you have an open network it's harder to anticipate what type of devices are going to be on there, which means that you have to model for more -- to use more spectrum because you don't know what's going to be coming on there? Is it more difficult to model that?

MR. SAW: The one (inaudible) system is growing and at this stage of its growth we can pretty much anticipate the type of devices that we see. It's not so much the device. It is one fact that a device capability, but it's more so the types of applications that is being developed almost daily, and some of them are very bandwidth intensive.

So, yes, as network operators we do need to plan ahead in different capacity planning to anticipate the higher growth of streaming video, as an example. We do see that as a growing trend so we do need to plan for that, absolutely. I think it's the new apps and, as I said before, the more capable your network, the more new apps that is going to be developed to benefit from it.

MS. RINNE: But if your devices were not typically 2-by-2 mile or something like that, that would impact your overall capacities?

MR. SAW: Yeah, well, you do need to -- yeah, right, you do need to take into account the capability of the device as well as, you know, if you have a better uplink then user-generated content is just going to grow and use up uplink. Absolutely. Yes.

MR. LEIBOVITZ: So, how do you -- when you're doing your modeling and your analysis, how do you factor that in? How do you quantify the sort of unknown risk, I guess, or opportunities some people might think of having an open network?

How do you -- do you just take everything and double the capacity? Triple the capacity? Is there just -- is there sort of an analytical way to think about it that you could share with us?

MR. STONE: As I think I said before, it's becoming more of an art than a science when you're going into uncharted territory. You don't have good trends on which to base it, so doubling and tripling the assumptions is not all that extreme.

MR. LEIBOVITZ: Okay. Well, we're getting toward the end of our panel and I appreciate everyone's time. It's been extremely informative. I thought maybe we'd close with sort of a hypothetical question. Imagine the spectrum fairy comes to town and can give you your spectrum wishes. How much spectrum? A hundred megahertz, 200 megahertz, 500 megahertz, a gigahertz?

MR. STONE: More than that.

MR. LEIBOVITZ: And where?

MR. STONE: Are you talking about --

MR. LEIBOVITZ: I guess let me narrow

this question. We're talking about in the next several years, three to five years or five years. Are we talking about needing, you know, 100 megahertz, 250 megahertz, 500 megahertz? Is it possible to kind of put a line in the sand as to what we ought to be shooting for? Taking reality constraints aside because that's obviously a big -- that will just, I think, chill the discussion a little bit.

MR. STONE: I don't -- I'm not ready to put a number on it, but I'll say in the five-plus year timeframe, I'd like to have north of -- I'd like to be in a position where I could acquire north of 100 megahertz. That feels right beyond five years to me. But as we've said, there's a lot of unknowns and we'll be able to answer -- I'll certainly be able to answer that better in another year or two, but that's where I'm at.

MR. LAROIA: That's just for Verizon?

MR. STONE: That's for me. Yeah.

MS. RINNE: Okay, I want 200.

MR. LEIBOVITZ: Maybe we should just go

down the line.

MR. GUPTA: I would suggest that our number is going to be adding Bill, Kris's, and John's because we're the backhaul guy, but I think it's going to be in the -- for backhaul, probably in the 100 megahertz-plus range as well because we can -- because we're not a -- or because it's a fixed type of environment you can take advantage of the bit per hertz and some efficiencies and some additional throughput that you just can't get on a mobile side.

MR. LAROIA: I'll just pass it along to the other operators.

MS. RINNE: All I could point to would be the work that went into the ITU in preparation for the WRC07 and that was targeting 1,280 based on the number of operators, some of the potential demands, et cetera. But I think we need to be planning now.

MR. LEIBOVITZ: Was that incremental, 1,200? Or was that --

MS. RINNE: Yes. That was for IMT.

MR. LEIBOVITZ: But was that an incremental over what we have now?

MS. RINNE: Yes.

MR. LEIBOVITZ: Okay.

MR. SAW: I agree with Kris. I think a lot of smart people at IMT has worked the math and their recommendation is minimum 40, ideally 100. And based on our experience so far, I think that's coming in a little bit conservative. So, 100 or more is definitely where we need to be positioning ourselves for.

MR. LEIBOVITZ: Okay. Well, thank you very much to all the panelists for coming from all over the place and sharing their views and we appreciate it very much. Thanks.

(Applause)

(Recess)

MS. MILKMAN: Am I allowed to start? Do I need a high sign from someone?

Good afternoon and welcome to the second panel of today's Spectrum Workshop. This panel is on sources of spectrum, opportunities, and mechanisms.

The first panel, which some of you may have heard, focused on spectrum needs going forward. And this panel is going to focus on mechanisms. How should we think about finding more spectrum? Our goal is to isolate the biggest opportunities and the biggest challenges as we attempt to address the country's future needs.

A few of the big questions to consider: How should we prioritize different frequency bands for potential broadband use. What are the most cost-effective approaches to determining the actual use of spectrum in a given band? What's the role of secondary markets, especially in rural areas where spectrum may otherwise go unused? And what novel policies or economic mechanisms should we pursue?

We have a fabulous set of panelists who bring a variety of perspectives to this set of complex issues. And let me introduce them.

First, well, is Rob Alderfer, who is -- I'm sorry, is one of the moderators, sorry.

Coleman Bazelon, where do we start? Coleman Bazelon is a principal for The Brattle Group. He frequently offers advice to regulatory and legislative bodies, including the FCC and Congress.

Michael Calabrese is vice president of the New America Foundation. His duties include directing New America's wireless future program.

Kathleen O'Brien Ham is vice president of regulatory affairs for T-Mobile. She oversees the company's work before the FCC and has been, as you know, prior to T-Mobile, she spent years at the FCC, including a stint as deputy chief of the Wireless Telecommunications Bureau.

Daron Mylet is a co-founder of Spectru-Station, a startup that offers wireless spectrum administration and management solutions. He previously worked at Cantor Fitzgerald and led that firm's business objectives relative to wireless.

And we have joining us, I think through an audio link, Dr. William Webb, who is the head of research and development and the senior technologist at Ofcom in the United Kingdom. Ofcom is the independent regulator and the competition authority for the UK's communications industries.

And we're delighted that Dr. Webb could join us today. The moderating panel includes, in addition to myself, Margaret Wiener, who is the chief of the Auctions and Spectrum Access Division in the Wireless Bureau; Phil Bellaria, who's the director of scenario planning on the Broadband Task Force; Rob Alderfer from the Office of Management and Budget; and Scott Deutchman, who is the deputy chief technology officer for telecommunications in the Office of Science and Technology Policy.

The panelists were each provided with one question in advance, and we're now going to ask them. They're going to be limited to three minutes in their answers. We may be asking follow-up questions, and we'll also have an opportunity for questions both from the audience and from our audience that's participating or viewing over the Web.

Margie, would you start?

MS. WIENER: This was a question for Coleman Bazelon. You are an expert in spectrum valuation. What actions can the Commission take that would unlock the most value in the electromagnetic spectrum?

MR. BAZELON: First thing, thank you for the opportunity to be here today.

Let me first distinguish between the value of spectrum and the value to society of spectrum being used. I think your question is really about how do we maximize the value of how spectrum is used. And that's not the same as maximizing it's price.

The amount paid for spectrum is really a reflection of its scarcity value. And what the FCC can do to increase the use of spectrum is to decrease its scarcity. And that would be reflected in lower prices for spectrum.

There's two ways that the Commission can go about that. First is--and foremost is adding more supply of licensed spectrum to the market. There's several areas that you could look for additional frequencies. We all suspect that the federal government controls spectrum that could more efficiently be used in the private sector. Unfortunately, we don't actually have the information at this point to be able to find those frequencies or make the economic case that they're more efficiently used elsewhere, which is why the spectrum inventory is such an important project.

On the private sector side, there's numerous other opportunities. I'll just mention two. There are two sets of white space spectrum: One in the television band and one in the EBS band. And there's quite a bit of unused spectrum or spectrum -- more than just unused, spectrum with no access to it at this time. And as a side note, I will note that there's no evidence at this time that unlicensed spectrum is scarce, but there's a lot of evidence that licensed spectrum is scarce.

The other thing that the FCC can do to increase the efficiency of how spectrum is used and what we get out of it is to allow it to trade more freely, and that's to promote secondary markets. I think the economists who promoted and worked for secondary markets earlier this decade, I don't believe that the amount of trading that we're seeing today is what they had in mind. That may be because the spectrum that's licensed is actually efficiently allocated now and there's just no need for it or it may be that the secondary markets aren't working as well as they should.

And it would take further research to sort those two issues out. But for the moment, assuming that it's because the secondary markets aren't working as well as they should to promote better working markets, the FCC should do things that make spectrum more property-like that allow people -- licensees the rights that look more like property rights.

And I'll just mention one area there, is there's no -- currently with any other real property, if you -- if there's a dispute over its use or ownership, you can go to a court and have that resolved. And legal precedent means that people can predict how disputes will be resolved. And, therefore, they're -- most disputes are avoided before they start. In spectrum, that doesn't exist and, in particular, with interference. And I've had proposals before that I'll repeat that the FCC could have a spectrum court that establishes a jurisprudence for resolving interference disputes and creates what looks more like a property right in spectrum.

Thank you.

SPEAKER: Thanks.

MR. BALLERIA: This is for Michael. Some claim that commercial licensees authorized for flexible use are not fully utilizing the spectrum. If that is true, what are the key drivers for that inefficiency? And would new users do any better with the resulting white space?

MR. CALABRESE: Okay. Well, yeah, I mean, it's fairly clear that we're not using the entire spectrum resource or anywhere near that. As you know, we often talk -- I think in Washington there's this conventional wisdom that there's a shortage of spectrum. But, of course, that's, you know, just entirely wrong. The only shortage is government permission to access.

So, actually use measurements have shown -- you know, we measured here in Washington where, you know, it's below 20 percent. A National Science Foundation study of 7 different places showed on average the use of the so-called beachfront spectrum below 3 gigahertz is, you know, on average around 10 percent and nowhere more than 20 percent.

So, in most places at most times, the spectrum is not in use. And yet, it's all assigned. And so what we need, you know, really is more opportunistic access to the airwaves as well as, you know, the clearing of some new bands. So we actually support the identification of some bands that could be cleared, perhaps auctioned.

But that's going to be a limited amount of spectrum relative to the need and it's going to take a long time. What can be done much more rapidly is to identify frequency bands that are not being used, you know, on different dimensions. The primary one will be geographic, of course, or by time or by angle of reception or altitude.

And then we can -- what we've proposed, actually, is to build on the TV band's database that will be coming along, we hope, shortly. And that was the database that will give devices permission -- a list of channels by discreet geographic area to access the vacant TV channels. So, this is under the Commission's white space order last November. Devices will have GPS, they'll check a database at least once every 24 hours, the mobile devices, and get a list of frequencies that are available.

There's no reason to limit that database to the TV channel frequencies when we could be adding much, much more spectrum to that. And that will allow a tremendous amount of use. I mean, one thing that's totally forgotten on the prior panel, for example, is that a lot of the -- you know, what may be a projected shortage for commercial, you know, wireless operators could be offset if there was more use of unlicensed.

So, for example, there was actually a fairly large survey, it showed that of smart phone users, 81 percent preferred to use Wi-Fi for their Web browsing -- you know, Google search, even for e-mail -- and 90 percent want a hybrid phone with seamless roaming between -- with Wi-Fi as a default.

If we had that and we had a lot more opportunistic access, then you could actually offload a lot of the demand toward opportunistic use. It would take multiband radios, but it really could be, you know, a big part of the solution.

MR. ALDERFER: One way to free up new spectrum is to relocate incumbent users. Kathleen, T-Mobile has significant experience with this process in the AWS-1 band in working with federal agencies. Can you talk a little about T-Mobile's experiences there, how the relocation process can be improved? And are changes essential to any future similar processes or can success continue to be achieved under the current process?

MS. O'BRIEN HAM: Yes. Thanks, Rob. Well, T-Mobile purchased spectrum, AWS spectrum, back in 2006, and has been working dutifully to clear that spectrum since then, a portion of which is federal spectrum.

There are 12 government agencies on it and there was a fund set up as part of the Commercial Spectrum Enhancement Act, a law that was passed back in 2004, I believe. And the fund set up the proceeds from the auction would go in to pay for the relocation of the government users there. And there was about 1.1 billion -- Rob would know these numbers better -- but something about $1.1 billion was the original cost estimates for that relocation. And, you know, the good news is, I think, it's -- we've accomplished a lot in the last two years. We're still actually clearing the spectrum in a number of markets. So, there's still more to be done. We're hoping to get to 200 million pops by the end of the year.

But I think that some of the things that we learned from the experience was, first of all, there was a lot of emphasis, I think, on the money, what the amount of the relocation costs would be. And that's appropriate, but I also think there wasn't as much attention paid to the timeframes.

Frankly, we as a licensee thought that the timeframes were less important because we were hoping we're going to be able to share the spectrum. What we found out was that, unfortunately, because of some of the uses that were in the band after the auction, that we couldn't share it.

So, the spectrum -- then it became an issue of trying to clear some of the government users that were occupying it nationwide. And to

Michael's point, I mean, some of these users have very important uses, you know: FBI, DEA, and so forth. But they're not using it 100 percent of the time in 100 percent of the locations, yet they have a nationwide assignment. And so, you know, T-Mobile had to work with those agencies to clear the spectrum to make it available to us and that became sort of a very big hurdle. So, I think, you know, the timeframes are really important.

The other thing we found is that some agencies were using the spectrum for the same types of uses, but the timeframes were very different. So, the Secret Service could be out of the spectrum in a year, the FBI needed four years, even though, you know -- and I may not have those exact timeframes right, but something along those lines. We found that even though they had very similar technology, they were -- had very different timeframes that they had set up.

So, going forward, I think what we'd like to see is, you know, more -- certainly around the timeframes, a little more leverage for the licensees. I mean, we found in our negotiations that we were pretty much pushed off to the side and the negotiation largely became between OMB and the government agencies in terms of the clearing, and the licensees had very little leverage in those negotiations. And that was very frustrating. We spent $4.2 billion for the spectrum. We thought that would give us a little bit of leverage, but.

So, those sorts of things I think we'd like to see some reform made to make that process work even better. And there's -- the good news is that there's a law that's been introduced by Congressman Inslee that attempts to do a lot of that. And T-Mobile very much supports that law and would like to see some of those improvements made.

But very good start. We learned a lot from the process. I think it can be -- definitely be improved and be an opportunity for future relocation.

MR. DEUTCHMAN: Great. Daron, Dr.

Bazelon touched briefly on secondary markets. I know you've got a fair bit of experience in that area, and, in fact, at Cantor Fitzgerald you established a spectrum marketplace. What's your sense? Are secondary markets functioning as expected? Yes, no? If not, what are the obstacles?

MR. MYLET: Thank you. Great question. I think yes and no and a mix of both, actually. I think the initial regulatory framework for trading leasing is there. However, I think it needs to evolve and become even more robust, more dynamic, more fractional over time, space, and frequency.

From 2004 to 2009, I spent a great deal of time developing spectrum management systems, processes, ideas, along with looking at the outputs of spectrum ownership, allocation, and more importantly, utilization. I tend to agree with the experts and those who have done real spectrum analyzer studies showing 85 to 99 percent of the spectrum, you know, not used either at all or maybe even over a long period of time, a year or so.

So, it appears to me that there is supply out there. There is supply of spectrum. You know, it's finite.

I don't believe that it's scarce. On the other side of the equation, on the demand side, you know, the demand is obviously growing every day from commercial interests. More importantly, federal missions, public safety, and utilities who are going from either narrow band land mobile radio systems now to having to build robust, secure data systems and moving beyond using 25 kilohertz channel sizes to 5 meg or 10 meg channel sizes. So, there's obviously a tremendous amount of demand.

And also that demand, I think, needs to be broken up into different segments of the United States geography. It's not a one-size-fits-all environment out there. You've got rural needs where spectrum analyzers typically show maybe 90 percent of the spectrum's never used at all. But yet, you try as a county or a city or a public safety entity to try to go get your hands on some of that spectrum and the processes aren't there. You just can't get it for whatever reason, whether the incumbent has publicly stated that they can't build a business case for that particular market. But yet, you try to go say, well, you know, I'd like to get a little bit of that in that county.

Well, you either -- they don't want to deal with you or they're not interested in selling it, the transaction cost. So, you know, we really have to kind of break this down, I think, into geographies, into urban, suburban, and rural. But, overall, the real measure of success -- and I just about fell out of my chair this morning when I heard Commissioner Copps say that he wished he could look up on a board and see spectrum utilization and see, you know, where it's used, where it's not used, know specifically. You know, that is great news to hear Commissioner Copps mention that today. But I don't believe over the past four or five years we've had a big spike in utilization of actual spectrum substantial.

Let's talk about secondary markets real quick. The more specific buy and sell activity that you get, you know, there's big transactions. There's NBNO operations. But as a percentage, when you look at 3.7 -- if we're going to talk about 3.7, it has 3,700 megahertz. And you break that down to what's actually trading in a real secondary market, not a commercial transaction or a merge and acquisition transaction, I would venture to say that it's probably.1 percent. Just purely on guess.

So, there's just not a lot of activity in the secondary markets. But I believe the winds of change are coming. I think the spectrum inventory is going to shed the reality of the situation and we're going to know specifically over time, space, and frequency, both on the public and private sector side equally, and be able to come up with some good analysis and some good mathematics and be able to make, I think, much better decisions going forward.

MS. MILKMAN: Dr. Webb. And now that

I've realized what time it is in the UK, I'm even more grateful that you're with us today.

MR. WEBB: You're welcome.

MS. MILKMAN: What lessons can the United States learn from the UK's 10-year history with administered incentive pricing about giving spectrum users appropriate incentives for efficient use of spectrum? Is the UK program mature enough to draw significant conclusions or is it still too soon to judge?

MR. WEBB: Okay, thank you. First of all, can you hear me okay?

MS. WIENER: Yes.

MR. WEBB: Great, okay. So, I would say the answers are split very dramatically, compared for commercial spectrum and governmental spectrum.

On the commercial side, the use of what we call AIP -- as you said, it's sort of a mouthful -- it hasn't had a dramatic affect, for a number of reasons. Firstly, it hasn't been applied everywhere. So, for example, we have not yet supplied it to forecasters because they have other duties that require them to forecast a certain number of TV channels and so on. And they have argued that actually it would be unfair for them to have to pay for the spectrum to do that when they're required by law to use the spectrum to do that in any case. So, there's a number of reasons why it's not been applied there.

Also, the economists have told us that if you can't get AIP and test it slightly too high, that could be quite poor spectrum efficiency. Because potentially you could get all the spectrum returned back to you if you set the IPH level where it's actually above the value that all the users on the spectrum. And that's actually not really necessarily what you want. Because you may be in a situation when nobody wants to use the spectrum anymore because you've priced everyone out of the market.

And so, the economists have recommended to us we set AIP at a conservative level. And the result of that, I think, has been that for most commercial users, what AIP may be a significant amount of money, it still is actually below the value that they place on the spectrum. And so it's not resulted in much change.

And that's particularly been the case for the sender operators. We've seen some small amounts of activity with picked links and potentially with land mobile radio, but not a great deal.

So I would say AIP has not changed a lot there, the one thing that's held with absolute perception of fairness. So, in cases where some spectrum users have obtained their spectrum for free, perhaps as a result of a legacy grant and so on -- I know those who have paid at auction for their spectrum. The fact that the former pay AIP each year on their spectrum goes some way to leveling the playing field between the two. However, it's had a dramatic effect in the UK in the governmental sector, where we've applied pricing predominantly to the military.

And as a result of that, the military has very substantially changed the way that they regard spectrum. They now put spectrum into their business cases for all major programs. They market -- they increase the size of their spectrum management team. They've handed back a number of pieces of spectrum. And they have voluntarily come up with a long-term spectrum plan showing what pieces of spectrum they feel they can hand back in the coming years and what they're using the spectrum for and so on.

So, it really has focused their minds very substantially and brought about a change that I suspect we never would have achieved simply through pressure on them to do the right thing rather than the economics of actually having a strong business case reason for handing back spectrum.

So, I think our summary, having used AIP in various forms for about 10 years, is the--it's a useful tool, it has its place. But its key value is probably in the area where market forces just don't really apply very well. I mean, that's mostly in the governmental area.

Thank you.

MS. WIENER: Thank you.

SPEAKER: Do you want to ask?

SPEAKER: Sure.

MR. DEUTCHMAN: Sure. I'm going to pick up on Dr. Webb's point. And I don't -- Dr. Webb, if maybe this is to you and then the other panelists, but what have other countries been doing in this area that you think -- in terms of efficiency, repurposing, optimizing, spectrum use, that might be lessons learned that either for good or for bad that we should keep in mind?

MR. WEBB: We haven't seen that much activity from other countries, actually. A lot of them are tending to follow what the UK has been doing and, to some degree, what the U.S. has been doing because that's led the way in certain areas. So, I've not spotted any particular activity that I would say I can learn a key lesson from from other countries.

There have been some differences, for example, in the way secondary markets work in countries like New Zealand and Australia. But a lot of the lessons that you saw there, you have to take a fair degree of care about because those countries are so much smaller than both the UK and definitely the U.S. in terms of population size. But their ability to significantly change the spectrum is very much diminished that they just don't have the economies of scale to enable them to move to different frequency bands that aren't forced around the world.

So, I've not extensively surveyed every country and it's possible, I suppose, I'm missing out on something, but I'm not aware of any standard lessons outside of the UK and the U.S. But I think it's worth drawing upon here.

MR. DEUTCHMAN: Thank you. Others? Anybody?

MR. MYLET: I guess kind of like when E.F. Hutton speaks, people listen. When William Webb speaks, I tend to listen. And I've been watching what's been going on in the UK for the last five, six years pretty intimately.

You know, the entire mobile ecosystem over there, I believe, subsists on about 270 total megahertz of spectrum allocated. I don't know what the utilization and how much actually spectrum they've actually put on the air, maybe half, maybe more. I don't know. But -- and then I recently read where they're actually making people move. So if you want to go to a different band, then you have to give up spectrum.

So, it seems like -- and they do a tremendous amount of backhaul over there with microwave. I think 90 percent of their backhaul and their mobile systems appear to be microwave, where I think in the U.S. it might be opposite, 90 percent T1s or something along those lines. So, I think the UK's doing some interesting things and is doing some interesting analysis with spectrum utilization, driving trucks around the country, measuring the airwaves over long periods of time and long periods of space.

So, that's pretty interesting.

MS. WIENER: Go ahead -- I have a

question for the panel. With this -- if you're looking to relocate or repurpose -- relocate incumbents and repurpose spectrum, how should we -- what should we be thinking about in terms of whether or not there's a higher valued purpose than the existing purpose? I mean, what do we look for? How do we tell when it's the right spectrum to repurpose?

MR. BAZELON: I'll start. There's sort of two measures to keep in mind. I mean, one is the value of that spectrum in its current use. And if -- and the second approach you could look at it is, what's the cost of actually clearing the spectrum out?

In a well-working market, those two approaches devalue in spectrum should get you to the same point. But because spectrum markets aren't well-working, they can be quite different. So, a band of spectrum could have a very -- a reasonably high use value in its current use and still have a very inexpensive way of moving that use to either another band of spectrum or off the radio spectrum altogether. But I would suggest that you would want to look at both approaches to valuing it.

MR. ALDERFER: Can I follow up on that, Coleman? When you look at valuation, what specific data points do you look for? Is it just FCC auction values or is there other secondary market indicators? And is there anything on the government side that you might incorporate?

MR. BAZELON: So, I think you're actually asking about the demand side, so it's really a two-part question. There's the -- what's the cost to make the spectrum available, the supply curve, shall we say, of spectrum? And then there's the demand curve.

The demand curve starts with the auction values or some adjustments to those auction values, accounting for changing economic conditions and the increases in supply that you'd be looking at. It's when the price of traded spectrum is above the cost of making it available that you're leaving money on the table by not bringing it out.

As to the government side, it's hard to say. We have this problem that under our constitutional system, the Congress controls the purse strings. So, you're -- you run into a problem trying to pay an agency for its spectrum, although they can sell it. They can't reap the profit or the benefit from selling it because they can't credibly -- Congress can't credibly commit to not offset that revenue in another way, which creates a real dilemma.

The beauty of the administered prices in the UK is that it sets some sort of opportunity cost to using spectrum for government users, whereas they face none because they don't face any market forces.

MR. WEBB: Can I pick up on that? So, I agree very much with everything that's said. I think in an ideal world that the regulator wouldn't be asking itself the question about relocation, repurposing. The market would take care of that. So, you'd ideally hope that someone who held spectrum and didn't value it very highly would realize that they could sell it or trade it to someone who valued it more highly and then that would result in a change of use of that spectrum without anyone and the regulator having to intervene. And we see a very limited amount of that taking place, but often, you find there are standard roadblocks.

So, for example, we are looking in the UK at doing what you did with the 700 megahertz spectrum, turning off some of the TV, forecasting, and repurposing that for other uses. And because of all the restrictions around forecasting, both governmental and European harmonization and so on, that's been a much more practicum hands-on business.

And we've actually looked at in some detail, the value that arises from spectrum as it's currently used, forecasting, and also in a number of other possible uses we've predicted what the value might be in those uses, and then showing what the most likely use going forwards would be and it's value.

So I think you can do those kind of studies. As Barry spoke, you have to do them for each particular band and for a range of different uses. They're necessarily speculative because you're looking forward and guessing what the best use might be and trying to put a value on for that, but, nevertheless, worth doing to a reasonable degree. The other point as well is that the value can change very substantially quite quickly, depending on activities like harmonization. So, if you have a band that at the moment there's no equipment available for it. It's not used for anything apart from perhaps some governmental use, then (inaudible) might be fairly low. But if around the world it suddenly becomes used for cellular, for example, I know there's a huge range of equipment available for it and so on. That very substantially changes its value and the idea that harmonization might occur can take place very quickly in a particular band. So, valuation is a very difficult topic. And for those reasons, it's best left to the market, if you can. But I think we do have to recognize that there are some incumbents who just won't respond to market forces as well as they might.

By the way, in the UK, we are allowing our military to keep any proceeds from spectrum sales and spectrum trades. Otherwise, we figured that there wouldn't be enough incentive for them to do that. And so, hopefully, that will encourage them to release some of their spectrum into the market.

Thank you.

MR. BALLERIA: We're using Dr. Bazelon's framework, then, of the demand side and what the value is -- could be for alternative uses versus the supply, which would be calculated from sort of a cost to relocate and also the fundamental value of it's current use. What bands do you think are kind of grossly undervalued in their current use that we should be looking at for relocation?

MS. O'BRIEN HAM: Therein lies the question.

MR. BAZELON: Almost anything other than the current commercial mobile bands are probably undervalued. That's overstating it a little bit.

Obviously, everybody is interested in looking at the broadcast bands, and it would be worth taking a look at the value of those bands to broadcasters and the cost of making the spectrum available. But other -- the same analysis can be done on literally all of the bands.

I'd like to illustrate this opportunity, cost point, with us. What's a somewhat absurd example, but I think it makes the point.

I think it's channel 37 or 36 is reserved for radio astronomy?

SPEAKER: 37.

MR. BAZELON: 37 is reserved for radio astronomy. Potentially you could put radio astronomy telescopes on the far side of the moon and continue to do science and make those frequencies available on Earth. So, that's a measure of increasing that supply. Probably not worth it for 6 megahertz of spectrum, but someday it might be.

MS. O'BRIEN HAM: Somewhat along those lines, I just wanted to -- in our experience with the clearing on the AWS, what we found with a number of government agencies, actually, was that they realized that they could do some tradeoffs. So, they didn't need spectrum, maybe they could do the same thing through fiber. And they were sort of forced to make -- you know, if they had a pot of money there to be able to make those kind of tradeoffs, they were able to do that. So, some of them abandoned their spectrum use completely through those sorts of tradeoffs.

So, I'm not an economist, you know; Coleman is. But it strikes me that you want to create those kind of incentives where you can actually have the parties through negotiation. The more you can try to trigger those sort of natural determinations, I think, in the marketplace as opposed to the FCC trying to determine what's more valuable or not. I mean, there's something wonderful about the marketplace doing that in and of itself and trying to do that.

The other thing I would say is another sort of measure of success here that I just sort of turn the tide a little bit is investment in the spectrum. So, something that I think the FCC should look at is -- and I'm just picking 20 years because wireless has been around for about 20 years -- but look at the users of spectrum and how much investment has been made in the spectrum and, therefore, into the economy. So, looking at some of those uses, too. You know, compare broadcast, compare satellite, compare some of the government use, whatever. I think some of that is also maybe an appropriate way to look at, you know, spectrum utilization as well.

MR. CALABRESE: Can I add -- you said one thing on, you know -- to what Kathleen said in terms of incentives for federal users in particular. Kathleen mentioned earlier the spectrum relocation fund, which is a great way to -- you know, it's worked well as a model for clearing a band entirely. And, you know, hopefully, there will be some opportunities to do that, but I have a feeling that they will be somewhat limited. But you could also dual-purpose that spectrum relocation fund because something that might have a much broader impact would be to use the fund to -- and perhaps other streams of revenue that would go into it, to have federal users upgrade their systems to facilitate shared access and greater spectrum efficiency.

So, Michael Marcus, who was the -- you know, worked in OET as a chief spectrum engineer for lots of years, he wrote a short paper for New America Foundation -- you can get it on our website, NewAmerica.net -- back in June, but he talked about this affirmative federal -- you know, requiring federal users to -- at least federal users to take steps to affirmatively share because we've gone already through two generations of sharing with federal radar uses, so in 900 -- in the 900 band first, and then in the upper 5 gigahertz band. And that opened two big, unlicensed bands for sharing, which have been quite valuable. But those -- that sharing was done on a completely passive basis.

In other words, the attitude of, you know -- I mean, the military was constructive, and yet the attitude at the same time was, look, at long as we don't have to do anything, as long as you can work around us and we don't notice you, you know, God bless. But as a result, you know, the amount of capacity shared there is far more limited and less robust than it could be if federal users actually had the funding and the wherewithal to upgrade their systems, you know, even things like, you know, in terms of receiver standards, in terms of sharing information, in terms of beaconing, all sorts of means that they could use to free up a lot of capacity short of, you know, being cleared out entirely.

MR. ALDERFER: Can I relate this discussion to the last panel, actually, that there was an observation on the importance of having contiguous blocks of spectrum?

And when we talk about federal

market-based reforms, often federal agency systems are operating in particular geographic areas on frequencies that may differ in various parts of the country. And so, the effect of reforms may be -- may not be to have a contiguous clearing or contiguous efficiency affect.

So, can you rectify those two potentially conflicting observations? Would firms be interested in --

MR. CALABRESE: You can imagine the scenario you're saying, but I think I would challenge the premise, which is if you look at federally held spectrum, that that's where you have the greatest opportunity for large, contiguous bands of access.

Because, for example, there are -- you know, the actual spectrum measurements that I mentioned before, various studies, all of them show, whether you're in urban, suburban, or rural areas, no more than 3 percent use of bands -- of 3 bands below 2 gigahertz that are 175, 95, and 90 -- 90 and 95. So, about 400 megahertz of spectrum anywhere from 90 to 175 megahertz contiguous, where there's virtually no activity. And at any given place and any given day, you know, 99.9 percent at a time.

And so, those are opportunities, certainly at a very minimum, at low power, at ground level for contiguous spectrum.

MR. BAZELON: I would just add that the problem you identify of noncontiguous and lumpiness of spectrum is what exists in all the white space bands almost by definition. And many of us seem to think that those bands are still valuable and particularly as supplemental to existing systems.

MR. MYLET: You know, I think we get back to we're talking about contiguous, we're talking about public and private sector spectrum. I mean, this is where I really think we got to get down to the real transparency.

When you look at different commercial bands that have been sitting fallow for 15 years or 10 years that have been allocated, maybe by an

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auction design, a lot of spectrum is sitting fallow because it's such a large auction footprint. And spectrum is only built out in cities and highways. So, you have spectrum that's sitting fallow.

And with software-defined radio and with cognitive radio and with the needs of the different federal missions, I mean, they're not out there doing iPhone applications when they're trying to save lives with the Coast Guard. So, efficiency, you know, becomes a different subject within, I think, the federal spectrum versus commercial spectrum.

But, you know, the transparency is going to, I think, teach us a lot here in the short term about the reality of how much spectrum is there, how it's used, and then I think breaking it down into two more layers of a history of that band so that people can actually see the history of that band and why it's been sitting fallow or why it might be used for emergency cases if we get a national type of emergency.

And then the last point is really this technical -- you know, this independent third-party technical analysis to really tell us, you know, how much spectrum we think people are going to need in different -- for different types of missions, you know, to listen to some people say that 1,000 megahertz. Well, you know, I listen to people like Marty Cooper say that, you know, a 10 megahertz channel today might be worth -- or might be functionally equivalent to 100 megahertz in 3 or 4 years because of technical efficiency.

So, you know, that transparency, that reality, and then that third-party independent technical analysis I think will go a long way to helping us free up more spectrum and get more spectrum into the ecosystem.

MS. MILKMAN: Let me ask an online question and combine it with a question from the audience.

One question for all the panelists: You've all talked about efficient use of spectrum and that spectrum is not being utilized today. What would constitute your definition of efficiently used spectrum and how would you know if it was being efficiently utilized? Is there--an online questioner says, if you're doing a spectrum survey, can you see low power signals that require high gain antennas, 10- to 20-foot dishes, and a low noise amplifier?

MR. WEBB: Okay. Can I pick up that one to start with?

MS. MILKMAN: Please.

MR. WEBB: So, we've always been quite clear that from a spectrum management point of view, we are seeking economic efficiency. So, we want to get the greatest contribution to the GDP of the UK through the use of the radio spectrum. And we've always been clear that that may not necessarily mean technical efficiency. In general, the two go hand-in-hand, so if you can use the spectrum technically more efficiently, you can tend to get more users on it and, therefore, you can get more value out of it. But it's not always the case.

And, for example, there are situations where it's worth leaving the spectrum fallow as an option for things that might happen in the future and that actually gives you more economic value than making use of it immediately. So, you might make use of it immediately and then a new technology comes along in a year or two. And because you don't want to take out this old system, you may effectively have the spectrum sterilized for many years or use not as efficiently economically as it might be.

So, we don't actually look to our measurements of spectrum utilization in order to determine how efficiently the spectrum is used. That gives us other useful information on what's going on and where we might change things, but it's not our overall objective.

Instead, we take -- we survey about every three years what we think the economic value of the use of the radio spectrum is adding to the UK. And based on that, we can make some assumptions and guesstimates as to whether we think we could do it more efficiently, whether a bit more of a certain use and a bit less known use might make a difference.

However, I don't think it's possible to say that the answer is a GDP of 4.2 percent or whatever, and when you hit that, the spectrum is used as efficiently as it might be.

There's an ever-changing problem or an ever-changing opportunity because technology changes, uses changes, the value of different things changes all the time.

So, I guess it's not really possible to know if you ever got it perfect. But I think by looking at the value that is generated, you can at least have a pretty good idea of any gross errors that there might be.

MS. MILKMAN: And Dr. Webb, what do you do with -- in that case, with military spectrum?

MR. WEBB: Nothing.

MS. MILKMAN: Is that part of the survey or no?

MR. WEBB: No, it's not. Partly because in the UK, Ofcom is not responsible for military spectrum in the same way that the FCC has that split with the NTIA in the U.S., and, therefore, we don't have a re-list survey.

But also, I think it's pretty difficult to determine what the economic value of military usage of spectrum is. The military achieve different objectives than increasing the GDP of the country. So, it is very, very tricky to bring that in. And I guess that's one of the shortfalls of an economic value approach that any spectrum that's used for noncommercial activities is very difficult to bring into that, including things like radio astronomy as well.

MR. BAZELON: I would just like to reiterate or reinforce the point that efficiency of spectrum use -- efficiency in the use of spectrum is itself an economic concept and not an engineering one. And although spectrum measurements of -- physical measurements of spectrum use can be useful and informative, they're not what this is all about. It's not about making sure the bits are -- the airwaves are filled with bits. It's about making sure we're doing something productive with it.

On the military side, there is no way to put a market value on the military's mission, but that doesn't mean that you can't use market mechanisms to inform decisions. And the administrative pricing for the military puts an opportunity cost on their spectrum and it allows them to evaluate their mission.

It's similar to tanks are important to the military's mission, but there's no need to nationalize steel production, despite what President Truman tried to do; that they can still understand what the opportunity cost of a tank is through market mechanisms.

MR. CALABRESE: I just wanted to -- you had mentioned in the question -- the question implied an important point that I almost gave as a caveat, but didn't want to run too long, which is even when you do actual spectrum measurements, you know, that's not the entire story.

There can be receive only sites. For example, that you're not hearing that are very important -- and, you know, most of those are federal use and so they would have to be accounted for.

At the same time, I think, you know, that actual spectrum measurements will be a critical part of an inventory of the airwaves, that just doing a static snapshot is really not going to -- and particularly one that only just maps assignments rather than measuring what we're actually using and with what technologies. You're going to really need that to identify where the greatest opportunities are.

And now, you know, we're reaching a point -- I know at least one company that's going out in the field shortly to the -- you know, to deploy spectrum analyzers that are mesh that can cover areas and can measure very inexpensively, you know, use over periods of time.

And so it's no longer a question of, you know, the NTIA had those big white trucks, you know, that would have to do a truck roll at great cost, and we're not even doing that anymore. But now, you can put these things up the way we do weather stations on school buildings. You can put these sensors that are a few hundred dollars, put them up -- either put them up on schools, let them ride around on police cars, however you want to do it. And as long as there's an Internet connection, they can be collecting and then sending the data back.

And I think we need that actual use measurement to inform the inventory process. And, you know, I hope we'll do that.

MS. O'BRIEN HAM: I would just reiterate, I do think it's only one side of the story, the technical efficiency. I think the economic investment, the productivity that Coleman talks about that comes back into the economy, the jobs, the innovation and all those things economists can measure and I think that's all a factor. Are people actually making productive use of the spectrum that's benefiting society?

So, that's harder to measure, I think, the noncommercial sector. It may be easier to measure in the commercial sector.

You know, when I was at the Commission, I remember former Chairman Reed Hunt had his famous up and down chart, you know, that showed -- he would go up to the Hill and he had -- everything that should be going up is and everything that should be going down is going down. And things like investment -- you know, prices were going down, investment was going up, jobs was going up.

Those type of indicators are things, too, that I think the Commission should look at when it's considering spectrum management because you want to make spectrum allocation choices that are good investments in the U.S. Economy.

MS. MILKMAN: One more audience question and then we may -- I think we're going to have to wrap up.

I think in both the -- GAO has commented that neither the FCC nor NTIA has ultimate decision-making, and I think we've just heard Dr. Webb say it's the same in the UK.

You have an agency that's responsible for the commercial spectrum and a separate agency responsible for government use, but some countries do have a single entity that manages all spectrum. Could you comment on whether this is -- the current setup is something that hinders the ability to meet future spectrum needs for both federal and non-federal users?

Daron?

MR. MYLET: I think what's interesting in the UK is the Ministry of Defense controls -- and my numbers might not be entirely accurate -- but, you know, 4- or 500 megahertz of spectrum. And they actually -- there's a process going on I think right now in the UK where they pay a fee, let's just say it's $100 million. And they have to pay that fee and if they can sell it or lease it out to commercial sector or the utility sector or public safety sector and make a profit, then they can potentially do that.

They can make a choice with that asset and get it out into the marketplace.

And I think this is something our country has to look at. All this spectrum and we really get a grasp of what we have, how it's used. I think we can generate a lot of money into the Treasury and into the OMB. And the spectrum can be put to use and drive jobs, create competition, you know, do all the stated goals that this administration is about.

MR. WEBB: I'll pick up on that question. So, in terms of governmental use in the UK -- and I assume it's the same in the U.S. -- there's really two users that dwarf all the others, and that's the aviation use -- mostly aviation, radar -- and the military use. Outside of those, the other users really have a small percent of the spectrum. And it seems to me that if you take, say, the military, they're always going to need to have their own spectrum manager because they're going to want to look after the spectrum that is within their remit. And the same is going to be true for the civil aviation authority.

So, the only question really is, then, do you need an intermediary that sits between the commercial spectrum manager and the military and civil aviation authority and kind of negotiates between those?

And I guess the answer to that is you probably don't need that. You may as well negotiate directly between the commercial spectrum manager and those two very large users.

What I don't think equally -- that hasn't fell in the middle necessarily makes a big difference unless they're being particularly instructive. So, I suspect structural reform lost -- it can always bring some benefits -- may not be the big key thing to look at here. It's the incentives that are applied to the governmental users to encourage them what only they can do, which is decide which bits of the spectrum that they have they can do without.

Thank you.

MR. BAZELON: I would just add that, looking at where the large reallocations have come from, you might think it made a difference in, say, the AWS band came out of some legislatively-directed government and private spectrum that is mixed, and you think, oh, Congress had to get involved. But then again, the 700 megahertz which was completely within the FCC's control was also only came about because of legislative direction. So, it's -- even when it's all within one manager, there still seems to be trouble to have the political will to do the reallocations.

MR. CALABRESE: One thought I -- you know, not that it -- this doesn't -- don't have a position, haven't thought this through a lot, but we might at least consider the possibility, you know, on the federal side at least, of separating allocation from assignment or -- there's allocation from coordination.

Because, for example, you know, NTIA is

-- its office of spectrum management is charged with -- you know, it's making -- coordinating assignments for federal users. And that's a very necessary and important function, although it tends to give you a culture that that's who you're serving, that that's your client. And there's not, you know, necessarily any weight given to the larger public interest as far as what allocations you're working within.

I mean, even to the point where over the years, folks at the Commerce Department have told us, look, go to the Hill and get a directive, you know, go get some legislation so that we can tell our clients -- we can tell the federal agencies, sorry, but we're forced to do this.

So, you know, I don't have a specific proposal about how to do this --

MS. O'BRIEN HAM: Legislation helps.

MR. CALABRESE: But you may want to think about if there's some way to separate the allocation of the amount versus the management of how you work within that allocation.

MS. O'BRIEN HAM: Yeah, one thing -- I know there was a proposal and these things are always hard to do and the probably require legislation, too. But there was some discussion years ago when I was at the FCC with NTIA about giving leasing authority to the government to be able to lease some spectrum. I know there's all the appropriators on the Hill and everything get all crazy over that, but creating an incentive for them to give up spectrum through some, you know, monitoring mechanism.

Fees are another thing. I mean, if -- the UK is doing this. But, you know, there are some fees on government users. But I don't think they're the -- I don't think Coleman would tell you they're true cost of doing business with that spectrum. And I think that forcing some of those tradeoffs to think, well, do I need this spectrum for this or do I need to buy more tanks or more something else. Those types of tradeoffs, I think, are another tool that maybe -- you know, to get the government to take another look.

MS. MILKMAN: Unfortunately, we need to end because it's 4:15.

MR. BALLERIA: Can I just give a homework assignment?

MS. MILKMAN: Sure.

MR. BALLERIA: This is part of my job on the Broadband Task Force. So, we've heard a lot about transparency and the need for more transparency in spectrum utilization. And we've heard a lot about that, too, on the broadband side, more transparency in terms of what kind of service you receive versus what you pay for and you're promised. I would love to hear other suggestions or more creative suggestions for how to create this spectrum inventory and understand how it's being used, other than driving around trucks and doing collections and things like that that may not be the most efficient way. There may be better ways with modern technologies and processes and so forth.

So, if you guys have thoughts about that that you haven't submitted yet through, you know, the public notices that have gone out or the NOIs that have gone out, please submit those to us so we can take those into account.

MS. MILKMAN: Thank you all very much. Can we give our panelists a round of applause?

(Applause)

(Recess)

COMMISSIONER BAKER: Welcome to saving the best for last panel, Innovating in Spectrum Access. I want to welcome the panelists. I want to welcome the many members in the audience, some who I haven't seen in a while. It's great to see you.

I really do think this has got -- this is sort of where the rubber meets the road. So I really want to thank the great brain trust that we have here on the panel.

I'm going to skip my opening remarks because everybody knows this is important. So let me go straight into telling you who we've got here, the experts we've got here with us today. And I'm going to skip our esteemed moderators and come back to you.

We've got Dr. Ranveer Chandra, who is a researcher with Microsoft's Network Research Group. His research is focused on systems' issues in computer networks, including white spaces networking. He has published more than 25 research papers and filed over 30 patents.

We have Dr. Bruce Fette, a program manager with DARPA XG Project's Strategic Technology Office. His current programs involve cognitive techniques to enhance the scalability of radio communications networks, enhance the usability to soldiers on the edge, improve situation awareness, and to lower radio system costs. Big job.

Dr. Paul Kolodzy, an independent telecommunications consultant with Kolodzy Consulting, LLC. He consults with clients on development for advanced communications, networking, electronic warfare, and spectrum policy. That really doesn't say it all.

Dr. Paul Mankiewich, chief technology

officer of the Wireless Networks Product Division, Alcatel Lucent. He is responsible for the global vision, technology strategy, product evolution, and standards associated with the mobile network.

And Dr. Joseph Mitola III, who is a distinguished professor and vice president for the Research Enterprise at Stevens Institute of Technology, where he focuses on cognitive radio. He develops large scale, cross-disciplinary research initiatives with the Institute's centers, laboratories, and contract research projects.

So, really, just a heartfelt thanks to all of you all for being here. We're very grateful for your input.

I am Meredith Baker and I work here at the FCC. I am also joined by Jon Peha, who is the chief technologist at the FCC; and Juli Knapp of the FCC's Office of Engineering and Technology. And in between them, Rashmi Doshi, chief of the Office of Engineering and Technology's Laboratory Division. It's a great laboratory.

So before I forget, because I can't

remember everything, I'm going to go ahead and plug for DOD their 2009 Spectrum Symposium. Just so everyone knows, it is October 14th through 15th at the Hyatt Regency Hotel. And it's a great event, too. So that's my commercial.

So, let's get started. The way this format's going to work is kind of familiar to you all, I think. We will start with questions that the panelists were provided ahead of time. And they will have three minutes to respond to these questions. And afterwards I'm going to encourage an open exchange between the panelists, and also we might take questions from our very friendly audience and from the Web as well.

So I get to go first because I started. So, Ranveer -- who is, again, the researcher, Networking Research Group from Microsoft. Microsoft has been one of the leading developers of technologies for the TD white spaces. Where do you believe we are today in developing that technology? What are some of the lessons learned from a technical standpoint? And what do you see as the challenges that lie ahead? What actions, if any, can the FCC take to help address those challenges?

DR. CHANDRA: Well, thank you. First, thank you for having me here. It's a great honor to be here at the FCC. This is my first time and I'm excited. Being a researcher, I guess I don't get many opportunities.

So, let me tell you what we are doing at Microsoft. This will be very brief. I do not have time to talk about all of them. We've been writing many research papers on this and presenting it in academic conferences. You can find more at the following website: Research@microsoft.com/knows, k-n-o-w-s.

So while most of the research in white space networking has focused on building smarter radios, radios that can sense very well, that can produce really good waveforms, we in the Networking Research Group at Microsoft have been looking at the networking challenge. The challenge of how do you take these radios and actually build a network?

How do you get them to communicate, get good throughput out of the system? And this is what we've been developing as part of the KNOWS project.

So when we started doing this, this was back in 2005, and all that time when we started getting into the details, the first question we asked was how is building networks in white spaces any different than building networks in any other unlicensed spectrum? What's so different about white spaces?

So we found out that there are three main differences, which we characterized as part of our study. The first is that there's spatial radiation in spectrum availability. The spectrum that is available in north of New York City might not be available in downtown Manhattan because of TD contours and the way they exist. That's the first challenge.

The second challenge is that of temporal radiation. Spectrum that is available at two nodes might not be available at a certain point of time because a primary shows up. Nodes -- two communicating nodes will get disconnected; they need to reestablish the network and so on.

And the third challenge, the first two being spectrum radiation and temporal radiation, the third is that of spectrum fragmentation. If you look at any other unlicensed band, most of them, it's just a contiguous swath of spectrum, a huge contiguous swath of spectrum. Here in the TD bands, what you have is you have the spectrum, but parts of it is occupied by the incumbents. So the entire spectrum, depending on where you are, you won't see the same spectrum available, and the spectrum is noncontiguous. So we need a way to make use of this noncontiguous spectrum.

So in MSR, in Microsoft Research, we've looked at -- we've worked on this project in three different versions.

Back from 2005 to 2007, we looked at how do you build a mesh network given these three characteristics. So when you wanted to build --

so this is what we did then, we showed -- we analyzed through simulations a solution user control channel that existed in -- that we used 900 megahertz ISM band as a control channel where nodes coordinated with each other, figured out what part of the spectrum is best to use, and when a primary showed up, they communicated that in the 900 megahertz of the spectrum; they used coordinated sensing.

In Version 2, this was WhiteFi, which we finished around December, January last -- January this year, which was in the press very recently. What we did was we want -- here we moved to the second version of the project, where we wanted to build a Wi-Fi like network. Imagine you buy it from Best Buy, you plug it at home; we want it to work. We want it to give very good throughput. We want HD video to go over it. How do we build such a network?

So here what we did was we got away from the concept of a control channel; we used distributed rendezvous.

We also came up with new metrics. And we have the theoretical analysis in our research paper, where we showed, given the non-contiguity of the spectrum, what center frequency, what rate should you use to get the best throughput. Note that common conception is that you should always go widest, the widest bandwidth you can get. Here we show that's not always the case. We came up with a proof around it.

And Version 3, thank you for the FCC, for giving us the experimental license. Now we are working, so -- just to recap, Version 2 was a system which we prototyped; we built. We showed that it can get good throughput in the lab setting, not outside. But now, since we have the license, we are going out. We are building a campus deployment in Microsoft. So Microsoft is a huge campus and there are shuttles that go around within buildings. And these -- we want to provide Wi-Fi Internet access within the shuttles, but the backhaul will be over white spaces. This is a proof of concept, where we want to study how

WhiteFi, the system we finished last year, can be adapted along with your location, and what are the new challenges. And we would love to come back and present our solutions, back to the FCC in three or four months, and tell us how we actually solved that problem.

So this is where we are. Moving forward, there's two requests. I'll elaborate more later in the panel, it would be. So, as part of the geolocation effort we are looking into how would you build a database. And we found out that, well, the FCC database is not very clean. To get any information about who the incumbents are, what the antenna height is, what range they're transmitting at, we had to parse through several of these spreadsheets -- these files, and it was cumbersome. We are still going through.

The (inaudible) database is also not clean. I know you don't maintain it, but I'd love to talk to you more about it. And it'd also be nice if you could establish the (inaudible) constants and the assumptions because it would make it easier to maintain consistency across the different databases.

The other one, which I'm sure you've heard a lot about, is that we really think that the sensitivity thresholds are too low. The coverage zones are too big. And -114 even as being -- is a bit too low. It would be nice if you could go up. And I think we can build systems even to -- up to, like, -107 sensitivity.

Thank you.

SPEAKER: Paul or me next?

COMMISSIONER BAKER: I'm going to go -- do you guys have a preference?

DR. PEHA: All right. Am I on? A question for Bruce. I want to ask about the lessons learned from the DARPA XG Project. In particular, what are the tradeoffs that affect the viability of spectrum sensing? What other elements might be needed to integrate with spectrum sensing for accessing spectrum, geolocation policies, something else? And what actions, if any, can the FCC take to help the provision of those elements?

DR. FETTE: Thank you for the opportunity to talk about some of the excellent work that we've done at DARPA.

First of all, I have to make it clear that I speak for what's going on in the Department of Defense as opposed to the commercial field.

And for the most part these will be my perception, rather than a DARPA perception.

And finally, I have to be sure that I make it clear that I will speak not only to the XG Program, but the subsequent follow on to the XG Program, which is the Wireless Network after Next, or WNaN Program.

So I think there's some really important things that have come forward from those developments, which DARPA performs for the purpose of creating new technologies and showing the way forward with these new technologies.

The XG Program actually completed a couple of years ago, and substantial value has been demonstrated from the XG Program. An example of that is a tenfold improvement in the utility of available spectrum to the radio networking functionality. That was demonstrated by spectrum surveys that were done under the XG Program, as well as spectrum surveys that were done by the SDR Forum and by the National Science Foundation. We clearly demonstrated that cognitive radios must sense, adapt, and protect other systems, the -- essentially the primary users from interference by their behaviors and their use of policy.

XG has subsequently been integrated into other defense radios of, in fact, multiple vendors. And so it's been clearly demonstrated that the technology can be integrated into a variety of platforms.

And thirdly, and equally importantly, it's been demonstrated that the spectrum awareness involved in these type of cognitive radios require some fairly sophisticated signal processing and a detailed understanding of the interaction of the various layers of the protocol stack. The interaction between, for example, the physical layer, the MAC layer, the link layer. All play into doing a good job of understanding what's going on in the spectrum that a cognitive radio intends to use, recognizing the primary user, and the interaction of your signal with any other users that are in the environment to minimize any possible interference you may play onto a primary user.

Similarly, we have learned in the WNaN Program that it's really important that cognitive radios understand interference and be able to be adaptive to interference in their own network and be very efficient at managing interference, not only by interference avoidance, but by the ability to suppress interference.

And so we believe that it's relevant and appropriate for cognitive radios to understand the interference suppression, interference minimization techniques as an important part of their architectural design.

We have demonstrated a substantial number of capabilities in the WNaN Program. We are now demonstrating scalability to thousands of nodes with ad hoc networking. We are demonstrating the scalability is achieved with a fairly sophisticated collection of technologies and techniques. We have demonstrated that the ad hoc networking is far more efficient when there's more than one channel available to the radio to use. And we have demonstrated early versions of this radio at Ft. Evans last December. And we will be continuing to demonstrate additional advances in the WNaN Program over the next nine months.

Thank you.

SPEAKER: Paul, I had the great pleasure to work with you when you were here at the Commission. And as a former chair of the FCC Spectrum Policy Task Force, what's your perspective today on the viability of the ideas that came out of the task force? Which of the recommendations from the task force that have not yet been implemented do you think the Commission should pursue first?

DR. KOLODZY: Do first? Okay. Well, if you remember, when we did the Spectrum Policy Task Force, one of the first things that we actually tried to do -- and I think in any of these issues, when you talk about technology and the like -- was to look at the cross between both the technology and the economics and the (inaudible) policy aspects, and trying to combine those. And the second thing that we tried to learn off of the task force was that spectrum, even though we all like to think that it's all either broadcasting, cellular, or Wi-Fi considers all the spectrum. Really spectrum is a lot bigger than just those three big application areas or big three surfaces. And so we have to actually take into consideration all of those.

When the task force came out, it basically had about -- I look at five major types of themes. One of them was that no single spectrum model, access model, actually worked for all the surfaces, that basically there were different models and that you had to look at the

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cross between those two -- the cost between those three.

The other aspect is that you had to get the rights and the responsibilities of the spectrum policy right. So when you actually build up rules, it's not just good enough to show about the rights, but also the responsibilities. And those can either be implied responsibilities or direct responsibilities.

And the next one was that spectrum scarcity. And we've heard that already before, that spectrum scarcity actually is more of a policy-driven concept and not really a reality; that there actually is a lot of spectrum out there that can be used. The question is getting access to it. And I think you're hearing a lot about that from a lot of the panelists here about how to get access to that spectrum. And that policy should be developed to try to stop the balkanization, reverse the balkanization spectrum, getting smaller and smaller slices. Because if you're trying to go to broadband, you're going to go -- need to get larger and larger.

And finally, that the rules -- and this is what one of the rules -- things that the FCC already did was that the rules for rural environments should actually be different than the rules for the urban environments. And actually, FCC, you did that. You actually went out, and actually some of your rules, you've actually made differences between the different environments. So bravo in that respect.

So the question is, which of the -- or these policies or these ideas that were put forth on the Spectrum Policy Task Force are still viable today. Well, they're technically viable today. Now, the question is, is there a -- are they politically viable today. And that'll be a question more for the Commission to deal with, and the like.

But there's still a lot of work that has to be done to really implement some of this framework. In fact, I think that Ofcom, you heard from William Webb earlier, they have actually moved forward, I think, at a little bit faster pace than the United States has. And since we came up with the Spectrum Policy Task Force, they've actually embraced some of that and looked at spectrum user rights, and trying to do a better way of defining those rights, and the like.

However, if you want to start looking at where to begin, I would start looking at our Section A of Chapter 9. If you want to (inaudible) I can get you a page number.

Basically it's the recommended key elements of a new spectrum policy. Basically it takes way too long for spectrum to get out there to the users, especially for new services. Sometimes it takes 11 years, 13 years. Lots of proceedings. In fact, Mitchell Lazarus just published an article on the IEEE spectrum on all those roadblocks. Most of the roadblocks come down to delays on -- from arguments on ill-defined interference rights and responsibilities, or rights and responsibilities that were defined in a different RF era.

And so if you're really going to start taking a look at right now, you have to take a look at how are you going to start defining those rights and responsibilities, and start getting them right. And the other aspect, start learning how to implement them and actually stick by your guns and actually enforce them.

Thank you.

COMMISSIONER BAKER: What page?

DR. KOLODZY: Actually, it was page 64.

COMMISSIONER BAKER: Page 64, everybody. Rashmi.

DR. DOSHI: All right. I guess I get to ask Dr. Mitola a question on some of the software-defined radios that we've been working on for a long time. And I'm going to just do -- editorialize the question that was sent to you because there are probably some changes.

As one of the world leaders in first developing the concepts of software-defined radio and cognitive radio, you have seen a lot of technological changes.

Here it says, when do you think we will start to see the first affordable, conveniently sized software-defined radios that are easy to use and offer commercially reasonable battery life comparable to today's cell phones?

I'll just editorialize that. I guess SDR recently published that they think iPhone and others are already software-defined radios. So you may want to comment on how you would think the current marketing definition of software- defined radio versus your initial concepts, and how can Commission action impact this timing going forward, and what are some of the issues you see.

DR. MITOLA: Thank you for your question. I'm really pleased to be here.

I didn't coin the term -- although I did coin the term "software radio," I did not coin the term "software- defined radio." It was actually Stephen Blust. And at the first meeting of the SDR Forum in 1996, he described what he regarded as a multiband, multimode radio where you basically had a lot of knobs to be able to turn the knobs on the radio to do multi technologies such as GSM and CDMA.

And this is a world phone. There are many manufacturers, so I won't say who the manufacturer or service provider is, but it has two GSM bands, two CDMA bands, and of course Bluetooth. And this is relatively primitive now compared to the chipsets and configurations that are coming.

It has a lot of knobs. Last night I was -- I had dinner with an expert in LTE. And if you think there are knobs now, just wait.

So, these are highly software-defined. And the ability for the networks to learn how to optimize so they really truly maximize erlangs per hertz that -- per kilometer is a key, I think.

But now turning to white space, which I think is also important, and to the greater agility outside of these licensed bands. I think that there's a lot of exciting things going on in heterogeneous bands for smarter radios, cognitive radios to do things. But the issue really for deploying these kinds of software-defined radios more broadly is mostly economics. At the APCO 25 meeting, actually one of Bruce's contractors, Tyco, has this, you know, P25 multiband, multimode radio that's in part based on the WNaN work. So it's getting out there. But it's got to be affordable. It's got to be affordable to the market niche, with or without subsidies, and so forth.

So the things that the FCC can do to promote affordability and leveraging the technology that's available -- somebody mentioned location, I think, in a question to Bruce. It's just like in real estate. For the next several years it's -- I think it's location, location, location because when you look at the way that radios actually propagate, Longley-Rice isn't it.

So if you look in even a reasonable suburban environment, put a radio here, get it to transmit. And in my position paper that I submitted in conjunction with this talk I have a picture of what the actual heat map is from that radio. And it's sitting on a corner near a building. And down the street it's hot for almost a kilometer. And 30 meters this way, inside the building, there's nothing. And 50 meters in the other direction there's a certain amount of energy that has ricocheted around the buildings and got into the back there, but there's still very little energy.

So it's really about 3D spatial modeling. And in the old days that would have taken, you know, racks of computers working over the weekend and so forth. But now these high-fidelity models can run on a laptop in real time.

So my recommendation to the FCC is to build on the superb job that you all did with the RNO in November and to augment the database requirements there to true 3D high-fidelity spatial modeling. And over time to have a plan to do temporal aggregation because what happens is during the week there's one set of things going on and there's a daily cycle, and on weekends it's different. And then if there's a football game at the University of Florida at Gainesville, where I'm from, everything's different. So those kinds of space-time differences really matter a lot to the use of radio spectrum, especially if you're trying to provide cell phone coverage inside, you know, Gatorland. So those, I think, are really important.

The next area is in policy languages. The IEEE P1900.5 is developing cognitive radio policy languages. And for the Commission to engage with the IEEE a little bit more perhaps on the value to the larger community and to productization of high-fidelity modeling in your databases I think would be key.

And then the final point has to do with testing. Again, the Commission has had tremendous success and reputation in the laboratory system. Well, today we can digitize the transmitting signals and create incredibly sophisticated emulated, not simulated, but emulated environments, real radio signals bouncing around in real -- in emulated environments using gigabit a second switches and so forth. So that real radios can interact with each other in strange and unexpected ways, creating environments that stress the system in the digital laboratory without having to go out into the real world to discover things. So some -- a greater attention to digitizing the testing for testing in sophisticated environments, I think, would be a great contribution from the Commission.

And by the way, seeing how much has happened over the past decade has been really exciting for me. So I really applaud the work of the Commission over the past 10 years in this area. Thank you.

COMMISSIONER BAKER: Thank you. Although it wasn't full disclosure that you're from U of F.

DR. MITOLA: I live in Gainesville.

COMMISSIONER BAKER: Paul. Sorry we got the order mixed up here. It happens. We're still federal here. We get things mixed up occasionally. We have just heard about a number of new technologies related to innovation that are really, really exciting. And you sit at Bell Labs in New Jersey where so many of the innovations in commercial telecommunications were actually developed. So my question really is what do you think a cellular network architecture of the future will look like and how will it differ from today's architecture? And what actions or policies can the Commission pursue to facilitate this new architecture?

DR. MANKIEWICH: Well, thank you all for having me. I've been here quite a few times in the last couple of years and I really do enjoy all the conversations, the technical conversations. I'm not real good at the business conversations, but the technical ones, I'm okay.

So let me start with probably just giving a bit of an example. You know, the iPhone or other smart phones nowadays are routinely deployed with both a 3G technology and a Wi-Fi technology. And probably even in the conversations that we had this morning with Kris Rinne and Bill Stone and John Saw, I don't think any one of them was taking into full account the throughput that goes to a device like an iPhone.

Probably 10 percent of the throughput to an iPhone comes through the 3G interface and the other 90 percent comes through the Wi-Fi component. If you took my iPhone, which is 32 gigabytes, and ran at about 700 kilobits a second over -- that's a pretty good pace -- over a 3G network, 700 kilobits, it would take you four days to download the three -- 32 gigabits into the iPhone over the 3G network. Which I think is a pretty sophisticated network, which --

So what you're having is -- this is a very key component of what I'm about to fill you in on on some of the technologies we're working on, is that the data use that is -- that people are now using data on things like iPhones and BlackBerrys that just are mind boggling as we move from business people using laptops doing e-mail to people watching an hour worth of -- I'm sorry --

cancelled television show ER. To download an hour worth of ER is 460 megabytes. That's a lot of megabytes. It comes over the Wi-Fi network.

The 3G network won't actually allow you to download it because it's bigger than a certain size.

Keep that in mind. That's a policy. We're going to use the initial policy in a much more complex way in a few seconds.

So as we step forward and see all this data use coming, we also realize -- and I think Bill Stone or Rajiv might have mentioned it -- this earlier, is that we're running out of space with Moore's Law. We are very close to the limit in how much bits per second per hertz we can get out of the air interface. We're basically -- we can do a few more things, but really what we end up doing is throwing spectrum at it. You use sort of an average of 1 bit per second per hertz to 3 or 4 bits per second per hertz, multiply it times the frequency, the amount of bandwidth, and you get about the total throughput of that spectrum.

And that's pretty much it. And then so you have to go to sort of spatial means to get more out of it, as was mentioned a little bit. And I'll get into that.

So there are some technologies we're working on that are very, very complex, to reduce interference and try and squeak a little more out of the air interface, to just go at it brute force. One is called coherent network MIMO. It's actually being standardized, as we speak, and LTE Advanced. The complexity, what we're going to do is share the antennas from the various space stations, and rather than using multiple antennas on one base station, actually coherently combine at the mobile for multiple antennas for multiple base stations. The complexity of doing this is about 10 times higher than the complexity of the LTE networks and the WiMAX networks we have yet to deploy.

You're talking -- and what we get out of it from spectral efficiency is somewhere between a factor of two and three. That's a huge amount of complexity for not much gain in spectral efficiency.

The next thing we're doing, though, we've realized that that is pretty much -- that road of just grinding out the air interface, running out of gas, the way to do it is to do it as, as Rajiv mentioned, is to go to heterogeneous networks. Basically start adding smaller and smaller cells to the macro network and get spatial distribution of that capacity. So a Wi-Fi is an example of that distribution. What you can then do -- what -- so the big technology, then, is if I do add a lot of small cells to the macrocell to get spatially higher throughput -- because think of it as each person gets sort of their own cell, like a Wi-Fi, you end up with a problem with how do you manage getting the data to the user in the most optimum way. Through which cells do you do it?

So probably the biggest effort that's going on inside of our company, and also one of the biggest efforts in standards for LTE Advanced, is the area around self- optimizing networks. How do I basically take a network such as that and decide am I going to send the data to the end user through the macrocell or through the picocell, through the femtocell, or even through the Wi-Fi node? How am I going to manage that data at the network level and decide how to optimize the routers, the backhaul, and all the different, other network components to be able to deliver that data?

And so that self-optimizing concept, to basically not increase the bits per second per hertz, but to increase the bits per second per hertz per square meter is really what we're going after here. And that's really the only direction we've got left.

Now, around the area of cognitive radio, really quick. We do -- are doing some of that today. When you buy a femtocell from us for wideband CDMA and you put it in your house, it wakes up, it looks around, it sees what frequencies are available, it turns its power down depending on how close or far it is from the macrocell, talks to the macrocell over the network, sets and allocates resources, and away it goes.

Maybe not as sophisticated as my colleague's cognitive radio, but it's a start in the right direction.

That's -- thank you.

COMMISSIONER BAKER: That's great. I'm going to go -- why don't I go ahead and announce the -- go ahead with a couple of the questions that we've had from the floor and online, just so we make sure that we are inclusive.

So, Dr. Chandra. If we solve the three technological -- the technical challenges, which are spatial variation, temporal variation, and spectrum fragmentation for TD white spaces -- could we open up other licensed spectrum bands for white space usage? Could we open up the entire usable spectrum band for white space usage?

And this could also -- I'm going to start with you, but if anybody else has something to add, go ahead.

DR. CHANDRA: That's an interesting question. What we are looking at is the networking challenge here, right? So sensing and geolocation is an addition which you would use to build these networks.

As far as other parts of the spectrum go, so there is a lot of research going on. Not at MSR, but if you're following other research conferences, people are looking at other bands and how would you detect primary users in that band. And of course, that is -- if that's the way to go, if you can do -- detect primaries properly, as people are doing research on, then with these three networking challenges of course you can build networks. If you can solve these three challenges properly, you can build efficient networks. Yeah.

DR. MITOLA: Let me just comment that when you try to do that, the laws of physics can be pretty daunting. As long as you're within a band, or maybe 10 or 15 percent of the carrier frequency, then you can build the electronics pretty affordably. But as soon as you start to try to get outside of that, it becomes really, really difficult.

So relatively modest white space is pretty affordable and pretty doable. But then as you get outside of it, the heterogeneous networks that Paul was talking about is really the direction that you have to go.

SPEAKER: This is a terrific panel. Hardly know where to start, there's so many questions.

How do you reassure incumbents who are concerned about getting interference? I think it's also influenced by -- at least my observation -- and people thinking about whether this is licensed or unlicensed.

So do the same techniques apply, for example, if we were to do overlaid licensed?

If you can comment a little bit about -- because I know, with some of the statements that were made, we're heading down a path where the devices are getting more and more intelligence. Rather than picking up one piece of information, they're really gathering a lot from the universe.

How do you reassure the incumbents that they're not going to get interference?

DR. MITOLA: You know, I like to say, measure and report. These devices know what's going on. They measure intensity levels. And with these cognitive radios, they don't just know what's going on in the channel they're trying to use, they know what's going on in the other channels as well.

That database idea for cognitive radio is terrific because it provides a place for handsets made by some other manufacturer to measure and report back to the database about what they are seeing. So it makes it really clear if an incumbent is actually being interfered with or what, and also the cause and effect relationship of what is causing the interference. It might be an aggregate of some out of band interference that's happening, and that's hard to diagnose.

But with that database as a mechanism, the ability for mobile handsets from any manufacturer, at white space or not, to be able to measure and report to an independent third party will shed an incredible amount of light on this question. And will therefore really help assure the incumbents that they are not going to get interfered with.

DR. FETTE: I'd like to add just a thought or two on that exact point.

Excellent work was done on this exact subject and described as the Radio Environment Map. And the Radio Environment Map has been documented by several authors at Virginia Tech. And the whole notion of the Radio Environment Map providing information to a well-structured database that makes it then available to the decision process as to what's available and where, it makes it a straightforward process for either the radio itself or the database server to describe what geolocations, what frequencies, and understand both the receiver's selectivity and the transmitter splatter patterns so that good decisions can be made about frequency power, modulation, and the so forth.

DR. KOLODZY: Things have -- there is two parts to that question. How do you, first of all, determine what interference is, okay? And that needs to actually be better defined for the Commission. It's right now a very subjective term in a lot of ways and it has not been made objective. So, some way, an objective term needs to be made.

I think Ofcom has tried to deal with some of those issues. And I think the Commission needs to go off in some of those same ways. And there are lots of ideas out there of how to define it, but there needs to be some definitions.

But the second aspect, which is more interesting, which is we're in a very different environment now. So I'm going to go down Paul's road here. We have lots of networks out there. And we have lots of resources out there.

So we keep talking about a cognitive radio, or radio that senses. Actually what you have is lots of users out there with devices that could be sensing. And so therefore it's no longer just that one radio needs to figure out what the environment is, but that actually the network can actually determine what the environment is, and to be able to do some control mechanism associated with that.

And we have to start thinking about things in the multiple network side and the infrastructure side. What has changed? When you -- if you asked these questions 20 years ago when cellular was just brand new, for example, if we're using cellular as an example, there was only one or two networks out there in a sense that were at any one location.

Now you have many networks that have been overlaid. They've had multiple build of different frequencies and different devices, radios that actually sense across multiple domains.

And so if you can actually start exploiting some of that technology and then integrating it together is some coherent way -- sort of like what you're trying to do with the spatial diversity across all the cellular towers, I think you have an idea of a direction that you might be able to go into. Actually be no longer just modeling, but measuring. And no longer just be measuring, but reacting to the actual environment.

DR. MANKIEWICH: I'm going to take the contrarian side here because we are doing a huge amount of work on -- in this space of cognitive radio.

And I think that, you know, if you have a -- there are two types of situations you're trying to deal with. One is the, you know, how does cognitive radio work in sort of a white space type of world. And then I'm sure you're alluding to the concept of could you put cognitive radio into the already licensed spectrum. And then how would you assure a Verizon or an AT&T whether, you know, you're not going to damage that traffic?

So far, at least, we have not seen the

technology progress enough to be able to actually analyze, in real time, and fast enough for each of the users that are coming up and down in the spectrum to be able to then correct and to be able to make sure you don't interfere with the users that are already there.

So there's a lot of great demonstrations for cognitive radio. There's a lot of questions still open on how do you measure interference, is it --

So when we do a cognitive radio type of thing in the femtocell, we're actually demodulating the entire signal.

These cognitive radios are not going to be demodulating GSM, CDMA. I mean, that's just ridiculously expensive. They're going to be looking at an RF signature and then trying to interpret what's going on. And it's changing extremely rapidly because there are a large number of users.

So I think we're not quite ready. We're actually not there by a long shot to be able to convince an operator, who has paid a lot of money for spectrum, that I can put these radios in and they're ready to go and they're not going to damage your existing users.

DR. MITOLA: If I can comment a little bit further.

The cognitive radio that you're thinking of may be different from the one that I'm thinking of. Because the one that I'm thinking of is the cognitive handset or laptop that actually does have the CDMA chip in there and it does have the GSM chip in there and it does have the WiMAX chip in there and it has a white space chip in there as well. And so its ability to measure BER is the same as your network's ability to measure BER, or the incumbent's network ability to measure BER. Do they do it today in this way? No, they don't.

SPEAKER: Right.

DR. MITOLA: Could they, and could they report their results to the FCC database? I think they could.

DR. MANKIEWICH: Well, I'm not saying it

can't be done some time in the future. I just don't think -- I think the technology's quite a bit a ways from being able to do that now.

DR. KOLODZY: I just want to follow up, just for a second.

I'm also not saying, generally, that it has to be on the cellular networks. The cellular networks tend to be very heavily used. And so that actually would not be the first place you would like to try and look at this kind of technology. I was just using that as an example since you have a lot of basically sensing devices. In fact, you could use the cellular radios as being sensors for other bands, and being able to be tied into networks and be able to survive in (inaudible).

DR. MANKIEWICH: Sure. In a visionary way, sure.

DR. KOLODZY: Yeah. Right.

DR. DOSHI: I guess there is a question from the floor, and I would kind of modify that as a follow-up to Dr. Mankiewich's point.

It may be not today, but considering the amount of data being collected by even a smart phone like an iPhone or a BlackBerry or others that essentially is being shipped back to whoever the service providers are. I mean, isn't there opportunity to start aggregating a lot of that information and using that either through some kind of a network database or others on what the local usages are. And starting building up a better -- I understand it's an extra layer of complexity on top of self-organizing or -- and recognizing it's not going to happen today, but at least over the next several years. And add to that the concept of building up current usage databases, at least in terms of spectrum use.

DR. MANKIEWICH: I just want to make sure we're clear that my point in the cellular network would be that you have to do things in real time because users are coming up and down. You're not really going to put a database together of who's on and who's off at any given millisecond. All right? This is more of who's in the band in general. And it's -- and when you do see someone in the band that comes on, you try and back your radio -- you back your radio off. Right?

So I'm not sure that the -- I do not believe the databases are going to be real time databases. They're going to be basically who's been allocated those bands, who's in those bands. Who is in those bands, you know, who, for instance, in the white space domain? Someone sets up in a white space domain, that would be then put into the database.

So what I worry about a little bit is that we think of this -- if we think of this database concept, if you go too far towards the real time, there are two issues I worry about. One is we already -- the network is already buried in signaling issues. So, for instance, a BlackBerry or any location-based technology probably uses a few percent of data on the network, and 50 to 60 to 70 percent of the signaling on the network because it's constantly banging back and forth: Send me e-mail, you know, give -- here's my location.

So the more and more I ship back and forth information -- and it hurts us, too, because we have to back off on some of the reporting we would like to do from the mobile because of all of the load it starts to put on the network. So that's one issue.

The other issue which we've looked at is can you do some of this on a per person basis. And to be perfectly honest with you, we get wound up with a lot of privacy issues. Collecting data on individuals is just not acceptable. So you have to somehow make sure that when you're collecting this data, you are making it anonymous in some way. And those rules today are very, very strict. Anonymous is very anonymous. So one has to make sure that you're very careful with that.

DR. MITOLA: Well, we've been doing some research at Stevens on this particular topic. And one of the sort of undeveloped opportunities, I think, is the amount of storage that's available in a cell phone. My wife has a 2-gig card for videos on her, you know, her phone. And that's nothing compared to what, you know, what's coming down.

So the opportunity to put data -- to collect, measure in real time. But to store it on the phone and then to aggregate it over time, you know, deliver it when she's home near the femtocell and not interfering with the network or on a Wi-Fi access point on the cable network results in an ability to create data -- to aggregate data. And with reasonable security provisions for hashing and so forth, that data can go into a database with anonymity provided.

So we think that there's some undeveloped potential for this kind of network characterization, including the ability for the network to determine sort of who the individual radios are. We're doing work, and we call it the radio biometrics, where transmitters have a little bit of IQ imbalance (inaudible) and so forth, for instead of having to remember all these passwords for doing banking and so forth, to have my voice, my cell phone's voice basically, and other characteristics of the propagation channel -- become my password, so that it becomes a lot more secure and more user-friendly. This does require more data inside of the network, but it doesn't have to be passed over the air interface. It can be handled on the backhaul. And in non-real time. Non-real time.

DR. MANKIEWICH: So I can see the use of that, if for a non-real time application. Like I've got a hole and, you know, I take the data because I drive through that hole and I can sort of map (inaudible). But I'm not sure how you would take that data and do real-time cognitive radio because you have to wait and download it. So it's -- it has an application, but it's not -- it's limited to a more static type of measurement.

DR. CHANDRA: So just to add to their point. So I don't know if you're aware of this, but certain companies, they do it -- so they do collect war-driving data for Wi-Fi using cloud sourcing; that's what they call it. Devices to figure out what are the APs around them. They send it back to the database. So this is not real time data. It uses Wi-Fi, but a certain amount of this cloud sourcing is possible. Yeah.

And as a researcher, I think this would be very interesting to get this kind of data because it would help in spectrum assignment and all that stuff. You can measure quality of spectrum at certain locations if you use this technique.

DR. PEHA: Let me ask a -- there's a lot of expertise here to my left on dynamic spectrum access of various kinds, both from spectrum sensing and geolocation. And most of the debate here has been about the television band. Forget the television band for the moment.

If someone were to try and identify another band that was conducive to that kind of spectrum sharing, what criteria would you use to try and evaluate where the most promising bands would be?

COMMISSIONER BAKER: You stumped them.

DR. PEHA: The type of license holder? Would that matter? Would --

DR. MITOLA: If it's military, leave it alone. Just kidding.

I think when we've characterized white space we haven't done as good a job as we could. Because, for example, when you look at the numbers in these reports, you find that in navigation bands and radar bands that the spectrum occupancy attributed to a radar -- in at least some of the reports that I've, you know, dug into in depth, give you credit for spectrum occupancy during the pulse, and then no credit for occupancy during the return. So you've got this radar band with a.1 duty cycle. And I'll tell you what, if you start trying to use that as white space, the radars are not going to be happy with the hot clutter that you're going to create. So that's actually fully utilized, even though from an instantaneous power measurement it's not, you know, fully occupied.

In addition, somebody mentioned earlier

about a 20-foot dish looking at the sky, and that's certainly the satellite communications' communities. Most of the reports that I've seen do not give the Satcom credit for being fully utilized or anything above what they can measure. And a Yagi from here, you know, that's this big from across the river versus a 60-foot dish pointing at the sky with the appropriate georatee is a whole different ballgame.

And then the third area is the use of code spaces. So if you look at some of the spectrum occupancy reports in the GSM -- in the GPS band, what's the spectrum occupancy of GPS? Because of the way that it was measured, it winds up being nothing, zero. Sorry, guys, but that's not white space.

So I think that the more, higher fidelity measurements of utilization versus occupancy are important. And then the value of that utilization to the community, such as aviation or military or public safety or whatever are the criteria that you really want to use.

Because I think the Commission has a social contract between the Commission and the people for fairness and for market development and for safety that are, you know, there's a balancing act. And so it's those kind of criteria that I would use for trying to identify the next band after TD white space.

And I think those things are actually used in coming up with white space as the first opportunity.

DR. KOLODZY: If you take a look at where white space came from, it basically was saying white space isn't time, space, and frequency. And one of the criteria maybe we want to think about is what is a high beta use. And a high beta use being either in time, space, or in frequency.

So high beta, what I mean in here, and it's an old Stock Market term which means it's a low average, but a very high peak rate. And so, therefore, those are the kind of usages where you can get out of the way when they need the peak rate, but that you're already -- but you're there when the low -- rate is low.

And the question is where are those users with respect to high beta use in space? Meaning there are very, very particular places where they are, and not elsewhere. That's sort of a little bit where the broadcasting thing came in; you thought you had location or, you know, localization of it.

Or you take a look at that in time or in temporal use, where it's not very -- used very often, but very peaky.

And that you have an ability to actually use other bands. And so the idea is that if you want to have usage that's always around, then you actually have to multiple bands in which you can do that. So when a peak user comes in, you can actually jump out. And that's sort of what the XG Program tries to do, which is when it hears one band, it tries to jump to another band. It's not meant to find an empty hole; it's find an empty hole until it's used, and then it's meant to jump away from it.

DR. MANKIEWICH: So let me take a different tact, which is we tend to focus a lot on the RF and -- but what about the business models. Is there a way that we could look at underutilized -- and, unfortunately, I am going to go back to a TV station for a minute. But I'm going to go to, you know -- and I apologize to anyone on the Internet, watches channel 51. But, you know, there's this famous channel 51 that sits at the edge of the 700 megahertz auction spectrum and it serves a certain number of people. But it doesn't serve a huge number of people. And a lot of the people that are in the channel 51 area get -- already get channel 51 over cable or Verizon or AT&T or whatever.

I mean, shouldn't we be looking at business models where if there are underutilized -- if there is underutilized commercial television spectrum, that the service providers that -- and if you think about it, where you need more spectrum the most is actually where you have the most people.

Because we have other -- we have different issues in -- and we could talk about that. But we have different issues in the rural and -- in the rural areas. But in the rural areas you probably don't need spectrum as much. Right? But you have issues with business models. The rural area issue is a business model issue, not a technology issue.

So to go back to this, that you have -- you need more spectrum, you basically make a deal with those wireline providers that have coverage in that area. Let's everybody give the person that -- the one person that has a TV antenna, that's listening to channel 51, give them service. Pipe their house with Comcast or whatever.

And, you know, we laugh at this, but we have been talking about this kind of thing with the operators because if you have these issues where you don't -- you have spectrum that might be available, it -- in another way, maybe not to use the spectrum, but just to remove the interference from that TV station, you know, you basically come up with a way to compensate the people by giving them a wireline connection so they don't -- so the few people that are using it don't need the RF connection. That's an idea. Different direction.

DR. FETTE: I'd like to take the other half of that question, if I might.

Paul previously mentioned high beta users. And I wanted to amplify that in the sense that the Department of Defense is one of those very high beta users. The Department of Defense has not only the need for high access to spectrum when it needs it -- and, you know, in the past, maybe it'd be about eight years ago, we had need for a high spectrum right away. And it's really important that in an unmeasurable and not economic way to provide the Department of Defense community with the spectrum they need when they need it.

And the Department of Defense is very much the same type of user as the 19 to 35 group where, you know, everything that the 19 to 35 folks expect in their PDA, the Department of

Defense users expect and more when they go up against the asymmetric bad guys who are using exactly that type of technology against us. So we really do need to provide not only all those same functions, but vastly more functions when we go up against them.

Another thing that's often overlooked with regard to Defense use of spectrum is that in the Defense community, unlike the folks on the ground, the Defense community is in the air. They're in aircraft, helicopters, and other airborne and spaceborne applications. And so even on the ground, the propagation, loss of energy (inaudible) forth, and so if you're a couple of miles away, you don't see an interfering signal. In the Defense community, they see that signal from 30 miles, maybe 40 miles away. All thousand of those signals are visible. When you're trying to communicate in the Defense world, it's much harder to find clear spectrum. So it's really important to the Defense community to get the spectrum they need to do the jobs that they do.

So I just sort of wanted to take the other half of that question and get a few points on it. Thanks.

DR. MITOLA: Just one follow-up on that and your question regarding what kind of criteria might you use.

Another kind of different sort of criteria might be the poolability of spectrum. In one of my first papers on this topic I described how I went out and did some measurements and found that the public safety -- the police chief had a tower on his police station. The fire chief had a tower on his fire station. And they were pretty much -- and that was it for public safety. And there were about 10 cellular towers in the town. So what I proposed was that the police allow the cellular providers to use their spectrum in exchange for having 10 more towers and power management, so that they could fill in the gaps and reuse and so forth.

And when I presented this paper there was a police chief in the back of the room that wanted to issue a warrant for my arrest, I believe, because it was just so, you know, he wanted to own his spectrum. So, you know, I know that there's been a little bit of that, and some of that thinking kind of went into the 700 megahertz D Block. I think there are legal and economic and, you know, social reasons -- impediments.

But I think that that's another thing to consider when you're looking at how to promote greater spectrum efficiency. And so the poolability -- so that you can actually create reuse opportunities in ways that we haven't been doing before because of the lanes in the road and the regulatory climate, driven more by that than anything else.

COMMISSIONER BAKER: I'm not sure how much -- what -- how much more time do we have?

SPEAKER: Pretty much clueless.

SPEAKER: Can't see the clock.

COMMISSIONER BAKER: Five minutes. Okay, we have five minutes. Good, we have time for -- you want to go first? Do you want to go?

MR. KNAPP: Well, I'll try one.

COMMISSIONER BAKER: Okay.

MR. KNAPP: So in the prior panels, we heard about the need for, take your pick, anywhere from 120 to more than a gigahertz of spectrum. And having been at this for a while, I know it doesn't come from nowhere. We're not manufacturing it. So the choices get pretty hard. You either take it from one and try to figure out where that service goes or --

How much of the technology that we talk -- we've been talking about be part of the solution? In other words, we've talked about -- and I think part of the question that Jon was talking about -- immediately sometimes we leap to white spaces when we're talking about the TV bands. I don't think we're really kind of getting at that, nor licensed or unlicensed. So much is -- the question is, we've got folks who've said, well, you know, 90 percent of the spectrum is unused most of the time. How do we squeeze more juice out it without telling services that are there now, well, you've got no place to go?

DR. MITOLA: I really think that there are tremendous technology opportunities that are really near at hand. For example, I've been using my cell phone in this room and there is plenty of fiber backhaul feeding this room.

So if, you know, that water thing there were a 60-gig link, then I could simply put my handset on the table and get a gigabit a second to that link. And I would -- and get traffic off of the CDMA network.

So I think that what Paul was talking about earlier about -- I think it's still location, location, location. If we can off, you know, create -- use the laws of physics to our advantage in radio spectrum and use the high bands that are not the sweet spot. You know,.3 to 3 is indeed the sweet spot for what we've been doing in the past, but with the proliferation of infrastructure in suburban home environments and apartment buildings and all that, going into the higher bands for services like this would be a way of offloading these low bands and augmenting and getting us gigabits a second to the handset instead of just the hundreds of megabits a second of the incremental LTE kind of evolution.

DR. FETTE: I guess I would agree with that. And I guess the obvious examples are implied by the proper use of the spectrum for matching up with the application. So, for example, at -- as Joe was mentioning, when we need really wideband applications, if we do that at really high frequencies like 60 gigahertz -- which has been proposed by commercial applications that I'm aware of, that really are in fact ready to be commercially viable. Lots of spectrum is available for very short range, for very high data rate applications, and it's fully appropriate to provide the opportunity to use real wide bandwidth for really short range. And we should enable them, the folks that need that kind of application, to be able to do so. It seems to me that that just makes sense, to use the right spectrum for those kinds of applications.

DR. DOSHI: Can I just -- maybe it -- wasn't that the proposal in terms of heterogeneous networks that Paul Mankiewich was talking about, in terms of using various types of infrastructure? Isn't that already discounted in the request for hundreds of megahertz of spectrum? Probably looking at Dr. Mankiewich when cellular folks already talked about needing hundreds of megahertz. I thought they were already discounting the fact that they can use hybrid networks.

DR. MANKIEWICH: You know, that's a good point. I don't -- so the issue is, you've got -- we're trying to estimate -- and the reason I made that example in the beginning -- we really are fairly clueless about how fast data is taking off. Those were my examples from the beginning. I believe that you're not going to find a gigahertz of spectrum available below 3 gigahertz. That's just not there.

DR. KOLODZY: Do you know where it is?

DR. MANKIEWICH: So there's got to be a tradeoff of -- and that's why we continue working on these technologies and look at much more elaborate methodologies around heterogeneous networks.

I don't think there's one answer, at all. I think that cognitive radio is going to help the wireless providers, even if you don't put anybody else in their spectrum because we'll use it to pack more in. Because what will happen is, you know, I think, you know, I still believe there's unutilized spectrum. There's underutilized TV stations. More people are having wireline connectivity. One can go after that, but that only goes so far.

So we have to use combinations of the two. Advances like I was talking about, and my colleagues here, around cognitive radio coupled to heterogeneous networks. And really, I'll use the term self-optimizing networks because that's really the term. Because without that self-optimization, you don't really get any benefit from just throwing cells all over the place.

So all of those technologies may get you part of the way there because you can't find all the spectrum you need because this data explosion is a tidal wave that we just can't get our arms around right now. And so it's just going to keep growing. We've got an exponential here. And you'll find more spectrum with our help, we'll develop new technologies, and we'll probably be always short of it.

COMMISSIONER BAKER: Well, okay, then if we can keep going, we can have a -- ask another couple other questions. I didn't realize that was an option. I realize everybody's ready to go, but let's just keep going just a tiny bit more.

I think this is kind of along some of the same lines, but could you all comment on whether it's feasible to move away from the traditional type or when it might be feasible to move away from the traditional type of tower and power cellular overlay network to more of a self-forming, self-healing kind of ad hoc underlay network.

DR. FETTE: I'd like to say that in the Defense community we have, in fact, demonstrated that ad hoc networking is extremely useful, extremely valuable, and extremely efficient with regards to use of spectrum. It is, in fact, the primary methodology that's used in advanced radio communication applications in DOD planning at this time.

So we are finding it to be extremely useful and successful. It has been, in the past, common for the Department of Defense to adopt technologies before the commercial community does. And since we're finding this to be desirable and efficient, I think that we will see the commercial folks begin to pick it up as soon as the protocols are available on the street.

DR. KOLODZY: I look at those types of networks or one you'd have used, you develop, and the DOD developed them, I believe, because they were going after infrastructure-free areas. So there's a balancing act here that you look at, is that if you have an infrastructure, why are you developing a network that actually doesn't need an infrastructure. You actually want to have that balancing act because you use it where it's necessary. And so if you have gigabit Ethernet sitting on the -- in the ground and you have towers that have availability to it, or at least in your home, you basically want to balance that act and use the wireline, that infrastructure that's available to you, and then balance that off of where you need the infrastructure for.

The DOD really needs it because they go places where there isn't infrastructure. But in our urban areas and in our homes, we usually have a lot of infrastructure. But maybe in rural cases, where infrastructure is much more difficult, then that actually has a play. And then maybe, possibly these technologies the DOD and others have been developing, like Microsoft has been developing, might actually be applicable.

DR. MITOLA: One of the things we haven't talked about this afternoon, at least that

I've noticed, is green radio. How do we reduce the energy footprint of wireless systems? And this -- these heterogeneous network -- these multi-element networks that can move data around from radio to radio, if you can -- if you look at, you know, one of our (inaudible) the fourth or the fourth law or in -- like in Tokyo, it's the seventh law kind of phenomenon. You're saving a huge amount of power by being able to send the same data on multiple hops. And so there is, you know, that aspect.

I think you've got to have both, but I believe that over time what Bruce is saying about the migration of these technologies from the DOD into the commercial sector will help. And I think that they'll be accelerated somewhat by the green radio. You really do reduce the power footprint, and service providers spend a lot of money on electrical energy on the electric bill.

DR. CHANDRA: The power footprint is a good thought. And especially from the research community, it's just speaking of what's going on in research. We organized this cognitive radio summit at Microsoft Research. Jon was there last year. So the proceedings are online. All the slides are there. So Bob Brodersen from Berkeley, he gave the keynote. And this was his vision, the eventual vision. So the research community is looking at this and there are some advances.

But I think, coming back to what was mentioned here, I think we should use both. When an infrastructure's available, use it. And otherwise I think white spaces is a very good initiative. And the lessons learned here will be applicable in other parts of the spectrum as well.

DR. MANKIEWICH: So, I don't want to go over, you know, basically the concepts we have, that I mentioned around self-optimization, are a form of ad hoc network, right, from the network side. And as far as a self-healing network, these, you know, the even today technology -- we sell technology that can, as I said earlier, you know, basically self-configure itself. You drop it into place and you don't do, you know, you don't have to do a lot of drive testing and things like that. These elements already recognize the network around them.

I think the thing to keep in mind also is that from a failure point of view, it's very important to have a self-healing network. Cell sectors go down. There's no reason why the rest of the sectors can't realign themselves in real time and try and cover an area that has now gone out because of whatever reason, whether it was hit by lightning; whether you actually, God help us, a piece of our equipment fails, whatever. And that type of technology is available now, and in the coming years it's going to get more sophisticated.

So the self-healing, self-optimizing network is well on its way. And a lot of those ideas came from a lot of the research done around ad hoc networking.

COMMISSIONER BAKER: Do any of the other moderators have a final question?

DR. DOSHI: Just one question. I guess it was discussed, and maybe there was a discussion in the earlier panels, in terms of needing contiguous spectrum. And some of the work that Ranveer and his groups have been doing is really using discrete spectrum. And I understand the issues in terms of mobility and others. But are there opportunities to use discontinuous spectrum more than continuous, given that more and more we're not going to get continuous bands of spectrum available?

DR. CHANDRA: So we have been actively looking at it and playing around with some devices from certain companies where you can, for example, for FDM, you do subcarrier suppression to use the noncontiguous spectrum. In our Wi-Fi system, the way we handle it is just adapt to how much bandwidth is available. If you have just six megahertz and we accordingly just adapt the width that we use.

As far as mobility and all that is concerned, we have protocols to handle it. We haven't tested it out yet in the scale of a cellular system or anything, but hopefully we will be able to do it with the deployment that we are going to do in the campus-wide -- in the Microsoft campus pretty soon.

DR. FETTE: And I'll report that in my presentation May 13, 2003, to the FCC, I showed an example of doing exactly that. At that time, it was practical to do discontiguous spectrum over 20 megahertz or so of bandwidth.

And today it's practical to do that over approximately 100 megahertz. Although power and complexity do play into the commercial deployment of that sort of thing.

DR. KOLODZY: Actually, I was going to say the same thing. It was back around 2003/2004 that a lot of these were coming up.

Another area that's to understand is that there is multiple file layers, been going on for an awful long time, in a sense, and being able to actually integrate multiple systems together. So if you're asking for what's called a single-file layer versus a multi-file layer, that's somewhere where the distinctions are going on. But this has been going on for quite a while.

It's obviously easier to do certain things when -- if it is contiguous, but it doesn't necessarily mean it precludes it. There's lots of technologies out there.

DR. MANKIEWICH: So, actually, if you look right now -- of the standardization that's going on for LT Advanced, I think there are as many as 10 different classes of bands being grouped together to be able to do wideband with a system over discontinuous spectrum. And it's being standardized as we speak.

So they tend to want to stick to spectrum that's a little bit close to each other, like 1900, 2100, or 1800, 2100, you know, 700, and 850. You know, those kind of things where they're grouped somewhat close. You don't -- people are shying away from grouping, say, 700 with 2100 because of the expense of trying to allocate the LFTM tones over that. It's not that it can't be done; it's just expensive to the handset to do it. But it doesn't mean it -- technologically it's possible, it's just an expense issue.

You know, we are -- to my colleague's point from this -- from the -- early this afternoon, I agree with AT&T and Verizon and others that it is much better to have contiguous spectrum. But there is a certain reality right now, and we're working and even standardizing technology now to be able to try and take advantage of that discontinuous spectrum.

So you might actually want to take a look at the -- some of the submissions into LT Advanced, where people are looking at what we call multicarrier LTE.

DR. DOSHI: I guess what would be useful, if there isn't a submission, in terms of what are the cost differentials between not doing contiguous versus contiguous.

Because if one just listened to the first panel, you would have walked away with the impression that if you didn't get contiguous, it was a significant penalty. And the question is what's that penalty?

DR. CHANDRA: I'll give you a -- it's -- okay, I'm speaking with the researcher hat on. I'm not -- this is from my personal perspective, from my own experiments. This is especially in the context of white spaces where we're dealing with wireless microphones. So we're just looking at, okay, how can both of these devices coexist? One of the things is you don't need to barricade the entire channel; that's a bit too much. And this is one place where if we use noncontiguous channels, it would really help improve spectrum efficiency.

COMMISSIONER BAKER: Okay. I'm afraid we're going to lose our entire audience if we don't draw this to a close.

So we'll continue this discussion here. I want to thank my esteemed colleagues who are moderators. And I want to just, again, just tell our panelists how wonderful they are and how grateful we are for their participation. I guess we are all excused to go find Section A, Chapter 9 and do our homework.

Thanks, everyone, for coming.

(Whereupon, the PROCEEDINGS were adjourned.)

* * * * *

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I, Carleton J. Anderson, III do hereby certify that the forgoing electronic file when originally transmitted was reduced to text at my direction; that said transcript is a true record of the proceedings therein referenced; that I am neither counsel for, related to, nor employed by any of the parties to the action in which these proceedings were taken; and, furthermore, that I am neither a relative or employee of any attorney or counsel employed by the parties hereto, nor financially or otherwise interested in the outcome of this action.

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Notary Public in and for the
Commonwealth of Virginia
Commission No. 351998
Expires: November 30, 2012