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VZ - Verizon Communications Inc at MoffettNathanson Media & Communications Summit

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PRESENTATION

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

All right. Good afternoon, everyone. So thank you for joining us today for the Sixth Annual MoffettNathanson Media and Communications Summit. Thank you to those of you who are joining us on the web as well. I'm really delighted to have Adam here today. Adam is the Senior Vice President for Technology, Strategy and Planning at Verizon. In most of these kinds of just presentations, I only get to ask 1 or 2 questions about the network. But for Verizon, that's not enough. Verizon is a company that has made network advantage not only a stated strategy, but actually in organizing principle. It something that everybody in the company understands. And so I asked Brady if we could really do a deep dive on the network, and he was kind enough to agree. And so I'm really excited to have Adam here today so that we can dig in, I promise I won't geek out too much, but I really want to have an in-depth conversation on the network.

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Thank you, Craig. Appreciate it.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Thank you for coming, Adam.

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

No. My pleasure.

QUESTIONS AND ANSWERS

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Let's start with a pretty high-level question which is when Verizon announced it's One Verizon strategy with its One Verizon fiber network in Boston, it was a transformation not only for the network, but really for the way the company was organized. Can you talk about how that came about and what it really means organizationally? And how it's different than what came before?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Absolutely. In fact, the coolest thing I can do first though is reference our safe harbor. As many of you have heard some of what we'll be talking about is forward-looking so it may involve risk and results may vary. For more information, you can go to our SEC filings or certainly Investor Relations page on verizon.com. With that said, yes, the concept is really a culmination of many years of really synergizing the way we engineer and design the network. And for those of you that remember, Vodafone had a large stake in Verizon Wireless, when we bought them out, we started a process of really bringing our engineering teams together to find synergies within network design. And in a scenario like Boston and like is



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happening in multiple other markets around the country, we're looking at a single build with a multipurpose use case network. And what that means is when you look at fiber being put in the ground in a market, we're serving not only our own individual front-haul and back-haul needs but then also opening up opportunities in the enterprise space, in the small medium business space, in the wholesale space from kind of that one network design. And so that took a while to bring together, but the important focus there for us was taking those engineering teams and bringing them together physically and from a network architecture standpoint and really driving that home. So you have 1 multipurpose network in the ground.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

And I think some people may not appreciate what a big deal that is. I mean it used to be if there was a fiber cut across the street here in New York, you'd have to deploy 3 separate teams to fix it, right?

Adam Koepp - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Yes. There were from an operational standpoint, not much has changed in that regard, and it certainly brings a lot of simplicity to the way the business is run. And again, the important part for us is when you look at the growth that's occurring on the network, both wired and wireless, in franchise and out of franchise, combining our engineering efforts there to really take one holistic view of how the network is designed with multiple use cases in mind is a huge point of synergy for us and something we spend a lot of time on.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

All right. So now let's turn to what everybody wants to talk about, and that's 5G. And it's also fair to say that 5G has become an organizing principle for the company. So just first take us through kind of what that really means, how it affects the way decisions are made, for example, in the company as you think about 5G from a network perspective and what's needed.

Adam Koepp - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Absolutely. Yes. So it's definitely a huge growth engine for us overall. The thing that sticks out for me the most is the tangible excitement that our -- of engineering and technician teams have. And when you bring something new like this to the market, you get the teams rallied around to this technical innovation that's occurring realtime. And we have the best engineers and technicians in the workforce and getting them charged up about something like this is not only fun to watch but then we see tremendous innovation on top of it. And from a business perspective, 5G will have extensions through all of the various ways we monetize our network assets to end consumers. So whether it's small medium business or enterprise or consumer, wholesale, there's a lot of aspects there that 5G is going to bring even further innovation, to. And then open up new lines of revenue, which is really the important part for us.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

So I'm going to start with one of those. Fixed wireless is only a part of the Verizon 5G story, and it's probably -- it's not even the most important part probably, but I want to start there because our own analysis of 5G Home in Sacramento I think illustrated a lot of the issues that are broadly applicable to the discussion of 5G. And it really starts with spectrum. So our analysis suggested that availability using your own 5G Home tool falls off pretty sharply after about 400 feet from the small cell. And even within those kind of short distances up to 400 feet, that availability is probabilistic I assume meaning that there's a higher probability of obstructions between the small cell and the target home. Now our analysis was done pretty early on, and you were using NF instead of NR, you were using 4x MIMO instead of 64, 400 versus 800 megahertz of your available spectrum. I get all of that. But just step back and help explain how it gets better and how much better it gets because the takeaway I think from our work was that it's going to be really hard to build that profile into a business.



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Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

So first, your team did fantastic work. It is actually flattering to have so much attention from you on this topic. But no, the work that you guys did in that report was very thorough. It was a great assessment, so really fantastic work. Your team deserves some kudos.

Craig Moffett - MoffettNathanson LLC - Founding Partner

My team is in the back, and Jessica in particular did all the work. I get mostly credit, but Jess did all the work.

Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

Well done. Fair enough. So just for background, and I'm not sure if everyone is familiar with how we've deployed 5G so far. But when 5G Home was deployed using, as Craig referenced, our Verizon tech form specification. It was a specification that we built ahead of standards working with our technology partners. It was designed to do 28 gigahertz millimeter wave, fixed wireless only, period. It's a subset, if you will, of 3GPP, 5G NR, acronym-heavy standard, which is what's now being deployed for mobility and fixed use cases nationwide, okay? That 5G TF specification had a finite life candidly. In fact, the characteristics of it while it works great for 5G Home where it's been deployed in our 4 launch markets, solid feedback and performance on that. It has limitations because we don't have any additional development occurring on that spec, on the infrastructure, on the software or on the CPE in the home. So a little different than what's being deployed, if you will, in our NR-based deployments, which I'm sure we'll get to Chicago and Minneapolis in a few minutes, but -- so the 5G Home experience there met with a very purposeful use case. I would say the feedback that we're seeing from the user community that's on that today has been very positive. We were using 28 gigahertz spectrum as you mentioned before, which is not a new band, that's been used for point-to-point communications for many years. And in that context, we've got 400 megahertz worth of bandwidth deployed. We have up to 800 megahertz at our disposal, so yes, I think the NR deployments will look a little bit different. From a usability standpoint, we were actually basically seeing what we expected to see. We've got very solid performance from a 5G accessibility standpoint. These 5G Home devices have 4G as a backup but 5G is the prevalent use case on that. The performance and throughput has been phenomenal and really truly differentiated experience. The propagation characteristics of millimeter wave are not new, right? I mean there's academia on this that goes back many, many years. The important thing that we focus on is networks are not just a function of the propagation of the radio, right? There's a design, there's a performance and an optimization that goes along with it. Same is true for 4G and 3G and everything prior to that. So our focus right now is optimizing the use of millimeter wave in this case to ensure that, that experience for the customer is truly transformational. Not that everything is perfect on day 1 obviously but there's plenty of work to do there. In the home concept -- the 5G Home that we deployed today, we are seeing very good results, and we're pleased with what we're seeing in the field.

Craig Moffett - MoffettNathanson LLC - Founding Partner

But I'm going to keep pushing on this for a second. Is millimeter wave going to turn out to be line-of-sight only? Because to me, ultimately that's the real question, right, is in your work with obstructions in the field, can you get past this being a line-of-sight spectrum band?

Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

Absolutely. In fact, when you go back to just a little bit of kind of history on how we got to where we are, back in 2015, we started the tech form, that's where the 5G Home spec that's now deployed comes to be. But in '16 and '17, we did a series of really pilots and commercial trials, if you will, names like that in actual field deployments. And what we were focused on was exactly that, Craig. It was how can this band work in an actual access deployment. What do you have to care for in your design and optimization of the network? And today and then, we see 3 categories of access to the end device. And you referenced line-of-sight, which we use LOS to represent. There's also virtual line-of-sight, so where the device on this end is seeing not a line-of-sight signal from a radio that's transmitting, but perhaps a reflective signal or reflections from multiple transmit nodes in the equation. We call that virtual line-of-sight, okay? You may see it off of service nearby. And then there's none line-of-sight so the radio is transmitting and that end device cannot see that radio transmitter at all, period. And it's gathering signal from either reflection or refraction off of objects in the environment. All 3 of those are live today, both in our 5G Home footprint and also in the mobility footprint in Chicago and Minneapolis. So we know it works.



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Craig Moffett - *MoffettNathanson LLC - Founding Partner*

But to a sufficient extent -- so the takeaway from us was eligibility and again, we were relying on a tool that I think you had specifically said was intentionally conservative. But we were relying on a tool that said, eligibility dropped below 50% of homes within even after 300 feet. What kind of median cell radii can you get in millimeter wave such that it's not just going to be so expensive to blanket neighborhoods with so many cells that they just aren't any economics in it?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Yes, no, great question. So referencing the tool that does the home eligibility. A couple of notes on that as well. Much like the TF spec, the home eligibility is looking at exactly what's deployed, right, where the homes are, and this is the TF deployment, okay, and then doing an assessment based on that actual customer location. Our actual deployment of 5G Home today is very much a white glove experience, and we'll probably get to that in a little bit, and some of the lessons learned there, but our goal there is actually deploy a technician to that house and then capture feedback from the actual deployment of said equipment and validate the tool. Since that has been launched, that tool has evolved just like the network has, and we've been putting refinements into that to sharpen the models. We did take a very conservative approach on that because in these 4 5G home markets that were initially launched, there were very specific reasons for us to look at this is what I want to put my -- how I want to build the deployment model for these 4 markets because of a finite amount of equipment and a really a limited capability and limited number of CPEs. So a lot of lessons learned from that, that will help refine the tool. I would say to that in that exact deployment, we have examples where the CPE is 4,400 feet away from the actual transmit node. So we know we've got very short distances that we're transmitting over and also very long ones as well. Right now it's a mix of both.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

So you described the white glove experience. The first step is sending a technician to test, to validate the eligibility of the tool. Can you just share what kind of percentage confirmation you're getting?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Yes, so a couple of things go on in this white glove experience. And I would -- in our 5G Home markets today, we're doing the white glove, everything is a [guided-install] (corrected by the company after the call). The customer actually doesn't have a choice because we want to capture a lot of information from that home experience. And so what we're seeing there as Craig references we have a technician validate that the model and the street-level coverage, the in-home coverage are accurate. So we are seeing actually very good alignment there between the model and the actual field results.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

You don't care to put a percentage on it? Or can you...

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

It wouldn't be even meaningful at this point in time because the scale is so small, but what we're seeing in that, the other piece of that equation is what percentage of those homes actually need an external antenna versus an internal antenna. And this has actually been a pretty interesting evolution of technology as well. So when you think about the 5G Home experience for us, the goal for this when we relaunch in the second half of '19 with the NR spec and updated CPE, the goal is to have the vast majority of those installs as a self-install. Router gets shipped to the customer, we have either some guided material or phone support to help them place the CPE, and they are off to the races. And the majority of what we're doing today on the TF spec is actually a guided-install. Two things that are evolving there. One, we're seeing an advancement of antenna technology

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that is also self-install, so could be a window cling antenna or something else that the customer can easily install for themselves should they need an external antenna placement. And then there's obviously a professional install that would be available either way. But we are learning now that we expect the bulk of our installs to be a self-install experience when we relaunch 5G Home in the second half of the year.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

And when do you think you can do that?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

That's the second half of this year.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Second half?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Yes.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Okay. Now before I turn to some of the bigger issues around 5G which relate to mobility, I just want to ask a couple of business model questions around fixed wireless. I guess the first one or one of the pervasive ones that kept coming up as we did the work was because density is so important, because the radii are small and therefore density to make it economically viable is so important, you end up being guided to places that already have fiber over builds. T-Mobile went in the other direction, now arguably it was just to sell a transaction, but they argued that if you're going to do fixed wireless broadband in the 2.5, the place to do it is in rural. Can you just talk about that? Is there room for doing this outside of dense urban markets? And what's more important, the fact that you're up against what may be 2 wired networks in a dense area? Or is it more important to make sure the density is high enough to make the math work?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

So the way I would look at it is when we pair our 5G Home activity with our fiber deployments, which we're doing in markets all over the country, we could be very selective for where we target broadband in the home opportunities. We can look at the level of competition, we can look at the level of service offerings, run the math on how viable it is to compete in that market and then be very selective for where we deploy. We have a large number of customers that use our 4G LTE Advanced network today as their broadband solution. A lot of that's in rural, a lot of that is in suburban, so we see that today. That's data we know and then can use to inform ourselves where the best places for us to deploy 5G Home are going to be. As a result, we can be selective with our build. So one of the benefits of having a broad small cell base network that extends beyond just dense urban into suburban is that our ability to augment that architecture, build laterals off of it, if you will, to use a basic term, is fairly straightforward. It's a very light lift for us to take existing node density that we have today and build off of that to incorporate new household, new neighborhoods with the 5G experience. So whether that extends into really far rural is a different story, but that urban-to-suburban migration is very logical for us. And then we can also use our existing network to figure out all right where there are additional opportunities for home broadband based on where we see that kind of traffic today.



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Craig Moffett - *MoffettNathanson LLC - Founding Partner*

So here's one of the places where I've gotten confused in conceptualizing the business model and that is if the logic is that I need to densify my network anyway. As long as I'm going to densify my network anyway, I might as well put in place the capability to address an additional revenue stream, which is fixed wireless. And therefore I do fixed wireless. And isn't it the case that the other wireless operators will end up in the same place, which is also trying to address of opportunity? And if they do, then aren't there in effect half as many available homes for each of you because the 2 of you or the 3 of you, as it turns out, will have to divide up the market share that wireless is going to get?

Adam Koepp - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

It's certainly you can look at what others have talked about from a deployment and say, okay well, they're going to participate in some way, shape or form, which they've all indicated they may. What we're focused on right now with that though is we have the path to the 30 million homes that we've referenced passing with our 5G Home experience, and that is built on 2 things. One, an existing deployment model that we have today that extends beyond dense urban into suburban aligned with our fiber deployment, right? Those 2 things going hand-in-hand is really what's puts us ahead of the curve from that side of the deployment. The second piece of that is when you look at how the network is going to be designed with 5G coming, you're going to have kind of an inside-out strategy. We see the bulk of our usage in certainly the dense urban areas, right? You add 5G on top of that, you have a tremendously differentiated experience there. And then you start to grow beyond that and the growth beyond that, when it's paired with fiber, is what gives us the competitive advantage. So that lift based on our small cell design that extends into the suburbs with fiber deployments is a very effective deployment model for us. So if there tends to be more competition because other operators are talking about the same thing, A, we feel we have an advantage, and B, we can see today that we tend to do this better than anybody, so we're going to leverage that skill set as well.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

So I'm going to wrap up on 5G Home with the obvious question and that is, can you update us at all in terms of take rates, particularly in MDUs? At least in our study, we didn't have any visibility into MDU's but can you update us on take rates, churn rates and customer service?

Adam Koepp - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

We haven't shared anything publicly yet and I would expect we may when we have more meaningful numbers. So when it starts to pick up and ramp up and certainly it will go past the second half of this year where we relaunch, you'll probably see some of that information.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

And any change in the 30 million home target, the 25% of the country?

Adam Koepp - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

No to share it today. No.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

All right, got it. So now let's turn and I promise I know what I'm guessing what people really want to talk about is mid-band spectrum, we're going to come to that in a second. But first, I want to get to the broader questions around 5G, and those obviously have to do with mobility, really. When I think about the use cases of 5G, one of the use cases I hear about all the time is driverless cars. There is to say, the least, a pretty rich debate though about whether you can rely on a network for mission-critical functions like steering and braking. What's your take on the driverless car use case for 5G?



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Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

It's a great question. In fact, when we started the early 5G work, we referred to an aspirational use case of having an intersection like maybe one here in Manhattan that has no traffic lights or stop signs or anything else. And the network -- the collective network, if you will, will pilot all the vehicles and pedestrians through the intersection. That's about as far-reaching as you can get from a use case perspective because the number of industries that would have to change to do something like that is phenomenal, right? So yes, you can put the network in place, you can even add multi-access Edge compute at that intersection so that your latency is single digits. But what about all the vehicles and all the people and the people that still stare at their phone when they're crossing the street. There's a lot you have to account for in that scenario. So driverless vehicles at scale using a network I think has a long way to go. What I would expect to see though in some of the early use cases that are emerging here involves things like drones. So LTE networks and 5G networks as a kind of a communication of pilot layer for drone technology is something that's emerging fairly rapidly and has some interest internally and externally.

I think you'll also seen use cases like virtual reality and augmented reality where you need high bandwidth and low latency combined. That's something that 5G can deliver that really 4G can't. You'll start to see those use cases emerge pretty quickly.

Craig Moffett - MoffettNathanson LLC - Founding Partner

To push on that for a second though because I think -- so drones are an obvious one right, because they are truly mobile devices?

Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

Yes.

Craig Moffett - MoffettNathanson LLC - Founding Partner

When I hear a lot of the use cases, telemedicine or remote surgery, for example, we're not doing surgery in corn fields. So as I think about the places where mobility is required that you can't do it over a fiber, which is going to have very good latency as well, it narrows the set of applications somewhat. 5G factories, the same thing. To each individual machine it is probably not going to communicate out to the public network and back, you're probably going to do a location-specific private network. Which applications, when you think about the applications, pop up as, yes, these are ones where Verizon can really add a lot of value and there's real revenue there.

Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

Yes, it's a great -- there's a ton of thought going into this exact question, right? Because when you look at, we'll call it the standard verticals that you participate in, whether it's health care or industrial automation, Telematics, every one of them has an existing use case today that can likely be augmented by 5G and can likely create new use cases that don't exist today. So a lot of the focus right now is on identifying what can 4G not do that truly requires 5G. And we come back to examples today, I'll give you 1 enterprise example and 1 kind of consumer example. In the enterprise space, industrial automation is a hugely important thing for them. And you have a lot of assembly lines that are being built on robotics and automation. There are limitations to communications networks that are being used for that today, WiFi or otherwise. And a combination of 5G radio access inside a plant, right, combined with multi-access Edge compute where the computation for the decisions that have to be made on the assembly line are done on site as opposed to in the core of the network. That is gaining a tremendous amount of traction right now. And you can't solve that with a WiFi solution or a 4G solution. We feel uniquely positioned there through a combination of 5G with millimeter wave and multi-access Edge compute to deliver that type of spot solution to an enterprise use case. On the consumer side, and I was in DC a couple of weeks ago talking with our fantastic government team there, I had a few quick minutes to do a battle field tour. And what struck me that when you think about a tour like that where you're walking through a visual display of our nation's history and if you're having a VR and AR experience that is we'll call it easy-to-wear as opposed to the traditional giant VR goggles, there's tremendous use case opportunities there in the context of VR and AR



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when you incorporate it into daily life like that. And simply the bandwidth that's needed for that and the latency that's needed for that can't be delivered by today's networks. So I see VR and AR in the consumer side as something that should emerge fairly quickly from a use case standpoint.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Is there a race with China? It's one of the things I admit, I struggle a little bit to sort of conceptualize how we're in a race with China for a 5G.

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

I struggle with you. Yes. We look at it -- our customers -- we compete for customers domestically. I don't compete with other countries on the purely wireless side, I certainly compete with other countries on the enterprise side. But in the context of 5G, we know our customers are going to make their decisions largely domestically. So racing China isn't necessarily a thing I spend too much time worrying about.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

But there is 1 piece of that, that it's clearly real and relevant and that is ensuring that there is a supply chain that exists outside of Chinese manufacturers and the security issues associated with Huawei and others. Can you just comment on that? Are you comfortable with the global supply chain outside of China?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Yes, I am actually, because we don't actually use any of the Chinese suppliers today, and I have no plans to on our 5G or 4G network or really any of our Verizon networks. And we've had a long-standing history in the context of 5G, we have 3 major radio access network providers, Samsung, Nokia and Ericsson, and we have a long standing history of basically co-innovating with them. And we're very comfortable with their position in the industry. They've been great technical partners. And in the context of the larger standards universe, all of the operators and all the technical partners basically play in that same space. So the contributions that feed into a body like the GSMA that helps facilitate the writing of 3GPP standards, that is a huge collaborative effort across the globe. So we're all very active in that space. From a pure supply chain standpoint though, we have a lot of confidence in our existing partners and know they'll be successful.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

All right. Now let's turn to the topic I think probably what most people really want to talk about, I'm guessing, and that is back to spectrum for a minute. On your last earnings call, Hans, for the first time, said that you shouldn't think of millimeter wave spectrum as coverage spectrum. Can you talk about what role millimeter does and doesn't serve -- the millimeter wave spectrum does and doesn't serve in the network? Because I think there's now -- that sort of muddied the water a little bit with what people thought they had understood your company's position to be.

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Yes. So without going through the litany of spectrum characteristics, every band has unique characteristics, and I'll give you a really simple near-term example. When we launched LTE, we started with a coverage layer at 700 megahertz, nationwide coast-to-coast, contiguous spectrum. Shortly thereafter, we added AWS spectrum right, as a capacity layer. We added PCS spectrum that we re-farmed from EVDO as a capacity layer. We're re-farming 850 where we have it for capacity on LTE. And you've got a cycle here that is referred to as spectrum re-farming where you take the old stuff off said spectrum and put the new stuff on it, right? That is a standard practice we happen to be usually at the far front end of that because of the growth of traffic on our network. So you look at that incredible growth on the network on the wireless side and where it's occurring is no secret. It's in the dense urban areas where the people and the usage are. You put millimeter wave on top of that, right, and you get an immediate capacity uplift when you start serving that traffic through 5G on millimeter wave. You made your 4G network better, and you provide new experiences



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on the 5G side. We've spent a lot of time ensuring that the customer transition between 5G to 4G back and forth is working exceptionally well. In fact, when you look at some of the other markets around the globe that have launched 5G on millimeter wave, they didn't spend as much time on that, we did. We spent a lot of time ensuring that, that 4G, 5G worked very well together. Now when you think about the bulk of your usage in the dense urban centers, using millimeter wave to support that growth on the network is extremely logical.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

In dense urban markets?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Yes. Yes. Where the people are. So when you have a large concentration of people and traffic putting say, 400 or 800 megahertz worth of bandwidth in front of them provides a very large pipe to accommodate new use cases that would emerge with 5G, right? So not just the raw throughput you're getting out of millimeter wave, but new use cases that emerge on top of that. Now if you take that same spectrum and try to build literally a nationwide 700 megahertz like footprint with millimeter wave, none of our engineers would ever sign up for that. That would make no sense whatsoever, which is why when you look at that concept of re-farming your existing bands of spectrum for new use cases, you're going to start to see things like dynamic spectrum-sharing come into the fold where operators can target existing bands to put 5G services on top of them that meet a specific use case. So if I need a coverage layer, can I use an existing band to help provide a coverage layer as opposed to a 400 megahertz millimeter wave pipe where I want to provide multiple gigabits of throughput.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

So if I just stay with the millimeter wave, at least for a second, if I go to your dense urban markets example, even then that's -- am I right that because of the propagation characteristics of those through walls and windows and low-e glass and what have you that in urban markets those are going to be outdoor coverage only? That may address, if I put small cells on every corner of every intersection, I can address the outdoor use case even then it's not entirely clear to me that I can use it in a taxi if I roll up the window. But...

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

You absolutely can.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

But how about getting into buildings? Is it a completely separate network use case to say I also have to build small cells inside buildings?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

So you probably see something very similar to what we saw with LTE networks which was in the beginning letting 700 megahertz crank through the building was good enough because people didn't even know how dependent they would be I think devices, right? And then what happened over time? Well, the network design actually shifted from outside to in for in-building coverage to inside stays inside and outside stays outside. And places like this, stadiums, venues, shopping malls, big cities, the proliferation of in-building solutions has -- was rapidly advancing.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Including WiFi but also...



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Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

Sometimes including WiFi but why would you need that when have an LTE experience that flows WiFi out of the water, right? So you saw a lot of keep the inside covered by the inside systems. Now one thing that we'll see with 5G and really in the millimeter wave bands and otherwise is that the in-building portfolio will start to show up towards the end of this year.

No secret that NFL stadiums and NBA arenas and other places like that absolutely ripe for 5G innovation. So you'll start to see network infrastructure solutions that fit those profiles between now and the...

Craig Moffett - MoffettNathanson LLC - Founding Partner

And millimeter wave may be very well-suited for those kinds of applications?

Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

Absolutely. Yes, without a doubt. Yes.

Craig Moffett - MoffettNathanson LLC - Founding Partner

Let's talk about the Chicago and Minneapolis markets because those -- the press reports were -- at least that coverage was pretty limited when you first started, and you waived the \$10 fee, I suspect in part because the press coverage was relatively rough. One of the reports said that, that's -- that, that was only -- that 5G was only available for downlink. Is that right? And if so, when do we start to see uplink from 5G? And then just how much further do we have to go before this is really a sort of a user experience that lives up to the Verizon reputation in Chicago and Minneapolis.

Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

Yes. I would say to start in Chicago and Minneapolis, we're seeing what we expected to see, and so we've had a mix of really good experiences and some that have had challenges which candidly is not new. I don't want to date myself much but having been through the 3G and the 4G evolution, this is stuff we typically see when new technology is put into the market at scale. So what the approach we're taking in both is almost daily software improvements between the device and the network. And it's -- to use the buzzword, it's a fairly agile process and working with our radio partners, we find problems in the field, we fix them realtime, software gets pushed out, it's tested, it's made operational, it's a very rapid process. Uplink is included in that context, right? So we've already tested the uplink on 5G. It's an approved software that's going to be deployed to the network over the next few weeks so that solves that problem.

Craig Moffett - MoffettNathanson LLC - Founding Partner

But using millimeter wave, the power levels in a handset of 4 milliwatts or 6 milliwatts or whatever are just not going to propagate very far in those frequencies, right?

Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

We don't -- we have uplink in the lab that's testing and working exactly as we expected on 5G. And that will come for the devices in the market shortly.

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Craig Moffett - *MoffettNathanson LLC - Founding Partner*

But what is -- I don't know what you're expecting?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

We're expecting it to work, so, yes. Right now, that's what we're working on.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Okay. And so but you can do millimeter wave uplink in a commercially viable?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Correct.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Okay. And what about with issues like rain fade passing objects and body obstructions, hand obstructions and things like that?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Yes. A lot -- so we had a lot of questions on that going back to some of our early pilots, in '16 and '17. We debunked most of those and I guess what I'd point out is that the RF design is not a new science certainly. It evolves when new spectrum is put into use. But things like obstructions in the environment is part and parcel to designing an RF network. Yes, you take different things into consideration when you're looking at a millimeter wave network. You also take things into consideration differently when you're looking at a rural versus urban versus suburban. So there's a lot of variables in that, that are tools and are constantly updated to reflect and capture so that the RF design is best-in-class for the operator or for the operator and for the consumer at the other end of it. And the distances we're talking about with all of our deployments, and that's everything from what's in TF today to what you would see in a dense urban environment, and everything in between, rain and snow don't factor into that. If we're talking many miles that we're not trying to shoot that signal over, you would take weather like that into account. But in the scenarios that we're deploying that does not come into that type of thing.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

So now you talked about mid-band spectrum in the context of re-farming what you already have. One of the obvious questions that I get in every conversation about Verizon is, but they need more mid-band spectrum, where are they going to get it? First do you buy that premise that you need more mid-band spectrum, whether it's for 5G or just in general?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Well, I don't want to get too far over my skis here because we're in a quiet period for millimeter wave. But couple of things to take into consideration, mid band has had a lot of different connotations over the years, right? So I think at one point, you could look at PCS at 1,900 and AWS at 2,100 and call that mid-band. We have deep holdings in both of those. Certainly, in the U.S., CBRS 3.5 gigahertz is targeted for 4G, right? Power settings are pretty low for that, so it's got a very particular 4G use case, and we're really looking forward to the FCC blessing the sharing mechanisms for that so that can be put to use for 4G LTE. And then beyond that, every available domestic spectrum, we have a plan for how we would use whatever becomes or whatever could become available. And so should additional mid-band spectrum become available and there's the CBA alliance as part of that, the FCC is part of that, we're ready to go when we understand what the path forward is.

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Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Do you think you need it? There was a time when you went to unlimited a couple of years ago, everyone said you are teetering on the brink of spectrum exhaustion.

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

I remember those days.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

And your network has done just fine and proved everybody wrong.

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

So part of that is due to the re-farming. So there's a couple of ways to look at this. We have a lot of confidence right now in the millimeter wave of holdings that we're deploying. We've got a great portfolio of bandwidth to deploy for end-user cases. We feel really good about that. We don't say -- we don't rule out any particular consideration when it comes to spectrum being made available for operators to deploy. And so we do better than anybody as so those opportunities come up, we look at every one of them equally and determine if it fits the portfolio, if it's something we need to augment services, if it can create new use cases, et cetera. So we're fairly opportunistic in that regard.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

So you mentioned a minute ago something that I thought was really interesting where you talked about the days when we used to think of mid-band as PCS up through maybe 2.1 gigahertz. In fact, it was sort of anything from 1 gigahertz up to 2.1 gigahertz but there's just wasn't anything in that lower part. But now, the definition of mid-band has expanded and expanded and expanded. Do you worry that, that the -- just because we call it all mid-band that there is a tendency to view it all as if it's the same? The propagation distance in free space, for example, of 3.5 gigahertz to take one example at a constant power level is about 1/4 that of 2.5 gigahertz, which means 2.5 gigahertz, which Sprint always struggled to make a business case out of would still take 1/10 as many cells as 3.5 gigahertz would to cover an area, right? It's about a 10x?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

It kind of depends, and it depends on a couple of things. One, it really depends on the band plan. So if you look at the way, for example, the FCC has constructed the use for 3.5 gigahertz, the power levels are very low for that band. So its ideally suited for like really small, small cells. That's just the way that band plan was approved through the FCC, okay? Each band has its own characteristics and a band plan. So what we have to do constantly and this is not -- and this is BAU if you will, is every known available band that's in the United States, we have a plan should it become available to use on our network. And they all have different rules when they come to market. So you have to be a little bit forward-looking and say, all right, if this spectrum becomes available, what would we do with it? But then you also have to be fairly reactionary because when that band is released for use, it's going to have a band plan from the FCC. It may have incumbents, it may have restrictions, it may have other parameters that you have to work through, and you won't know that until it actually comes to market. So everything depends on how the band plan is constructed.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Do you think about -- so the trade-off or one of the trade-offs that we all have to think through as we think about the various mid-band options that may or may not be out there? Is block width versus spectrum frequency, that is lower frequency within the mid-band within this now expanded range of what is called mid-band is clearly better than higher. But more block width is clearly better than less. Which of those is more important in



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your mind? Is it more important to have big contiguous blocks even if it's higher frequency? Or is it more important to have better propagation and penetration from lower frequency?

Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

I think it really depends on the use case you're trying to solve. I know that it's probably a lame answer, but it's the real one. And so think of it in this context, right?

Craig Moffett - MoffettNathanson LLC - Founding Partner

So what's the use case that you need to solve then.

Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

Well, I'll give you a generic example, if you will. So if you think of 700 megahertz, which is our LTE coverage layer, right, we have 22 megahertz worth of bandwidth in that band, right? So with 22 megahertz at our disposal, we're fairly limited in what we can do. Now it's a great coverage layer for LTE, right, and that's nationwide deployment for us. So things like our IoT network can absolutely use that to its fullest extent and run exceedingly well on that band. But the reason you then move to bands like AWS and PCS where your traffic growth is, is because we have a wider pipe that we can put into the hands of consumers for use. So it really depends on the band that you have at your disposal and then what problem you're actually trying to solve. That would then dictate the strategy you take for, for pursuit of both, a band or your response to what's available in the market.

Craig Moffett - MoffettNathanson LLC - Founding Partner

So staying on this topic of block width for a minute. So if 5G is deployed broadly on 20 or even 40 megahertz wide, but let's call it 20 megahertz wide blocks like some of your competitors or peers are talking about. My fear is that people's expectations based on the hype around 5G have said this is going to be 20x faster, and you're going to download a season of Game of Thrones in 4 seconds. And what kind of speed and experience upgrade is it when you deploy all the best characteristics of 5G, but it's only deployed on a 20 megahertz wide

block?

Adam Koeppe - Verizon Communications Inc. - SVP, Network Strategy and Planning

You know it's a fantastic question, and it's one that I think the industry should ask probably more often. Because the reason we got so excited about millimeter wave and the amount of bandwidth we have in our deployment today is that the advanced use cases of 5G -- we'll just pick on 3 currencies, right? Your throughput, right, which is a very common thing for customers to understand, also breeds a lot of innovation, which is exactly what we saw with 4G, right? So providing throughput in the gigabit-plus range on a consistent basis, you're not going to be able to do that with 5G on a small swath of spectrum. You just not. So you need the bandwidth that a millimeter wave can bring to market there. Certainly, low latency would apply to probably any of the bands, right? So the NR spec and its low-latency characteristics could work in all those different bands that you may deploy for a 5G. Then you look at also the bandwidth available to consumers in a place like Manhattan, accommodating additional bands and additional usage at that high-throughput gigabit-plus range, you're not going to be able to do that with small stripes of spectrum. So that's really -- it's an important question to ask and part of what differentiates 5G from 4G is the ability to do things that you can't do today. It's not just an icon on the phone that changes. There's an experience that is very different here, and that's what we're pushing with our millimeter wave deployments and what we see in the market today and the markets we've launched.



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Craig Moffett - *MoffettNathanson LLC - Founding Partner*

I guess it's, again, one of my own concerns is that the hype machine around 5G has gotten so tightly spun at this point that I was on CNBC a couple of weeks ago and started talking about block widths and high frequency versus millimeter wave and why those might mean 20x difference in the speed that you're going to see. And you could see they just don't bother us with the details, right? And it's kind of more than just the detail, right?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

I mean just to put it may be in context, our -- and this is all public, right? Our national average spectrum depth is around 116 megahertz. And in Chicago and Minneapolis, we've already deployed 400 megahertz worth of additional bandwidth on millimeter wave and have 800 megahertz total bandwidth that we're going to deploy for consumers. That creates a differentiated experience, that creates real innovation on top of what's already a best-in-class LTE network. So yes, those are important questions to ask, and that's why we feel so strongly about our position here.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Is there a risk that we actually deepen the digital divide because the block widths of millimeter wave only economically makes sense in urban areas and therefore there's a problem coming of rural America being left behind in 5G?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

One of the most important things in that discussion and we have a tremendous amount of activity on this front just generally because we are such a large broadband provider in rural areas is you have to define rural the right way. So in the example I'll give you is a population center that's separated by hundreds of miles of roadway, right, you may say that's rural but putting 5G in that population center, that's pretty straightforward. The single individual home separated by hundreds of miles of roadway is a very different definition of rural, right? And if your nearest tower is 20 miles away, solving that with millimeter wave is probably not the best thing you can do. So it's very important in that context, and we are really passionate about digital divide. And in fact, we've done films on this exact topic is having the right definition so that you can then have the right problem statement and put the right technical solution in place to solve it.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

And is the challenge of educating policymakers on those kinds of topics, is that hopefully proceeding a bit?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

It's part of the discussion absolutely. Because if you think about that, rural broadband is a very vague term, so you got to drill down into a couple of layers to figure out what am I solving and where? And then you have this huge portfolio of technical solutions that you can employ to solve it.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

We've just about come to the end of the clock here. I could go on all day about this because I really...

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Me too.

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Craig Moffett - *MoffettNathanson LLC - Founding Partner*

I guess, but I am really -- it's really a privilege to have someone as knowledgeable as you.

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Thank you very much. I appreciate it.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Are there any thoughts that you want to leave us with, the things we didn't talk about or things -- technology issues facing Verizon that you want to make people aware of things that you're particularly excited about?

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Yes, we spent a lot of time on 5G, right? And there are complementary technologies that are evolving with that very, very rapidly. We've talked about virtualization in the context of network functions running in a cloud. That's an important component of our Intelligent Edge Network. We've talked about multi-access edge compute. When you talk low-latency use cases, part of that latency improvement comes on the 5G AirLink. The other part comes in how you process that traffic. And when you want to assemble VR imagery in 20 milliseconds or less, you're going to do some of that with a 5G AirLink latency improvement, the rest has to be solved by multi-access edge compute where you're doing that processing closer to the customer right. So there are complementary technologies on the 5G front that really drive this future home and make the entire industry really exciting to be in.

Craig Moffett - *MoffettNathanson LLC - Founding Partner*

Well, I'm very much looking forward to that excitement, and I thank you for being here.

Adam Koeppe - *Verizon Communications Inc. - SVP, Network Strategy and Planning*

Thank you, Craig. I appreciate it. Thank you.

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