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INTELLIGENCE ON ALL THINGS WIRELESS

JULY 2022

Building the business case for 5G mmWave **CHARTING A COURSE TO ROI**

By Sean Kinney

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The mmWave imperative

As 5G has gone from R&D and executive talk tracks to lab testing and standardization to field deployment and commercialization and onto further scale, technological enhancement and network optimization, the value proposition--particularly with regard to the role of mmWave spectrum--has similarly evolved. If your vision of 5G is about multi-Gbps downlink speeds, the role mmWave has to play is obvious; if your vision of 5G is something around the notion of ubiquity, mmWave has very clear limitations both in terms of propagation characteristics and the economics of densification.

But if you take something of a middle path, where 5G is both widely available and, in some particular contexts, offering speeds so fast there's not currently a clear application for them, you get much closer to where we stand today. To say that another way, mmWave has a very important role to play in 5G but it's certainly not wholly synonymous with 5G. Rather, the latest generation of cellular in its best and most functional form, is a mix of low-, mid- and high-band frequencies that collectively yield

an advantageous mix of speed and coverage. In this report we're going to take stock of where mmWave 5G deployments are today, what to expect in the near-term, how operators can monetize investments in mmWave, and what the bigger picture shows.

To that last point around the bigger picture, and if you don't buy any of the closer-in mmWave selling points, perhaps you'll find compelling the sheer disparity between projected demand for mobile data and the inability of currently deployed spectrum bands to support future usage. Looking to the end of the decade, GSMA's Head of Spectrum Luciana Camargos, writing in a recent blog, points out that mmWave is indeed vital "in delivering the growth that consumer, enterprise and household data will demand leading to 2030." Approximately eight years from now, "An average of 5 [Gigahertz] of mmWave spectrum per market will be needed" to support enhanced mobile broadband, fixed wireless access and enterprise-specific consumption. "To deliver on this, bands such as 26 GHz, 28 GHz, and 40 GHz are needed," she concludes.

In a detailed analysis, Vision 2030: mmWave Spectrum Needs," GSMA Intelligence researchers look at the key role mmWave will play in supporting primary 5G use cases both consumer- and enterprise-facing. The consensus is that regulators need to deliver "successful and effective mmWave spectrum assignments...to ensure 5G achieves its true potential in terms of performance and socio-economic impact. Any spectrum capacity constraints should be addressed early by licensing adequate mmWave spectrum for IMT services." The why of it all, again, gets back to simple demand and supply. "As mobile data traffic continues to grow rapidly... mmWave spectrum will play a key role in guaranteeing 5G network capacity, as it can accommodate more capacity and bandwidth than other band."

NI has reached the same conclusion in analysis conducted with Joe Madden's firm Mobile Experts. NI's Chen Chang, senior director of strategic business development, points out that capacity demand has continued to go up and with the introduction of mmWave in recent years "capacity of the network has really increased" based

on modeling of consumption and spectrum deployments in New York City and other major global metros. “Basically now there’s more capacity in the network [that] can service more customers over the same geographic areas. That same trend is actually...expected to grow. A lot of this is sort of oscillating behavior...We’re definitely anticipating in the next 10 years and beyond additional bandwidth needs to be opened up in order to sustain the user throughput and the demand from the customer.”

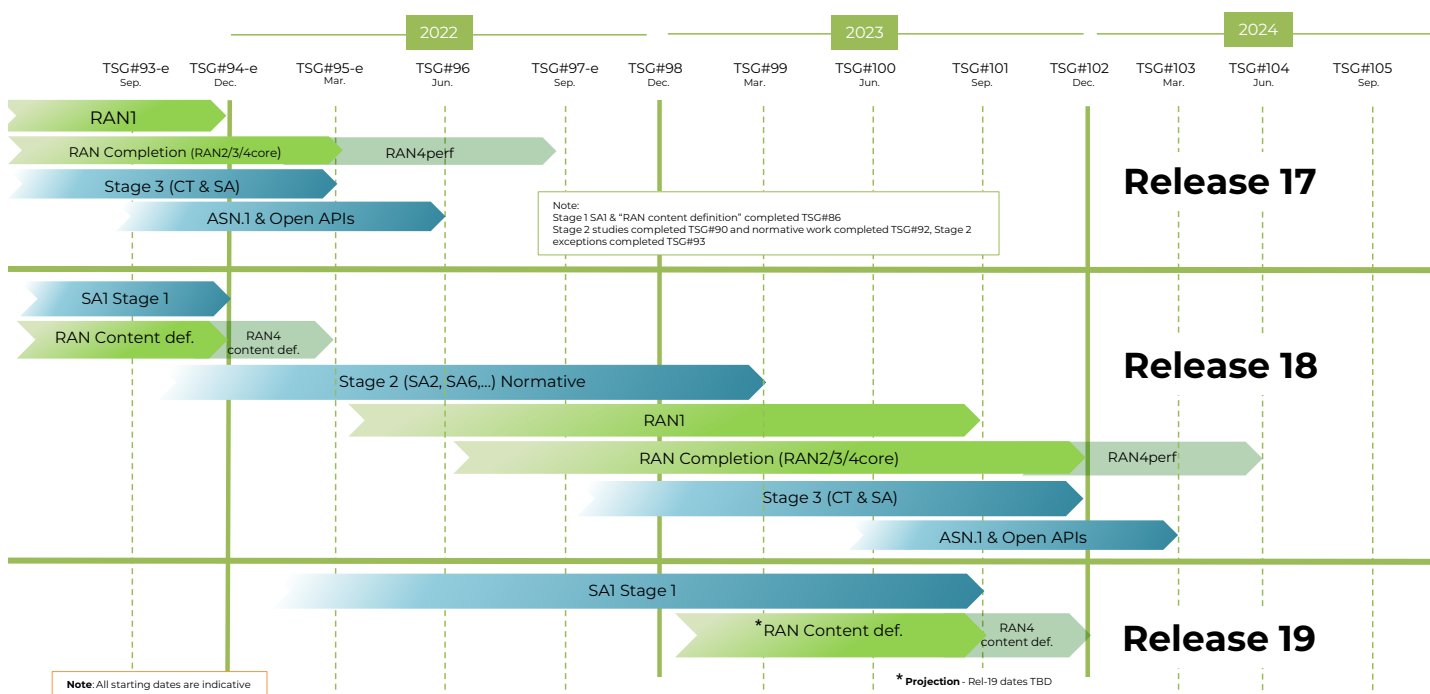
Where we’ve been and where we’re going: mmWave spectrum and standards

The U.S. moved comparatively early on making mmWave spectrum available for 5G services with Verizon launching a pre-standard fixed wireless access service in the second half of 2018. Since then, in addition to the completion of the initial 5G New Radio standard by the 3GPP, spectrum has become available and commercialized with increasing momentum around the world; and, on the standards side, there have been continued

enhancements to make mmWave more performant.

In Release 17, which was frozen relatively recently, the global standards body has expanded the frequency range of 5G NR in unlicensed frequencies from 5 GHz and 6 GHz to now include the 60 GHz band; additional frequency expansion now brings 5G into the 52.6 GHz to 71 GHz range. Also withing Release 17 is better support for inter-band uplink and downlink carrier aggregation; spatially separated full-duplex for Integrated

Ongoing Release timelines (March 2022)



mmWave 5G spectrum: 2020 vs. 2022

To understand global mmWave 5G adoption trends, we'll compare what was happening at the end of 2020 with what's happening today in terms of commercialization and spectrum allocation.

In December 2020, U.S. operators AT&T, T-Mobile US and Verizon all had commercial mmWave 5G offerings with widely varying degrees of scale. At that same time, Japanese carriers KDDI, NTT DoCoMo and Rakuten Mobile had also deployed mmWave for commercial 5G. Singtel in Singapore also had a commercial offering at that time and Italy's Fastweb was in the early stages of commercialization.

Fast forward to present and Claro in Puerto Rico, LGU+, KT, and SKT in Korea, APT and Chungwha in Taiwan, China Mobile and HKT in Hong Kong, and Optus and Telstra in Australia, are all in the early stages of commercialization.

Elsewhere, regulators are working to allocate mmWave frequencies for 5G services in the following countries: Argentina, Austria, Brazil, Bulgaria, Chile, China, Croatia, Denmark, Estonia, Finland, Germany, Greece, India, Indonesia, Malaysia, Malta, Montenegro, Netherlands, North Macedonia, Peru, Poland, Russia, Slovenia, Spain, Sweden, Thailand, United Arab Emirates, United Kingdom and Uruguay.

Access and Backhaul; and support for simple repeaters to help cost-effectively and quickly expand mmWave coverage.

Looking ahead to Release 18, the 5G-Advanced era, 3GPP is working on enhanced mobility with lower handover latency and better Layer 1 and Layer 2 inter-cell mobility. Also on the table are enhancements to IABs that contemplate mobility, expansion of C-V2X into mmWave, and, drawing on Release 17 work, improvements to repeaters that add contextual information about data flows.

5G mmWave industry perspectives

'To get to a point where the true potential of 5G is unlocked, you need mmWave. There's no choice.'



Danny Sleiman, Business Development Manager, 5G/RF, EXFO

EXFO Business Development Manager for 5G and RF Danny Sleiman sees fixed wireless access as a clear and present mmWave 5G use case that operators can effectively monetize; a new service can generate new service revenues. But in a larger context, again, it's all about the need for additional spectrum to support growing demand for capacity.

"The capacity issue, that's real," he said. "You take maybe a small operator like US Cellular [more on that later] and they want to grow their business and they don't have the capacity to grow it. mmWave... gives you more capacity but it doesn't give you that return on investment from that perspective. For ROI you need to capitalize on that capacity. When people need more data, you can offer more data." mmWave-backed fixed wireless access, he said, "is really a key growth driver today."

But beyond fixed wireless access, there are a number of coming applications that also benefit from the huge store of capacity represented by mmWave frequencies. To name a few, connected vehicles, the huge set of use cases that fit under the Industry 4.0 umbrella,



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and anything really that requires ultra-low latency which opens up real-time control and feedback.

“We said a long time ago that connected cars, connected industries, things that require stringent latencies that you can’t get with the mid- and low-band, you can only get there mmWave,” Sleiman said. “When we start with those new type of 5G applications, that’s how operators are going to benefit by making money. But, realistically, Industry 4.0...for us to get to a point where that works, we’re probably two years away because you need to change a lot of things. Reliability really needs to improve so there’s no failure.”

On the latency point, he gave the example of autonomous devices and processes on a factory floor with people sitting in a back office monitoring what’s happening. “That only gets unlocked when you have URLLC. And for that to kick in, operators are going to have to have a core that is ready, and they’re going to have to be fully 5G. When everything is completely 5G, at that point you’re able to completely transform an industry.”

In terms of not just mmWave capacity but ensuring latency and reliability, this is really key in commercializing mmWave 5G use cases that would serve to help operators monetize new services and help the enterprise buyers achieve new types of business outcomes. Sleiman acknowledged the difficulty in building a real-time infrastructure with real-time monitoring in support of real-time use cases. “To get to a point like that with those [mmWave] speeds, it requires I’d say a full revamp of the network. It has started.”

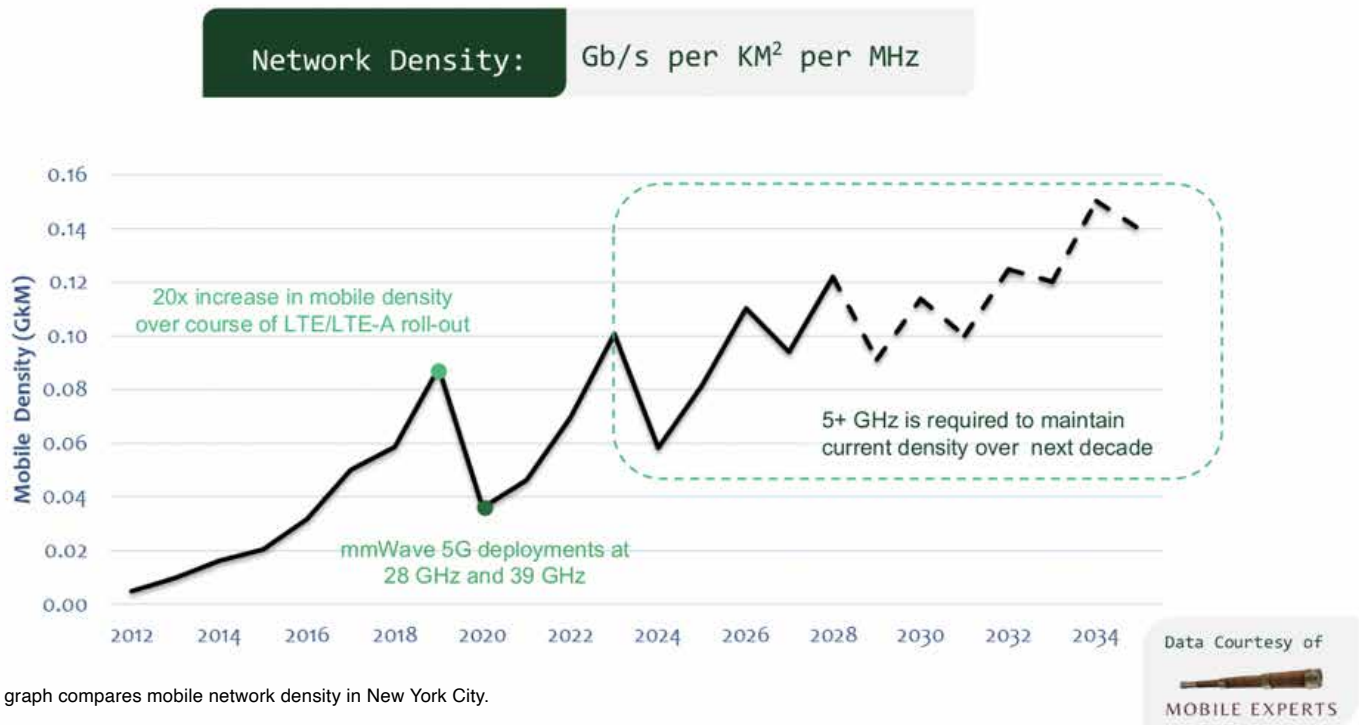
As it relates to EXFO’s core focus around test, measurement and service assurance, “It’s going to be all defined by KPIs and SLAs,” he said. It will be important for operators to work with their vendors and customers to understand “what is the threshold before you pull a red flag and take a pause because something is or isn’t going on. Operators are going to need service assurance systems that are monitoring this constantly to get to 1 millisecond end to end. We’ve made sure, from an investment perspective, that everything we have is scalable and future proof.”

‘There’s certainly a capacity advantage with mmWave. But how do we leverage that to give a better experience to the end user?’



Chen Chang, Senior Director, Strategic Business Development, NI

Chen Chang, senior director, strategic business development for NI, acknowledged the clear capacity gains mmWave enables but said high-band spectrum is still waiting on a killer app that will pass on that capacity gain to the benefit of end users. “The technology itself has proven to be viable but you also need to be in a fairly concentrated usage area. When you have a lot of users in a small geographic area, the offloading capacity of mmWave really shines through.”



This graph compares mobile network density in New York City.

Image courtesy of NI

As Chen said, mmWave is great at offloading capacity in a concentrated space as this lends itself to the propagation characteristics of the high-band frequencies. But those same traits that are an advantage in one scenario are also a broader challenge. “When you’re talking about mmWave,” Chen said, “you’re talking about a few 100 meters. If we were to have the same coverage with mmWave as with mid-band 5G, it’s 10x more base stations or towers to cover that. Economically that doesn’t make sense.”

This is why Chen views mmWave as an important part of a bigger whole, highlighting the importance of “seamlessness and co-existence” with other bands, something NI has long focused on.

But this positioning of mmWave as a capacity offloading solution isn’t necessarily permanent. Chen reflected on the emergence of mobile video as a “killer app” for 4G and said an eventual step-change in what applications will open up the market for mmWave. For consumers, “Maybe it’s the metaverse

usage scenario where the application demands high throughput and low latency. I think in the more industrial context, there are definitely applications people are trying to work out.” In this case, however, mmWave propagation characteristics are still a challenge; a factory isn’t just one, unobstructed room, not to mention the manufacturing sector, given its invested technological base and general conservatism, may be more hesitant to experiment.

Once the technology piece is



6G

The Next Generation of Wireless Communication

Although the first 6G consumer devices may be years away, thought leaders from academia and industry at the forefront of these cycles already are experimenting and building an understanding of key technologies critical for standardization. As we look at 6G's possibilities and promise, four candidate technologies stand out in terms of business opportunity and viability:

Integrated Sensing and Communication (ISAC)

The 6G experience requires more data as well as more environmental sensing and awareness. ISAC explores how to use the radio signals that cellular devices emit for radar. Autonomous vehicles, for example, have sophisticated sensing systems powered by machine-learning algorithms fusing data from cameras, lidar, and radar sensors. The advanced communications systems in these vehicles use cellular networks for streaming infotainment, environment and performance data, and vehicle-to-everything communications. The extent to which these two traditionally separate functions merge will depend on regulatory and technical factors, but the combination could potentially define 6G.

Sub-Terahertz Bands

The perpetual demand for more data bandwidth is pushing researchers to explore underutilized spectrum in the sub-THz frequency bands. Frequency bands between 90 GHz and 300 GHz offer many times the amount of spectrum currently used for cellular communications, but pathloss is one of the biggest hurdles in moving to sub-THz bands. While expanding to sub-THz bands may seem premature given the delay in 5G mmWave deployments to date, researchers are hopeful it could significantly increase network capacity.

MIMO

Building on popular multi-antenna techniques, MIMO promises potential benefits across many use cases and frequency bands. While beamforming is key to overcoming sub-THz pathloss challenges, multi-user MIMO

improves spectral efficiency for the heavily used sub-6 GHz bands. In bands where antenna size becomes excessively large, distributed MIMO disaggregates the large antenna arrays into multiple, geographically separated radio heads that are significantly smaller. The expansion of MIMO aims to increase cell capacity and provide improved location services.

Artificial Intelligence and Machine Learning

As complexity increases and we seek to squeeze every bit of bandwidth out of the available spectrum, AI/ML offers one way to help optimize the communications system. AI/ML-driven design or adaptation could offer improvements through capabilities such as automatic spectrum allocation, beam management, and RF nonideality cancellation. Deploying AI/ML at the application layer can optimize Quality of Service (QoS), which considers application-specific requirements, along with the environment, for factors such as latency or energy efficiency. The availability of big, open datasets for AI/ML wireless communication research and training will play a significant part in 6G development.

What's more important than technology?

In addition to technology buzzwords like immersive extended reality and KPIs such as 1 Tb/s data rates, 6G discussions now include social and sustainability goals such as "connectivity for all." As we work to develop 5G by extending it beyond enhanced mobile broadband, and as the definition of 6G coalesces, we need to answer these business and social questions as well as the technical ones.

sorted, there's still the lingering economics issues. "I think as an industry we've seen a lot of the early days of driving mmWave forward, talking about lots of new applications that can potentially be enabled. But when the reality sets in, it's extra components in the system, it's a whole new infrastructure rollout and when carriers look at that...they're trying to make practical decisions. Great, it has 10x more bandwidth but it's also costing a whole lot more so what is the practical use of that? User demand has to start to set in."

But, at an even higher level, there's still the animating imbalance between user demand and the ability of currently deployed spectrum to support it. "We're pretty much on track that every five years you need a couple gigahertz of spectrum to open up," Chen said. "It's pure mathematics. We just don't have the space anymore and mmWave is the consistent chunk and we've targeted it. I think the demand for capacity will absolutely expand and continue to grow. Where we're getting it is the current question mark."

'Fixed wireless access, if we can serve it through mmWave, is actually very beneficial. It's an attractive opportunity.'



Ranjeet Bhattacharya, Head of RAN Architecture & Solutions, Ericsson North America

Based on global engagements with leading Tier 1 operators, many of which are in various stages of mmWave deployment, Ericsson North America's Ranjeet Bhattacharya, head of RAN architecture and solutions, sees high-band spectrum making a difference today in venue settings and to support fixed wireless access. And with ongoing enhancements and strong momentum, he sees a bright future beyond these two well-established use cases.

Bhattacharya told *RCR Wireless*

News, "Today, as we know, everybody is focused on building out 5G coverage. That is primarily focused on building coverage with mid-band and low-band. There is also considerable focus on mmWave for high-density traffic areas." He gave the example of the Super Bowl earlier this year where the three major U.S. operators deployed mmWave spectrum that carried a staggering 82% of downlink mobile traffic and 68% of uplink traffic.

In the venue context like the Super Bowl, Bhattacharya called out the ability to push new types of experiences to attendees, things like the ability to simultaneously view the live action while using a device to engage with multiple camera views and other features that makes for a more immersive experience. He sees a path forward where this type of premium, cellular-enabled experience is something that could generate new revenues. "There is a lot of focus around monetization," he said, predicting that this type of revenue generation could happen fairly soon. He also noted how this type of attendee set-up could be further enriched with Extended

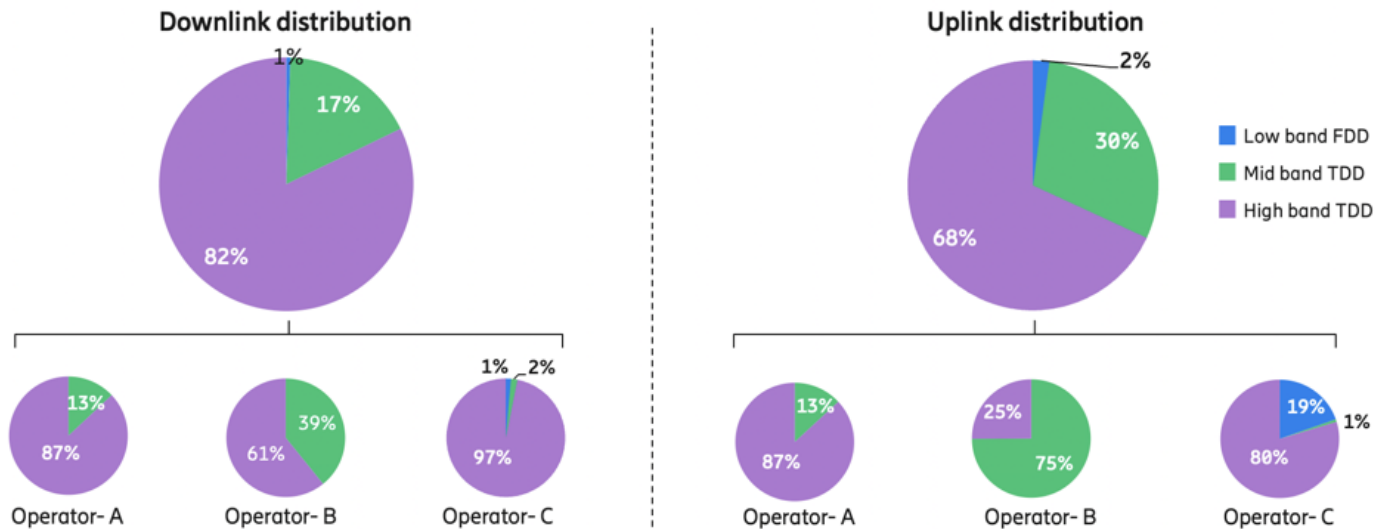


Image courtesy of Ericsson.

Reality wherein augmented and virtual reality adds new types of content engagement.

In terms of mmWave supporting enterprise digitalization, Bhattacharya pointed to Ericsson's own investment in a smart factory in Lewisville, TX, that uses 5G connectivity in the process of producing 5G network equipment. Specific to mmWave, autonomous guided vehicles in the facility use mmWave connectivity. He acknowledged that ongoing system-level enhancements will improve this type of mobility use case, specifically enhancements around ultra-reliable low latency communications and coordinated multi-point for improved handovers in changing

industrial environments.

Speaking more big picture about the future of 5G networks, particularly as it relates to harnessing the power of machine learning and artificial intelligence for RAN planning, including mmWave, mid-band and other frequencies, Bhattacharya said, "There's a lot of research happening there" that's largely geared toward creating digital twins of networks. "It's basically a replica of your physical environment." Giving the example of integrated access/backhaul for mmWave small cells not directly connected to fiber, he said, "If you have an IAB set up and you have a condition where the site gets congested, everything has to

reconfigure. Every base station needs to know what is the next link. If the system knows there's going to be an event, you could know before it happens and address it."

In this context, mmWave spectrum and infrastructure is part of a larger 5G continuum. "The idea," he said, "is to have smooth interworking between the bands so you're able to do intelligent traffic steering. We're getting there."

The fixed wireless access of it all

mmWave aside, fixed wireless access is emerging as a primary driver of new revenues for mobile operators. It's how Verizon initially went to market with 5G and has since evolved to a significantly larger

geographic reach and to include a mix of both high-band and C-Band spectrum. T-Mobile US, similarly, is going after home broadband share using fixed wireless access with an eye on rural markets and areas where traditional cable companies have something of an entrenched monopoly. The logic here is around maximizing use of available network capacity, realizing deployment efficiencies in terms of serving mobile and fixed use cases from the same sites, and as a way to generate new service revenues by taking on cable companies who are themselves trying to take mobile share through MVNO offerings.

More specifically to mmWave, if you were to have looked at the market a few years ago, you would've seen that fixed wireless access was only seen as viable in dense, urban areas due to the line-of-sight requirements and propagation challenges associated with the frequencies. That has gradually changed though with improvements at both the system-level and on the device side. Case in point is US Cellular. In May 2021 the company demonstrated a sustained average downlink speed of 1 Gbps and

peak speeds around 2 Gbps over a distance of 7 kilometers.

In this instance, the carrier worked with Qualcomm Technologies, Ericsson and Inseego on the field test, which took place in Janesville, Wisconsin, and applied extended-range functionality to Ericsson's commercial hardware Antenna Integrated Radio (AIR) 5322 advanced antenna system, along with an Inseego Wavemake 5G outdoor CPE FW2010, which uses Qualcomm's 5G FWA Platform (Gen 1) that includes the Snapdragon X55 5G modem-RF system and a Qualcomm QTM527 mmWave antenna module.

In addition to the 7 km line-of-sight link, US Cellular said that at a distance of 1.75 km with no line of sight, the partners were able to get sustained average downlink speeds of about 730 Mbps and sustained average uplink speeds of about 38 Mbps.

"We believe that every household and business deserves access to reliable internet access no matter where they are located, and the results we achieved in this latest mmWave test further confirm that wireless technology is key to

providing high-speed broadband service in both urban and rural areas," said Mike Irizarry, EVP and CTO of US Cellular. "By collaborating with companies like Ericsson, Qualcomm Technologies and Inseego, we will continue to drive innovation with extended-range technology to ensure that wireless customers across rural America have an exceptional wireless experience designed for their communities."

In September 2020, US Cellular [achieved an extended-range data call](#) – also in the Janesville location – over a more than 5 km distance with speeds exceeding 100 Mbps, working with Ericsson and Qualcomm Technologies. Irizarry called that test "a key strategic milestone in our 5G evolution."

Fast forward to April 2022 and US Cellular has launched its 5G mmWave high-speed internet service in parts of 10 U.S. cities. The carrier says that its Home Internet+ solution delivers speeds of up to 300 Mbps, which represents an increase of 10-15 times compared to its 4G LTE home internet offering. The fixed wireless access service is available in parts of East

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Moline and Rock Island, Illinois; Bettendorf, Cedar Falls, Davenport, Dubuque and Waterloo, Iowa; Yakima, Washington; and Beloit and Janesville, Wisconsin. The company said that it expects to increase the new offering within those cities and expand to new cities in urban and rural areas.

“This expansion of delivering high-speed internet to untapped cities is a testament to Qualcomm Technologies efforts to bridge the digital divide,” said Gautam Sheoran, vice president, product management, Qualcomm Technologies. “By equipping operators and OEMs with cost-effective, last-mile technologies, we are able to empower end users and enterprises with best-in-class 5G connectivity for homes and businesses, including those in previously underserved areas.”

If you consider US Cellular’s service area and take a careful look at the quotes above—words like “underserved” and “rural”—you can see that mmWave fixed wireless access, at least by US Cellular’s reckoning has a place outside of dense, urban areas. On a higher-level, this is consistent

with federal machinations to close the digital divide, a consummate talking point of politicians and bureaucrats, and something that receives a good deal of directed and subsidized funding. Here’s where the economics kick in; in a white paper, US Cellular suggests that fixed wireless access can be deployed at up to 40% less cost than fiber-based home internet while also enhancing cellular mobility.

From the paper, which also points out that the Federal Infrastructure Investment and Jobs Act (IIJA) sets aside \$45 billion to bridge the digital divide through broadband expansion, “Our current 2022 plans include expansion to economically viable areas, but to justify unsubsidized investment, we must be able to reach several hundred homes and businesses per tower (note: our economics require over 150 subscribers at \$65 per month to equip an existing tower with the necessary equipment; or approximately 500 subscribers to build a new tower, and we can’t assume that everyone will adopt the service.) This density is rare in unserved and underserved locations, which is a key driver of the current digital divide.

The cost of building and maintaining a tower in rural America can be nearly twice as expensive as building a tower in an urban area, and the density of customers in these areas is far less than in suburban and urban areas, thereby putting pressure on the revenue generation needed to drive a positive return on investment.”

So in addition to providing a refreshingly candid breakdown of the economics associated with serving mmWave-based 5G fixed wireless access, the company makes a compelling case for putting some of that \$45 billion to work for things other than wired broadband. “Importantly, in contrast to previous, more restrictive funding vehicles the IIJA is technology neutral, meaning both wired and wireless solutions can qualify for funding. This additional flexibility provides policy makers and local communities with a tremendous opportunity for rapid deployment upon distribution of funds. FWA technology can provide connectivity to homes and businesses in rural areas without some of the cost and timing burdens associated with wired solutions.”

So what about that ROI?

With deployment ongoing or planned in major global markets, 5G mmWave investment is positioned to ramp up in public and private mobile networks, as well as to support fixed wireless access and connect new types of cellular devices. For operators, 5G mmWave strategy should balance providing an enhanced user experience with adding capacity in localized hot zones and creating new service revenue opportunities.

While there are established challenges associated with 5G mmWave deployment, a new analysis by Bell Labs Consulting makes clear that with the right approach operators can achieve a four-year payback and 20% to 30% internal rate of return (IRR) following the payback period.

Bell Labs Consulting Principal Vikas Dhingra framed the issue: “mmWave has challenges, whether it is on propagation constraints, or whether it is on a lack of spectrum. But what we see as the key opportunity for telecom operators is the monetization of additional data traffic.”

Albeit to varying degrees, all three major U.S. operators have deployed 5G mmWave networks both mobile and fixed; the bulk of mobile investment is focused on urban cores, stadiums, airports, and other data-hungry locations. In Japan, all four operators—NTT Docomo, KDDI, Rakuten Mobile and SoftBank—have commercial 5G mmWave offerings. Earlier this year the Australian Communications and Media Authority auctioned off access to the 26 GHz band. And these are just some examples of what is accelerating traction around the world.

In working to realize the attractive payback period and IRR, operators have to think strategically about where to deploy 5G mmWave. “The key is to deploy 5G mmWave in localized, capacity-constrained areas, such as train stations, stadiums, indoor shopping malls, outdoor areas where there is much higher network capacity needs,” according to Dhingra.

Further to the capacity point, industry analyst Prakash Sangam, founder and principal with firm Tantra Analyst, wrote in a

contribution to [RCR Wireless News](#): “The straightforward answer to the mmWave skeptics who often point out its small coverage footprint is—it’s not coverage, but capacity! The [Bell Labs Consulting] report rightly points out the typical locations that they call ‘hot zones’ and use cases that are a perfect fit for mmWave.”

By adding capacity in these hot zones, operators can improve quality of experience and steer subscribers into more premium data plans while pursuing new business opportunities like 5G mmWave-based fixed wireless access and data plans for 5G-compatible laptops. This, Dhingra said, could potentially equate to up to an 8% increase in annual revenue.

TIRIAS Research Founder Jim McGregor concluded in a piece for [Forbes](#) that, “As with any new technology, the applications typically extend well beyond the initial intentions. It’s up to developers to innovate with the technology. However, there appears to be a clear financial benefit for operators to rapidly deploy mmWave.” ((“))



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