THE CHALLENGING STATE OF 5G

AFTER YEARS OF UNCERTAIN EVOLUTION, WHERE DOES THE TECHNOLOGY GO FROM HERE?

SUMMARY

Four years into 5G's evolution, the technology's rollout has been marred by poor coverage, poor speeds, and a lack of unique and compelling 5G applications for both consumers and enterprises. After years of carriers overpromising and under-delivering, many consumers today see 5G as merely a faster version of 4G. In fact, some customers even regard it as an inferior technology. One of the biggest problems industrywide has been that carriers overmarketed 5G to convince users to upgrade to new plans and devices, yet without delivering many of the applications and services that would have made upgrading truly worthwhile.

This report retraces the turbulent history of 5G, then considers some of its successes and promising developments, including private 5G deployments. It then assesses the overall state of 5G today, and what needs to happen among telecom operators and related companies to improve the situation going forward.

EARLY 5G DEPLOYMENTS

The roots of 5G reach back to 2017 and 2018, when the relevant spectrum was allocated by governments to telecom operators. By 2019, it seemed clear that many of the first 5G deployments in the U.S. would be in the millimeter-wave (mmWave) spectrum, which operates in the 26 GHz, 28 GHz, and 39 GHz bands. Limited spectrum was a key factor that drove the industry to start with mmWave, which was much more readily available and easier to clear than lower bands. Indeed, AT&T and Verizon initially had access to 5G only in the mmWave bands; in that context, 28 GHz and 39 GHz became the defaults for 5G. This technology delivers high throughput and low latency, albeit with limited propagation and penetration through barriers (even foliage) because of the physical nature of these high-frequency radio waves. The need for expensive densification to improve its propagation has also stunted its deployment.

In South Korea and the United States, mmWave was thus a key part of the first generation of 5G devices and services. In fact, some of the earliest 5G phones could handle only mmWave 5G alongside 4G. Given the limited footprint of mmWave 5G at the time, this negatively affected the user experience. Also, companies including Verizon were using mmWave 5G to deploy fixed wireless access (FWA) broadband to

homes, because it's a lot easier for a larger fixed antenna in a home modem to lock onto these signals in comparison with the miniature antennas found in phones.

From the start, overly ambitious marketing was a significant problem as both Verizon and AT&T pushed an aggressive 5G story. AT&T, worried about its 5G coverage, branded its LTE-Advanced technology as "5G Evolution" or "5GE," a move that confused customers and elicited pointed criticism in the market.[1] AT&T also invested heavily in multimedia partnerships; both it and Verizon touted extended reality (XR) as a key application for 5G, with AT&T investing heavily in XR device maker Magic Leap in 2018. AT&T even went as far as hosting Magic Leap device demos in some of its flagship stores to demonstrate the power of augmented reality (AR) over 5G.[2]

Unfortunately, in the early days of 5G, operators, OEMs, and even chip vendors pushed mmWave without enough realism about where it would work best. Verizon's marketing in this vein, dubbed Ultra Wideband, was by far the most aggressive, and its spending on mmWave densification was also the biggest, even as it struggled to cover more than 1% of the United States. The good news was that mmWave could deliver throughput above 1 Gbps even then. (Today it delivers up to 4 Gbps.) The bad news was that severe limitations in coverage meant that mmWave was not going to reach most parts of the country.[3] The carriers' marketing set an unrealistic expectation for customers, who expected to have multi-gig 5G everywhere but rarely saw it.

Verizon did make the wise move of partnering with the NFL and other entertainment companies to implement mmWave in football stadiums and similar venues, which are perfect settings for mmWave 5G.[4] Historical events worked against the company, however: Only a year after launching 5G, Verizon would struggle to prove the utility of these mmWave stadium installations in the midst of the global Covid pandemic. At the same time, venue owners missed a huge opportunity during the pandemic to upgrade their venues to mmWave 5G with improved backhaul, which would have provided fans with a significantly enhanced experience when they finally did return.

[1] See, for example, Nick Statt, "AT&T's 5G E marketing ploy is turning out to be a disaster," The Verge, April 22, 2019, and Jon Brodkin, "AT&T still refuses to kill misleading 5GE network icon for 4G service," Ars Technica, May 21, 2020.
[2] Anshel Sag, "XR and 5G at AT&T Shape 2019: A Match Made in Hollywood," Forbes, July 8, 2019.
[3] Jon Brodkin "Milimeter-wave 5G isn't for widespread coverage, Verizon admits" Ars Technica, April 23, 2019.
[4] See Angela Moscaritolo, "Verizon Launches 5G in 13 NFL Stadiums," PC Magazine, September 5, 2019.

While T-Mobile's initial approach with mmWave was similar to Verizon's and AT&T's, the company quickly pivoted towards a broader strategy. T-Mobile's acquisition of Sprint, which closed in 2020, gave it ample 2.5 GHz mid-band spectrum, which it further augmented by paying $8 billion for 600 MHz low-band spectrum. (Later on, T-Mobile would spend another $3.5 billion on even more of that spectrum.) The idea was to build a reliable coverage layer covering large geographic areas at 600 MHz and combine it with Sprint's 2.5 GHz spectrum for greater bandwidth and end up with the best of both worlds. T-Mobile's approach with 600 MHz didn't give it drastically better speeds on 5G versus 4G LTE. Still, with enough added spectrum, it was able to deliver connectivity to parts of the country that in some cases had never had cell service at all, including many rural parts of the U.S. Ultimately, this enabled it to cover more of the country with 5G than any carrier ever had (or maybe ever will), giving it an advantage that neither AT&T nor Verizon could match. It's a strategy that is still paying dividends for T-Mobile today.

Unlike T-Mobile, most carriers worldwide lacked such diverse spectrum. Many of them initially rolled out 5G in the 3.5 GHz to 3.7 GHz band and faced coverage issues. Both Verizon and AT&T had spectrum in the 700 MHz and 850 MHz bands, but already used most of that for 4G LTE; applying it to 5G would require them to refarm (i.e., repurpose) the spectrum, or else use dynamic spectrum sharing (DSS)—a technology that was not initially available.

In this context, AT&T was able to find some low-band spectrum to repurpose, and it built a respectable coverage layer of low-band 5G while it waited for the U.S. government to begin the huge C-Band auction at the end of 2020 to expand the total bandwidth available. In line with this approach, AT&T abandoned its mmWave-first strategy starting in December of 2019.[5] opting instead for a low-band strategy something like T-Mobile's, with the crucial difference that it was not able to acquire another carrier, as T-Mobile did with Sprint.

Eventually, Verizon was able to implement DSS, which it decided would be how it delivered 5G coverage to its customers. The company did so even though the performance of DSS was in many cases worse than simply using its world-class 4G LTE network.[6] Whatever the technical issues, there was a prevailing business logic behind this decision: Verizon faced major coverage issues and needed to ensure that

[5] See Francesco Rizzato, "Analyzing AT&T's spectrum usage to understand its 5G rollout plans," OpenSignal, March 9, 2020.
[6] See Sascha Segan, "Here's Why Verizon iPhone Users Must Turn Off 5G Right Now," PC Magazine, December 22, 2020.

customers could see coverage improving, even if that came at the cost of performance and battery life.

THE $81 BILLION C-BAND AUCTION OF 2020–21

The massive auction of C-Band assets in December 2020 and January 2021 was the turning point for 5G networks in the U.S., although it also presented some foreseeable issues that have only recently been (mostly) resolved. The C-Band spectrum—3.7 GHz to 3.98 GHz—was originally used for satellite communications. The auction made this crucial slice of the radio spectrum available for whichever U.S. carriers won the bidding on various blocks of bandwidth. Ultimately, Verizon, AT&T, and T-Mobile divided the spoils, with the lion's share going to Verizon.

Unfortunately, the auction was hampered even before it began by a lack of communication among the National Telecommunications and Information Administration (NTIA), the Federal Aviation Administration (FAA), and the Federal Communications Commission (FCC).[7] From the FAA's perspective, the major issue was that some of the airlines' older aircraft used altimeters operating in the 4.2 GHz band that lacked the proper filters to protect them from 5G interference in the C-Band spectrum. The airlines didn't want to pay for the altimeter upgrades themselves; they wanted the U.S. government to take some of the $81 billion it ultimately reaped from the auction to foot the bill. This single issue led to a years-long conflict involving the airline industry, the wireless carriers, and the relevant regulatory bodies. Eventually, the carriers agreed to operate at lower power levels near airports until the airlines could make the necessary upgrades—with money allocated by the U.S. government. While some airlines did make the necessary upgrades by the deadline of July 1, 2023, others have not. Now that the cellular operators are running at full power, this means that some aircraft may be grounded in less-than-optimal flight conditions such as heavy fog.

In line with industry expectations, Verizon was the biggest buyer in the auction, with a whopping bid of $45 billion before clearing costs. It paid so much because it was desperate to turn the tide for its 5G network and wanted the most desirable A-Block spectrum being auctioned to support that agenda.[8] In this case, "most desirable" means that the A-Block spectrum had the lowest radio frequency as well as the earliest availability. In total, Verizon netted about 160 MHz of spectrum across all three blocks,

[7] See Marguerite Reardon, "How the FAA went to war against 5G," CNET, January 28, 2022, which also includes an extensive timeline of related events.
[8] See Scott Moritz, "Verizon lost its network superiority – now it's paying the price," The Seattle Times, December 27, 2022.

some of which went live at the start of 2022. The enormous investment has paid dividends as the company has significantly improved its 5G coverage and performance nationwide. From a branding perspective, Verizon decided to give its C-Band 5G the same name as its mmWave solution—"Ultra Wideband" or UWB. This allowed it to continue the marketing for its UWB network while increasing overall 5G coverage, even though peak speeds for some customers would drop.

AT&T spent $23 billion and T-Mobile spent $9 billion in the C-Band auction. AT&T bid on some A-Block spectrum, but both it and T-Mobile were bigger bidders on B-Block and C-Block allotments. AT&T supplemented its mid-band strategy through a different 2021 auction (Auction 110) that sold off a total of 100 MHz of 5G bandwidth in the 3.45 GHz range; the $21 billion in net proceeds from that auction made it the third largest in U.S. history. In that instance, AT&T alone spent $9 billion for 40 MHz of spectrum that it started to roll out in the summer of 2022. It did this in conjunction with its C-Band rollout to save the money it would have spent on rolling out spectrum twice.[9]

In sum, over the last year or so, Verizon and AT&T have considerably improved their 5G coverage and speeds. However, T-Mobile continues to grow its own network with its 5G "Ultra Capacity" buildout, and it is still the leading U.S. carrier for both coverage and download speed.[10]

Standalone and True 5G

A major reason for the lackluster technical performance of today's 5G deployments is that most of them are not truly 5G in the first place. To explain this requires going back to the original publication of the 5G specification, which was formulated by a mobile industry standards body known as the 3rd Generation Partnership Project, or 3GPP. The specification was contained in the 15th release of the 3GPP standard, commonly referred to as 3GPP Rel. 15.

To appease mobile operators (who are members of the 3GPP) and accelerate commercialization, the 3GPP agreed that 3GPP Rel. 15 would include a half-step called "non-standalone" (NSA) 5G, which allowed operators to build 5G radio networks on top of their existing 4G infrastructure. They did this because the original 5G Standalone (SA) standard required a complete replacement of all layers of the network from the antennas and radios all the way down to the core. That is a capital-intensive

[9] "FCC Announces Winning Bidders of 3.7 GHz Service Auction," Federal Communications Commission, February 24, 2021.
[10] United States Median Country Speeds, Ookla, July 2023.

undertaking, and the concern was that it would overburden operators with excessive costs as they rolled out 5G. Industry groups lobbied for the inclusion of NSA, which allowed carriers to meet the 5G standard while initially replacing only radio access network (RAN) equipment and then introducing 5G core equipment later.

That compromise has led to the situation today, in which the vast majority of 5G networks are in fact 4G core networks with 5G RAN gear bolted on. In the absence of Standalone 5G running on a completely new 5G core infrastructure, customers end up with higher throughput and moderately better latency, but also higher power consumption. Because 5G SA doesn't exist in most places, many users end up using a combination of 4G for uploads and 5G for downloads. Besides the power drain, this leads to sometimes better, sometimes worse performance than using 4G alone—hardly a recipe for satisfying customers. The dissonance for consumers is made worse because of the overmarketing mentioned earlier. The reality is that carriers have spent years touting "5G" performance by conveying the most favorable use cases and speeds that might be achieved on pure Standalone 5G networks—which don't exist in most places—rather than on the real-life 5G NSA networks they have actually created.

Only a few carriers worldwide have deployed 5G SA, and those networks are still relatively new. In North America, T-Mobile has long been one of the biggest proponents of 5G SA. It launched its 5G SA network earlier this year and is likely ahead of its U.S. competitors in that regard by at least a year. Verizon and AT&T likely will not deploy 5G SA until their network coverage grows beyond 200 million potential users each. (Verizon reached this point in the first quarter of 2023.[11]) Besides that, so far there have been few unique applications created to take advantage of the new speeds and feeds of 5G SA, and until both AT&T and Verizon deploy Standalone 5G, app developers may not be motivated to build true 5G-worthy applications. The U.S. risks falling behind on exploiting the possibilities of 5G, and we probably will not even begin to realize the full potential of 5G until the end of 2024, when all three major U.S. operators have deployed most of their 5G spectrum and Standalone 5G infrastructure.

A 5G Success Story: Fixed Wireless Access

One of the earliest undisputed 5G successes is the wide deployment of 5G FWA for home broadband. Colloquially known as 5G Home Internet by Verizon and T-Mobile, 5G FWA has given consumers competitive broadband options in places where there previously weren't any. More than that, it has brought connectivity to rural areas that

[11] "Verizon's 5G Ultra Wideband now reaches 200 million people," Verizon, March 7, 2023.

had no such access before. 5G FWA enables the operators to broaden their footprint and customer relationships while also challenging cable in geographies where cable had previously strangled consumers on choice and price. Naturally enough, Verizon and T-Mobile have seen huge gains with 5G FWA,[12] while forcing cable companies like Comcast and Charter to offer better pricing and bundled services.

Early in 2023, T-Mobile CMO Mike Katz disclosed that the company now has 3.2 million FWA customers. He added that home FWA service is "one of the big killer apps for 5G."[13] Clearly, T-Mobile benefits from having the most mature 5G network—not to mention the most spectrum—among the three major carriers in the U.S. That said, Verizon is also a significant FWA supplier, and the two companies now have more than 5 million customers on 5G FWA between them. This is even more impressive considering that more spectrum is on the way for both companies, which should enable them to serve even more customers.

Meanwhile, AT&T has long stuck to its plan of a fiber build-out to serve more customers. However, it has recently begun to suggest that it may offer 5G FWA for businesses, another underserved customer base. For decades, many small business owners' only viable option has been to pay too much for low-performing broadband cable. If the wireless operators can market FWA intelligently to educate this user base, business FWA could create a great opportunity for all three carriers while drastically improving on the status quo for small business owners.

A Nascent 5G Success Story: Private 5G

Many consumers are unaware of private 5G, but it has become a popular component of digital transformation for large enterprises looking to upgrade their operations. Private 5G also tends to deploy as a 5G SA network, which means that it is inherently ready to enable all the possible improvements that come with true 5G. That is why companies like Accenture are working with their customers to improve workplace safety applications and deliver 70% reductions in latency using private 5G over Wi-Fi. Accenture has also talked about working with Stellantis in partnership with TIM Brazil to implement private 5G in an automotive factory to improve the operation and customization of different vehicle models. During Qualcomm's inaugural DX Summit in

[12] See Mary Lenningham, "T-Mobile US and Verizon look set to beat FWA target," Telecoms.com, August 17, 2023.
[13] Q1 2023 Earnings Call Transcript, T-Mobile.

May 2023 (attended by the author), Accenture spoke at length about how private 5G is helping improve business outcomes through examples like this.

Private 5G applications are moving from proof of concept into production environments. The opportunities in private 5G are vast, but they will take a lot of time to achieve in large enterprises with tightly integrated manufacturing and operations. Another challenge with private 5G are the multiple deployment routes to market. This is a likely contributor to a slow adoption ramp, but the long-term promise for private 5G looks bright.

IS 5G BAD OVERALL?

At the simplest level, the 5G experience is bad today because most users are not on true 5G—that is, Standalone 5G—services. This reality carries with it several key implications.

First, marketing 5G on the basis of "speeds and feeds" is the wrong approach. Sure, it is easy to tell consumers that you can deliver faster speeds on their phone. A bigger number is better. In the real world, though, speeds and feeds aren't everything. If applications don't actually take advantage of 5G's advanced capabilities, then there's little benefit from having higher speeds. This is especially true when you consider how much some wireless operators relied on the expectation that virtual reality (VR) and AR would be big drivers for 5G adoption and satisfaction. Both technologies can be compelling if given enough time, but VR is an inherently stationary experience—not at all optimal for mobile connectivity—while AR glasses will take longer to penetrate the consumer market than most observers (including Apple) anticipated.

Second, wireless carriers have not focused enough on latency. From the earliest days, one big thing that 5G was supposed to deliver was considerably lower latency. However, users will be able to rely on lower latencies consistently only with the deployment of Standalone 5G networks. It's true that mmWave has ultra-low latency; unfortunately, it isn't readily scalable to the level that would be required for a nationwide network. Because latency is crucial for the user experience, operators should focus more on deploying 5G SA to reduce latency across the board. Once that happens, gaming and XR will immediately become better, more compelling drivers for 5G adoption. Also, by deploying network slicing within their 5G SA networks, the carriers can custom-tailor the latency and bandwidth necessary for a given application based on its particular characteristics. This will enable the carriers to right-size the network resources allocated for each app while delivering better user experiences.

Finally, for 5G to become truly successful, customers need access to a wealth of applications built with Standalone 5G in mind. This means that operators must work together closely to help developers maximize 5G capabilities by taking advantage of the edge compute already in place. The original purpose of true 5G was to enable enterprises to operate on a cellular network as if it was Wi-Fi or better, enabling users to get rid of VPNs and feel like they are always working on campus.

Google and Apple are finally bringing more capabilities to their respective operating systems to take advantage of Standalone 5G and private 5G networks. Operators such as Vodafone are also starting to market their Standalone 5G offerings as a new tier of service, in Vodafone's case dubbed 5G Ultra. T-Mobile also just announced a video-focused network-slicing beta program with some of the leading video conferencing companies in the world. But the industry as a whole needs much more of this.

WHERE DO WE GO FROM HERE?

Fortunately, more operators are following the lead of T-Mobile and Vodafone by actively deploying and promoting 5G SA and focusing on compelling applications and use cases. For example, Reliance Jio, the carrier with the largest share of wireless subscribers in India,[14] is using Standalone 5G for its brand-new 5G network. Among other things, this could mean that some of the most successful new 5G apps may come out of India first. India can reach critical mass more quickly because it has more 5G users on a standalone 5G network, as well as a focused developer base with access to more than one hundred 5G innovation labs—some of them operated by companies such as Ericsson and Capgemini.[15]

Meanwhile, T-Mobile is tapping into its many industry partnerships to deliver new 5G apps for commercially deployed autonomous driving, XR, robotics, drones and more. In August 2023, T-Mobile announced a beta program for a new custom 5G SA network slice specifically designed for video communications traffic with companies including Google, Cisco, Zoom and Dialpad.[16] In the same month, AT&T announced that its Internet Air 5G FWA offering will operate on its 5G SA network, which should help with network load and latency.[17] It will be no surprise if AT&T and Verizon tie their new mid-

[14] Shangliao Sun, "Wireless subscriber market share in India as of December 2022, by service provider," Statista, August 15, 2023.
[15] Mini Tehaswi, "Budget 2023 | Government to set up 100 5G labs to develop new apps," The Hindu, February 1, 2023.
[16] "T-Mobile Launches First-Ever 5G Network Slicing Beta for Developers," T-Mobile, August 2, 2023.
[17] Monica Alleven, "AT&T expands Internet Air home FWA service to 16 markets," Fierce Wireless, August 22, 2023.

band network capacity buildout to Standalone 5G. In that case, they may try to follow Vodafone's lead with a new or rebranded 5G service to deliver lower latency and leave behind the bad user experiences of poorly marketed NSA 5G.

But along with new branding and network capabilities, the operators must also clearly communicate to app developers what Standalone 5G offers to them and their customers—and how network slicing can improve the experience even further. Once all three U.S. carriers have 5G SA networks in place, developers should buy into the true 5G vision with the confidence that they can deploy their apps and achieve similar user experiences across all carriers. After years of disappointing customers with big promises and uneven performance, carriers must deliver substantive changes like these to shift people's opinions on 5G.

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