February 7, 2023

SiGNALS *Flash!*

Dispatches from the frontier of wireless

SRG'S SUPER BOWL SCOUTING REPORT... OF LTE AND 5G CELLULAR CAPACITY

Our analysis of potential capacity in LTE and 5G cellular networks around the State Farm stadium in Glendale, Arizona

SiGNALS Research Group

www.signalsresearch.com

EXECUTIVE SUMMARY

During the week of January 16th, Signals Research Group (SRG) found itself "on assignment" in Phoenix, Arizona. Out of sheer curiosity and because this is what we do, we stuck around for an extra day to conduct a scouting report of available LTE and 5G cellular capacity around the State Farm stadium, where Super Bowl LVII will be played on February 12th. Scouting reports are not always the best predictor of future performance – Brock Purdy was drafted last in the 2022 draft yet "Mr. Irrelevant" went on to lead his team to an NFC championship game. Further, the only certainties for February 12th are that Rihanna will "bring it," at least one TV commercial will be hilarious and/or have multiple cameos while another one(s) will fall flat, and someone with the last name of Kelce will get a new ring.

The results in this *Signals Flash!* stem from driving around the stadium, armed with the drive test tools of the trade. As discussed in this report, our observations are largely specific to cellular capacity detected outside of the stadium, although we can't rule out low- or mid-band RF signals from inside the stadium reaching the sensitive scanner we used. We'd love to conduct a follow-on study inside the stadium during the Big Game, but once again our complimentary Super Bowl tickets from a large corporate sponsor with a VIP suite got lost in the mail. We also leveraged AI/ML to interpret the data and ChatGPT to write this report, so all bets are off on whether we hit the receiver in stride or tossed up a lame duck that gets returned for a pick six.

As always, unlike our subscription-based *Signals Ahead* reports, you may forward this *Signals Flash!* report to whomever you want. Without further ado,

- **Our Thanks.** Our study would not have been possible without the continued support of Accuver Americas, Rohde & Schwarz, and Spirent Communications. The bulk of our analysis is based on using the R&S TSMA scanner to monitor all LTE and 5G channels between 600 MHz and 3.9 GHz.
- **5G Rules.** For all three operators, we estimate that 5G accounted for more than 75% of their potential network capacity. The percentage was lowest for Verizon (77%), thanks to its heavy use of CBRS spectrum, which gave it much higher LTE capacity than its peers.
- **Mid-band and 5G mmWave.** For AT&T (90%) and T-Mobile (97%), their mid-band 5G assets account for at least 90% of their total 5G capacity. For Verizon, the percentage was only 29%, entirely because of 5G mmWave, which represented 69% of available 5G capacity. We also came across some AT&T mmWave sites. Our mmWave analysis does not include the impact of any inbuilding mmWave assets.
- **Doubling Down.** With a recent software update to our Galaxy S22 smartphone, we were able to take advantage of AT&T's recent addition of a second mid-band 5G carrier (3.45 GHz) to enable carrier aggregation with its other Band n77 assets. We discuss.

Save the Date for

The Greatest Coques on Earth!

WHEN
Tuesday, February 28, 2023
7:30 - 10:00 PM

WHERE
Hidden in the Gothic Quarter, Barcelona, Spain

WHO
You

Please contact us for details and to get added to the guest list

Cohosted by
Signals Research Group and Spirent Communications

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NOW AVAILABLE!!
5G: The Greatest Show on Earth!
MU-MIMO AND THE TOWER OF POWER
CHAPTER 1: THE 8-LAYER CONFRONTATION
PART OF "THE MOTHER OF ALL NETWORK BENCHMARK TESTS" SERIES OF REPORTS

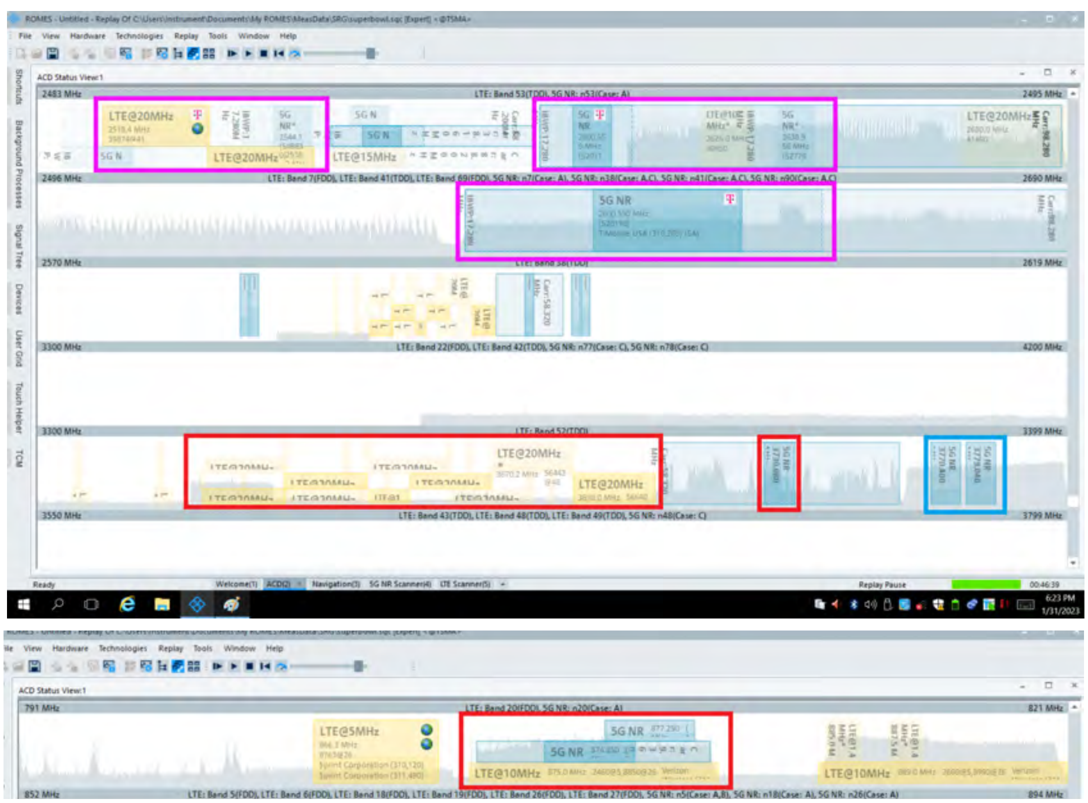
With MWC fast approaching, we welcome the opportunity to meet with people/companies that are attending. SRG clientele and Signals Ahead *subscribers are also invited to our soiree that we are cohosting with Spirent Communications on Tuesday night. Please RSVP and we'll provide the details.*

OUR APPROACH

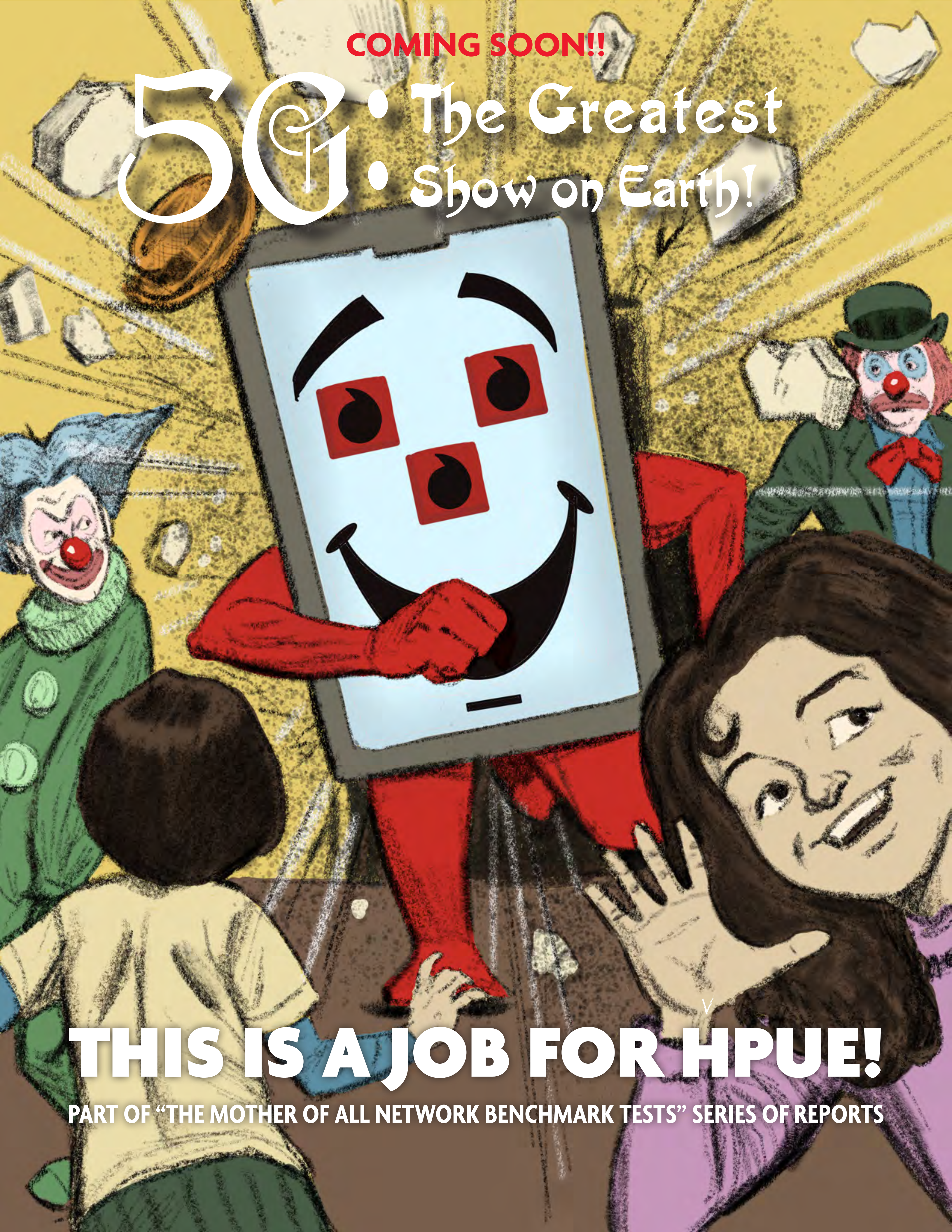
We leveraged a combination of the Rohde & Schwarz TSMA scanner and three Galaxy S22 smartphones (AT&T, T-Mobile, and Verizon) to obtain information about LTE and 5G network deployments in the area around the State Farm stadium. The R&S scanner constantly monitored all frequencies between 600 MHz and 3.9 GHz while capturing relevant information about the networks – cell IDs (PCI), operator, technology, and channel bandwidth. We used this information for the bulk of our analysis. We used the three smartphones to complement the information provided by the scanner. Most importantly, since we were using the scanner for the sub 6 GHz frequencies, we used the S22 smartphones to detect the presence of 5G mmWave. Accuver Americas provided its XCAL5 logging tool to capture the chipset diagnostic messages while we used Umetrix Data from Spirent Communications to generate high bandwidth data transfers from one of its servers. We provide additional insight on how we analyzed the information and some inherent limitations in our approach when we present the data throughout this report.

Figure 1 provides a screen shot of some sample scanner data, specifically mid-band LTE and 5G carriers. The top image includes T-Mobile LTE and 5G assets at 2.6 GHz, as well as Verizon and AT&T Band n77 assets (the lower 3.45 GHz channel for AT&T is outside the displayed range). The figure also shows ample use of CBRS spectrum on the part of Verizon. The lower image shows Verizon using DSS in Band 5/n5 and LTE in a second Band 5 channel, as well as a T-Mobile Band 26 LTE channel.

Figure 1. Sample Scanner Data



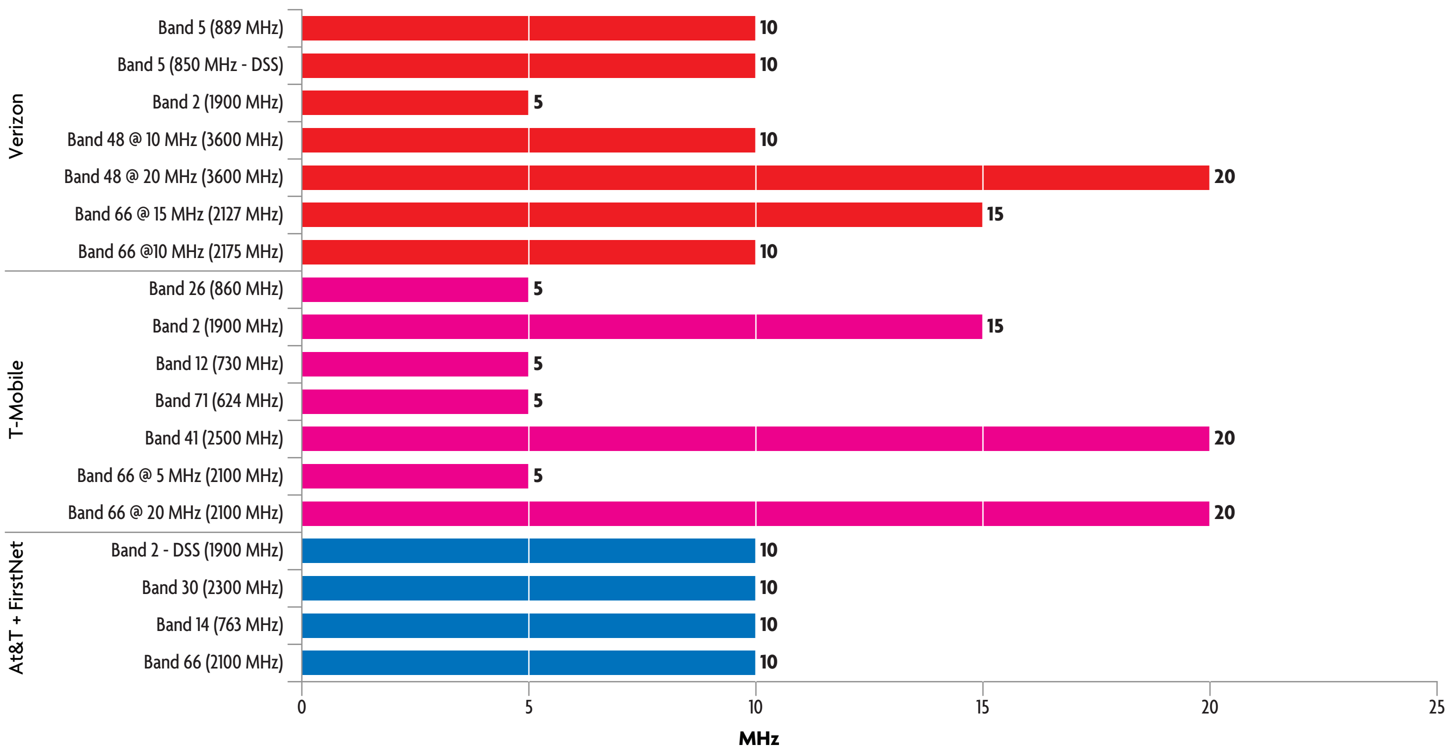
Source: R&S TSMA Scanner and SRG


COMING SOON!!
5G: The Greatest Show on Earth!
THIS IS A JOB FOR HPUE!
PART OF "THE MOTHER OF ALL NETWORK BENCHMARK TESTS" SERIES OF REPORTS

OUR BIG GAME SCOUTING REPORT

Although the TSMA scanner simultaneously captured LTE and 5G signals with each sweep, for purposes of our analysis, we've separated the results into the two technologies, starting with LTE. Figure 2 shows the LTE radio assets for each operator. The AT&T channels frequently broadcast AT&T and FirstNet so we labeled the figures accordingly. If an operator had two radio channels with identical bandwidth in an LTE band, then we combined the results. One example is AT&T who had two 10 MHz LTE channels in Band 66. If the channel bandwidths were different (e.g., Verizon and CBRS) then we listed the channels separately.

Figure 2. LTE Radio Assets – by operator

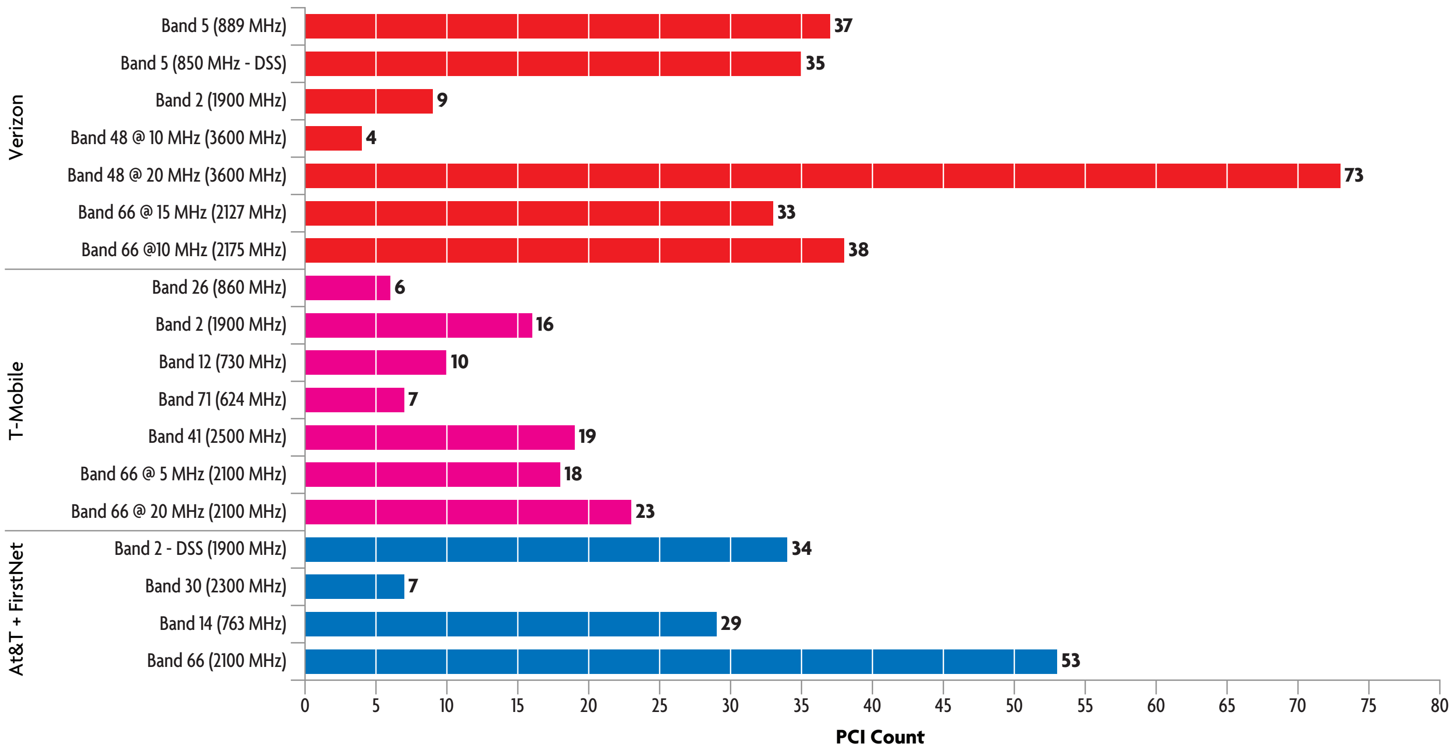


Source: Signals Research Group

Figure 3 shows the total number of unique LTE cells for each operator. For definitional purposes a single radio site likely has three cells for each frequency – 5G mmWave is a noted exception. These results only include PCI values with sufficient signal strength which allowed the scanner to demodulate the SIBs/MIBs. This caveat means that we are likely missing radio assets from inside the stadium – this statement is more likely true for the higher frequencies. Likewise, the list of PCIs likely contains cell sites that were not in close proximity to the stadium, but still detected by the scanner. Since the scanner treated each operator's radio assets equally, the outcome is not skewed by operator, although they could be skewed by frequency band – lower frequency bands travel further than higher frequencies. We also note that operators could have deployed radio assets after we did our scouting report (e.g., COWs), and if these assets were not present and/or not radiating RF energy then we would not have detected them.


NOW AVAILABLE!
5G: The Greatest Show on Earth!
GROUP 2
Galaxy S20 5G
Galaxy S22 5G
Pixel 6a
iPhone 13 mini
Motorola edge (2022)
VOLUME 29: CAGE MATCH
(FR1 IN THE WILD!)

Figure 3. LTE PCI Counts – by operator and frequency

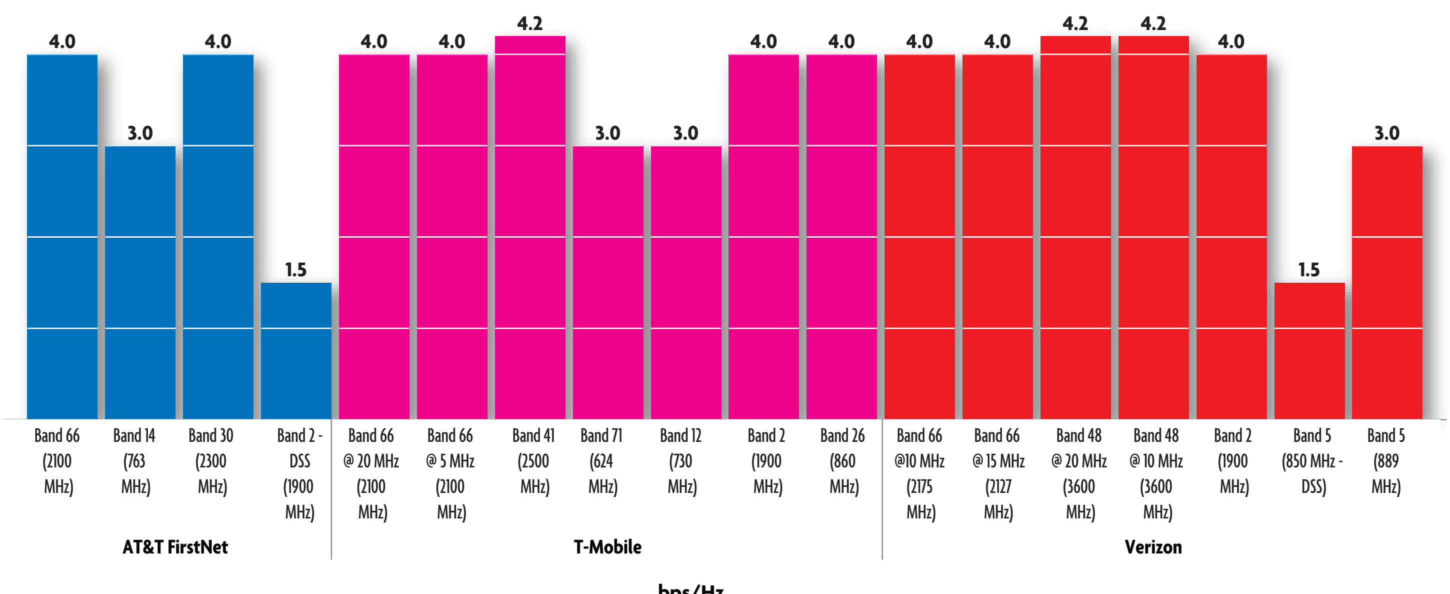


Source: Signals Research Group

We didn't think it was appropriate to conduct a comparative performance benchmark study of this area since operators could still be optimizing their networks or adding sufficient backhaul. Further, it would be logistically challenging to collect performance data on all bands and for all operators. Instead, we leveraged drive test results from earlier campaigns to estimate the spectral efficiency for each technology + band pairing. We attempted to use conservative values in all cases. We also note that mobile data users at the Super Bowl will likely be stationary or in low mobility situations. Our drive tests generally include higher vehicular speeds. Since higher

We leveraged drive test results from earlier campaigns to estimate the spectral efficiency for each technology + band pairing.

Figure 4. LTE Spectral Efficiency Assumptions – by frequency



Source: Signals Research Group

IN CASE YOU MISSED IT:
SIGNALS AHEAD BACK ISSUES

➤ **1/10/23 "5G: The Greatest Show on Earth! Vol 30: MU-MIMO and the Tower of Power"** SRG just completed its 30th 5G benchmark study. For this endeavor we collaborated with Accuver Americas and Spirent Communications to conduct an independent benchmark study of 5G 8-layer MU-MIMO, using the SRS-based implementation.

Highlights of the Report include the following:

Our Thanks. We did this study in collaboration with Accuver Americas (XCAL5 and XCAP) and Spirent Communications (Umetrix Data). SRG is responsible for the data collection and all analysis and commentary provided in this report.

Our Methodology. Testing took place on the T-Mobile network (Band n41) in southern California at commercial cell sites. We used 4 smartphones or 4 FWA CPEs to load the network with full buffer data transfers. We looked at the impact of UE placement within the cell as well as mobility. We analyzed all the typical KPIs, including RB usage, MIMO layers, MCS, and, of course, throughput, while also including vehicular speed and geo coordinates.

The Results. We observed significant double-digit throughput gains due to MU-MIMO pairing relative to SU-MIMO (we disabled SRS / MU-MIMO in the network). Close placement of UEs had little, if any, impact on the efficiency of MU-MIMO with excellent pairing maintained.

The FWA Implications. T-Mobile has already deployed the functionality at all Ericsson Band n41 cell sites on a nationwide basis. For reasons discussed in the report, MU-MIMO functionality can have a significant positive influence on the FWA business case, even though some limitations to MU-MIMO exist.

More in Store. This MU-MIMO report marks what we anticipate will be at least a few more MU-MIMO studies in the coming year. We anticipate looking at 16-layer MU-MIMO, more device placement scenarios, different geographies (rural), and traffic profiles. All these reports will be available through our Signals Ahead publication.

➤ **12/7/22 "5G: The Greatest Show on Earth! Vol 29: Cage Match (FR1 in the Wild!)"** SRG just completed its 29th 5G benchmark study. For this endeavor we collaborated with Accuver Americas and Spirent Communications to conduct an independent benchmark study of several 5G smartphones operating in mid-band 5G spectrum and representing chipsets from MediaTek, Qualcomm, and Samsung.

Highlights of the Report include the following:

Our Thanks. We did this study in collaboration with Accuver Americas (XCAL-M, XCAL-Solo and XCAP) and Spirent Communications (Umetrix Data). SRG is responsible for the data collection and all analysis and commentary provided in this report.

Our Methodology. Testing took place on the T-Mobile network (Band n41) in the suburbs of Minneapolis-Saint Paul, MN. The network is comprised of 140 MHz of Band n41 spectrum (100 MHz + 40 MHz) as well as 5G in Band n71 and the requisite LTE spectrum - primarily Band 66 and Band 2 serving as the anchor cell. We tested the smartphones in pairs with the Galaxy S22 serving as the reference smartphone used to evaluate performance of the other smartphones in the mix.

The Scope. We used the Galaxy S22, Galaxy S20 Ultra, iPhone 13, Google PIxel 6a, Galaxy A13, and Motorola edge (2022) smartphones. These smartphones represent 5G chipsets from MediaTek, Qualcomm and Samsung. GIven some limitations in logging detailed chipset data, we included a mix of physical layer and application layer results in our analysis

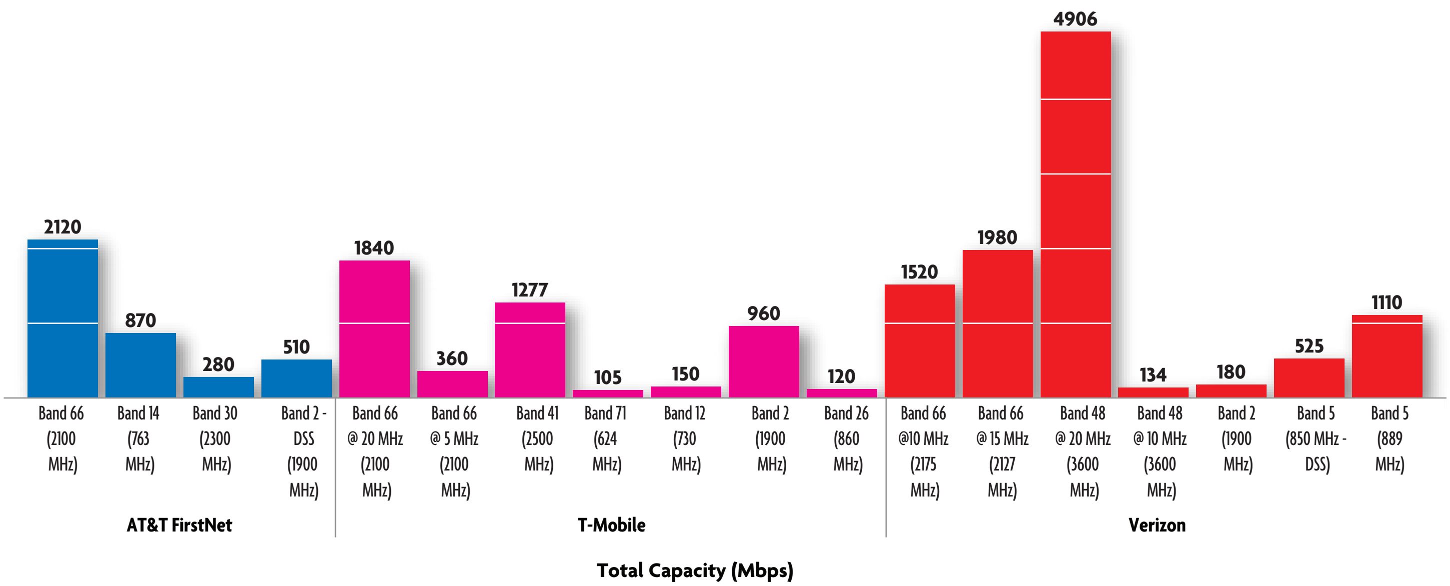
A New Sheriff in Town. Based on our analysis of the results, we declare the iPhone 13 as the ""unofficial"" top performing 5G smartphone of the group. We include the ""unofficial"" disclaimer because our analysis was limited to application layer throughput with this phone since we weren't able to log chipset data. Given the network pushed most of the traffic to Band n41 on the S22, we assume it behaved the same way with the iPhone, meaning potential differences in LTE performance between the two phones wouldn't explain the overall results we observed.

LTE is becoming less relevant on the T-Mobile network. In addition to 5G Band n41 carrying the super-majority of the total traffic, the 5G network is quickly moving to the standalone (SA) network architecture as the default architecture, even with Band n41. This situation means LTE is becoming inconsequential, especially for those smartphones that support SA mode in Band n41.

vehicular speeds generally degrade performance, our approach introduces an additional haircut to the spectral efficiency assumptions we used. For bands where there was DSS, we evenly split the spectral efficiency between LTE and 5G, hence the lower spectral efficiency in those channels.

The LTE capacity, as shown in Figure 5, represents a simple calculation in which we multiplied the channel bandwidth capacity (spectral efficiency x channel bandwidth) by the number of unique PCI values. Verizon's LTE capacity in CBRS spectrum really stands out, but it can easily be explained. Verizon had multiple CBRS radio channels, presumably collocated at each cell site, and each radio channel was 20 MHz – there was an additional 10 MHz CBRS channel used. Lastly, our spectral efficiency assumption (4.2 bps/Hz) is well in line with what we've documented when testing mid-band LTE TDD.

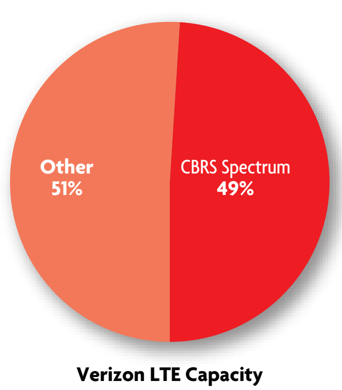
Figure 5. LTE Capacity – by operator and frequency



Source: Signals Research Group

To put things into perspective, Figure 6 shows the distribution of Verizon's LTE capacity between CBRS and all other bands. According to our analysis, CBRS-related radio assets accounted for 49% of the operator's total available LTE capacity.

Figure 6. Verizon LTE Capacity Distribution – CBRS versus everything else



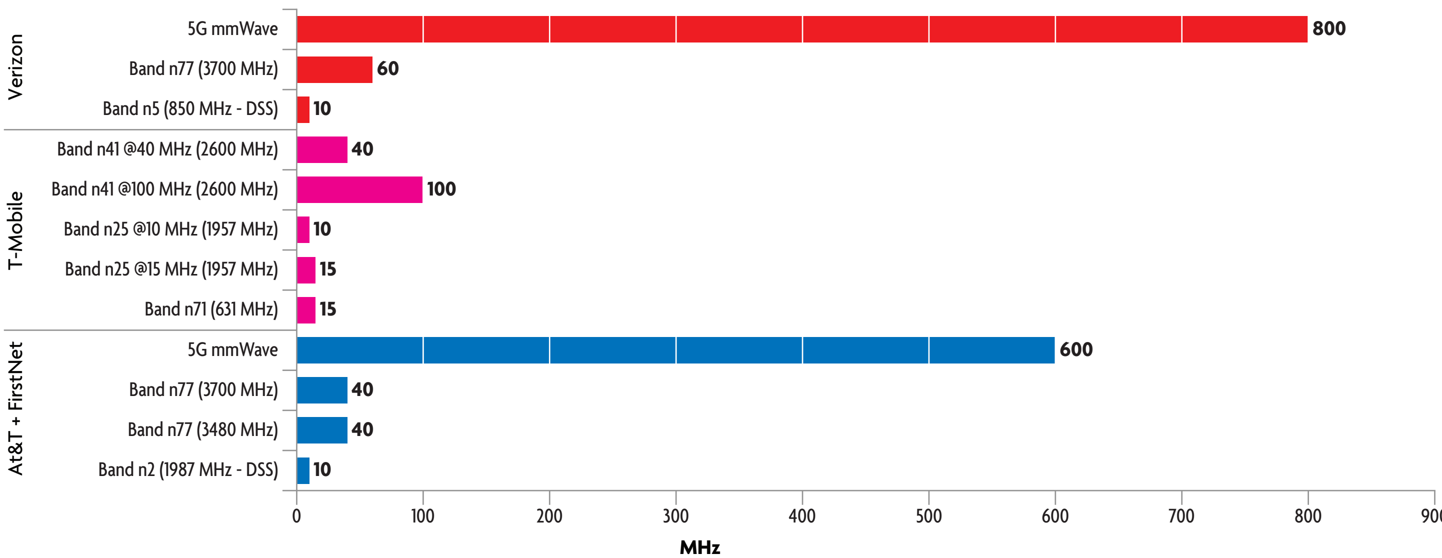
Source: Signals Research Group

Turning to 5G, we provide similar results. One key distinction is that the 5G mmWave results are based on information obtained with the three Galaxy S22 smartphones and how they were using their respective 5G networks. Given we have found that operators, notably Verizon, have very conservative handover thresholds between their mid-band 5G assets and 5G mmWave, not to mention our experiences which suggest handovers to 5G mmWave rarely occur during an active data session, we believe it is entirely foreseeable we have undercounted 5G mmWave radio assets.

It is entirely foreseeable we have undercounted 5G mmWave radio assets.

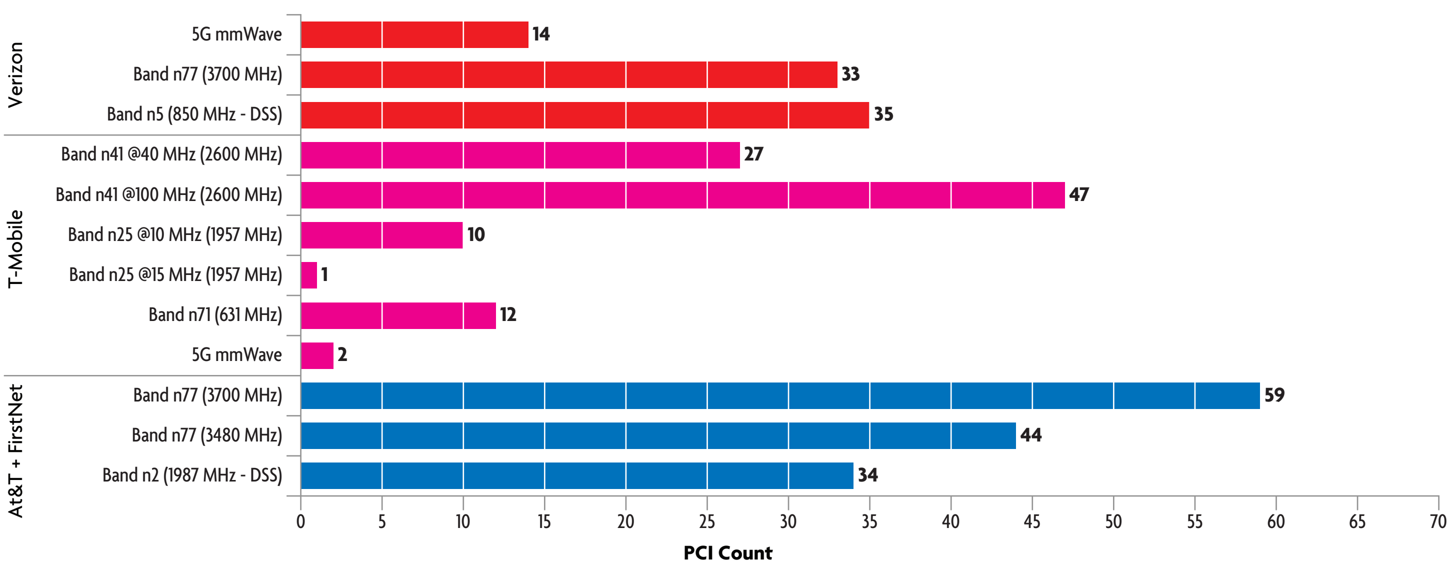
Figure 7 illustrates the 5G radio assets by operator. Consistent with the LTE results, AT&T and Verizon each had one channel used for DSS, meaning we included it in both the LTE and 5G figures. We adjusted the spectral efficiency to implicitly assume a 50/50 split of traffic between LTE and 5G.

Figure 7. 5G Radio Assets – by operator



Source: Signals Research Group

Figure 8. 5G PCI Counts – by operator and frequency



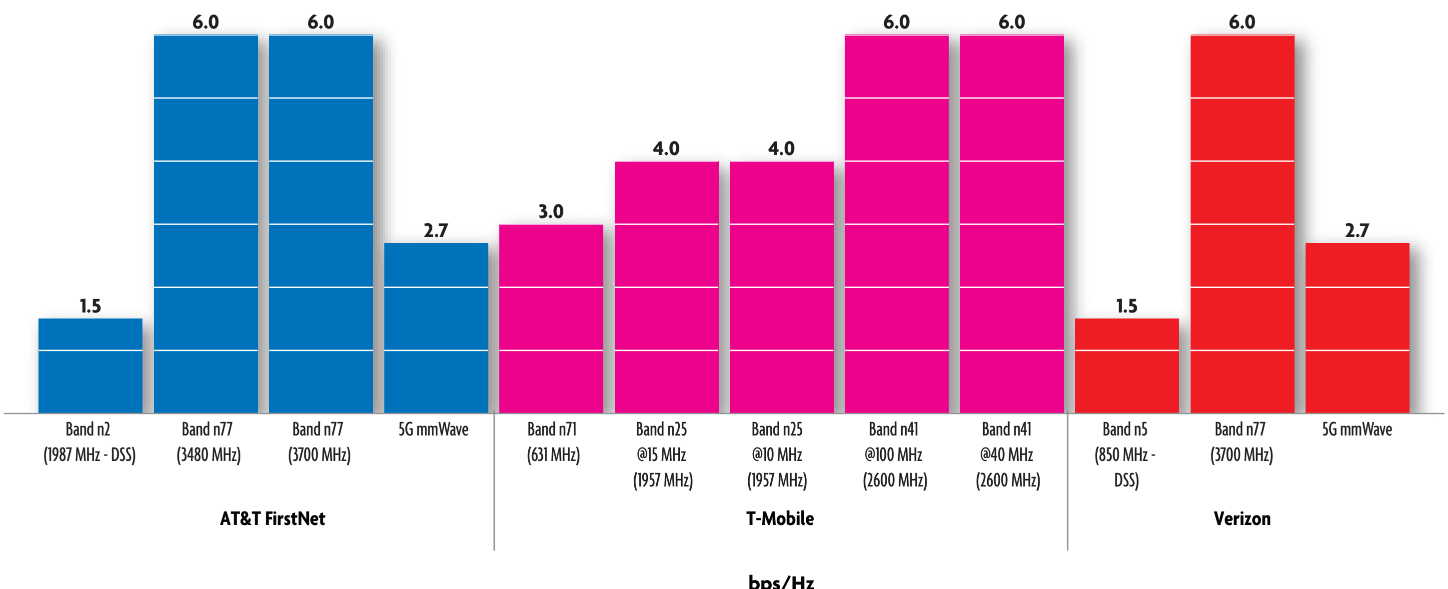
Source: Signals Research Group

Figure 8 shows the number of unique PCI values for each 5G channel. As indicated earlier in this report, the 5G mmWave information is based on the behavior of the Galaxy S22 smartphones. If a smartphone remained on mid-band 5G instead of handing off to 5G mmWave then it wasn't included in our analysis. Likewise, it is a certainty that we did not include any 5G mmWave radio assets from inside the stadium.

The 5G mmWave information is based on the behavior of the Galaxy S22 smartphones.

Our 5G spectral efficiency assumptions are shown in Figure 9. For spectrum below 2 GHz, we used the same spectral efficiency we used for LTE. For mid-band 5G radio assets we leveraged earlier drive test campaigns. Worth noting, during an extended walk test in Elisa's network in Helsinki, the Band n78 spectral efficiency was a much higher 8.7 bps/Hz than the 6.0 bps/Hz we used for this analysis. Lastly, our 5G mmWave spectral efficiency assumption stems from an earlier lengthy walk test where we felt the performance wasn't as good as it could have been due to non-RF related issues.

Figure 9. 5G Spectral Efficiency Assumptions – by frequency

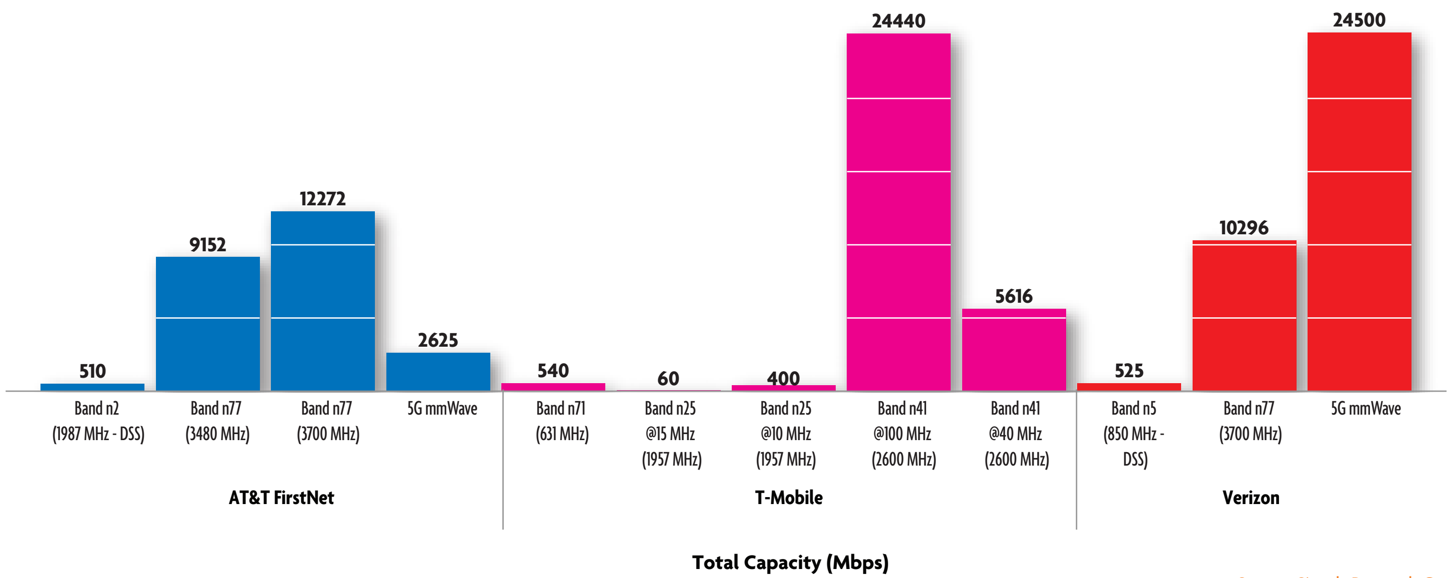


Source: Signals Research Group

Cutting to the chase, Figure 10 provides the 5G capacity for each operator and by frequency band. Not surprisingly, all three operators had a lot of mid-band 5G capacity. The Verizon 5G mmWave capacity may seem high, or misleading, but in this case, we believe the results are valid with a degree of perspective. Our analysis was limited to a concentrated and generally open area around the stadium where 5G mmWave performance shines. This situation is much different from one in which the coverage area is quite large and difficult to cover with mmWave. Further, our capacity results are merely that – capacity results. The numbers say nothing for how the capacity is spread over the area where we collected the data. That being said, we know for certain the mmWave radio assets were located within the areas where we drove. The mid-band 5G radio assets could have been located outside of the test area and/or within the stadium.

We know for certain the mmWave radio assets were located within the areas where we drove.

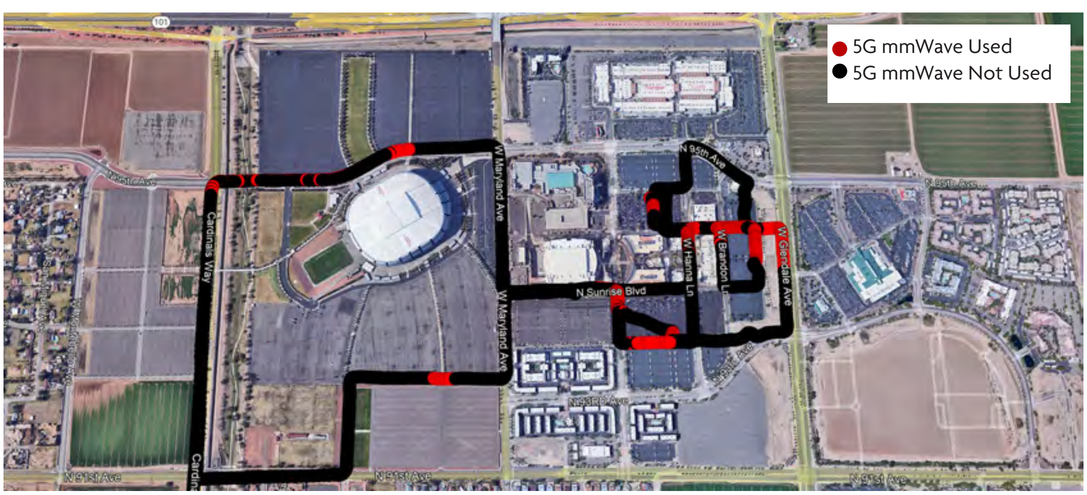
Figure 10. 5G Capacity – by operator and frequency



Source: Signals Research Group

Figure 11 shows where the Galaxy S22 on the Verizon network used 5G mmWave. As previously noted, we were driving and constantly pushing data to the phone, reducing the probability of the phone moving to 5G mmWave. Additionally, most of the parking lots were closed to the public so to the extent we encountered mmWave, the figure grossly underreports the coverage associated with each 5G mmWave radio. If someone invites us to a tailgate party, we'll bring along some test equipment and see if our thesis is correct.

Figure 11. Verizon 5G mmWave Detection Drive Test



Source: Signals Research Group

The R&S scanner detected multiple LTE and 5G radio assets where the signal was too weak to demodulate without dedicating a lot of processing power and subsequently limiting the scanning periodicity. Figure 12 shows the number of 5G radio assets, by frequency band, where the scanner detected their presence, but didn't specifically identify the operator. The figure shows a very healthy mix of mid-band 5G radio assets – the numbers in brackets identify the count in each row. 5G mmWave isn't included in this figure since the antenna was limited to FR1 (sub 6 GHz) frequencies.

Figure 12. We Know What We Don't Know

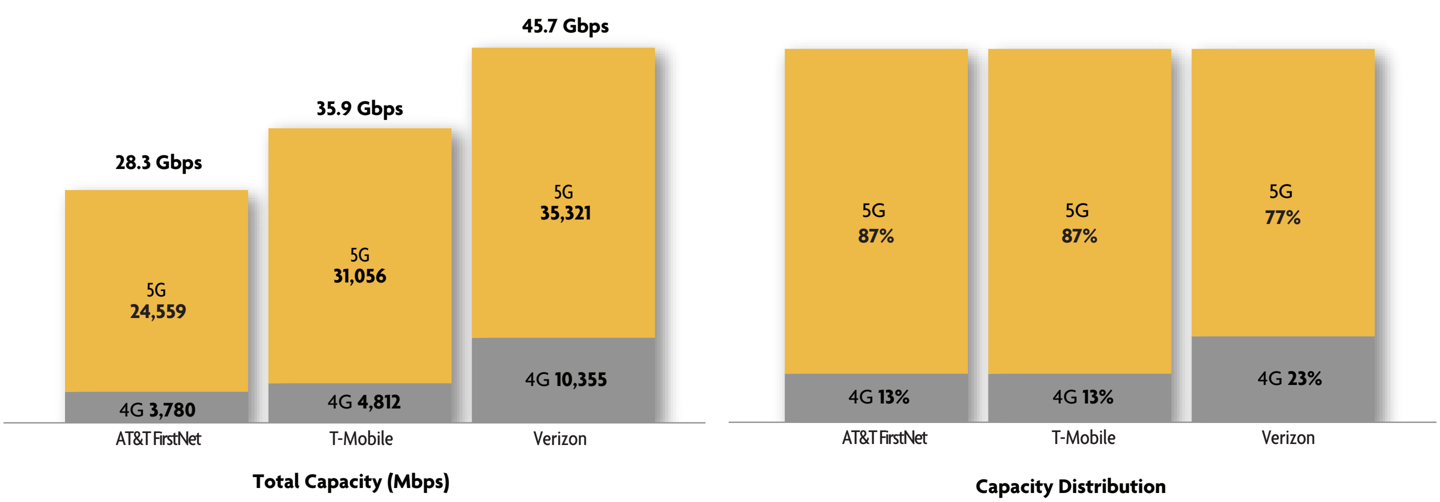
- Provider Information not decoded yet [1881/1881]
  - ACD#10 @ 3730.080 MHz (648672) [194/194]
  - ACD#11 @ 3770.400 MHz (651360) [135/135]
  - ACD#12 @ 3489.600 MHz (632640) [7/7]
  - ACD#13 @ 2544.150 MHz (508830) [32/32]
  - ACD#14 @ 877.250 MHz (175450) [9/9]
  - ACD#15 @ 1957.350 MHz (391470) [13/13]
  - ACD#16 @ 3779.040 MHz (651936) [9/9]
  - ACD#17 @ 2638.950 MHz (527790) [10/10]
  - ACD#18 @ 631.350 MHz (126270) [118/118]
  - ACD#2 @ 3480.960 MHz (632064) [128/128]
  - ACD#3 @ 1959.850 MHz (391970) [121/121]
  - ACD#4 @ 2600.550 MHz (520110) [320/320]
  - ACD#5 @ 1987.350 MHz (397470) [158/158]
  - ACD#6 @ 2510.550 MHz (502110) [84/84]
  - ACD#7 @ 874.850 MHz (174970) [227/227]
  - ACD#8 @ 2558.550 MHz (511710) [18/18]
  - ACD#9 @ 2560.950 MHz (512190) [298/298]

Source: Signals Research Group

To close this section out, Figure 13 shows the total capacity for each operator as well as the contributions from LTE and 5G. For all three operators, 5G accounted for at least 75% of total network capacity. Our scouting report provides our analysis of available bandwidth outside the stadium. It doesn't reflect how these networks will perform on game day. Finally, Figure 14 shows the distribution of 5G traffic between low-band, mid-band and 5G mmWave. Low band 5G isn't relevant from a capacity perspective for any of the operators. The Verizon results for 5G mmWave once again stand out, but the numbers are a direct reflection of the number of detected cells (n77 = 33, mmWave = 14) and the channel bandwidths (n77 = 60 MHz, mmWave = 800 MHz) associated with the two bands.

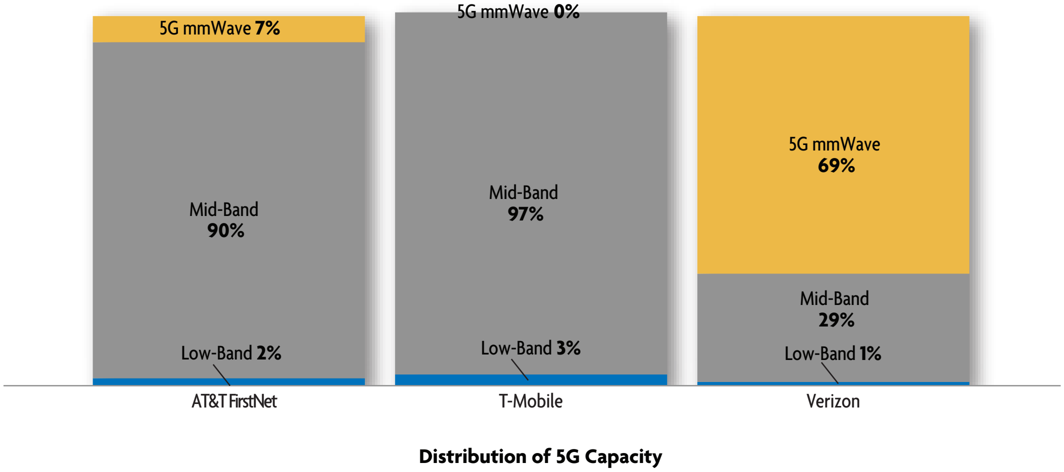
For all three operators, 5G accounted for at least 75% of total network capacity.

Figure 13. LTE and 5G Total Capacity Distribution – by operator



Source: Signals Research Group

Figure 14. Low-band, Mid-band, and 5G mmWave 5G Capacity Distribution – by operator



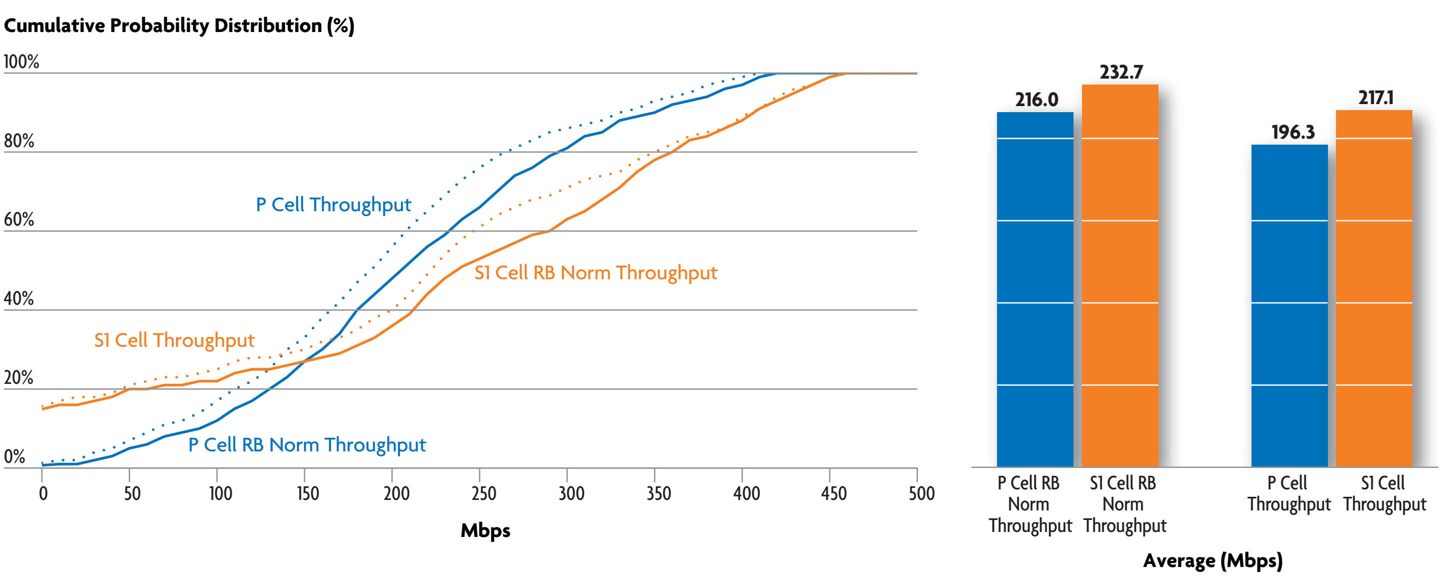
Source: Signals Research Group

DOUBLING DOWN ON BAND N77

We didn't analyze the performance of the three operators' networks near the stadium, but during our stay in Phoenix we did manage to capture a log of the AT&T 5G network since we had observed our S22 smartphone was using two mid-band 5G carriers, following a recent software upgrade. It is probably early days for the rollout, but the following figures may still be interesting.

Figure 15 shows the distribution of throughput for the primary and secondary cells. In all cases, the P cell was in the C-Band, and the S1 cell was at 3.45 GHz – the latter represents the newer addition to the portfolio. The figure shows the S1 cell provided higher throughput than the P cell, but it wasn't due specifically to loading, since even with RB normalized throughput the S1 cell delivered higher throughput.

Figure 15. 5G Primary Cell and Secondary Cell Throughput Distributions and Averages



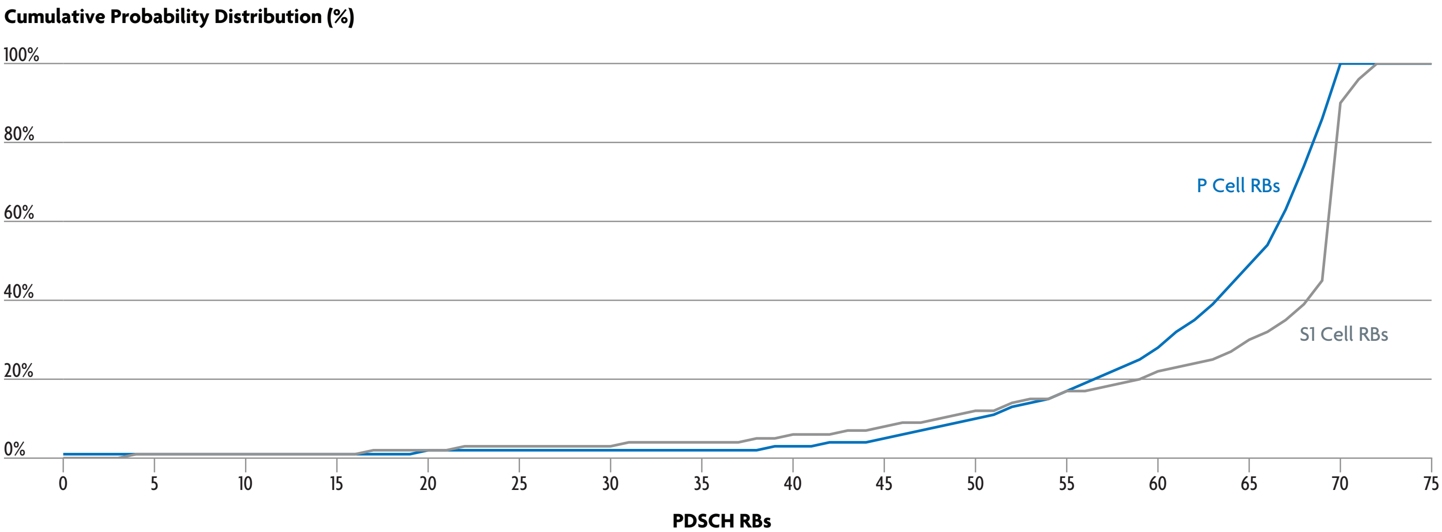
Source: Signals Research Group

Figure 16 and Figure 17 provide the distribution of resource blocks and MCS for the two bands. Although the RB distributions are much different, the average values were very similar. Further, it is evident the radio conditions were much better in the S1 cell, given the distribution and average MCS values. Our conclusion is that the S1 cell performed better than the P cell because of higher interference in the P cell, thanks to all the phones in the AT&T network which support the band. Very few phones currently support 3.45 GHz and consumers still need to accept the recent software upgrade to use the band. The phones in the C-Bock spectrum may not have been actively using the network in the same cell(s) where we tested, but their presence would have increased the interference, just as active phones in adjacent cells would have increased the interference in the cell(s) where we tested.

The S1 cell performed better than the P cell because of higher interference in the P cell

Figure 16. 5G Primary Cell and Secondary Cell Resource Block Distributions

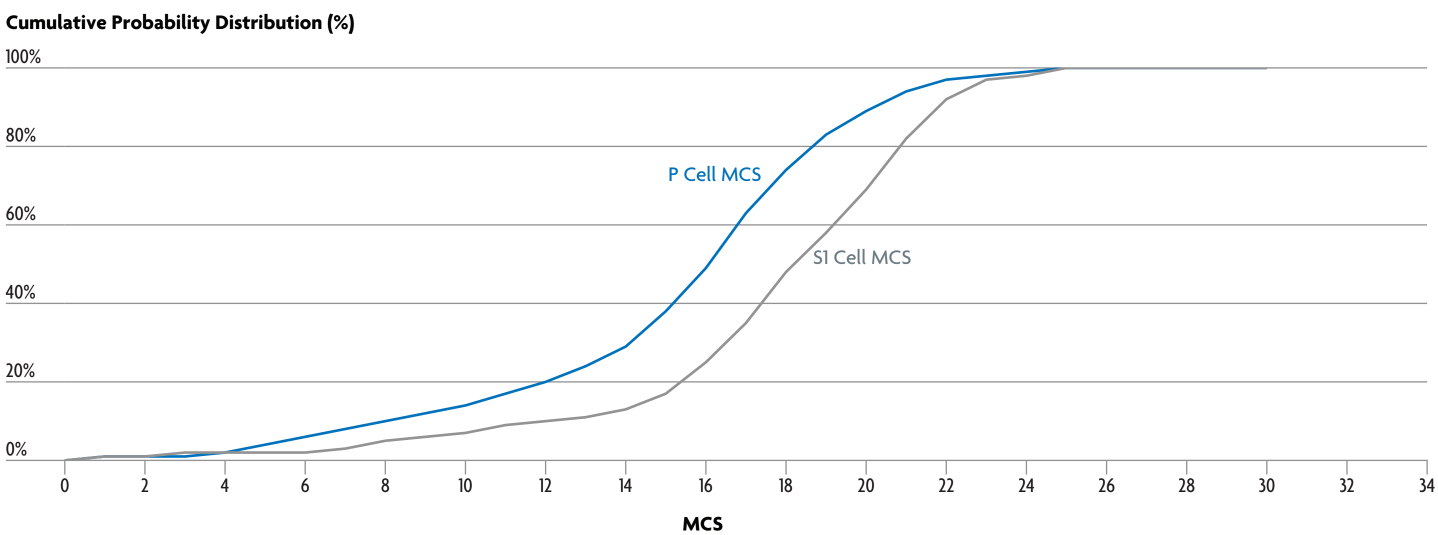
Average P Cell = 62.5 RBs
Average S1 Cell = 63.8 RBs



Source: Signals Research Group

Figure 17. 5G Primary Cell and Secondary Cell MCS Distributions

Average P Cell MCS = 15.6
Average S1 Cell MCS = 18.1



Source: Signals Research Group

With the addition of 3.45 GHz, AT&T now has 80 MHz of mid-band 5G spectrum which it is pairing with up to 3 bands of LTE – subject to device support. The figures in this section to not include LTE. Later this year, once the satellite spectrum holders vacate their C-Band spectrum, AT&T will be able to move from its existing 40 MHz of C-Band spectrum to 2x40 MHz of recently-vacated C-Band spectrum, resulting in an 80 MHz channel. At that point, AT&T will be able to deliver 80 MHz + 40 MHz for a combined 120 MHz mid-band 5G radio channel. AT&T is already setting the stage for this transition since all existing n77 sites and future n77 sites will already have the radio assets in place – a software upgrade will flip the switch to trigger the use of the new band combination. And thankfully, the SRG fleet of unlocked S22 smartphones will support the new capability as soon as AT&T turns it on.

Later this year, AT&T will be able to deliver 80 MHz + 40 MHz for a combined 120 MHz mid-band 5G radio channel.

Michael Thelander

Michael Thelander is the President and Founder of Signals Research Group (SRG), a US-based research consultancy that offers thought-leading field research and consulting services on the wireless telecommunications industry.

Its flagship research product is a research product entitled Signals Ahead, which has attracted a strong following across the entire wireless ecosystem with corporate subscribers on five continents. SRG's Signals Ahead research product and its consulting services are technology-focused with a strong emphasis on next-generation networks and performance benchmarking.

In his current endeavor, Mr. Thelander is the lead analyst for Signals Ahead and he guides a team of industry experts that provide consulting services for the wireless industry, including some of the largest mobile operators, the top equipment OEMs, trade associations, and financial institutions. He has also served as a member of an industry advisory board for one of the world's largest wireless infrastructure suppliers.

Mr. Thelander earned a Masters of Science in Solid State Physics from North Carolina State University and a Masters of Business Administration from the University of Chicago, Graduate School of Business.

Emil Olbrich

Emil Olbrich is currently VP of Networks with Signals Research Group. Prior to this he was head of LTE research, development, test and evaluation for the Public Safety Communications Research Program where he deployed the first and most diverse Public Safety 700 MHz LTE test lab in the world with over 70 participating vendors and commercial carriers. He was responsible for the specifying, deploying and maintaining the entire ecosystem of LTE which included devices, air interface, transport, radio access network, evolved packet core, IP networking, IMS core and application servers. He also led the team efforts, which include standards work, test case development and test case execution.

Mr. Olbrich has over 20 years of experience in the field of wireless telecommunications. He has worked primarily in R&D at some of the largest telecommunication companies in the world - such as Motorola, Qualcomm and Ericsson. His scope of work includes deploying and operating LTE infrastructure (RAN, EPC and IMS) from numerous Tier 1 vendors; testing new LTE mobile devices from multiple suppliers; testing, deploying and operating some of the first commercial CDMA networks; serving as Lead Project engineer for the 2002 Salt Lake City Winter Olympics and as the Project Manager for the China Ministry of Information Industry 3G testing in China; and supporting the early development of HDR (EV-DO and EV-DO Rev A).

He has been a speaker at events such as the GSMA Mobile World Congress, LTE North America, 4G World, International Wireless Communications Expo and LTE World Summit. Mr. Olbrich has a B.S. degree in Electrical Engineering Technology from Southern Illinois University.

ON THE HORIZON: POTENTIAL *SIGNALS AHEAD/SIGNALS FLASH!* TOPICS

We have identified a list of pending research topics that we are currently considering or presently working on completing. The topics at the top of the list are definitive with many of them already in the works. The topics toward the bottom of the page are a bit more speculative. Obviously, this list is subject to change based on various factors and market trends. As always, we welcome suggestions from our readers.

5G Standardization

- *5G from a 3GPP Perspective (ongoing series of reports – published quarterly or as warranted)*

Thematic Reports

- *Mobile Edge Computing and the impact of data caching at the cell edge*

Benchmark Studies

- *5G NR mmWave Fixed Wireless Access with IAB*
- *SRS versus codebook beamforming benchmark study*
- *Mobile Edge Computing*
- *Open RAN network performance benchmark study 1 – Dish Network Revisit*
- *Open RAN network performance benchmark study 3 – Scheduling Efficiency*
- *FR1 + FR2 NR-DC network performance benchmark study*
- *MU-MIMO benchmark study (FR1)*
- *High Power User Equipment (HPUE) benchmark study*
- *SRS-based beamforming benchmark study*
- *5G mmWave device/chipset lab-based benchmark study*
- *DSS Update benchmark study*

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