CRA Insights:
The Economics of 5G
CRA Charles River Associates

December 2020

The economics of 5G deployment in the "race" to 5G: The state of 5G in the US, South Korea, and other countries

As regulators in various countries consider when and how much spectrum to allocate for 5G services, valuable lessons can be learned from the experiences of 5G early-adopter countries, such as South Korea and the US. In this *Insights* we look at the progress in 5G deployment and adoption across several countries, with a more detailed case study of the comparison of the US and South Korea. We also look at the relationship between that progress and the quantity of mid-band spectrum available to major carriers in these countries.

Background: The importance of mid-band spectrum

We discussed the importance of mid-band spectrum for initial 5G network rollouts in our July ***Insights***. The *amount* of mid-band spectrum that a carrier has available to dedicate to 5G also matters. Wireless carriers must have access to a sufficient amount of mid-band spectrum (frequencies between 1 GHz and 6 GHz) to provide nationwide service that meets the 5G specifications for speed, latency, and capacity, and do so at reasonable cost. Industry organizations recommend that carriers should have access to 80-100 MHz of mid-band spectrum, preferably contiguous.[1] With respect to the speed of service, according to the GSM Association (GSMA), which collects data and issues analyst reports on the mobile telecommunications industry, when the spectrum band available to a carrier increases from 40 MHz to 100 MHz, both peak and average speeds more than double. Network costs also depend on the amount of spectrum available. For example, decreasing the amount of spectrum available to a carrier from 100 MHz to 60 MHz increases the number of cell sites needed to carry the same amount of traffic in the same geographic area by 64%, according to the GSMA. Because a significant driver of network cost is the number of cell sites needed to cover a given area, reducing the number of required cell sites allows for substantial economies in deployment. According to CTIA, a US-based association of wireless industry participants, wide spectrum bands are a prerequisite to achieving low latency for 5G service.[2]

Case study: South Korea and the United States

The contrast between the development of 5G in the US and South Korea illustrates the importance of mid-band spectrum.

The US and South Korea were the first two countries to launch 5G mobile service, launching service simultaneously on April 3, 2019. As of the third quarter of 2020, however, the 5G penetration rate—a measure of consumer adoption defined as the number of 5G-capable mobile devices in a country divided by the population—had reached almost 17% in South Korea, whereas the 5G penetration rate in the US remained under two percent.

A notable difference between the 5G deployments in South Korea and the US has been the spectrum bands used by the countries' mobile wireless carriers to launch the service. Carriers in South Korea launched their 5G networks using spectrum in the 3420-3700 MHz band. South Korea allocated the 3420-3700 MHz band to mobile wireless providers in June 2018. SK Telecom and KT, two major carriers in South Korea, each obtained access to 100 MHz of this mid-band spectrum, and LG U+, another major South Korean wireless carrier, received access to 80 MHz of this mid-band spectrum.[3]

Unlike South Korea, the US was not able to auction any mid-band spectrum until July 2020, a full two years after South Korea.[4] In July 2020, the US auctioned a small amount (70 MHz) of spectrum in the 3550-3700 MHz band.[5] A much more significant quantity of mid-band spectrum (280 MHz in the 3700-3980 MHz band) is scheduled to be auctioned in December 2020, but will not be fully cleared and available for use until at least December 2023. An early tranche of this spectrum will be cleared in some geographies by December 2021.[6] Before July 2020, major US carriers had access only to low-band spectrum (600 MHz) and mmW spectrum (24 GHz, 28 GHz, 37 GHz, 39 GHz, and 47 GHz); the exception was Sprint (now, T-Mobile), which had access to 2.5 GHz band spectrum via its historical spectrum holdings.[7]

The relatively late availability of mid-band spectrum in the US was not the result of a lack of recognition of the importance of mid-band spectrum for the full deployment of 5G in the country. Rather, it was due to the complexities of repurposing mid-band spectrum in the US that was already in heavy use for other purposes, including for satellite service used to deliver content to cable operators serving over 100 million American homes. South Korea, in contrast, has not extensively used the mid-band for fixed-satellite services (FSS) applications, and, in consequence, did not face the same complexities to repurpose the mid-band spectrum to 5G.[8]

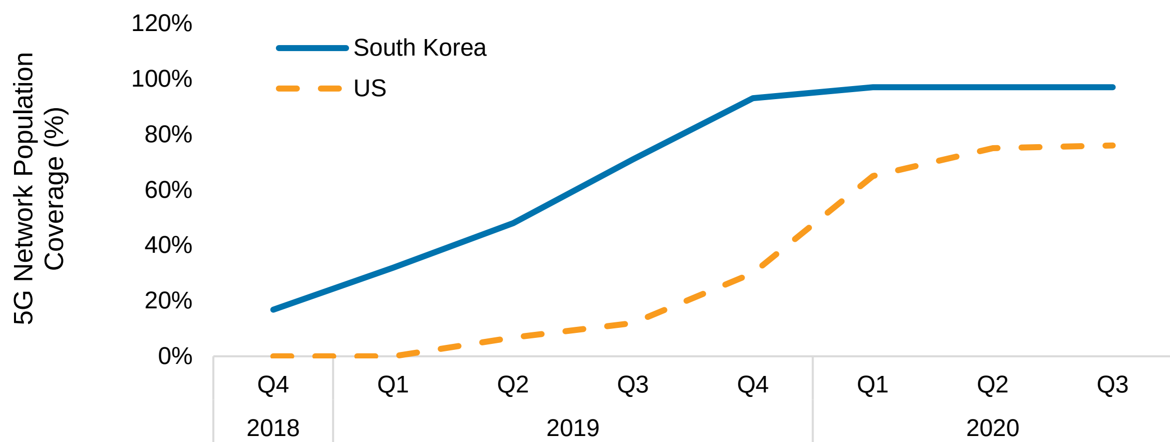
Delayed carrier access to mid-band spectrum increases reliance on either mmW or low-band spectrum for 5G deployment, or both. This has two types of effects. First, because deploying in mmW spectrum bands increases the costs of broad-based deployment, it tends to slow down the pace of deployment. Second, increased reliance on low-band spectrum bands can adversely affect the speed of service; a reduction in speed diminishes the customer experience, decreasing the contrast between 4G and 5G and, in turn, depressing adoption, all else equal.

US carriers have used the low-band spectrum (T-Mobile and AT&T) and mmW spectrum (Verizon, T-Mobile, and AT&T) that they obtained via Federal Communications Commission (FCC) 5G auctions in the last two years to begin deployment of 5G networks. Verizon reports that its 5G Ultra Wideband (mmW 5G) service is currently available in parts of dozens of major cities and will be available in more than 60 US cities by the end of 2020.[9] In addition, Verizon announced in October that its 5G service that is deployed primarily in low-band spectrum that it shares with its 4G service is available nationwide, covering more than 200 million people.[10] AT&T reported in July 2020 that its 5G network deployed using low-band spectrum is available to more than 200 million people in 395 markets in the US. In addition, AT&T offers 5G service in limited parts of 35 cities that uses mmW spectrum.[11] T-Mobile gained access to Sprint's 2.5 GHz band in April 2020 after its merger with Sprint and is now deploying 5G networks in low-band, mid-band, and mmW spectrum.[12] T-Mobile's 5G network currently covers more than 200 million people.[13]

Nevertheless, despite the deployment efforts of the US carriers, 15 months after the initial (simultaneous) launch of 5G service, the US lagged South Korea (and several other countries that launched after the US) in both 5G deployment by carriers and 5G adoption by customers. Figure 1 shows the differences in the 5G network population coverage between the US and South Korea between 2018 Q4 and 2020 Q3, (the most recent data available to us). Figure 1 shows that South

Korea started buildout of 5G networks earlier than the US, and even though the US ramped up build-out at the beginning of 2020, 5G network population coverage in South Korea was more than 20 percentage points higher than in the US as of Q3 2020.

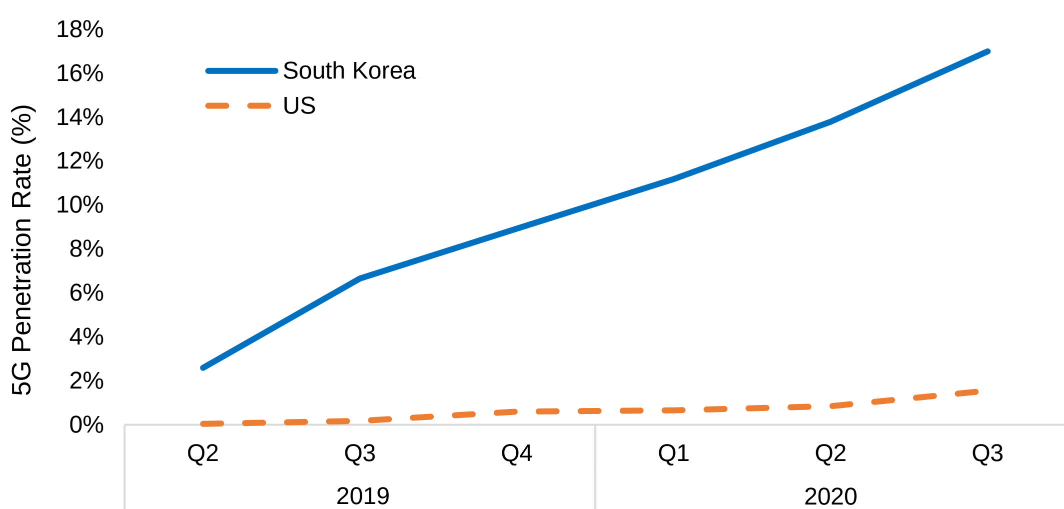
Figure 1: 5G Network Population Coverage: US and South Korea, 2018 Q4 – 2020 Q3



Source: GSMA Intelligence database

Figure 2 shows the differences in the 5G penetration rate between South Korea and the US between 2019 Q2 and 2020 Q3. The figure shows that the 5G penetration rate in South Korea has significantly exceeded the 5G penetration rate in the US throughout the period since 5G network service was launched.

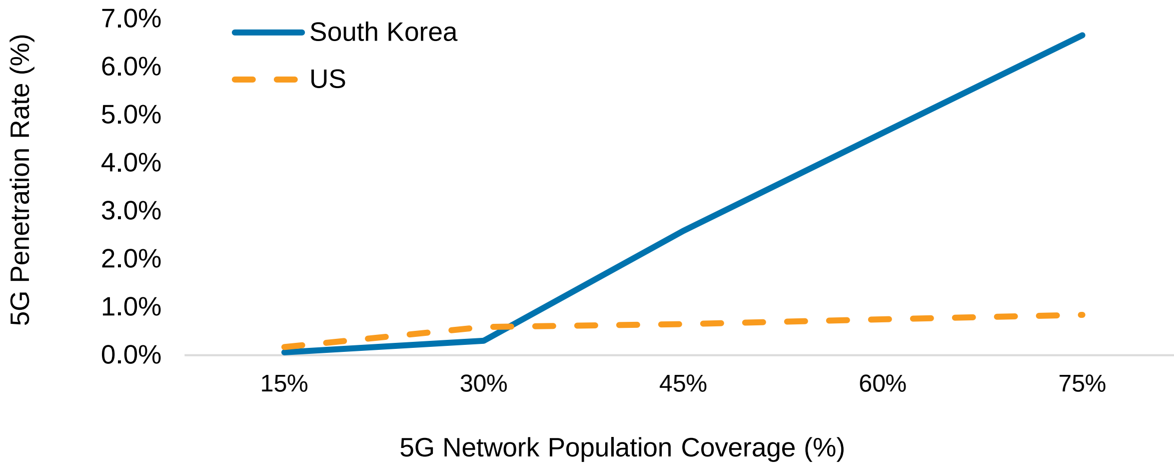
Figure 2: 5G Penetration Rate: US and South Korea, 2019 Q2 – 2020 Q3



Source: GSMA Intelligence database

Figure 3 reorganizes the data in Figures 1 and 2 to show the approximate 5G penetration rates in South Korea and the US at different levels of 5G network population coverage. The figure demonstrates that the difference in penetration rates between the two countries is not an artifact of the differences in the networks' population coverage alone, but rather appears to reflect differential responses of consumers to the available coverage. It suggests that the penetration difference between the countries reflects, at least in part, the differences in mid-band spectrum availability in the two countries and the associated differences in service speed and consumer experience.

Figure 3: 5G Penetration Rate in South Korea and the US at Different Levels of 5G Network Population Coverage



Note: The 5G penetration rate at 60% network population coverage rate was interpolated as the average of penetration rates at 45% and 75%.

Source: GSMA Intelligence database

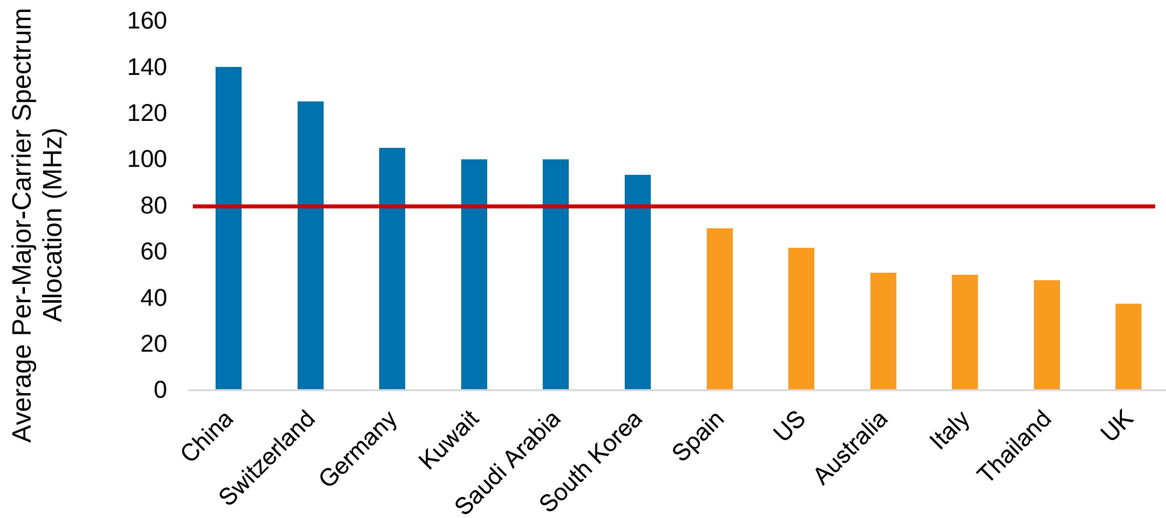
Of course, there are likely many factors that have affected the relative speeds of deployment and adoption of 5G in the US and South Korea other than the difference in mid-band spectrum availability. These include possible differences in handset availability, telecommunications equipment availability, relative costs of network deployment, and relative prices of 5G services between the two countries. However, none of these factors is entirely independent of the differences in spectrum availability. For example, handset manufacturers tend to focus efforts on devices that will function in the spectrum bands that are, or are expected to be in the near future, most widely deployed worldwide.[14] Outside of the US, 5G networks have been deployed almost entirely in mid-band spectrum, and handset manufacturers likely anticipated the deployment of mid-band spectrum for 5G in the US in the near future. As a result, handset manufacturers have understandably produced first a greater variety of handsets supporting mid-band spectrum bands than low-band or mmW spectrum.

Similarly, network equipment manufacturers would rationally invest first in development of equipment that would be in highest demand globally. For 5G technology, this would be networks configured for the mid-band.[15] In addition, the spectrum band in which the network is deployed affects the number and density of necessary base stations, which directly affects costs.[16] Finally, the prices carriers charge for service are affected by both the cost of providing service on the network and by the attractiveness to consumers of the service relative to services already available, both of which are affected, in turn, by the spectrum bands in which 5G is deployed. Hence, while we have no data with which to measure differences in prices and costs of service or handset and equipment availability in the two countries—a worthy research goal that we hope will be explored if data become available—the dependence of these factors on the spectrum bands available to carriers suggests that differences in mid-band spectrum availability are an important cause of significant differences in availability and adoption of 5G between the two countries.

Multiple-country comparisons also reveal an effect of mid-band spectrum on 5G adoption

When expanding this analysis to a broader set of countries, a similar picture emerges. Specifically, we looked at the relationship between the actual and projected 5G penetration rate and the availability of mid-band spectrum in 12 countries using data from the GSMA. Figure 4 shows the list of countries used in our analysis and the average amount of mid-band spectrum per major carrier that was released in spectrum auctions since 2018.

Figure 4: Average Per-Major-Carrier Mid-Band Spectrum Allocation by Country (in MHz)

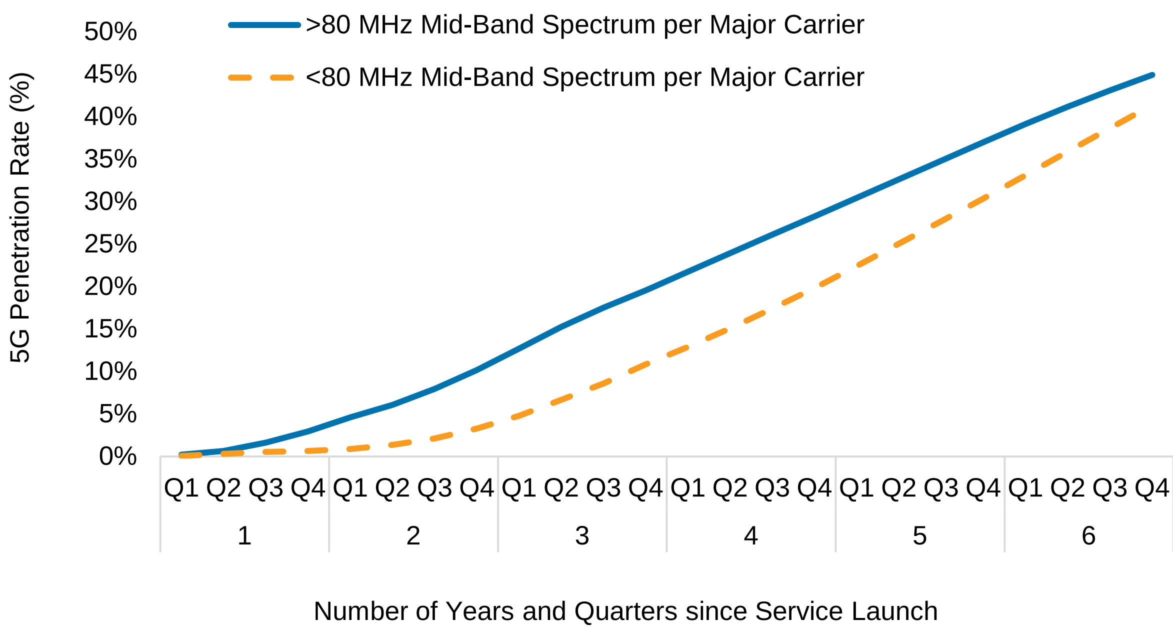


Source: Debra J. Aron, Andy Baziliauskas, and Olga Ukhaneva, "The Impact of Accelerated 3800 MHz Band Repurposing on the Canadian Economy," November 30, 2020

Figure 5 demonstrates that countries that, to date, have allocated on average more than 80 MHz of mid-band spectrum per major carrier have, and are projected to have, higher 5G penetration rates for at least the first six years after the launch of 5G mobile service in the country than countries that, to date, have allocated less than 80 MHz of mid-band spectrum per major carrier.

Figure 5 shows that the implications of mid-band spectrum availability from the case study of 5G penetration rates in South Korea and the US generally hold for a larger set of countries.

Figure 5: 5G Penetration Rate (Actual and Projected) by Average Spectrum Allocation to Major Carriers



Notes:

1. The penetration rate for countries with less than 80 MHz of spectrum was calculated by averaging the 5G penetration rates of Australia, Spain, the UK, Italy, Thailand, and the US. The penetration rate for countries with more than 80 MHz of spectrum was calculated by averaging the 5G penetration rates of Switzerland, China, Germany, South Korea, Kuwait, and Saudi Arabia.
2. The average penetration rates for the two groups of countries were calculated using the actual 5G penetration rates for the period from Q4 2018 through Q3 2020 and the projected 5G penetration rates for the period from Q4 2020 through Q4 2025. Projections of 5G penetration rates were made by the GSMA.

Source: GSMA Intelligence database

Lessons from the early adopters

Regulators and policymakers in countries that are allocating or are planning to allocate spectrum for 5G could learn from the early adopters of 5G technology about how the rate at which 5G technology becomes diffused in the country is affected by the amount and timeline of spectrum allocation. We are aware that in the US, the FCC has established a policy by which eligible space station operators that currently occupy mid-band spectrum (the 3700-4200 MHz band) will be provided financial incentives to vacate their spectrum sooner than the relocation deadline determined by the FCC.[17] We are also aware that Canadian regulators are currently determining how much mid-band spectrum should be allocated for flexible use, including 5G services, as well as the timeline of the spectrum allocation.[18] The analysis above indicates that in the “race” to 5G, availability of sufficient bandwidth of mid-band spectrum has a substantial and measurable effect on 5G deployment and penetration. These, in turn, drive the country’s GDP growth, supporting the premise that there are social benefits associated with the provision of incentives to be able to deploy 5G in the mid-band sooner rather than later.

Contacts

Debra J. Aron, PhD
Vice President
+1-312-577-4196
daron@crai.com

Andy Baziliauskas, PhD
Principal
+1-416-413-4072
abaziliauskas@crai.com

Olga Ukhaneva, PhD
Associate Principal
+1-312-377-2339
oukhaneva@crai.com

Chloe Sun
Associate
+1-312-619-3356
csun@crai.com

CRA Charles River Associates

References

1 Pau Castells et al., "5G and economic growth: An assessment of GDP impacts in Canada," GSMA Intelligence, November 2020, p. 30, at https://data.gsmaintelligence.com/research/research/research-2020/5g-and-economic-growth-an-assessment-of-gdp-impacts-in-canada; "Spectrum Considerations for 5G," CTIA, p. 10, at https://api.ctia.org/wp-content/uploads/2019/03/Spectrum-Considerations-for-5G.pdf; Stein Gudbjørgsrud, "Mid-band spectrum is important for 5G networks," Analysys Mason, June 25, 2020, p. 1, at https://www.analysysmason.com/research/content/comments/midband-5g-spectrum-rdts0/.

2 Pau Castells et al., "5G and economic growth," pp. 30-31, Figure 17; CTIA, "Spectrum Considerations for 5G," p. 10.

3 South Korea also allocated the 28 GHz spectrum band in June 2018, and each of the three major carriers obtained access to 800 MHz of this mmW spectrum. Iain Morris, "South Korea's 5G Auction Raises $3.3B," *Light Reading*, June 19, 2018, at https://www.lightreading.com/mobile/spectrum/south-koreas-5g-auction-raises-$33b/d/d-id/744066.

[4] The first mid-band spectrum auction in the US in the 3.5 GHz band was held in July 2020. See FCC, "FCC Starts First 5G Mid-Band Spectrum Auction Today," news release, July 23, 2020, at https://docs.fcc.gov/public/attachments/DOC-365702A1.pdf.

[5] "Auction of Priority Access Licenses for the 3550-3650 MHz Band. 271 Applicants Qualified to Bid in Auction 105," FCC, public notice, July 1, 2020, at https://docs.fcc.gov/public/attachments/DA-20-695A1.pdf; FCC, "FCC Concludes First 5G Mid-Band Spectrum Auction," news release, August 25, 2020, at https://docs.fcc.gov/public/attachments/DOC-366396A1.pdf.

[6] "Auction 107: 3.7 GHz Service," FCC, at https://www.fcc.gov/auction/107/factsheet.

[7] See our July *Insights*.

[8] "Frequency Allocations for the C-Band," Casbaa, Updated May 3, 2015, at http://www.casbaa.com/resources/regulatory/satellite-issues/korea/.

[9] "Explore 4G LTE and 5G network coverage in your area," Verizon Wireless, accessed December 1, 2020, at https://www.verizon.com/coverage-map/.

[10] "Verizon 5G Coverage – Maps, Cities, and More," Coverage Critic, accessed December 3, 2020, https://coveragecritic.com/verizon-5g-coverage-maps-cities-and-more/. Verizon uses 850 MHz spectrum for its nationwide 5G network in most locations and PCS and AWS spectrum in select locations. See Mike Dano, "Verizon: Nationwide 5G speeds will be 'similar' to 4G speeds," *Light Reading*, October 13, 2020, at https://www.lightreading.com/ossbss/verizon-nationwide-5g-speeds-will-be-similar-to-4g-speeds/d/d-id/764602.

[11] AT&T, "AT&T Continues to Build 5G on the Nation's Best Wireless Network," news release, July 23, 2020, at https://about.att.com/newsroom/2020/5g_announcements.html; Bevin Fletcher, "AT&T claims nationwide 5G with 40 new markets," *Fierce Wireless,* July 23, at https://www.fiercewireless.com/5g/at-t-claims-nationwide-5g-40-new-markets.

[12] T-Mobile, "That Was Fast! T-Mobile's Network Already Getting Bigger & Better with Sprint," news release, April 21, 2020, at https://www.t-mobile.com/news/tmobile-network-already-getting-bigger-better-with-sprint**.**

[13] Ibid.

[14] For example, according to Global mobile Suppliers Association (GSA), as of July 2020, only 23% of the commercially available devices are understood to support 5G services in mmW bands; 88.9% of the commercially available devices are known to support services in the sub-6 GHz spectrum. See "5G Ecosystem – July 2020 – Devices update," GSA, at https://gsacom.com/paper/5g-ecosystem-july-2020-devices-update/.

[15] Julber Osio and Erik Keith, "52 markets worldwide have commercial 5G services," S&P Global Market Intelligence, accessed December 3, 2020, at https://www.spglobal.com/marketintelligence/en/news-insights/research/52-markets-worldwide-have-commercial-5g-services.

[16] See our July *Insights*.

[17] Report and Order and Order of Proposed Modification, *In the Matter of Expanding Flexible Use of the 3.7 to 4.2 GHz Band*, Before the Federal Communications Commission, GN Docket No. 18-122, FCC 20-22 (Released: March 3, 2020), ¶¶ 155, 219, at https://docs.fcc.gov/public/attachments/FCC-20-22A1.pdf.

[18] "Consultation on the Technical and Policy Framework for the 3650-4200 MHz Band and Changes to the Frequency Allocation of the 3500-3650 MHz Band," Innovation, Science and Economic Development Canada, August 2020, pp. 35-40, at https://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11627.html.