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# The economics of 5G deployment in the "race" to 5G: The role of mid-band spectrum

## Background

Some policymakers, industry participants, and economists view the speed with which nations deploy and adopt 5G technology as a competition, or "race," in which success will have a significant impact on each nation's economic development in the coming decade. Indeed, there is substantial evidence that speed of deployment of new wireless technologies and the ability to outpace other countries does affect economic development. The effect of success in the technology race is of keen importance in the US.[1] After lagging behind other countries to roll out second generation (2G) and third generation (3G) wireless technologies, the US became a global leader in fourth generation (4G) technology.[2] One study estimated that US leadership in 4G resulted in nearly $100 billion increase in US annual GDP by 2016, a rise in wireless-economy-related jobs by 84% from 2011 to 2014, and more than $125 billion in revenue to US companies.[3] Other economic studies have also found that adoption of new wireless technologies translates into real economic benefits for a country, and that earlier adoption has generated greater benefits.[4]

The United States and South Korea were the first countries to launch fifth generation (5G) mobile networks, launching simultaneously on April 3, 2019.[5] Now, a year later, the US is lagging several countries in 5G network deployment, adoption, and performance. In this article we discuss one of the factors that have, so far, significantly impeded the deployment of 5G networks in the US—the lack of mid-band spectrum necessary for 5G deployment. Mid-band spectrum, considered the "key building block" for broad deployment of 5G, is currently unavailable to two of the three major US carriers. The lack of mid-band spectrum significantly impairs the ability of US carriers to deploy 5G networks and affects the quality of existing 5G networks in the US. Fifth generation wireless technology, currently nascent but at varying levels of deployment worldwide, is expected to provide massive capacity, speed, and latency improvements over 4G. Expected improvements from 5G technology include:

- the ability to support 100 times more traffic than 4G;
- a 20-fold increase in peak upload and download speeds; and
- the ability for devices to communicate in almost real time, with latency as low as one tenth that of 4G.[6]

Capacity improvements and real-time communications will enable augmented and virtual reality, 8K (ultra-high definition) video, new forms of social media,[7] as well as innovation in transportation, logistics, the Internet of Things (IoT), electricity distribution, public safety, health and wellness, robotics, and smart cities.[8] It is estimated that global sales across multiple industry sectors enabled by 5G may reach $13.2 trillion in 2035.[9]

Impaired rollout of 5G limits these benefits, however. The full potential of 5G is not expected to be realized until, among other factors, carriers are able to build out facilities in mid-band spectrum in addition to their existing spectrum holdings.

## The economics of efficient spectrum deployment in 5G

Economically efficient deployment of 5G nationwide requires a wide range of frequencies: low-band spectrum (frequencies below 1 GHz),[10] mid-band spectrum (frequencies between 1 and 6 GHz)[11], and high-band spectrum, also known as millimeter wave (mmW) spectrum (frequencies above 24 GHz).[12]

The cost, propagation characteristics, and efficiency of wireless technologies in any given geographic location depends on the spectrum frequency in which it is deployed. Generally, lower frequencies, having longer wavelengths, tend to travel farther without attenuation and tend to perform better at penetrating obstacles such as walls, glass, and trees.[13] Higher frequencies, having shorter wave lengths, do not travel long distances well. These physical properties, combined with the fact that spectrum is an economically scarce resource, create comparative economic advantages for deployment in different frequency bands in different geographic areas. In densely populated areas it is necessary to reuse spectrum in smaller, non-interfering geographic divisions to meet demand. This creates an advantage for high frequency spectrum when the objective is to reuse spectrum with a dense architecture of cell sites while limiting interference from one to another. In contrast, it tends to be inefficient as an economic matter to deploy wireless technology in sparsely populated areas on high-frequency spectrum, because doing so would require unnecessarily dense placement of cell sites to cover the area, driving up costs. Every additional cell site imposes a fixed cost of deploying towers, base stations, and equipment.

The general relationship between the physical properties of spectrum and their comparative economic advantages in different geographies apply to 5G technology as well. While mmW spectrum is very effective for high-speed and high-capacity applications, the economics of deploying 5G in mmW spectrum are not favorable relative to mid-band spectrum for mobile applications in any but the most densely populated areas, such as central metro areas, transportation centers (e.g., airports), and event locations (e.g., stadiums).[14]

Low-band spectrum is considered necessary to provide 5G coverage in suburban and rural areas economically. Low-band spectrum can also be used for 5G deployment in urban areas, but it does not offer the same high speeds that can be achieved with 5G deployment in mid-band and mmW spectrum. There are two reasons. First, the speeds available in 5G depend on the width of the available spectrum, and available bandwidths in low-band spectrum are relatively narrow.[15] Second, Massive MIMO technology, a key component of the 5G radio access network (RAN) that increases its speed and efficiency, is not currently feasible in low-band spectrum. Massive MIMO is a technology that permits a large number of antennas, each with a focused geographic target, to be deployed at a single tower site. Massive MIMO is not currently available for low frequency spectrum because the long wavelengths of low-band spectrum require antennas that are too large to fit into Massive MIMO arrays.[16]

For the geographic areas where large portions of the US population live and work, the physical properties of mid-band spectrum provide for good coverage and high capacity, making it the most suitable spectrum band for ubiquitous and robust economic deployment of 5G in urban and suburban areas.[17]

## The US is behind other countries in allocation of mid-band spectrum for 5G

Many countries, including Australia, China, Japan, Kuwait, Saudi Arabia, South Korea, Spain, Switzerland, and the UK, have allocated mid-band spectrum for 5G deployment.[18] Of these countries, China, Saudi Arabia, and Switzerland have also allocated low-band spectrum for 5G deployment.[19] Only Japan and South Korea have allocated mmW spectrum for 5G deployment.[20] The US, in contrast, prioritized allocating mmW and low-band spectrum for 5G, but mid-band spectrum has not yet been allocated.

All three major US carriers, AT&T, T-Mobile, and Verizon, hold spectrum in the 700 MHz and 600 MHz bands (low bands) auctioned by the Federal Communications Commission (FCC) in 2008 and 2017, respectively. They also acquired mmW spectrum in the 24 GHz and 28 GHz bands auctioned by the FCC in 2019.[21] Sprint (now operating as T-Mobile since their merger in April 2020)[22] owns spectrum in the 2.5 GHz band, which is considered mid-band. Indeed, the fact that Sprint owned this spectrum, while T-Mobile owned high- and low-band spectrum, was one of the synergies the parties touted to regulators as a public interest benefit of the merger as it would provide the US with at least one company with the spectrum assets needed to deploy 5G ubiquitously.[23]

Recognizing the necessity of allocating mid-band spectrum for 5G use, the FCC has ordered that mid-band spectrum currently used by satellite companies, government, and the military be vacated or shared by those users so that it can be redeployed for 5G use.[24] The redeployment of spectrum is a complex process, however, which has delayed the auction process. The first mid-band spectrum auction of the 3.5 GHz band is scheduled to take place in July 2020. The FCC is also planning to auction mid-band spectrum in the 3.7–4.2 GHz band in the latter part of 2020.[25]

In the meantime, US carriers have used their available low-band spectrum (T-Mobile and AT&T) and mmW (Verizon, T-Mobile, and AT&T) to begin to deploy 5G networks. Indeed, AT&T reported in June 2020 that its 5G network is available to 179 million people in 355 markets in the US.[26] Verizon reports that its 5G network is currently available in parts of 35 cities.[27] Both of these carriers, however, have publicly commented on the importance of obtaining mid-band spectrum for nationwide 5G deployment.[28] T-Mobile's 5G network that uses low-band spectrum as its foundation currently covers more than 200 million people.[29] 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 all three spectrum bands.[30] The US is the only country at the time of this writing to launch commercial 5G networks in mmW spectrum.[31] As of July 1, 2020, all three major carriers, AT&T, T-Mobile, and Verizon, have been qualified to participate in the FCC's auction of the 3.5 GHz mid-band spectrum.[32]

## 5G mobile networks in the US lag other countries in network deployment and performance

While US carriers have been rolling out 5G using the spectrum they have, the lack of mid-band spectrum available for 5G deployment in the US, along with other factors affecting 5G rollout and network capabilities in the US, is reflected in the moderate performance, availability, and adoption of 5G networks offered by US carriers compared to other nations.

Opensignal, a market research firm, measured the performance of 5G mobile networks in countries that are considered to be the leaders in 5G—Australia, Kuwait, Saudi Arabia, South Korea, Spain, Switzerland, the UK, and the US—during January 22-April 21, 2020.[33] Outside the US, all of these countries have deployed 5G in mid-band spectrum.[34] Performance was measured by network download speed and network availability (the geographic extent to which the carrier has built out its network). Network availability was measured as the percent of time that the tested phones spent connected to the relevant carrier's 5G service rather than defaulting to the carrier's 4G (or lower) network.

Opensignal found that the performance of US 5G networks by these metrics is, at best, average. Of the eight countries, US 5G networks had the slowest average download speed, clocking in at less than half of the second lowest country-level average download speed (the UK), and less than one fifth of the highest country-level average download speed (Saudi Arabia). As measured by availability of 5G networks, the US ranks in the middle, with 12.7% of time connected to the 5G network. The countries that lead the US according to Opensignal's availability metric include Kuwait (34.9%), Saudi Arabia (30.8%), and South Korea (14.2%).[35]

The extent of deployment and adoption of 5G networks offered by US carriers compared to other nations has also suffered. Some argue that the US, China, and South Korea are the three emerging 5G leaders,[36] but the US lags both South Korea and China in 5G deployment and adoption, according to available data. Table 1 summarizes the launch dates of 5G mobile networks in North America, South Korea, and China and the number of deployed 5G base stations, the number of 5G subscriptions, and 5G penetration rates (defined as the percent of 5G connections from the total wireless connections). As Table 1 shows, carriers in North America have deployed far fewer 5G base stations than either China or South Korea, and North America also has far fewer 5G subscribers measured in absolute numbers and as a wireless penetration rate.

**Table 1: Comparison of 5G deployment and adoption in North America, South Korea, and China**

| | North America | South Korea | China |
|---|---|---|---|
| 5G Commercial Launch | April 2019 | April 2019 | November 2019 |
| Number of Deployed Base Stations | 10,000[4] | 85,000[3] | 198,000[1] |
| Number of 5G Subscriptions | 587,000[5] | 5,770,000[2] | 36,000,000[1] |
| 5G Penetration Rate | 0.1%[5,6] | 9.67%[2] | 2.27%[1,7] |

**Notes:**

The Chinese Ministry of Industry and Information Technology reported that China had 50 million 5G subscribers nationwide at the end of March 2020, whereas *RCR Wireless News* reported that China had over 36 million 5G subscribers as of June 2020. Our calculation of the 5G penetration rate for China uses the more conservative estimate of the number of 5G subscribers. We use the number of 5G subscribers as a proxy for 5G connections.

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7. According to GSMA, the number of total mobile connections in China in Q2 2019 was approximately 1,583 million. Based on data from the database "GSMA Intelligence," at https://www.gsmaintelligence.com/data/.

US carriers have been competing with the rest of the world at a disadvantage, delaying not only 5G network deployment but also affecting customers' 5G experience. If customers do not experience a significant improvement from 5G over 4G in the US, it will be hard to convince consumers to pay extra to subscribe to 5G service and upgrade to 5G handsets. Consumer reticence to embrace 5G technology will, in turn, further impede the US in the "race" to 5G.

The lack of mid-band spectrum is not the only factor that has slowed deployment and adoption of 5G in the US. Public policy decisions related to availability of advanced 5G RAN equipment, especially Massive MIMO technology, have also delayed 5G deployment by US carriers as compared to other countries. We will discuss the availability of Massive MIMO and other RAN equipment in the US and the related policy environment in a forthcoming article.

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