The 5G Landscape, Part 2: Spectrum and Devices

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5G

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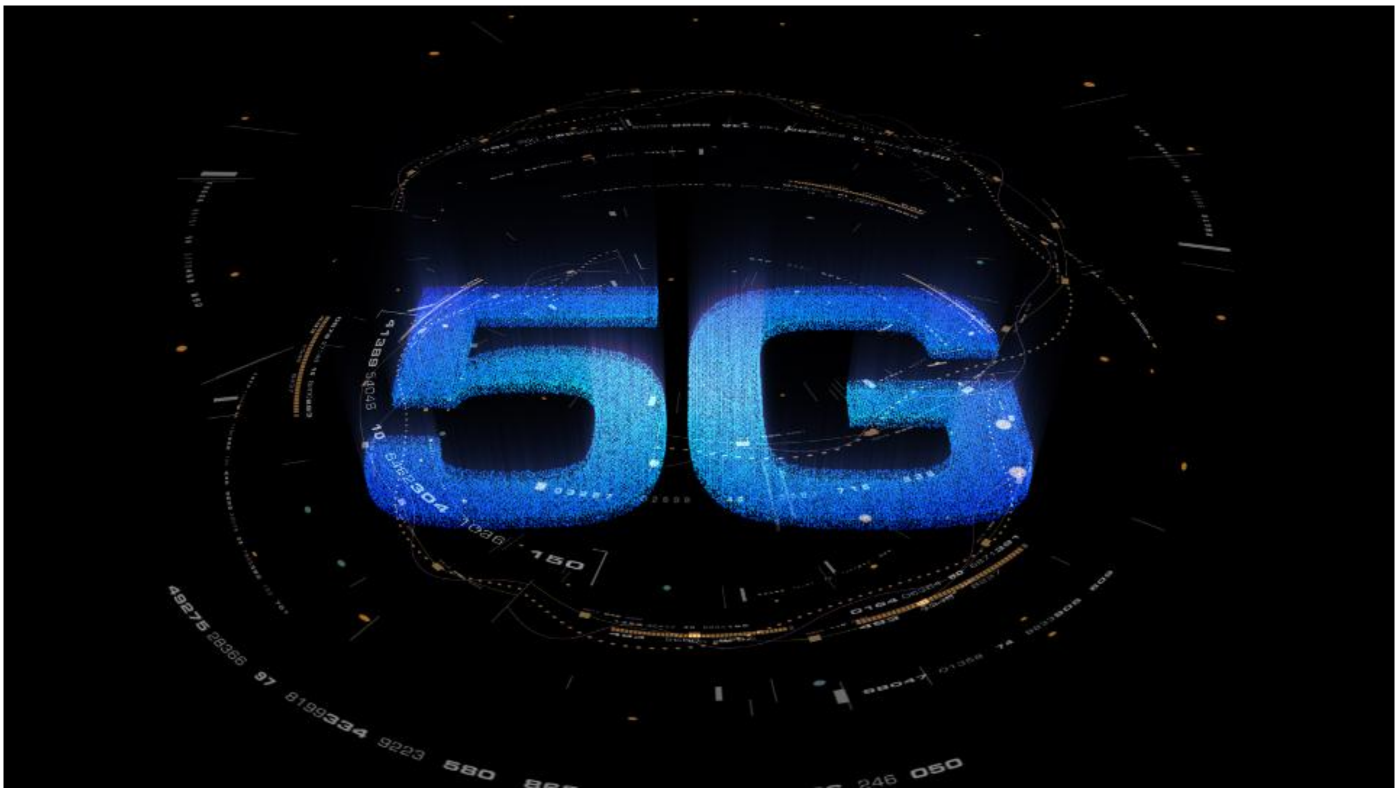

Futuristic holographic 5G icon digital wireless high speed fifth innovative generation for cellular ... [+]

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As mentioned in Part 1 of this 5G Landscape discussion (see previous column), the topic of spectrum—the radio frequencies that are used to transmit and receive signals that form the heart of modern wireless networks—is a crucial but very confusing part of the overall 5G story.

Different chunks of radio spectrum are like the lanes of traffic that allow multiple telecom carriers to operate simultaneously.

To understand spectrum, it's important to start with the basics. The two main types of spectrum are referred to as licensed (meaning it can only be used by the company that owns the license to those particular frequencies) and unlicensed (such as the 2.4 and 5 GHz frequencies used for WiFi, which any company can use).

Control over the spectrum and who can use what frequencies is so critical to modern communications that it is regulated by government agencies all over the world. In order to avoid complete wireless chaos, government organizations (the Federal Communications Commission, or FCC, in the case of the US) essentially take ownership of the entire radio frequency spectrum and then split wireless frequencies into different chunks. Fun fact: each country reuses the same frequencies and does its own splits because radio signals typically don't travel far enough to cross country borders. Those chunks of radio spectrum are then assigned or sold to different companies or different industries. For example, some frequencies are reserved for defense purposes, others for medical devices, some for transmitting radio and TV signals, and some, of course, for handling cellular network data transmissions. If this spectrum assignment wasn't done, virtually no wireless devices or services could exist, because all the signals would interfere with each other and prevent anything from working on a consistent, reliable basis.

> **"In additon to be incredibly important, the topic of radio spectrum can be incredibly confusing for several different reasons."**

In addition to being incredibly important, radio frequency spectrum can be an incredibly complex topic, often made even more confusing by the fact that some frequencies have names and/or band numbers associated with them for certain purposes. For example, the 3.5 GHz frequency band that many countries around the world are starting to use for 5G is part of a new range of services called CBRS (Citizen's Broadband Radio Service) here in the US, which is expected to be used for private LTE (Long-Term Evolution—a key technology used for 4G mobile networks) networks in what essentially amounts to a semi-licensed way. (Expect to read more on CBRS in future columns.)

To really start to understand 5G, you have to know at least a few basics about spectrum, because many important new capabilities and services that are at the heart of 5G are based around spectrum. For example, the phrases millimeter wave (often shortened to mmWave) and sub-6 are commonly used when talking about 5G. Both of those names are based on the frequency bands they use within the overall radio spectrum. In order for devices to properly communicate on those frequencies, a radio access standard called 5G NR (short for New Radio) was developed to serve as the means through which those communications can occur.

Millimeter wave frequencies (so named because the wavelength of the signal can be measured in millimeters) start at around 24 GHz and go up to 39 GHz and beyond. As the result of the physical characteristics of the waves generated at these frequencies, millimeter wave signals can't travel far, but they're very dense, making them well suited to carry a lot of data very quickly. On a practical level, that means the very fast data transfer speeds you may have heard associated with 5G networks and devices (well over 1.5 Gbps, or gigabits per second in real-world tests now and up to 10 Gbps in theory) are all done using phones and network equipment that support millimeter wave. Note, however, that not all millimeter wave is the same, and just because devices or carrier networks say they have millimeter wave support doesn't mean they can all work together—but that'll be a topic for a future column.

In the case of sub-6, the name refers to radio frequencies that are below 6 GHz, hence sub, or less than, 6. In the case of cellular networks and 5G, sub-6 spectrum goes all the way down to 600 MHz, or 0.6 GHz. As with millimeter wave, there are many types of sub-6 spectrum, and they are not at all equal. In fact, there's enough of a range of sub-6 frequencies that some people have started referring to a portion of the middle frequencies—such as the aforementioned 3.5 GHz—as midband. (Interestingly, these mid-band frequency wavelengths can be measured in centimeters, but instead of being consistent and calling them centimeter wave, the telco industry showed its annoying knack for confusing terminology and has stuck with sub-6 and/or midband.)

Once again, the physical characteristics of the sub-6 spectrum waveforms determine how they perform in real-world networks. Specifically, they can travel farther, but they're less dense. In real-world terms that means coverage with sub-6 spectrum is much broader from a given cell tower than millimeter wave, but the data transfer speeds are much slower. The midband frequencies are interesting to a lot of carriers—and the first to be deployed for 5G in most other countries outside the US—because, as you might surmise, they offer a reasonable compromise of reasonably fast performance and broad coverage.

> **"One way to think about the potential difference between millimeter wave and sub-6 spectrum is to compare it to audio frequencies."**

One way to think about the potential difference between millimeter wave and sub-6 spectrum is to compare it to audio frequencies. If you've ever heard a concert or other music source from afar, you can typically only hear the lower bass frequencies because waveforms at lower frequencies, such as sub-6, can travel farther, whereas the higher treble frequencies, such as millimeter wave, can only be heard when you're in plain sight of, or very near the sound source.

For both governments and carriers, spectrum is also an incredibly valuable asset. Companies spend, and subsequently governments are now earning, billions of dollars to get access to particular sets of frequencies. For example, it's common to hear about auctions for potential 5G spectrum where carriers will bid enormous amounts of money to get access to the frequencies they want to help build out overall coverage maps and performance capabilities.

A few other important things to understand about spectrum are that buying it is only the first step. You still need to purchase the appropriate network infrastructure equipment, tuned to transmit and receive at the correct frequencies, and install it before you can launch a 5G (or any other "G") service. Some companies have been known to buy and hold certain spectrum assets for potential use at a later date, or even for potential resale. Also, some frequencies end up being re-used or reassigned over time (sometimes called "re-farmed"), because the original intent or usage is no longer needed or isn't large enough to justify keeping the frequency from other uses. (This is what happened with the 3.5 GHz frequencies now being used in the US for CBRS—they used to be restricted to military applications.) As you can imagine, these last two points can lead to some highly charged discussions between industry and government or between different companies. So, whenever you may hear about the politics of 5G, it almost certainly has to do with spectrum-related issues.

The last piece of the 5G landscape is the devices that connect to the cellular networks. In addition to the obvious smartphone players that create the devices we all know and love, such as Samsung, Apple, Google, etc., several companies are starting to offer 5G-capable devices that are often called small cells or cellular access points. These devices are designed to compete with the wired broadband routers/access points from cable companies and telecom carriers to bring internet access into your home or business. Instead of using a wired connection, they're using a wireless cellular connection—in many instances a form of millimeter wave 5G—to make the high-speed link, and then sharing access via WiFi as with existing wired broadband routers.

Within both smartphones and wireless routers, it's also important to understand some of the key semiconductor components that go into making a 5G connection. Most notably, the modem (short for modulator, demodulator) is a critical cog in the 5G puzzle, as it's the piece that takes the digital data and instructions from inside your device and converts them into a complex analog radio frequency signal that's transmitted from your device. In addition, it's the component that takes the incoming RF signals and then converts them back into digital form so that your router can pass the data along or your device can use the data it's requested. The biggest player in modems, particularly for 5G, is Qualcomm, thanks in part to its many years of working to help create and develop telecom industry standards. In addition, companies like MediaTek have announced 5G modems, particularly for lower-end Android phones, and phone makers Samsung and Huawei also make their own 5G modems.

While modems get all the glory, they are not the only important component of a 5G-enabled device, however. In fact, the cellular communications capability of all devices depends on a system of components that work together. In addition to the modem, other critical elements are the antennas and what's called the RF (radio frequency) (radio frequency) front end, or RFFE, which itself is made up of several different sub-pieces, including filters, power amplifiers and more. While it may sound like digging into technical minutiae, it turns out the RF front end elements such as filters are critically important, because they determine if a given device can work with a specific frequency. As previously mentioned, not all millimeter wave nor all sub-6 frequencies are the same. As with many things in life, the devil is in the details, and the practical relevance is that without the right front-end sub-components, some 5G-capable devices might not be able to function (or function as well as they theoretically should be able to) on certain networks. This is why some early 5G phones, like the Samsung S10 5G, don't work in certain frequencies on different networks. For example, some of the first 5G smartphones available in the US don't support the specific sub-6 frequencies that AT&T has announced for its network and their other similar challenges with other networks. Over time those types of issues will likely disappear, but in these early days of 5G, it's still something you need to know.

Of course, there's much more to the overall 5G landscape than what's been laid out here—particularly the critical importance of worldwide standards set by organizations like the 3GPP—but hopefully this set of articles has provided you with basic groundwork for understanding what 5G is, what's required to make it work, and where it's headed.

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