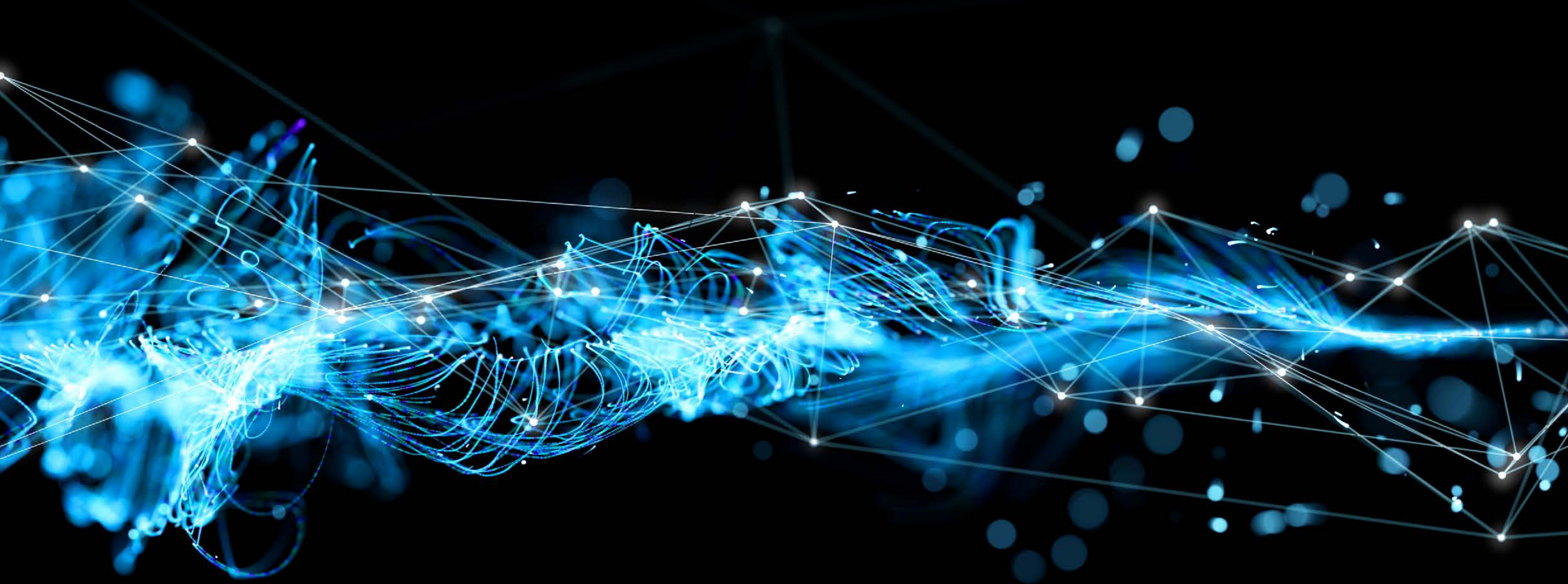
Understanding spectrum:

the cornerstone of a 5G experience

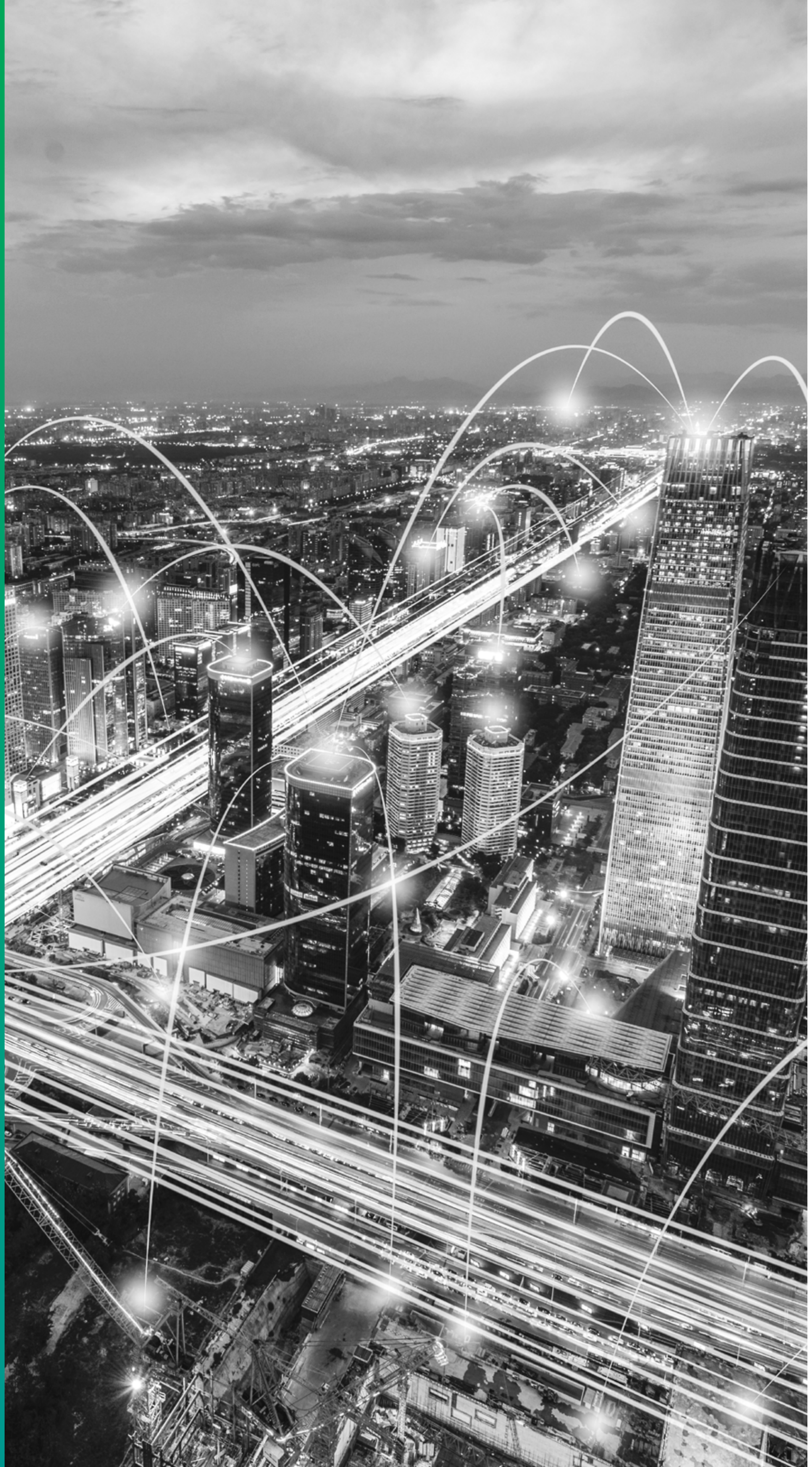
RootMetrics®
By IHS Markit



While ads on TV might make “5G” seem like a well-defined and easy-to-understand next step in mobile performance, the truth is that 5G is not a one-size-fits-all technology. There are multiple flavors of 5G, and one operator’s definition or implementation of “5G” can differ greatly from that of another.

Because of this complexity, 5G launches can often lead to confusion: confusion about what the different mobile operators are offering, where 5G is available, and what users can expect from different operators, among other things. Different implementations of 5G can lead to vastly different experiences for end users, and each operator’s 5G strategy differs.

The key to understanding 5G is understanding spectrum—the different types, the advantages of each, which operators have what spectrum holdings, and how those spectrum types can work together to deliver an optimal 5G experience.



What is spectrum?

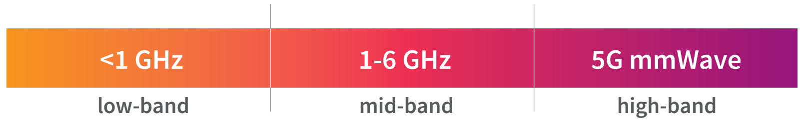
Spectrum is the range of electromagnetic radio frequencies used to transmit sound and data through the air. When consumers use their cell phones, their devices are not transmitting haphazardly over the entire spectrum of radio communications. Rather, they are connected over specific frequency bands. These bands are like invisible channels or pipes through which information is delivered. Generally speaking, the bigger the pipe, the greater the capacity and the more information that can be carried.

Sub-6 GHz and mmWave: the two main categories of spectrum

Spectrum for radio communication can be divided into frequencies above and below 6 GHz. While not technically accurate, in the context of 5G, spectrum above 6 GHz is considered millimeter wave (mmWave), and everything at 6 GHz or below is referred to as “sub-6 GHz” spectrum. For 5G deployments, 6 GHz is the tipping point, with potentially wildly different end-user experiences at higher frequencies compared to lower frequencies, because signal propagation can vary depending on the frequency. Propagation is a measure of how far a signal can travel and how well it can penetrate solid objects at a given frequency, with lower frequencies able to travel farther and penetrate solids better than higher frequencies.

Mid-band, low-band, and high-band: another way to look at spectrum

While it is easy and practical to divide spectrum into the categories of above and below 6 GHz, there is another way to look at it that provides more insight into the nuances of spectrum: low-band, mid-band, and high-band.



Advantages of each spectrum type

When it comes to spectrum, there are two key considerations to keep in mind: speed performance and geographical coverage. While mmWave is capable of delivering super-fast speeds much faster than those that sub-6 GHz can support, sub-6 GHz signals are able to travel farther than mmWave, cover a greater geographical region, and provide deeper penetration within buildings. Given these coverage and performance implications for different types of spectrum, mobile operators must manage a delicate tradeoff that becomes a question of offering potentially slower speeds but broader coverage with sub-6 GHz spectrum or providing faster speeds but smaller coverage areas with mmWave spectrum.

Let's take a look at the different types of spectrum and how they can be deployed for different use cases

Low-band

Under 1 GHz: This spectrum band travels far and deep. It can reach rural areas and other underserved communities, and low-band spectrum can provide 5G internet for both cellular and home broadband where fiber installations are generally cost-prohibitive. With deeper penetration indoors, low-band spectrum can provide 5G in parking garages and other places where connectivity can be a struggle. Low-band spectrum will also help the growth of IoT implementations, which will require extensive, far-reaching connectivity at both indoor and outdoor locations. How? In short, 5G is expected to be the only technology that can support the myriad connected "things" across the vast IoT ecosystem, and the broad coverage and deep penetration capabilities of low-band spectrum should prove vital for the growth of the IoT.

Mid-band

1 GHz – 6 GHz: This part of the spectrum is considered the sweet spot for 5G. Mid-band spectrum provides additional capacity in areas with heavy congestion such as event venues, busy city centers, and other areas where finding strong mobile service can be a challenge. That said, even amidst such congestion, mid-band spectrum can provide stable, consistent connectivity and fast speeds (though not as fast as mmWave).

High-band/mmWave

6 GHz+: High-band spectrum technically starts at 24 GHz, but for ease of explanation, we categorize mmWave as greater than 6 GHz in the context of 5G. Generally speaking, mmWave creates hot spots of 5G connectivity that, while easily obstructed by architecture and other physical objects, can provide much faster speeds than sub-6 GHz spectrum. In fact, mmWave technology offers the potential to deliver lightning-fast speeds theoretically as fast as 5.0 Gbps or better and can provide broadband connectivity to busy office buildings and other densely populated areas of cities much more easily (and cost effectively) than wired broadband. Additionally, even though mmWave signals can be obstructed relatively easily and don't travel more than about one city block, mmWave will provide fast speeds in areas of high congestions such as sections of busy city centers, stadiums, and concert venues. In addition to offering blazing-fast connectivity, mmWave will ultimately be able to support the ultra-low latency (potentially below 1 millisecond) necessary for connected cars, remote real-time healthcare procedures, and other technologies that will reshape our world.

Our recent 5G testing has shown that mmWave is indeed fast. For example, during our 5G First Look testing in Chicago in the summer of 2019, Verizon registered a 5G maximum download speed of 1.1 Gbps with its mmWave spectrum. That's the fastest 5G maximum download speed we've recorded across our worldwide 5G testing to date. Verizon's 5G availability and geographic coverage in Chicago, were, however, relatively limited. That said, this smaller coverage area is not surprising, given the propagation characteristics of mmWave spectrum. Further, Verizon has never intended for mmWave to cover an entire city or metro area.

A look at spectrum usage both today and in the future

Most 5G deployments outside of the US use mid-band spectrum, and 5G coverage is fairly consistent between operators. Mobile operators in the US, on the other hand, face a choice between implementing high-band (mmWave) or low-band spectrum, which is in the lower region of sub-6 GHz spectrum. Because cell phones cannot yet switch between mmWave and sub-6 GHz spectrum, US mobile operators must use one or the other, but not both.

The ability for a mobile phone to switch between low- and high-band spectrum (instead of choosing one or the other) will come with the release of smartphone modems that are compatible with different types of spectrum. Not only does choosing between the two wildly different spectrum types limit the 5G rollouts of each operator to a single strategy, it also introduces a misleading conversation of which strategy is "better."

Dynamic Spectrum Sharing (DSS) technology, expected in late 2020, will also play a key role in advancing 5G. DSS will allow operators to expand 5G coverage by using existing 4G spectrum and dynamically switching it to 5G service. Once smartphones can take advantage of different types of spectrum and 5G coverage is expanded with DSS (and via the acquisition of more spectrum in general), we could see a turning point for 5G in which mobile operators can take advantage of all spectrum assets and eliminate the argument of which type of spectrum is "better."

In the UK, where most 5G deployments are using mid-band spectrum, the forced choice between low-band and high-band is a non-issue, and 5G deployments have gone much more smoothly. That said, the UK will certainly also benefit from the release of DSS technology as more spectrum assets are auctioned in the near future, freeing up the use of a diverse range of low- and high-band spectrum for all operators.

Mid-band spectrum is often considered the most desirable of the spectrum divisions because it carries some benefits of both low-band and high-band. However, this spectrum is currently reserved for the US military, public safety, and emergency response agencies. While technically part of the "sub-6 GHz" category, mid-band is much more effective than other types of spectrum at providing the sweet spot of a 5G experience: broad coverage plus fast speeds.

The ultimate goal for US operators is to combine all bands, which will likely happen after the C-Band Alliance spectrum auction in 2022. Sprint is currently the only operator in the US that owns mid-band spectrum, though that will transfer to T-Mobile if the pending merger between the two operators comes to fruition.

Eventually, every operator in the US will have holdings within each spectrum range, which will provide an optimal blend of comprehensive coverage and speed, delivering outstanding mobile service to people in rural, suburban, and urban areas, as well as serving as the backbone of our connected communities and the IoT. The combination of DSS technology in 2020 plus the release of C-Band spectrum in 2022 will enable each US operator to have adequate holdings in (and take full advantage of) low-, mid-, and high-band spectrum to allow for an optimal 5G experience.

In the UK, telecommunications regulator Ofcom will release additional spectrum for 5G allocations at an auction in the spring of 2020. The offerings will include both low- and mid-band spectrum, with all four major UK operators agreeing to support the expansion of 5G into more rural areas of the UK. Ofcom has suggested they will release mmWave spectrum for 5G by the end of 2020.

Spectrum currently in use in the US and UK

While operators in the US and UK *own* spectrum across a variety of bandwidths, they are not all necessarily *active*. The following table shows what spectrum is actively deployed for each operator in the US and the UK for both 4G and 5G.

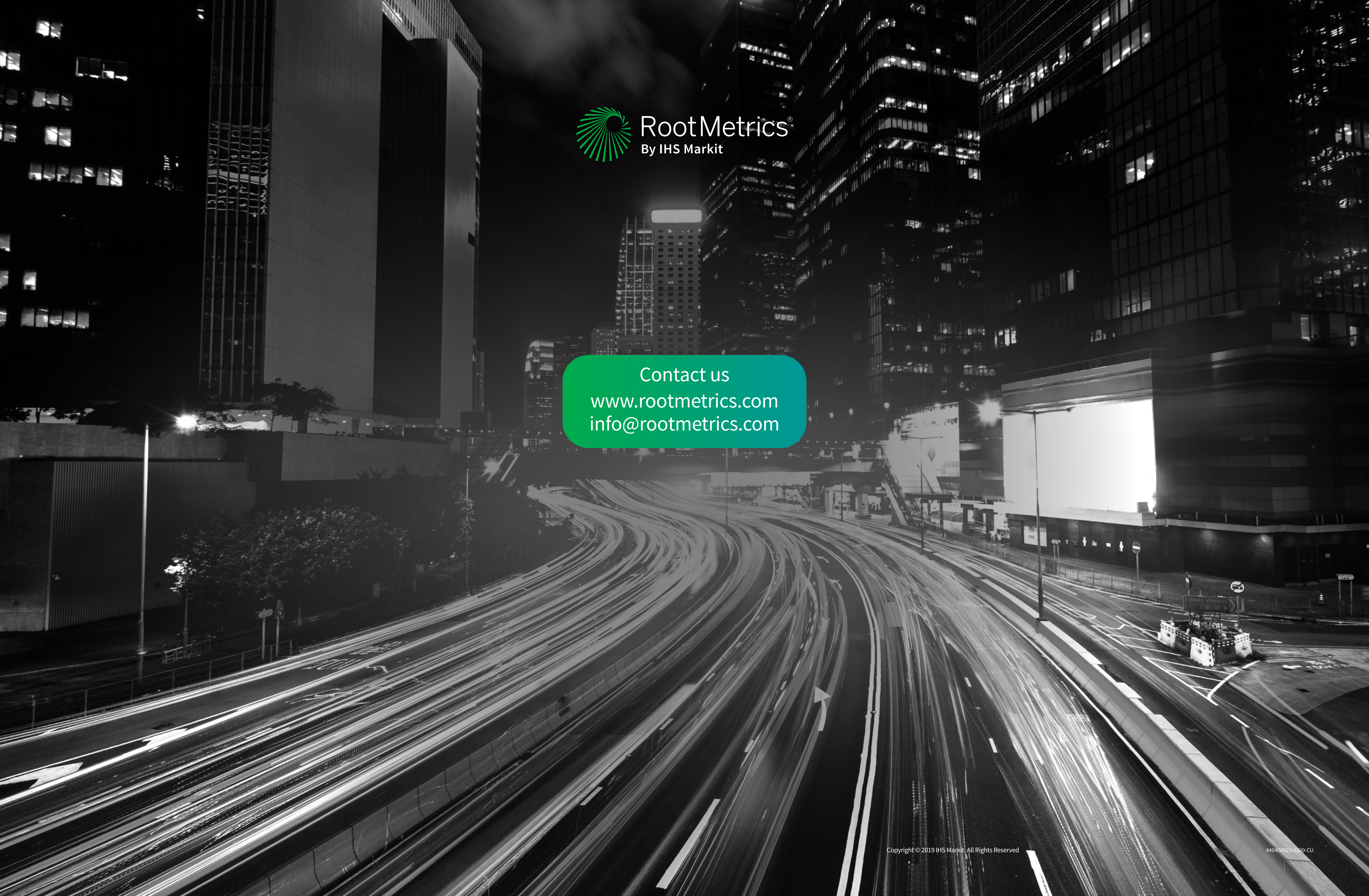
United States			
Operator	**Low-band**	**Mid-band**	**High-band/mmWave**
AT&T	**5G** 850 MHz 4G 700 MHz	4G 1.9 GHz, 2.1 GHz, 2.3 GHz	**5G** 39 GHz
Sprint	4G 800 MHz	**5G** 2.5 GHz 4G 1.9 GHz, 2.5 GHz	
T-Mobile	**5G** 600 MHz 4G 700 MHz	4G 1.9 GHz, 2.1 GHz	**5G** 28 GHz
Verizon	4G 700 MHz, 850 MHz	4G 1.9 GHz, 2.1 GHz	**5G** 28 GHz
United Kingdom			
Operator	**Low-band**	**Mid-band**	**High-band/mmWave**
EE	4G 800 MHz	**5G** 3.5 GHz 4G 1.8 GHz, 2.1 GHz, 2.6 GHz	
O2	4G 800 MHz, 900 MHz	**5G** 3.5 GHz 4G 1.8 GHz, 2.1 GHz, 2.3 GHz	
Three	4G 800 MHz	**5G** 3.5 GHz 4G 1.8 GHz, 2.1 GHz	
Vodafone	4G 800 MHz	**5G** 3.5 GHz 4G 1.8 GHz, 2.1 GHz, 2.6 GHz	

Putting it all together

As you can see, 5G is more complicated than it seems. Comparing 5G means more than just comparing speeds. A full view requires looking beneath the simple 5G acronym to understand which type of spectrum is being used and why. Building a comprehensive 5G strategy involves balancing the needs of delivering performance across highly congested urban areas while also providing coverage in both rural areas and urban environments where architecture and topography can present challenges to signals.

The release of DSS technology and major spectrum auctions should simplify things in the coming years in both the US and UK. The best 5G networks will achieve a balance between spectrum types with an implementation that highlights the best facets of each spectrum asset. The sooner that happens, the better, because only then can we begin to take advantage of a true 5G experience marked by high speeds, low latency, and seamless connectivity.

Correction: *On June 16, 2020, we made a correction on page 4 to clarify the benefits of DSS.*



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