Spectrum portfolios in a 5G world
Rethinking the value of spectrum

A report by the Center for Technology, Media & Telecommunications
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Introduction

What is spectrum really worth?

Ensuring that a spectrum portfolio is properly valued matters in three ways. It lets wireless providers better manage their spectrum assets, lower their operational and capital costs, and attract investors. The financial community can make better-informed investment and financing decisions. And policymakers can make more effective judgments on critical matters such as spectrum auctions and sharing mechanisms. With 5G on the horizon, getting it right has never been more important.

SPECTRUM, the lifeblood of our wireless world, is an extraordinary asset. It improves network performance, reduces costs, and never wears out. It can be repurposed through technology investments. And technological advances help “sub-prime” spectrum perform more like a “prime” asset. Recognizing this value, wireless service providers (WSPs) have invested hundreds of billions of dollars in licensed spectrum to enable the construction of wireless networks around the world.

Justifying spectrum purchases in the early days of cellular wireless communication was relatively straightforward. WSPs needed to acquire spectrum to add connections and to expand into new markets, and demand for additional spectrum to support voice services and data-light applications such as text-based messaging was relatively predictable. Then came the smartphone, along with the data-intensive applications it enabled. The explosive growth in data demand, beginning in the late 2000s, took the industry by surprise, and WSPs pursued spectrum purchases primarily to increase capacity rather than to expand coverage. Yet even as the underlying need for spectrum has evolved, WSPs continue to view it as a necessary but relatively static asset to be purchased and added to the spectrum inventory as needed, primarily to meet users’ still-growing appetite for data.

The advent of 5G promises to change this dynamic. 5G technology, coupled with a variety of other new technologies and regulatory approaches—including carrier aggregation methods, access to high-frequency spectrum, and unique spectrum sharing models—opens up the potential for a wide range of increasingly complex and demanding use cases. 5G architectures will make possible autonomous vehicles, industrial automation, better first-responder communications, mobile health, and other network-intensive applications.

Given these changing conditions, WSPs must consider how to adapt their strategies so they can best value and deploy their spectrum portfolios, ensuring the right mix of spectrum used in the right way, providing the intended coverage, performance characteristics, capacity, and cost-effectiveness. With a good balance and use of its spectrum bands, a WSP can serve its customers better and more cheaply and move into new markets faster. Properly managing spectrum portfolio will be a fundamental element of success for WSP business models.

Those WSPs that can crack the code of spectrum portfolio management can optimize their future spectrum and technology investments, determine where to shore up weaknesses, and decide where their greatest opportunities lie. Those that cannot will see their operational capabilities, market position, and financial position suffer by comparison.

Understanding the value of spectrum portfolios benefits the financial community and policymakers as well. Investors who can more accurately estimate portfolio values will be better equipped to estimate WSPs’ enterprise value, leading to better-informed investment and financing decisions. Policymakers will be better equipped to understand the inherent value of spectrum bands currently being used or under consideration, leading to more informed policy decisions spanning auction rules and prices, licensing terms, and sharing mechanisms.
Why spectrum portfolios matter

Over the past decade, the Federal Communications Commission (FCC) has provided access to hundreds of megahertz of spectrum via auctions and reallocations to satisfy the growing demand for data and to support the US government’s priority to become a pioneer in 4G technology. While these actions have significantly increased the amount of spectrum allocated to wireless services in the United States, the growth in data traffic continues to far outpace increases in available spectrum (see figure 1). Worldwide, mobile data traffic increased 18-fold between 2011 and 2016.

Figure 1. US wireless data traffic has outpaced spectrum

Worldwide, mobile data traffic increased 18-fold between 2011 and 2016.

In response, WSPs have spent hundreds of billions of dollars to purchase available licenses, with the result that spectrum is now a major—and still
As the prices and frequency of buying licenses have increased, they are representing a growing portion of total assets. Licenses make up a noticeably larger portion of US companies’ total assets (25–35 percent) than international providers (10–20 percent).

As of the third quarter of 2017, the nation’s top six publicly traded spectrum holders (AT&T, Dish, Sprint, TDS/U.S. Cellular, T-Mobile US, and Verizon) held combined spectrum assets of more than $265 billion on their balance sheets, representing almost a third of their total enterprise value on average. As the demand for data has grown, the cost of spectrum has increased accordingly. Yet while the market value of spectrum has increased substantially over time, WSPs typically carry spectrum already acquired on their balance sheet at the original purchase price. As a result, analysts often understate the “true” value of a WSP’s spectrum portfolio both in absolute terms and as a percent of the asset base. (See sidebar, “How spectrum is accounted for.”)
Figure 3. The amount invested in spectrum licenses drives service revenue for WSPs

Ratio of annual service revenue to spectrum investment (2016)

United States

0.7x 1.6x

Average (1.0x)

Europe, Middle East, & Africa

0.7x 1.7x

Average (1.1x)

Asia

0.6x 2.3x

Average (1.4x)

Source: Deloitte analysis based on annual report data of major US and select global WSPs. Analysis weighs WSPs in a given region equally.

How Spectrum Is Accounted For

In the United States, both WSPs and investors have historically treated spectrum licenses as indefinite-lived intangible assets not subject to amortization. Licenses are tested for impairment annually, generally using a Greenfield Approach to estimate fair value despite the inevitable changes in how spectrum is used and the value of the services it enables.\(^8\) As a result, the book value of spectrum assets is generally a poor indicator of the spectrum portfolio’s fair market value. Figure 4 provides further detail on how spectrum is treated under US GAAP and IFRS accounting rules.\(^9\) The book value of spectrum purchased years or decades ago and booked at cost is often substantially undervalued relative to market, while the book value of more recently acquired spectrum tends to be closer to fair market value.

Figure 4. Treatment of spectrum purchases and wireless licenses around the world

<table>
<thead>
<tr>
<th>General accounting treatment</th>
<th>US GAAP</th>
<th>IFRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Indefinite-lived intangible assets for US FCC licenses</td>
<td>• Licenses classification as indefinite-lived vs. definite-lived varies by country and depends on the term of the license and ability to continuously renew at nominal costs</td>
<td></td>
</tr>
<tr>
<td>• No amortization</td>
<td>• Where treated as indefinite-lived intangible assets, IFRS is generally aligned with US GAAP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Where treated as having finite-lives, accounted for as finite-lived intangible assets subject to amortization over the useful life</td>
<td></td>
</tr>
</tbody>
</table>

CONTINUED ›
## HOW SPECTRUM IS ACCOUNTED FOR, CONTINUED

### Figure 4. Treatment of spectrum purchases and wireless licenses around the world (continued)

<table>
<thead>
<tr>
<th></th>
<th><strong>US GAAP</strong></th>
<th><strong>IFRS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Useful life</strong></td>
<td>• FCC licenses are issued for a fixed period of time (generally 10 years); however, license renewals have occurred routinely and at a nominal cost</td>
<td>• Generally the term of the license, unless there is a presumption of renewal at a negligible cost</td>
</tr>
<tr>
<td></td>
<td>• WSPs have determined that there are no legal, regulatory, contractual, competitive, economic, or other factors that limit the useful lives of their wireless licenses</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• The useful-life determination for wireless licenses is re- valued each year to determine whether events and circumstances continue to support an indefinite useful life</td>
<td></td>
</tr>
<tr>
<td><strong>Impairments</strong></td>
<td>• Tested annually for impairment through qualitative and quantitative assessments, comparing the estimated fair value to the carrying book value</td>
<td>• Amortization expense reduces asset value on balance sheet as well as shareholders' equity</td>
</tr>
<tr>
<td></td>
<td>• Fair value for licenses is determined by using a discounted cash-flow model (&quot;Greenfield Approach&quot;) and a corroborative market approach based on auction prices</td>
<td>• Impairments will further affect the balance sheet value</td>
</tr>
<tr>
<td></td>
<td>• Impairment loss is recognized if the carrying amount of the indefinite-lived asset exceeds fair value</td>
<td>• Impairment loss is calculated as the excess of the asset's carrying amount over its recoverable amount</td>
</tr>
<tr>
<td><strong>Balance sheet impact</strong></td>
<td>• Generally no impact to balance sheet, as asset values reflect cost</td>
<td>• Net asset value decreases over the life of the license as amortization is taken into account</td>
</tr>
<tr>
<td></td>
<td>• Balance sheet affected only if impairment is taken</td>
<td></td>
</tr>
<tr>
<td><strong>Income statement impact</strong></td>
<td>• Generally no impact on income statement unless there is an impairment</td>
<td>• Amortization is charged on a straight-line basis over the estimated useful life</td>
</tr>
<tr>
<td><strong>Spectrum swap treatment</strong></td>
<td>• Generally exchanged at fair value, resulting in gain or loss</td>
<td>• Generally exchanged at fair value, resulting in gain or loss</td>
</tr>
<tr>
<td></td>
<td>• Additional accounting consideration is given to certain provisions of the swap agreement—for example, whether the swap involves a monetary exchange, a third party, or issuance of financial instruments</td>
<td>• Additional accounting consideration is given to certain provisions of the swap agreement—for example, whether the swap involves a monetary exchange, a third party, or issuance of financial instruments</td>
</tr>
<tr>
<td><strong>M&amp;A treatment</strong></td>
<td>• Assets acquired are measured at the acquisition-date fair value; this may result in a step-up in value</td>
<td>• Assets acquired are measured at the acquisition-date fair value; this may result in a step-up in value</td>
</tr>
</tbody>
</table>

Note: Investors should consult with a qualified professional adviser and consider the facts and circumstances of their situation prior to finalizing accounting conclusions or decisions.

Source: Deloitte analysis.
The problem this understatement creates is that, while book value can be a useful starting point for understanding a spectrum portfolio’s value, current accounting standards limit its usefulness. When prices are rising, the growing gap between book value and market value not only masks the true value of a given purchase to the enterprise—it clouds the potential synergies that individual spectrum purchases, past or present, can create within an integrated spectrum portfolio.

The effects of this discrepancy extend well beyond the operational value of a spectrum portfolio. A more robust understanding of spectrum value drivers for a given WSP, for both individual spectrum blocks and the broader spectrum portfolio, can lead to a better overall understanding of the WSP’s value for the broader financing and investment community. At present, however, the stock market barely reacts to the outcome of spectrum auctions—which firms improve their portfolios and which do not—no matter how valuable that spectrum might be, now and in the future. (See sidebar, “Spectrum valuation and shareholder value.”)

Proper valuation will enable WSPs that can identify, build, and leverage a strategically valuable spectrum portfolio to create new financing opportunities. Spectrum asset-based financing can fund network innovation, while lowering WSPs’ capital costs by funding select, strategic spectrum investments.

In late 2016, for example, Sprint issued $3.5 billion in bonds, leveraging a portfolio of licenses representing approximately 14 percent of the company’s total spectrum portfolio on a MHz-Pop basis. \(^9\) By securitizing these bonds with spectrum holdings, Sprint was able to nearly halve its coupon compared with previous transactions, substantially reducing its cost of capital.

Individual spectrum holdings are only now being recognized as valuable assets that can be traded or used to secure financing. As the financial community gains a better understanding of the importance of spectrum valuation at fair market value, and the factors that affect that value, additional financing mechanisms and investment opportunities will likely emerge, such as the leasing of spectrum to gain access to the associated revenue streams.

Because spectrum assets, even at book value, generally comprise a considerable portion of a WSP’s enterprise value, material changes in a spectrum portfolio position should have a significant impact on its WSP’s valuation and stock price. A WSP with a more advantageous portfolio position, strengthened through targeted spectrum purchases, can achieve a competitive advantage through better geographic or in-building coverage, improved service performance, reduced investment and operating costs, improved time to market for deploying new technologies, and greater responsiveness to changing market conditions. On the other hand, WSPs with portfolios less suited to their strategy and market position—or that miss out on an opportunity to improve their portfolio through a smart purchase—will be at a competitive disadvantage, and their business performance, value, and stock price will likely suffer.

How a WSP chooses to deploy its spectrum portfolio can also affect valuation. If a WSP deploys its spectrum judiciously, it can better align its use of spectrum with its strategic priorities, such as improving network performance to provide high-value service to high-revenue customers at low cost. And spectrum selectively held in reserve can be readily activated to accommodate future growth needs and
SPECTRUM VALUATION AND SHAREHOLDER VALUE

Despite the changes in how WSPs and investors measure spectrum’s value, the financial community rarely reacts much to major market events involving spectrum acquisitions through auctions. As figure 5 shows, changes in both the stock price and the trading volume for WSPs that successfully participated in spectrum auctions are typically muted. The phenomenon becomes especially clear when auction announcements are compared to other major events such as comparably sized mergers or acquisitions, which generally lead to significant increases in both stock price and trading volumes.

This dynamic suggests that few investors have the tools to understand and value the short-term impact of spectrum transactions, forcing them to wait for the transaction’s impact on business cash flow—and that may take years.

Figure 5. M&A announcements vs. spectrum auctions

U.S. WSPs experienced a larger impact to their stock price and trading volume for corporate M&A announcements than comparably sized announcements of spectrum auction results.

Source: Deloitte analysis based upon publicly available company reports and investor notifications.

technology migrations that may enable a WSP to move quickly in competitive markets. In some instances, managing which spectrum not to deploy can be just as valuable as managing the spectrum that is.

The key question for investors to consider: How will a WSP’s spectrum portfolio help it advance its future growth plans, fend off competitors, and support lower capital and operating costs? A well-managed position will allow a WSP to meet its performance goals at the target cost, while maintaining flexibility to accommodate strategic uncertainties.

Other factors being equal, WSPs that succeed at acquiring and deploying attractive spectrum should see a multiplier effect in their enterprise values. The
disconnect we often see between analysts’ auction predictions and actual auction results, and the lack of subsequent stock trading activity, suggests that investors’ ability to understand the effect of spectrum positions on enterprise value needs considerable improvement. (See figure 6.)

**Figure 6. As spectrum has become a more complex asset over time, its value has become harder to predict**

<table>
<thead>
<tr>
<th>FCC auction #</th>
<th>Analyst estimate range</th>
<th>Auction results (gross)</th>
</tr>
</thead>
<tbody>
<tr>
<td>66</td>
<td>$7–20B</td>
<td>$13.9B</td>
</tr>
<tr>
<td>73</td>
<td>$6.5–11B</td>
<td>$19.1B</td>
</tr>
<tr>
<td>97</td>
<td>$10–19B</td>
<td>$44.9B</td>
</tr>
<tr>
<td>1000</td>
<td>$19.8B</td>
<td>$20–54B</td>
</tr>
</tbody>
</table>

Source: Deloitte analysis based upon publicly available company reports and investor notifications.
The ways in which WSPs value spectrum have evolved considerably over the past several decades. Early on, when providers were focused on increasing subscribers and building out coverage, valuation depended on a per-population covered basis. When their focus shifted to data capacity, they turned to a network capital avoidance basis, calculating the potential for spectrum to add capacity at lower capital investment relative to other options such as investing in more towers or upgraded network technologies. Today, valuation depends on spectrum’s capacity to improve performance as WSPs bring on line Internet of Things and next-generation services enabled by 5G (see figure 7).

Even as more sophisticated bandwidth management schemes have been deployed through 4G technology, allowing WSPs to increase capacity and coverage, extend the capabilities of their spectrum assets, and deliver services at a lower cost per bit, a few underlying spectrum portfolio value drivers have remained consistent:

- Employing more spectrum yields lower network costs for the same network capacity. WSPs with larger spectrum holdings can maintain a competitive cost advantage.

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**Figure 7. Evolution of spectrum valuation across generations of technology**

<table>
<thead>
<tr>
<th>US launch</th>
<th>1G</th>
<th>2G</th>
<th>3G</th>
<th>4G</th>
<th>5G (est.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basis of competition</td>
<td>Local voice coverage</td>
<td>National voice coverage</td>
<td>Data capacity</td>
<td>Data speeds</td>
<td>Ubiquitous connectivity</td>
</tr>
<tr>
<td>Valuation driver</td>
<td>Population covered</td>
<td>Voice subscriber capacity</td>
<td>Cost reduction and migration to data services</td>
<td>Improved performance for data services</td>
<td>Competitive position, performance, and new uses</td>
</tr>
<tr>
<td>US end of generation users</td>
<td>35M subscribers</td>
<td>140M subscribers</td>
<td>300M subscribers</td>
<td>750M devices</td>
<td>10B+ devices</td>
</tr>
</tbody>
</table>

Source: Deloitte analysis.
• Larger blocks of contiguous spectrum are more efficient than an equal amount of fragmented spectrum. WSPs with larger contiguous blocks of spectrum can operate at a lower capital and operating cost than WSPs with more noncontiguous blocks.

• A combination of lower- and higher-frequency spectrum is necessary to effectively and efficiently provide both coverage and capacity. Lower-frequency spectrum provides better coverage and in-building penetration, while higher-frequency spectrum can carry more traffic but over shorter distances.

• Holding unused spectrum allows faster, more economic migration to new network technologies such as 4G and 5G without requiring complex and time-consuming spectrum clearing techniques that may impact the customer experience. WSPs with this position can have time-to-market and customer satisfaction advantages.

However, once spectrum is acquired and accounted for as an asset, WSPs often fail to reconsider its value as their portfolios evolve—even as they repurpose their spectrum portfolio to accommodate new spectrum additions and for generational changes in technology and use cases. Factors to be considered include:

Once spectrum is acquired and accounted for as an asset, WSPs often fail to reconsider its value as their portfolios evolve.

**Frequency and bandwidth.** These have always been the primary elements in valuing spectrum. Operators are generally willing to pay more for 10 MHz of contiguous spectrum, for example, than for two noncontiguous 5 MHz blocks, due to the efficiency and performance benefits of the larger block size. For example, moving from 5 MHz in 3G to 10 MHz in 4G delivers more than 10 times improvement in spectral efficiency (see figure 8).\(^1\) Larger chunks of a contiguous frequency range provide increased capacity, as less spectrum is used in guard bands and power can be more efficiently allocated.

Moreover, lower frequencies have better propagation characteristics, more effective at penetrating

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**Figure 8. Evolution of spectrum efficiency across generations of technology**

<table>
<thead>
<tr>
<th>US launch</th>
<th>1G</th>
<th>2G</th>
<th>3G</th>
<th>4G</th>
<th>5G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed channel width</td>
<td>25-30 KHz</td>
<td>200 or 1,250 KHz</td>
<td>1.6 or 5 MHz</td>
<td>10 MHz</td>
<td>20-100 MHz</td>
</tr>
<tr>
<td>Representative spectral efficiency (bits/s)/Hz</td>
<td>&lt;0.1</td>
<td>0.5</td>
<td>3</td>
<td>30</td>
<td>100+</td>
</tr>
</tbody>
</table>

\(^{1}\)Including the impact of massive multiple-input, multiple-output antennas

Source: Deloitte analysis.
thick walls and other barriers, while higher frequencies carry more data and can be reused more frequently given their propagation limitations.

**Duplexing scheme.** The duplexing scheme for a spectrum band has gained importance as a factor due to differences in the way the schemes manage asymmetric traffic. While 4G systems in the United States were primarily built using frequency-division duplexing (FDD), this approach can lead to a significant portion of the portfolio being reserved for uplink capacity, even though far more traffic typically flows in the downlink direction, as is the case for video streaming services. Now, with the advent of 5G, time-division duplexing (TDD) is receiving renewed interest. Compared to FDD, TDD could also enable device size and capability advantages with modern multiple-input, multiple-output (MIMO) antenna systems, further increasing the value of spectrum.

**Impairments and sharing.** A variety of factors can reduce the value of spectrum compared with its inherent value if unencumbered. These include signal interference from adjacent channel users, regulatory restrictions across international borders, licensed sharing mechanisms with incumbents who have priority access to the spectrum, and coordination of spectrum sharing in unlicensed bands via device certification. While the use of unlicensed spectrum is “free” in that the rights need not be purchased, understanding the value and role of unlicensed spectrum within a WSP’s portfolio can also affect the value of licensed spectrum.

**Clearing and build-out requirements.** Spectrum that must be cleared before it can be used for wireless services may have lower near-term value. For example, broadcasters must be cleared from the recently auctioned 600 MHz band before WSPs can use these assets to generate revenue. WSPs may also risk forfeiting licenses if FCC-mandated build requirements cannot be met, due to lack of financing, network equipment, end-user handsets, or adequate standards. Such requirements can have an impact on the value of spectrum in the secondary market, with value generally decreasing over time as forfeiture deadlines approach.

**Handset and network equipment availability.** The availability of end-user devices and network equipment supporting a new frequency can further affect spectrum value. To avoid delays in the deployment of spectrum, WSPs, network equipment suppliers, standards bodies, and device manufacturers must collaborate to make available equipment and devices compatible with the WSP’s implementation strategy. Unique national or regional standards have largely been replaced by global standards, affecting not only the radio interface but device support for a given WSP’s frequency bands and the device’s ability to aggregate those frequency bands and radio interfaces.

Mobile device original equipment manufacturers (OEMs) limit the number of bands in popular phones due to cost, power consumption, device size, and interference challenges. To reduce the number of device variations and achieve higher-scale production volumes, manufacturers focus on combinations of bands that are most likely to address the largest portions of the market and align with internationally standardized bands. Understanding when devices will be available at competitive costs to utilize new spectrum will likely affect how the spectrum is valued—a factor that will only increase in importance as 5G networking becomes widely implemented and WSPs begin to deploy higher-frequency bands and bands not yet aligned with international standards.

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Spectrum portfolios in a 5G world

Understanding the value and role of unlicensed spectrum within a WSP’s portfolio can also affect the value of licensed spectrum.
New ownership paradigms, new spectrum

As complex as the effort to value spectrum portfolios is today, further developments—notably, the introduction of spectrum sharing and access to a large amount of higher-frequency spectrum—are on the horizon and will only make the process more complicated.

**Nontraditional ownership and access.** Because opportunities to make more sub-6 GHz spectrum available will be limited going forward, the FCC recently allocated an additional 1,000 MHz of sub-6 GHz spectrum for cellular use on an unlicensed and shared basis. Expanding the use of nonexclusive ownership models will open the door for technologies such as LTE-Unlicensed (LTE-U) and License Assisted Access (LAA), which can improve network capacity and performance through the use of unlicensed, combined licensed/unlicensed, and shared spectrum operations in the 2.5, 3.5, and 5 GHz bands.

Unlicensed spectrum permits the use of spectrum with approved equipment but without a license from the FCC and without strict requirements for the coordination of frequency among users. The best-known uses of this framework are the 2.4 GHz Industrial, Scientific, and Medical (ISM) and 5 GHz Unlicensed National Information Infrastructure (U-NII) standards, over which Wi-Fi typically operates. This spectrum can provide significant capacity boosts for commercial networks without the need for WSPs to acquire the licenses themselves. However, these bands may not be reliable enough for critical applications such as first responder use, communication between connected vehicles, and remote surgery. Furthermore, to guard against interference, maximum allowable transmission power levels in these bands are much lower than in licensed bands, severely limiting transmission ranges and greatly increasing the required number of “cell” sites relative to traditional towers operating with licensed spectrum.

Due to the challenge of finding additional spectrum for exclusive licensing, the FCC is also considering ownership models involving the sharing of licensed spectrum. This approach would allow a current legacy user, such as a government agency, to continue in service while new users, such as WSPs, use the band on a secondary rights basis, constrained by geographic restrictions or concerns about interference. Shared spectrum generally allows higher power levels and more predictable service than unlicensed spectrum, but its management comes at increased cost, given the more formal and complex sharing regime.

Further developments are on the horizon that will make the process only more complicated.
Defining rule sets, regulations, tools, and data to facilitate efficient coordination among all users will be critical for harvesting the benefits of shared spectrum, as interference among users has a negative impact on value and could create broader public service issues as well, such as interference with a government agency’s use of that shared spectrum. For example, radar systems could cause interference with cellular systems based on their higher-powered transmissions, and the same cellular systems could cause interference with satellite communications. Compared with exclusive licenses, sharing spectrum demands considerable coordination among users, but it allows WSPs to “self-select” into the appropriate sharing tier and regime based on their needs and their capacity to invest in their network. This approach, in turn, could have a considerable impact on their portfolio valuation, depending on how effectively it is managed.

While unlicensed and shared ownership spectrum can provide capacity boosts and ease network congestion for WSPs, these solutions should not be seen as equivalent replacements for exclusive licensed spectrum. Licensed spectrum will still be necessary for network control and critical use cases, and lack of access to adequate exclusive licensed spectrum can have negative impacts on service quality. Figure 9 outlines the benefits of each approach.

**Advances in high-frequency spectrum.** The FCC is also working to mitigate the growing shortage of available licensed spectrum. The commission recently set the stage for giving WSPs access to mid- and high-frequency (mmWave) spectrum, starting with the Spectrum Frontiers notices in 2016. This includes spectrum in the 24–39 GHz frequencies to promote the implementation of 5G as well as several additional bands for future use. Recent technological advancements in semiconductors and antennas, leading to applications such as beamforming and small cells, have made these bands more attractive for commercial use, and triggered a wave of M&A activity, including Verizon’s acquisitions of Straight Path Communications and XO Communications and AT&T’s acquisition of Fiber Tower.

Higher-frequency spectrum can be used in a variety of applications spanning mobile wireless, fixed wireless (wireless broadband), and wireless backhaul. The latter two are expected to arrive first as WSPs look to lower the “last mile” cost of broadband and open up new competitive fronts against wireline and satellite broadband offerings. While still unproven, these bands will become an integral part of networks in the future, and players that quickly learn how to maximize their value could reap considerable benefits by being fast to market with new services and solutions.

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**Figure 9. Benefits of licensed vs. shared and unlicensed spectrum**

<table>
<thead>
<tr>
<th>Licensed spectrum</th>
<th>Shared and unlicensed spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Maintaining a Quality of Service guarantee is simpler for critical wireless applications</td>
<td>• Increases network capacity</td>
</tr>
<tr>
<td>• Requires less complex technology for monitoring and protecting incumbents from interference</td>
<td>• Provides more opportunistic access to spectrum, increasing utilization</td>
</tr>
<tr>
<td>• Easier to manage user access across networks</td>
<td>• Extends wireless benefits to entities such as cable operators or other new entrants that currently lack access to licensed spectrum or the opportunity to acquire it due to high up-front costs</td>
</tr>
<tr>
<td>• Higher transmission power and therefore greater range or higher bits/Hz</td>
<td>• Requires lower transmission power with shorter range or lower bits/Hz</td>
</tr>
<tr>
<td>• Provides more public funding for the government, as licensed spectrum auctions can help raise billions of dollars</td>
<td>• Addresses certain economic inefficiencies, such as spectrum hoarding and windfall gains for incumbents</td>
</tr>
</tbody>
</table>

Source: Deloitte analysis.
While use of mmWave spectrum is still in its infancy, the magnitude and characteristics of the available spectrum create a major opportunity to redefine WSP spectrum portfolios.

<table>
<thead>
<tr>
<th>Category</th>
<th>Bandwidth (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-6 GHz licensed (allocated)</td>
<td>736</td>
</tr>
<tr>
<td>Sub-6 GHz shared and unlicensed (allocated)</td>
<td>1,000</td>
</tr>
<tr>
<td>Sub-6 GHz under consideration</td>
<td>845</td>
</tr>
<tr>
<td>mmWave &amp; mid-band licensed (allocated)</td>
<td>4,950</td>
</tr>
<tr>
<td>mmWave &amp; mid-band shared and unlicensed (allocated)</td>
<td>14,600</td>
</tr>
<tr>
<td>mmWave &amp; mid-band under consideration</td>
<td>17,500</td>
</tr>
<tr>
<td></td>
<td>2,580 total</td>
</tr>
<tr>
<td></td>
<td>37,050 total</td>
</tr>
</tbody>
</table>

Note: A limited amount of mid-band spectrum (between 6-GHz and mmWave) is being considered for license by the FCC but is not a primary focus of this article.21

Source: FCC and Deloitte analysis.

In aggregate, the FCC is considering approximately 5 GHz in licensed mid-band and mmWave spectrum for mobile use, nearly seven times the 736 MHz of licensed sub-6 GHz spectrum available to WSPs in the United States today.22 Even more substantial is the approximately 32 GHz of unlicensed or shared spectrum above 6 GHz that has been either allocated or is under consideration. (See figure 10).23

While the availability of higher-band spectrum opens up tremendous opportunities for WSPs and the broader wireless ecosystem, its physical characteristics are fundamentally different from the traditional sub-6 GHz spectrum. As such, spectrum above 6 GHz presents considerable management and investment challenges.

- The limited propagation distances of high-frequency spectrum (a few hundred meters versus several kilometers for low-frequency spectrum), susceptibility to rain fade, and limited ability to penetrate buildings will require owners to establish extremely dense networks and deep fiber connectivity relative to past practices, and to develop plans to differentiate in-building coverage from outdoor coverage.

- The band structure of higher-frequency spectrum is also noticeably different than the traditional 5–10 MHz building blocks found in sub-6 GHz spectrum. WSPs will need to account for acquisition and use of much larger contiguous spectrum blocks, with some exceeding 200 MHz.

- New site designs, location selection, access to power, and permitting will also play critical roles in deployment costs and timing. As the number of sites grows and physical cell size shrinks, WSPs will need to consider nontraditional locations for their small cells, such as building walls, telephone poles, street kiosks, and streetlights, while taking into account power needs, backhaul requirements, regulations, and aesthetics.

Given these considerations, WSPs planning to acquire and deploy higher-frequency spectrum face new uncertainty and risk. The technology has improved, carriers have refined their 5G deployment strategies, and underlying valuation models have evolved. As a result, acquisition prices for these bands on the secondary market have risen tenfold on a population-weighted basis in just the past two years. Still, mmWave technology is still in
the early development stage, and questions remain concerning the viability of rolling out this technology on a large scale, nationwide. WSPs seeking to understand the impact of high-frequency spectrum on their portfolios should keep in mind several key questions:

- How quickly will the performance characteristics of high-frequency spectrum—its speed, capacity, latency, and reliability—improve to the point at which it will support high-value use cases, and will these use cases drive material revenue growth?

- What investment is required in new spectrum, new network and device technologies, and network densification, and is this investment justified, given the expected returns?

- How should WSPs manage relations with regulators, legislators, and local municipalities, given the importance of issues such as spectrum allocations and auction design, spectrum sharing principles, and access rights and permitting for small-cell deployment?
Spectrum value in a 5G world

The advent of 5G will have a profound impact on the value of WSPs’ spectrum portfolios. Network architectures and use cases will dramatically shift, leading to changes in the underlying drivers of value for every frequency band and creating even greater complexity in the effort to value portfolios properly. The market values of spectrum holdings will continue to diverge from their historical prices and become more greatly influenced by how each band complements the broader spectrum portfolio in the overall effort to meet business objectives.

The longstanding relationship of a device communicating with a single tower, tracking its connection with other towers, and handing off to the next best tower as the user moves will change. The architecture of 5G allows devices to communicate simultaneously with several towers, over several frequencies and even using several radio protocols, profoundly transforming the current paradigm and allowing multi-level network deployment. Femtocells and home spots (both user-hosted devices) connected to broadband will combine seamlessly with wide-area network assets. New architectures dependent on lower-cost cell sites will achieve greater performance and reliability through sheer numbers. Even direct device-to-device communications will become practical.

In this environment, WSPs will continue to prefer owning larger blocks of contiguous spectrum, and contiguous blocks will likely remain more valuable than smaller, more fragmented blocks. But the emergence of new technologies such as carrier aggregation (see figure 11) and multi-connectivity will allow network operators to logically combine fragmented spectrum and physical assets to offer the same capacity to end users.

Figure 11. Carrier aggregation can help overcome spectrum fragmentation issues, though a more contiguous position is still preferable

Source: Deloitte analysis. Note that five-carrier aggregation is still under development.
Multi-connectivity—the ability to combine traffic from multiple sites and across multiple radio access technologies at the handset—will enable WSPs to combine a licensed control layer with unlicensed capacity and use different frequencies for different user needs. For example, traditional sub-2 GHz spectrum, with its better propagation characteristics, can be used for macro tower high-mobility and broad-range coverage, while higher frequencies, with higher bandwidth characteristics, can be devoted to small cells for higher-speed links and high-capacity services.

These capabilities will generally come at a cost, as managing more fragmented spectrum holdings will require more physical equipment. However, they also provide WSPs with the flexibility to increase bandwidth, speed up peak user data rates, and improve overall network throughput without fundamentally changing or adding to their spectrum portfolios.

Indeed, carrier aggregation could profoundly change the current dynamics of spectrum portfolios. Implementing this technology could enable a WSP with relatively fragmented, disparate bands of spectrum to combine those assets, virtually, into a single larger and more efficient block and, in doing so, substantially improve those assets’ operational value (see figure 12).

Carrier aggregation is a useful example of how a spectrum band’s unique technological and operational characteristics can shift over time, changing its role within a WSP’s broader spectrum portfolio and creating the opportunity to redefine the value of that holding relative to its original purchase price. Given spectrum’s strategic value, these shifts have the potential to alter the competitive landscape, making today’s laggard tomorrow’s contender.

It is imperative to remember, however, that the intended benefits of any particular purchase of spectrum may not materialize for years, until the carrier brings the new spectrum into service or migrates from old technology to new technology. In many cases, investors will reap the increasing value of spectrum only indirectly, when the network improvements it fuels contribute to top-line growth or operating efficiencies. Understanding the relationships between spectrum holdings, technology advances, and deployment strategies in the context of the fast-changing competitive landscape in which WSPs operate will give deeper insight into how their spectrum portfolio strategies will impact their overall enterprise value.

**Figure 12. Carrier aggregation could change the relative competitive value of spectrum portfolios**

Despite fundamental differences in their licensed spectrum portfolios, two WSPs could achieve the same downlink bandwidth with Four Carrier Aggregation:

<table>
<thead>
<tr>
<th>Band</th>
<th>Paired spectrum</th>
<th>Licensed spectrum portfolio</th>
<th>Four Carrier Aggregation downlink bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>2x5 MHz</td>
<td>100 MHz</td>
<td>40 MHz</td>
</tr>
<tr>
<td>D</td>
<td>2x15 MHz</td>
<td>100 MHz</td>
<td>40 MHz</td>
</tr>
<tr>
<td>G</td>
<td>2x30 MHz</td>
<td>100 MHz</td>
<td>40 MHz</td>
</tr>
<tr>
<td>A</td>
<td>2x5 MHz*</td>
<td>100 MHz</td>
<td>40 MHz</td>
</tr>
<tr>
<td>B</td>
<td>2x5 MHz</td>
<td>100 MHz</td>
<td>40 MHz</td>
</tr>
<tr>
<td>C</td>
<td>2x5 MHz</td>
<td>100 MHz</td>
<td>40 MHz</td>
</tr>
<tr>
<td>D</td>
<td>2x10 MHz</td>
<td>100 MHz</td>
<td>40 MHz</td>
</tr>
<tr>
<td>E</td>
<td>2x25 MHz</td>
<td>100 MHz</td>
<td>40 MHz</td>
</tr>
</tbody>
</table>

*Band not used for Four Carrier Aggregation downlink. Current standards support a maximum of 20 MHz per carrier.

Source: Deloitte analysis.
SPECTRUM portfolio valuation is a complex undertaking, and it will become only more challenging. Valuing spectrum properly requires a realistic assessment of numerous interrelated factors: spectrum market supply and demand on a band-by-band basis; an understanding of network and device technologies and how technology evolution will impact spectrum value, operational performance, and network investments; consideration for the roles and interplays of individual bands within a broader portfolio; and an accounting for significant regulatory action spanning auctions, ownership models, build-out mechanisms, and international harmonization. And valuation must be performed in the context of increasingly complex demand requirements, an intensifying competitive landscape, and the most dramatic technology evolution in the industry’s history.

Maximizing spectrum portfolio value matters—a lot. Spectrum is a wireless service provider’s most critical resource, and its spectrum portfolio is likely its biggest single asset. With the right portfolio and spectrum strategy, a WSP can serve its customers better, achieve a lower cost structure, move into new markets and technologies faster, and attract investment from the financial community. Conversely, a weak or undisciplined approach to spectrum management can effectively hinder a company’s performance and competitive prospects for years to come.

Understanding the value of a spectrum portfolio also benefits the financial community and policymakers. Investors can make more informed decisions about company prospects and the impacts of spectrum transactions, and identify new investment or financing opportunities. Policymakers can better judge the economic impact and interplay of policy decisions such as spectrum availability, auction structuring, and sharing methods. (See sidebar, “Key considerations for spectrum valuation.”)

Spectrum is no longer a static asset. Its value increases and decreases dynamically, as technologies, portfolios, regulations, and market conditions change. As the industry prepares for the shift to 5G, valuing it properly has never been more important.
KEY CONSIDERATIONS FOR SPECTRUM VALUE, CONTINUED

• Do you have a spectrum portfolio strategy that supports your corporate strategy, competitive positioning, operational plans, and technology roadmaps, and do you regularly update it?

• Do you perform a regular, comprehensive review of individual spectrum holdings within the portfolio to ensure they are being leveraged in a way that is consistent with your portfolio strategy and that generates the most value?

• What is the role of spectrum sharing with other users or players in the industry?

• What is the role of unlicensed spectrum?

• Do you have a prioritized set of target holdings, supported by strategic, competitive, and economic value analyses, that if acquired will best strengthen your existing portfolio?

For investors and analysts

• Do you have accurate estimates of fair market values for existing WSP portfolios based on the results of the most recent auctions, competitive landscape, and WSP plans?

• Have you established sufficiently robust investment analytics and tools to estimate the impact of changes in spectrum holdings on a company’s enterprise value, accounting for strategic and competitive impacts, operational implications, and technological trade-offs?

• Do you have the means to estimate how new spectrum being put into the market will affect industry dynamics and economics?

For policymakers

• Are you providing adequate and timely access to spectrum in sufficient quantity, quality, diversity, and through innovative ownership models to meet rapidly evolving market needs while encouraging competition and innovation?

• Have you established the appropriate incentives and standards for ecosystem players to advance mobile broadband and make the best use of spectrum by pursuing, investing in, and supporting the deployment of more efficient and higher-performing technologies?

• Is spectrum being brought to market in a way that balances the competing needs of fueling existing use models while fostering innovation?

• Will the spectrum being made available promote international leadership as the industry transitions to 5G?
ENDNOTES

1. Deloitte estimate based on publicly available company reports.


4. Ibid.

5. Deloitte analysis based on annual report data. US WSPs include AT&T, Sprint, T-Mobile US, and Verizon; international WSP companies include Deutsche Telekom (T-Mobile US excluded), SK Telecom, and Vodafone. Analyses weigh WSPs in a given region equally.

6. Deloitte analysis based upon publicly available company reports.

7. Ibid. Spectrum investment reflects the as-reported cost basis of spectrum. US companies include AT&T, Sprint, T-Mobile US, TDS/U.S. Cellular, and Verizon; EMEA companies include Deutsche Telekom (T-Mobile US excluded), and Vodafone; Asia companies include Grameenphone, Maxis, and SK Telecom.


9. Ibid.


11. Deloitte analysis based upon publicly available company reports and investor notifications. Analyses compare absolute change in the stock price and trading volume of US WSPs that announced either significant spectrum auction allocations or corporate M&A transactions with comparable transaction size. The change is compared to the trading day prior to the announcement (“Base Day”). Spectrum auction announcements include AT&T, Dish, T-Mobile US, and Verizon for Auction 73, Auction 97, and Auction 1000, if allocations were at least $6 billion. Corporate M&A announcements include comparably sized transactions (Verizon & Alltel, Comcast & NBCUniversal, and AT&T & DirecTV). All announcements occurred between 2008 and 2017; all events were adjusted for the S&P 500 performance during respective periods.

12. Deloitte analysis based on spectrum auction outcomes estimated by select large investment banks.

Spectrum portfolios in a 5G world


16. Deloitte analysis based upon various FCC reports and orders.


20. XO Communications, “Verizon to acquire XO Communications’ fiber business,” press release, February 22, 2016; Business Wire, “Verizon to enter into definitive agreement to acquire Straight Path Communications for $184.00 per share in all stock deal,” May 11, 2017; AT&T, “AT&T in advanced discussions with power companies and others to trial project AirGig,” January 31, 2017.


23. Deloitte analysis of various FCC reports and orders.
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