Shared Spectrum Market Opportunity for Mobile Network Operators

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Executive Summary

Mobile Operators have a new and unique opportunity to densify their networks and improve indoor coverage and capacity, while being at the forefront of business model innovation. It's called spectrum sharing. In 2016, the FCC released its Second Report and Order to create the Citizens Broadband Radio Service (CBRS) in the 3550-3700 MHz band, making available 150 MHz of spectrum for mobile broadband and other commercial users. The 3.5 GHz band has historically been used by the Department of Defense and fixed satellite service providers. The 3.5 GHz band represents the first iteration of an ambitious spectrum sharing framework, which the FCC plans to extend to other bands over the next several years.

For 3.5 GHz-based services, an operator (MNO) will not be required to buy and permanently own spectrum. The band will rely on a unique and innovative shared spectrum scheme. Services will be either unlicensed, or an organization would purchase a "temporary" license that would be good for a designated period of time.

Initial deployments of spectrum sharing will be focused on network densification. This will also lead to opportunities for improved in-building coverage – similar to the use case for indoor small cells, but based on a neutral host model popularized by larger and more extensive Distributed Antenna System (DAS) deployments. Spectrum sharing has the advantage of providing coverage and capacity augmentation using LTE, but employing a Wi-Fi like business framework and economic model.

Cellular data usage is growing more than 50% per year, and some 80% of that use is indoors.[1] However, providing adequate cellular coverage and capacity indoors has been a challenge. Indoor small cell solutions remain expensive and are typically tied to a single operator, which has limited their deployment. Wi-Fi has its own challenges with coverage and capacity, and relies exclusively on enterprise-led deployments. MNOs lose potential revenue, control over the quality of experience, and information on the activity of their subscribers. Plus, some Wi-Fi service providers are now aiming to compete with the MNOs. We believe spectrum sharing could be a viable new model for indoor wireless coverage.

For MNOs, spectrum sharing opportunities such as that enabled by 3.5 GHz offers several potential benefits:

- **Revenue enhancement**. Either directly through traditional service plans, or indirectly, with more data staying "on-net".
- **Speed of Deployment**. With spectrum auctions, such as the recently completed 600 MHz "Incentive Auction", it can take years before the spectrum is available

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[1] *Sources: Ericsson Mobility Report, Analysis Mason*

for commercial use. This model presents a way for network extension to be much more expedient.

- **Cost savings**. Historically, operators have relied on expensive DAS or carrier Wi-Fi solutions. This presents the possibility for a more cost-effective, 'on-demand' service model.
- **Quality control**. Operators can extend the high quality of experience built into LTE, rather than relinquish it to the vagaries of Wi-Fi.
- **Competitive Advantage**. A high capacity, quality coverage LTE network that can be extended indoors offers MNOs a competitive advantage in network capabilities over other cellular operators who aren't using shared spectrum, and could help gain share in the enterprise segment. Shared spectrum would help MNOs keep traffic on their network, which is important given increased competition from cable MSOs, cloud providers, and so on.

In addition to being an important element of an MNO's network densification strategy, we believe spectrum sharing offers the potential for an entirely new network framework, based on the idea of 'network as a service'. Network capacity or coverage could be acquired on an as-needed basis, similar to cloud-based services we are seeing across the business landscape. This is consistent with operator moves toward virtualized, software-defined network services. We believe this could result in potentially dramatic savings in CapEx.

Spectrum sharing has growing regulatory and industry support. It's a lynchpin of the FCC's effort to release substantially more spectrum for wireless broadband, while also encouraging a shared spectrum approach. All of the major equipment vendors have committed to making equipment available for 3.5 GHz, and we are encouraged by what we've seen from the device OEMs. In August 2016, six wireless technology leaders — Access Technologies (Alphabet), Federated Wireless, Intel, Nokia, Qualcomm and Ruckus Wireless (now part of Arris) — announced the launch of the CBRS Alliance, to promote LTE-based solutions utilizing the shared spectrum of the U.S. 3.5 GHz band. The Alliance now boasts more than 70 members.

We believe spectrum sharing is a game-changing approach to solving wireless coverage and capacity challenges, providing MNOs with revenue enhancement, cost savings, and competitive advantage opportunities in the coming years.

This White Paper will discuss opportunities in spectrum sharing, with a focus on 3.5 GHz-related opportunities for Mobile Network Operators (MNOs). We begin with an overview of how the 3.5 GHz spectrum sharing structure will work, current status, and the timeline for market readiness. The bulk of this report is focused on the advantages of spectrum sharing, use cases, the business/economic framework, and our recommendations for a successful go-to-market.

1. **Brief Overview of the 3.5 GHz Band**

The 3.5 GHz band has historically been used by the Department of Defense and fixed satellite service providers. There has been a movement over the past several years to open up the band and make it available for shared use between government and commercial interests, provided the incumbents are given the proper protection. On April 28, 2016, the FCC released its Second Report and Order to create the Citizens Broadband Radio Service (CBRS) in the 3550-3700 MHz band, making available 150 MHz of spectrum for mobile broadband and other commercial users.

The 3.5 GHz band will be primarily unlicensed or 'lightly licensed', in that an operator will not be required to buy and permanently own spectrum. Rather, they will rely on a unique and innovative shared spectrum scheme (more details below). Spectrum sharing deployments will allow MNOs to densify networks. This will also lead to opportunities for improved in-building coverage – similar to the use case for indoor small cells, but based on a neutral host model popularized by larger and more expensive DAS deployments. This would provide the advantage of coverage and capacity augmentation using LTE, but employing a Wi-Fi like business framework and economic model.

The FCC's proposal is for a three-tiered access system, shown in the diagram below. Users in each tier will be protected by a new and innovative spectrum sharing structure called the Spectrum Access System (SAS).

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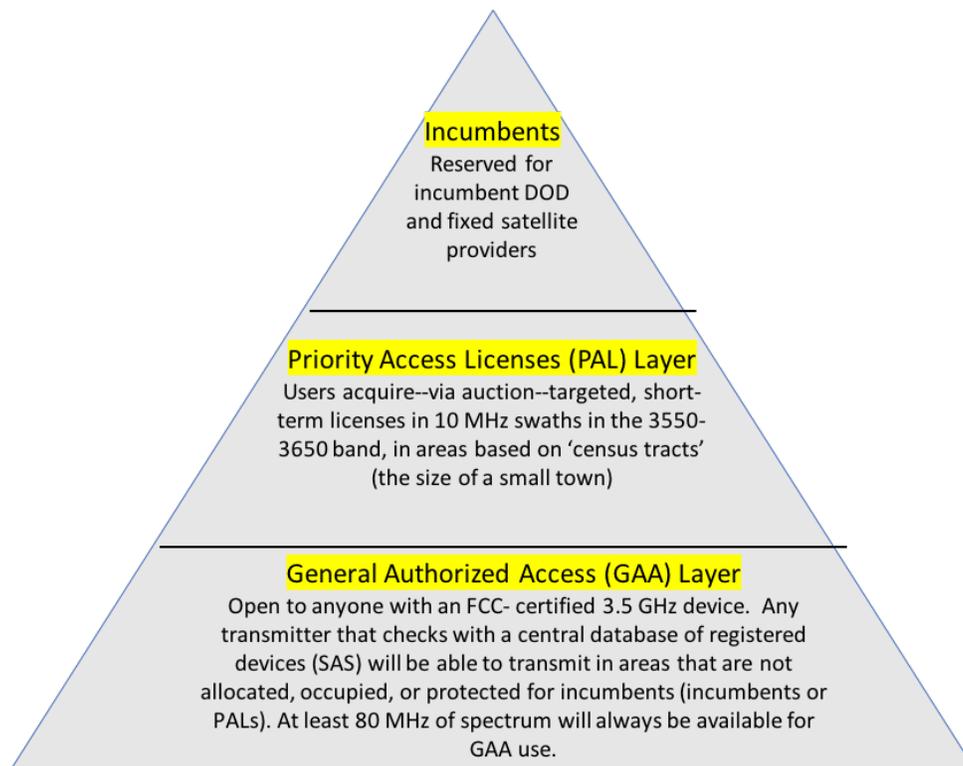
Spectrum Access System (SAS) and Environmental Sensing Capability (ESC)

The most unique and innovative element of the spectrum sharing concept is the development of the Spectrum Access System (SAS). The SAS administrators will serve as advanced, highly automated frequency coordinators across the band, protecting higher tier users (i.e. incumbent and PAL layer) from interference from lower tier users (GAA layer). They will check availability of spectrum resources, assign channel(s), provide a certificate, and coordinate and ensure interference-free operation.

Note that the FCC is currently reviewing petitions to both increase the geographic areas covered by a PAL license beyond census tracts (i.e. make the areas larger) and to make the PAL license terms longer. Decisions on these requested changes are expected by the end of 2017.

There will also be Environmental Sensing Capability (ESC) operators. The ESCs will consist of networks of sensors that will detect the presence of signals from federal systems in the band and communicate that information to one or more SASs to facilitate protection of federal operations in the band. The ESCs will also protect incumbent users within a certain radius, particularly around 'exclusion zones', which are principally within 200 km of the coast.

In December 2016, the FCC conditionally approved seven entities that have met the rules to be SAS administrators: Google, Federated Wireless, Amdocs, Comsearch, CTIA, Keybridge, and Sony. In May 2017, additional applications were submitted by Rivada Networks, Nokia, Fairspectrum and RED Technologies. We believe Google and Federated Wireless are the two most serious candidates at this time. It is generally believed there will be between two and four (2-4) SASs. Over the next few months, the FCC will certify the approved applicants through testing, with full certification expected in early 2018. A few of the organizations who submitted applications to be a SAS administrator have also applied to be ESC administrators, including Google and Federated Wireless.

How Spectrum Sharing Might Be Used

These services will primarily employ small cells, for outdoor and indoor network densification. The major difference is that these cells could support multiple operators, in a way that neutral host DAS do today. The cells need only one antenna, and do not need to coordinate with the outdoor/macro network in the same way as a traditional small cell deployment. This overcomes what has been one of the major inhibitors of the indoor small cell market to date. The FCC constructed the 3.5 GHz band rules such that whoever controls the venue can control the spectrum in that building for that band.

With this new framework, it is likelier that an enterprise, a building owner, or a systems integrator might deploy equipment, using a neutral host model. They will do deals with any one of a number of service providers, either at the PAL or GAA tier. Private enterprises, venues and fixed operators, for example, could autonomously deploy high-quality in-building LTE networks into which all mobile network subscribers can roam. MNOs would benefit from an expanded footprint and capacity on new spectrum while their subscribers could get a consistent wireless broadband experience, at indoor locations, including in the enterprise.

The equipment being developed uses the same form factor as today's indoor and outdoor small cells but at a new frequency and with new software. The indoor versions will look like Wi-Fi access points but with LTE capabilities, and some vendors are simply adding 3.5 GHz radios to W-Fi APs. We expect that much of the network administration, control, authentication, and so on, will be managed in the cloud.

Note that the FCC has also modified its original proposal to create a new category of CBRS devices that allow for increased output power of 3.5 GHz cells, extending their radius to potentially as much as one mile. **This means that there are also outdoor applications being planned for 3.5 GHz services.** Compelling opportunities here could include university campuses, business campuses, and venues such as stadiums.

Status and Timing

Spectrum sharing has been gathering momentum. Major infrastructure OEMs and chipset manufacturers have indicated support for spectrum sharing and the 3.5 GHz band, including committing to timelines for equipment support. A year ago, six wireless technology leaders — Access Technologies (Alphabet), Federated Wireless, Intel, Nokia, Qualcomm and Ruckus Wireless (now part of Arris) — announced the launch of the CBRS Alliance, to promote LTE-based solutions utilizing the shared spectrum of the U.S. 3.5 GHz band. The CBRS Alliance has since ballooned to 70 members.

Exhibit 1   Update on Network and Device Readiness for 3.5 GHz

Category	
Equipment OEMs & Operators	• Verizon leading first end-to-end carrier grade CBRS trial, partnering with Ericsson, Qualcomm, & Federated Wireless. Verizon has said that all new Verizon small cells will be equipped w/CBRS capability. • Numerous demonstrations and trials: Ericsson demonstrated 3.5 GHz small cells at MWC 2017; Alphabet, Nokia and Qualcomm completed a live test of 3.5 GHz technology over a private 4G network at a Las Vegas race track in Feb. 2017. • Federated Wireless and Alphabet demonstrated SAS-SAS interoperability in Dec. 2016. • Federated Wireless has announced interoperability with all key 3.5 GHz radio vendors, including Ericsson, Nokia, Ruckus, Samsung, and SpiderCloud Wireless.
Chipset OEMs	• Qualcomm announced support for 3.5 GHz in their Snapdragon™ X20 LTE chipset/modem in Feb. 2017 • Intel announced support for 3.5 GHz in their XMM™ 7560 modem in Feb. 2017
Industry Organizations	• ***CBRS Alliance***. Formed August 2016 by Access Technologies (Alphabet), Federated Wireless, Intel, Nokia, Qualcomm and Ruckus Wireless (now part of Arris), now has over 70 members, including Charter, Comcast, and all 4 U.S. Mobile Operators. Involved in commercializing 3.5 GHz through certification programs. Has conducted live trials at CBRS events. • ***Wireless Innovation Forum (WInnForum)***. Involved in setting standards for 3.5 GHz based on the rules set by the FCC. Has published Release 1 specs.

There has also been a significant amount of trial activity. This fall, Verizon will be leading the first end-to-end carrier grade CBRS trial, partnering with Ericsson, Qualcomm, & Federated Wireless. Verizon has said that all new small cells will be equipped w/CBRS capability. Charter and American Tower are also engaged in CBRS field trials.

We believe the first commercial spectrum sharing services of the 3.5 GHz band could be launched by 2018, initially at the GAA layer. It is likely that the MNOs will lead commercial availability of the market. The principal milestones that need to be reached are:

- **Finalizing rules for the SAS and selecting the vendors.** The FCC is setting the rules of how the SASs will operate. The FCC has conditionally certified seven vendors, with final certification expected in early 2018.
- **Determining the auction process and scheduling the auction**. There will be an auction process for temporary spectrum at the PAL layer. The FCC has issued a framework for this but still has to finalize rules and announce a schedule. We expect a PAL auction during the second half of 2018.

- **Equipment Availability**. As shown in Exhibit 1, equipment and chipset support has fallen into place. There should be device support by the end of 2017 and into early 2018.

2016	2017	2018
• FCC NPRM • Google K.C. trial • Trials in coastal cities • Finalize rules for SAS	• FCC conditional certification of first SAS vendors • Some network equipment avail. • Chipset availability • Device OEM announcements • Several field trials underway • Schedule PAL auction	• Final certification of SAS vendors • GA of consumer devices • Select GAA market launches 1H, broader launch 2H • PAL auctions, likely 2H

Mobile Ecosystem believes that mobile network operators will lead the early CBRS deployments, starting in 2018. MNOs will also play an important role in pushing the development of the device ecosystem.

2. Spectrum Sharing Benefits to MNOs

These services allow an MNO to provide much greater LTE coverage and capacity, but with economics more akin to Wi-Fi. It is lower cost, and easier to install and maintain than traditional indoor solutions. Traffic stays on the LTE network, rather than migrating to Wi-Fi or a competitor's network. By 2020, we believe CBRS and other spectrum sharing opportunities could become a viable complement to, or substitute for traditional indoor small cells, DAS, and carrier Wi-Fi in many contexts.

Exhibit 2   Summary of Key Benefits of 3.5 GHz to MNOs

Benefit	Notes
Reduced Complexity	• Less need for situational evaluation of alternatives (i.e. DAS, Wi-Fi, etc.) • MNO in greater control of in-building solution • MNO in greater control of how spectrum is utilized
Lower Costs	• Capex more favorable than traditional DAS, Wi-Fi • Opex cost reductions – billing, customer care, backhaul • More efficient use of spectrum resources (i.e. macro offload) • Lower churn
Revenue Enhancement	• Higher ARPU potential • Lower churn • Increase share in enterprise segment • Customer acquisition potential (3.5 GHz a differentiator) • Keeping usage on cellular is more convenient for guests, if coverage/speed/capacity is sufficient • Possible premium service
Subscriber Experience	• Better coverage • Capacity, speed improvements • More seamless experience

A. Network Densification

Network densification is a leading use case for shared spectrum for MNOs. The structure proposed for the 3.5 GHz band presents an added, and important tool for MNOs to improve outdoor coverage and capacity. They are able to do at far lower cost than traditional spectrum auctions, or expensive alternatives such as DAS and carrier Wi-Fi. The FCC's rules allowing for increased power output for 3.5 GHz devices improves the densification business case still further.

B. Improved In-Building Coverage and Capacity

Improving coverage and capacity for indoor wireless is one of the key strategic priorities of operator network executives. Providing good in-building wireless coverage and adequate capacity continue to be a challenge in many situations. Despite the need to improve in-building coverage, there have been few solutions that have found significant scale. They're either too expensive, complex to deploy, or the business model is not workable in large numbers. And because indoor small cells are tied to a particular operator, it is difficult to get enterprises or building/venue owners to fund these deployments.

Distributed Antenna Systems, which provide a neutral host solution, are effective for outdoor coverage and capacity, and also make sense for certain large venues, such as stadiums. However, they can be an overkill solution in certain contexts, both in terms of cost and time to deploy, at an enterprise level.

One could view spectrum sharing as the opening up of a new market opportunity for the traditional DAS/neutral host model. It is more cost effective, and can be deployed more quickly than traditional DAS. Additionally, the on-demand nature of shared spectrum means that MNOs can acquire whatever network capacity they need.

Today, every indoor deployment is situational for an operator. Depending on the type of customer and building size/type, an MNO must evaluate three options: indoor small cell, carrier Wi-Fi, or DAS. Shared spectrum is an appropriate solution for most of these contexts, making the decision-making process simpler.

C. Quality of Experience

A common argument against traditional in-building solutions is that Wi-Fi provides a suitable alternative. Wi-Fi offers a compelling solution, but additional in-building wireless coverage would be a good complement. Some key areas of value-add include:

- **Improved capacity**. 2.4 and 5 GHz Wi-Fi channels can get congested in many in-building environments. Mobile Ecosystem research indicates that in public or quasi-public venues such as hotels, convention centers, stadiums, and restaurants/cafes, the average LTE speeds experienced by the user exceed that of Wi-Fi 50% of the time. This is a huge change from several years ago where Wi-Fi was the default for in-building.

- **Enhanced Coverage**. Even where enterprise Wi-Fi is deployed, it can't be everywhere. LTE might be a good complement to Wi-Fi in certain contexts.

- **Quality of experience**. Keeping users on the LTE network offers a seamless and consistent quality of experience. For example, there might be situations where an enterprise or venue owner might prefer that users, such as visitors, stay on cellular, rather than having to provision extra Wi-Fi capacity, guest access, and so on.

- **An additional option for coverage and capacity.** Deploying additional access points to improve Wi-Fi coverage and capacity makes sense in certain contexts. LTE can be a complement or substitute in certain venues. For example, a hospital might prefer that visitors stay on LTE rather than use Wi-Fi in the building.

D.   *Keeping The Subscriber on the Network*

With the added capacity gained through spectrum sharing, operators can keep customers on the network. Not only does this save the cost of elaborate network offload strategies, but if cellular network quality and coverage are good, the customer would much rather stay on the network. This also provides revenue enhancement opportunities for the MNO: the subscriber might choose a larger 'data bucket,' which increases ARPU; and/or the MNO might be able to charge separately for shared spectrum in some contexts.

E.   *Competition*

Finally, MNOs might need to consider a shared spectrum model for competitive reasons. There are two angles here. First, improved coverage and capacity can certainly be a competitive advantage vis a vis other MNOs in the market. This could be a reason to choose MNO A over MNO B. Second, we believe that over time, the number and type of competitors to the MNOs will continue to intensify. This could include cable companies, Internet companies such as Google, MVNOs, Wi-Fi players, and other entities who were involved in the 600 MHz auctions, exploring LTE Unlicensed, or are in the early stages of considering 5G.

As the competitive landscape expands and intensifies, this is an opportunity for the MNOs to prevent customer migration to alternative service providers.

F. *Complement to Other Combined Services Such as LAA and MulteFire*

There are numerous options emerging in unlicensed services as a complement to traditional licensed spectrum. MNOs are looking at LAA as a way of expanding capacity, using channel aggregation with their licensed spectrum. There are also options emerging for Wi-Fi centric companies that do not require a licensed anchor, such as LWA and MulteFire. The industry is moving forward on ways to better leverage WLAN infrastructure. Shared spectrum could be a suitable complement to these initiatives.

3. <u>Business Use Cases</u>

Mobile Ecosystem believes there are four primary use cases for shared spectrum for mobile network operators, as outlined below.

A. *Enterprises*

We believe that the enterprise market presents the most compelling near-term opportunity. This is where the need for greater coverage and expanded capacity is most acute. As described earlier, enterprises have been looking for indoor small cell solution for years, but the economics and business framework have proven challenging.

Spectrum sharing presents the opportunity for a neutral host small cell/DAS network for enterprises. We believe that the economics are different enough from traditional small cells that enterprises or building/venue owners could be involved with some of these deployments. It is also possible that a tower company or systems integrator wholesale the solution using a neutral host model, and then the MNO would purchase capacity on that system.

Building and venue owners would view providing superior wireless coverage and significant network capacity over a building envelope as one of the features/benefits of that venue in order to attract tenants—much like utilities, LEED/green initiatives, and so on. This could also take the load off enterprises having to deploy Wi-Fi as extensively.

B. *Particular Verticals*

Mobile Ecosystem believes that there are certain types of buildings or venues for which shared spectrum is particularly suited. Some examples are in the table below.

Exhibit 2   Target Verticals

Vertical	Benefits of Shared Spectrum
Hospitals	• Complement Wi-Fi network • Secure, dedicated network to manage competing interfering devices • Large number of outside users/visitors
University Campuses	• Large number of users moving in and out of buildings • Wi-Fi coverage can be a challenge for every building • Extra capacity needed for multimedia • Diversity of MNO relationships speaks to need for hosted solution
Hospitality/Hotel	• Improve indoor wireless coverage and capacity • Balance traffic between Wi-Fi and cellular, and possibly charge for premium service • Keeping customers on LTE might be preferable to some building/venue owners
Sporting Venues	• Complement Wi-Fi network • High capacity LTE services more cost-effective than DAS • Elastic, event-driven network (add capacity as needed) • Premium fan services such as in-game highlights, statistics, and other featured content
Retail	• Subscriber continuity of cellular • Traditional DAS solutions not suitable for most retail locations

C.   Coverage/Capacity Boost

The recent FCC ruling allowing higher output power for 3.5 GHz small cells adds an opportunity to provide coverage and capacity augmentation in certain *outdoor* locations/contexts. Historically, these situations have been addressed by DAS, or carrier Wi-Fi solutions. Now, we have a new and potentially superior option in certain contexts: neutral host, less expensive, and faster to deploy. Additionally, traffic demand in these sorts of scenarios is dynamic and changeable, which lends itself to a more flexible spectrum sharing framework.

D.   Last Mile Access

We also see the potential for last-mile access. This could be used for backhaul purposes in Non-Line-of-Sight (NLOS) situations, or as a less expensive alternative for short range backhaul. For MNOs, this provides a less expensive way to increase capacity, and opens up revenue opportunities for fixed wireless type services.

4. Framework/Economics

The approach being taken for the 3.5 GHz band places the United States at the forefront of how network services will evolve. Relying on a spectrum sharing scheme and a cloud-based hosting model, MNOs will acquire network resources on

an as-needed basis. Shared spectrum provides the benefits of a neutral host DAS for only a slight price premium over Wi-Fi.

The business framework being proposed by certain potential SAS vendors is for a cloud-based subscription model. The enterprise or MNO acquires the spectrum on an as-needed basis.

Advantages of a Neutral Host Model
• Allows for multi-operator framework to be used, much like DAS, for indoor and enterprise market
• Improves the customer experience compared to Wi-Fi by maintaining QoS of LTE and reducing issues associated with Wi-Fi, such as interference
• Increases opportunities for cost sharing – enterprises, building/venue owners
• Greater likelihood that other parties will deploy access points: systems integrators, tower companies, building owners, enterprises
• Significantly lower cost of service than in a single operator environment

The cloud-based approach is necessary for effective nationwide operation of the shared spectrum network, providing scale (up or down), elasticity, processing power and data storage – all dynamically. For the operators, it allows for a subscription-based pricing model, a la AWS, so the MNO can buy only what they need on a highly flexible basis. As a result, MNOs can increase the variety of their service offerings by putting together efficient pricing structures, such as a "pay for what you use" model, for their customers.

5. Go-to-Market

MNOs are going to have to get comfortable with three game-changing elements enabled by spectrum sharing: the idea of a neutral host solution (which they have already done for DAS); an expanded ecosystem of potential partners, such as SIs and building owners; and new/alternative business models for mobile services (cloud/subscription based). CBRS should be an important part of an operator's broad strategy to leverage unlicensed spectrum.

Deploying spectrum sharing is not akin to adding another set of channels, such as in a carrier aggregation scenario. It requires a specific go-to-market strategy, like any new product or service.

We believe the following are the key ingredients to a successful MNO go-to-market strategy:

- **Test/Trial spectrum sharing.** MNOs, MSOs, and other organizations are actively engaged in trial activity. We believe these trials should include:

- Working with enterprise customers, and/or building or venue owners. Pick a key target vertical, such as hospital or hospitality
- In cooperation with other MNOs, test the feasibility of a neutral host solution

- **Determine primary use case on a per opportunity basis.** What is the mix of coverage vs. capacity?

- **Build a sales and business development organization.** Determine which types of customers will be acquired via direct sales and which will be through partners, such as tower companies and systems integrators. The partner development organization will forge relationships with SIs, venue owners, and so on. This organization will need to be knowledgeable about the economics and have business models at the ready.

- **What are situations where spectrum sharing will be MNO specific vs. shared/neutral host?**

- **Build business cases**, to determine which types of opportunities are appropriate for shared spectrum vs. alternatives, such as Wi-Fi, LAA, DAS, conventional small cell, etc.

- **Business cases and models should also delineate how cost responsibilities shall be shared**, depending on the opportunity, between MNO/enterprise/venue owner?

- **Develop business models/cases to classify type of opportunity (internal)**
  - Customer retention?
  - Revenue enhancement?

- **Develop a pricing model** for different situations/customers/contexts
  - As an extension of licensed services—no extra charge
  - Premium charge for enhanced capacity/coverage, where customer shares in the cost of deployment
  - Are any charges for hardware passed on, or are charges only for services?

It will also take some time and experience with spectrum sharing to determine what types of opportunities are PAL vs. GAA, and how to value the spectrum and temporary licenses.

Conclusion

We are particularly excited about the shared spectrum and 3.5 GHz band opportunity, for three reasons. First, it unleashes a game-changing amount of spectrum, allowing for a new way of thinking about capacity and coverage. Second, it provides a potentially viable solution to what has heretofore been an intractable problem: in-building wireless coverage. Third, this represents true business model innovation, vaunting the U.S. to a global leadership position. We believe the spectrum sharing market will be led, particularly at the outset, by mobile network operators. There is opportunity to help solve the in-building challenge, in an economically favorable manner, while opening up new opportunities in the enterprise and at venues.