



Multi-Carrier Small Cell Solutions for In-Building Wireless

Taking a Closer Look at Underserved 'Middleprise' Venues

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INTRODUCTION

Economically viable in-building solutions have become critical as mobile carriers expand and densify their 4G LTE networks and begin planning 5G access solutions to meet the ever-increasing capacity requirements.

This whitepaper presents the market trends and technologies that are enabling the critical evolution of small cells. The cost advantages of neutral host access and cost effective radio access network (RAN) sharing allow the underserved enterprise customers to 'take control of their own destiny' in getting high quality cellular service into their premises, with CapEx and OpEx savings of 50-80%.

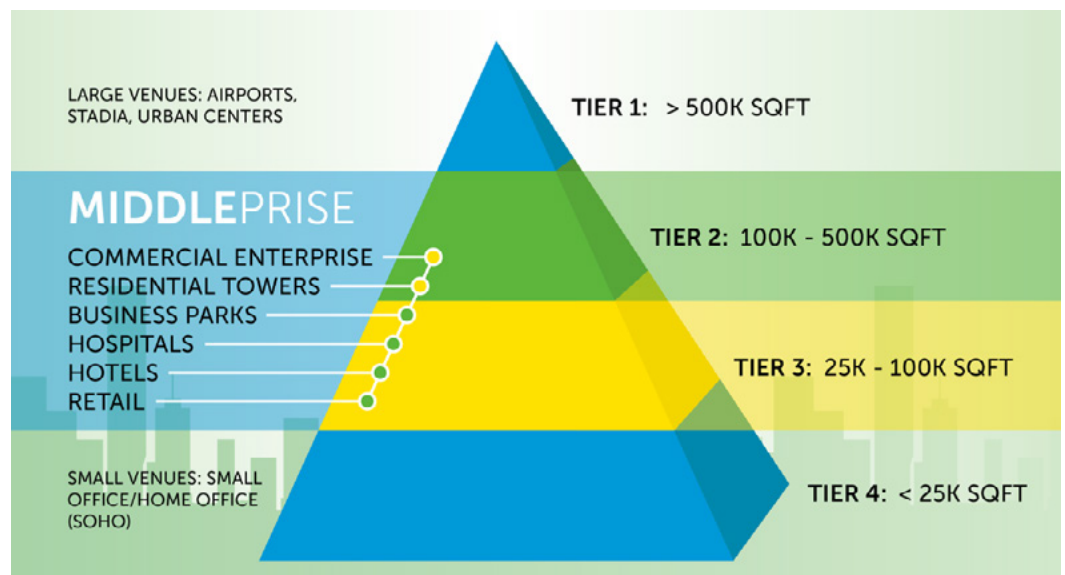
Today's in-building voice and data solutions can be classified as:

- **Distributed Antenna Systems (DAS)**
DAS solutions have been able to provide multi-carrier networks in the largest venues, such as stadiums and airports. These are often venue or carrier sponsored.
- **Single Carrier Small Cells**
Providing coverage for a single carrier in a building with no mobile reception or to support buildings with sporadic or poor coverage. This is usually a mobile carrier sponsored solution.
- **Multi-Carrier Small Cells**
Supporting the emerging need of multi-carrier in-building solutions. This is a neutral host or Enterprise sponsored solution.

For the great majority of enterprises, the high cost of DAS solutions is prohibitive, and the needs of this market segment are not well served by most mobile carriers. Exhibit 1 demonstrates that the 'Middleprise' is a large segment of the in-building wireless market covering small and medium-sized commercial buildings, hotels, hospitals, colleges and even small retail stores. This segmentation scheme for the in-building wireless market was initially developed by DAS vendor SOLiD, and has been enhanced by Wireless 20/20 research. These venues can benefit from a cost-effective neutral host small cell solution flexible enough to support multiple carriers.

Wireless 20/20 observes that several current trends in the mobile market are defining a new "universal service" standard for cellular coverage, capacity and quality of service for every mobile user, regardless of the mobile carrier affiliation, as a cornerstone for the 'Middleprise' segment of the in-building wireless market.

Exhibit 1
*Middleprise Market for In-Building
Wireless Network Solutions*



Source: SOLiD and Wireless 20/20

It is increasingly critical that residents, visitors and workers have access to strong and reliable coverage in order to properly make use of their mobile devices. A recent global survey of building managers, facilities managers, real estate managers and architects conducted by Coleman Parkes revealed that indoor wireless coverage could increase a property's value by 28% on average, meaning that a \$2.5 million office building could be worth \$700,000 more with a dedicated indoor cellular system. Despite this, the survey commissioned by CommScope revealed that only two percent of commercial buildings have dedicated technology to ensure strong and reliable indoor mobile coverage and capacity.¹

Many companies now offer employees the freedom of BYOD (Bring Your Own Device), and visitors depend on good mobile service as a requirement in 'Middleprise' commercial buildings, hotels, hospitals, colleges and retail stores. As people have grown reliant on connecting to cellular networks wherever they go, only 30% of those small and medium-sized businesses believe their in-building coverage is sufficient to handle rapidly growing volumes of mobile traffic.²

TRENDS IN IN-BUILDING WIRELESS NETWORKS

Several key trends contribute to the need for improved in-building wireless networks:

- Increased adoption of smartphones and tablets.
- Changes in building construction standards (esp. LEED) that prevent outdoor coverage from penetrating indoors
- Introduction of IoT devices.
- Eighty percent of traffic is generated indoors for mobile carriers based on Small Cell Forum research and data from the Cisco VNI survey (2016).
- The expansion of BYOD usage in enterprise environments means that multi-carrier mobile service is now a mission-critical requirement.
- Quality wireless service has become the expected norm, including inside offices, in hospitality environments, retail environments or any place of entertainment.
- Venue owners have seen occupancy rates fall as a result of poor cellular service, even with good Wi-Fi coverage in the building.

These trends have pushed carriers to invest in larger, high-profile venues like stadiums, large commercial buildings and airports. Small and medium-sized venues, that are still seeking a cost-effective solution, far outnumber the larger venues. A recent survey conducted by WiredScore reveals that prospective Tier 2 Venue tenants rank cost, location and connectivity (including mobile communications) over access to transportation, quality of building management, environmental sustainability of the building, and features such as gyms and rooftop spaces.³

The underlying message: **Indoor cellular connectivity is not an amenity. It is an absolutely essential utility like heat, light and electricity.**

As Ken Sandfeld, President of SOLiD NA said in a recent AGL Magazine article "in-building wireless looks less like a real estate play where third parties lock up venue rights and more like a utility to be provided by the building owners".⁴

As a general rule, only large venues over 500k sq ft have been candidates for an expensive, multi-carrier, in-building DAS network. Compared to the Tier 1 Venue market, the Tier 2 and Tier 3 building universe is more than 15-times larger and, heretofore, virtually unserved.

Exhibit 2 highlights the Tier 2 and Tier 3 'Middleprise' market segments representing venues from 100-500k sq ft and 25-100k sq ft respectively that can also be served by multi-carrier small cells. To be sure, both Tier 2 and Tier 3 venue segments represent a large and rapidly growing market opportunity for in-building wireless solutions, with increasing revenue to compete for each year.

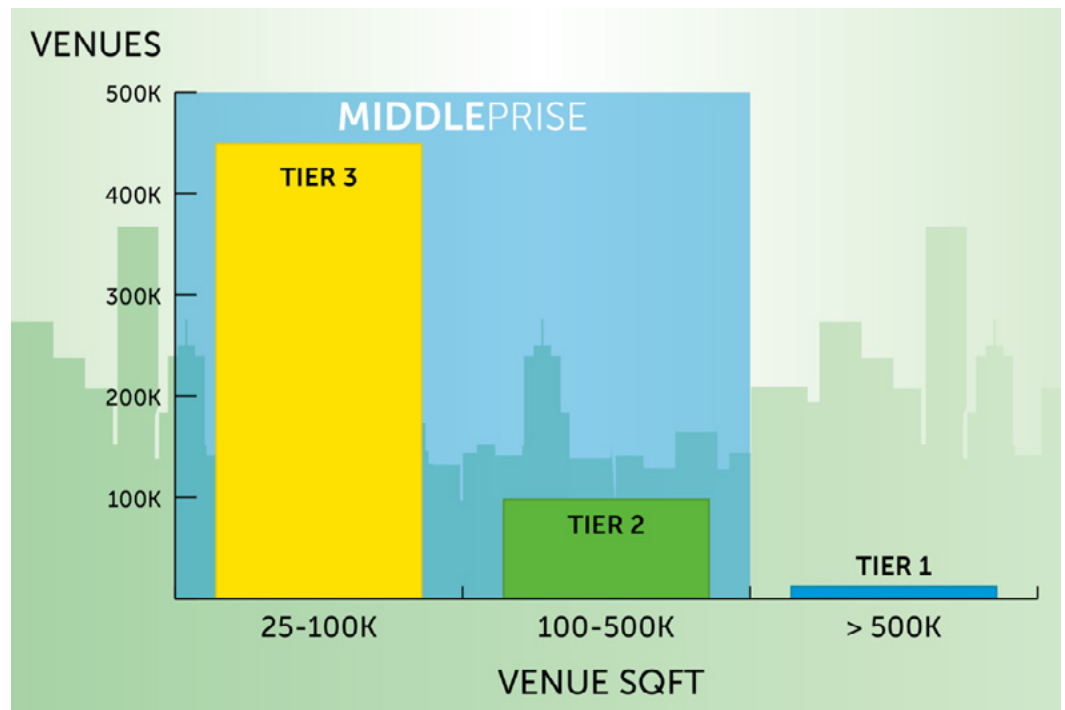
The Tier 2 venue market segment, within 'Middleprise', consists of venues from 100-500k sq ft corporate and multi-tenant high-rise buildings, hotels, retail, smaller hospitals and educational institutions. There are approximately 99,000 Tier 2 venues in the US, according to data from the Rocky Mountain Institute⁵. In these venues, cellular connectivity has

become an expectation commonly described as the “fourth utility” to enable business and personal communication, academics collaboration, healthcare, ecommerce, entertainment and safety applications, as well as many others.

Skyline Marketing projects the U.S. Tier 2 Venue Serviceable Available Market (SAM) for in-building wireless networks to grow to \$1.4bn by 2021⁶. Wireless 20/20 estimates these Tier 2 venues, defined as venues between 100-500k sq ft, represents a \$20bn global market of which less than 2% has been addressed with any sort of in-building cellular coverage solutions.

With the simple introduction of the Neutral Host, capable of managing shared resources, including spectrum, on behalf of the mobile carrier, this segment becomes immediately addressable. Development of a cost-effective solution is key to tapping this potential growth market. Carriers understand the need to improve in-building coverage as one of the highest priorities in improving their networks. But it is a cost and resource challenge for each carrier to expand their coverage to every building that they would like to cover.

Exhibit 2
Distribution of U.S. Commercial Buildings by Size



Source: Rocky Mountain Institute

Two challenges must be met to unleash this potential growth market:

- Shared access technology that can reach the cost points needed to provide a positive cost basis for the carriers.
- A business model that benefits all the constituents concerned with excellent in-building wireless service.

Traditionally, an in-building network solution would include a combination of:

- DAS solution: A DAS solution can support multiple carriers over one antenna network distributed throughout the building. This can be effective from both a cost and resource standpoint. But the overall cost of the overhead for a DAS network makes them most cost effective for larger venues.
- Small Cell solution: A small cell solution has been favored in cases where only one or two carriers might be present in a building, or specific areas of a building might be covered. Small cells are cost effective and targeted. Small cells can also augment DAS networks with targeted coverage and capacity. But when multi-carrier coverage is

needed, typically it is required to have a set of small cells for each carrier, adding cost and complexity of installation and management. While there are companies making a business from this model, there is a better way, as we shall see later.

Each of the stakeholders can derive value from an improvement in the wireless support in a particular building or venue, if the business model makes sense. In all scenarios, starting with a lower cost basis, regardless of the business model approach, provides more options and opportunities to reach an acceptable deal among the parties. Some examples include:

- The venue owner can benefit from the value of excellent wireless service in its venue.
- A commercial building owner may achieve a higher rent to support the cost of the in-building network CapEx and OpEx.
- Building owners see the benefit of improved coverage directly in their tenancy rates.
- In other business models, the carriers ultimately pay for the service since network represent extension of their macro networks.

A reduced cost base also expands the market by extending the carriers' reach into low traffic, but high value areas cost-effectively.

REQUIREMENTS FOR IN-BUILDING WIRELESS SYSTEMS

The Tier 2, 'Middleprise' segment of the in-building wireless market includes hotels, hospitals, colleges, retail, and multi-level commercial office buildings. If this is extended to include Tier 3, smaller venues such as retail stores and restaurants, the market for low cost multi-carrier in-building network solutions is even larger.

- Enterprise Buildings: In a large high rise enterprise building, it is likely that there are multiple tenants. This means there is a strong requirement for multi-carrier support. In the past, some companies may have had a contract with a particular carrier. But with the advent of smart phones, companies continue to move to a BYOD (Bring Your Own Device) approach. The trend is multiple carrier support, not single carrier.
- Middleprise' commercial buildings have been largely ignored in in-building deployments, still have the same requirements for multi-carrier networks.
- Shopping malls and retail: A large shopping mall has a dense user population, so often they are capacity limited more than coverage limited. Since anyone can be shopping in a mall, coverage is needed for all carriers. A DAS network can provide a multi-carrier solution for large shopping malls, but these smaller retail environments still need a multi-carrier solution without the cost overhead. In small shopping centers, both individual stand-alone shops and the shopping center owner benefit from a small cell solution capable of multi-carrier operation.
- The hospitality sector: hotels and conference venues, schools and universities and medical facilities have a similar set of requirements, with high levels of non-resident, transient subscribers generating medium levels of traffic, with specific hotspots in hotel atria, canteens, common spaces, and so on.

In common with almost all of these use cases is the high level of operator independent traffic. Any enterprise campus landlord, hospital administrator or retail owner will expect to serve subscribers from all the mobile carriers, not just one or two. And the evidence is that subscribers complain to the building, rather than the carrier when service is lacking. And as we see anecdotally, that complaint is often silent and only felt in empty offices, retail units and apartments.

In-building networks for the 'Middleprise' are sometimes provided and sponsored by a single carrier for a much-targeted subscriber base. As the figures show, this is not a model that scales. The 'Middleprise' owners will invest in solutions that benefit them and their customers, but object to paying to extend one carrier's coverage. As the market continues to develop, more venues will require comprehensive in-building solutions. And each venue has a different set of requirements. Many 'Middleprise' venues can take advantage of more cost effective, multi-carrier small cell solutions.

When carrying out research for this whitepaper, we identified an example in a central London shared workspace: occupancy was unaccountably stuck at 40% until the landlord started asking potential tenants why they were looking elsewhere. After installing multi-carrier in-building cellular, occupancy grew steadily to 96%.

MULTI-OPERATOR SMALL CELL SOLUTIONS

Wireless 20/20 has conducted a thorough study of multi-carrier small cell network solutions to determine which are best at meeting the needs of 'Middleprise' venues. The critical question is which solutions can provide the multi-carrier capabilities needed for most venues at a cost point which can encourage a faster rate of deployment. While small cells can meet the cost-points required for in-building coverage, they have been challenged to provide coverage for more than one carrier at a time.

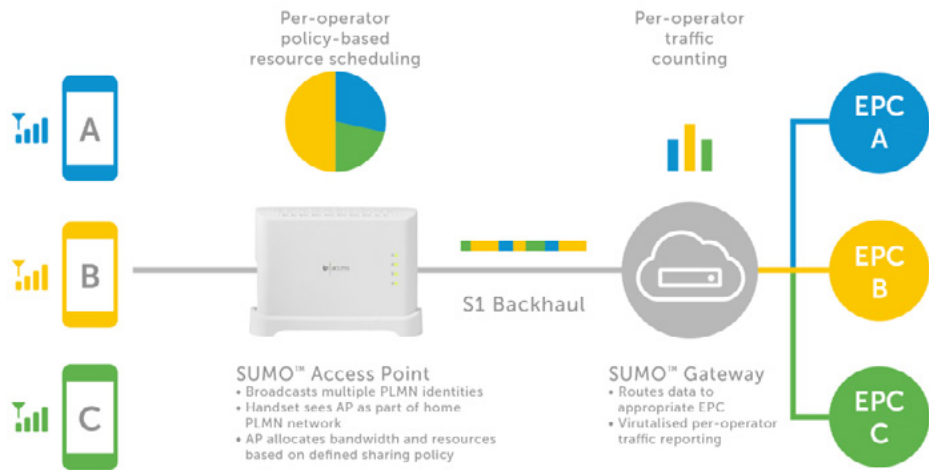
But new virtualized small cell solutions have become available that can face the challenge of addressing the economic and multi-carrier requirements of the small and medium size venues.

Small cell innovator ip.access has introduced Viper™, an enterprise RAN platform, which allows Neutral Host controlled resource and capacity sharing. Viper™ is a virtualized small cell platform which can be optimized for venue owners, mobile carriers and neutral host carriers. Exhibit 3 provides a summary diagram for the Small Cell Solution from ip.access targeting the 'Middleprise' venue market. The Viper™ Virtualized Integrated Platform features ip.access' innovative SUMO™ multi-operator capability enabling one small cell access point to provide in-building coverage for all MNO networks, thus minimizing costs, footprint and disruption.

Viper™ integrates ip.access' award-winning 4G Access Points, virtualized Access Control Gateways and Small Cells as a Service (SaaS) offerings into an end-to-end enterprise-focused solution that simplifies small cell deployments and addresses the unique needs of small and medium enterprise customers. Security, automated provisioning and network configuration are an integral part of the Viper™ platform, with access points requiring only Ethernet and mains power connections. The Viper™ platform allows in-building cellular infrastructure to be deployed as easily as Wi-Fi, allowing service partners and enterprise customers to easily rollout new sites without burdening the network operator, with the Viper™ platform taking care of new cell provisioning.

The ip.access' Viper™ platform also supports Super Multi-Operator (SUMO™) capability as a fully featured commercial multi-operator small cell platform. SUMO™ is the new ip.access' technology for neutral host deployments. This unique set of capabilities is a real game changer for bringing neutral host small cells to in-building networks, especially in small to middle size venues that cannot afford current in-building DAS solutions. Viper™ with SUMO™ capability incorporates a variety of small cell Access Points suitable for medium, small enterprise and SoHo users. Viper™ Access Points support a wide range of worldwide frequency bands and spectrum access methods, including traditional licensed operation, Citizen's Broadband and Licensed Shared Access. The fully virtualized 4G Access Controller gateways in Viper™ provide industry standard interfaces to the operator's core network and Operations Support System (OSS), and can be cloud hosted, or deployed on dedicated server hardware.

Exhibit 3
ip.access SUMO™ Neutral Host
Small Cell Solutions
Part of the Viper™ Platform



Source: ip.access

THE GROWING IMPORTANCE OF NEUTRAL HOST ENTERPRISE SMALL CELL SYSTEMS

There are two options to provide connectivity if multiple carriers are to be supported in an in-building network:

- 1) support all the frequencies required for each of the carriers
- 2) find one neutral spectrum which can support all the traffic for all the carriers

Typically, carriers prefer all their frequencies be supported by a Neutral Host Enterprise DAS or Small Cell System. But this leads to a network supporting a dozen or more frequencies, which is expensive for the radios, infrastructure, and mobile carrier BTS equipment necessary for a complete DAS network.

If one frequency can be used in a small cell network, this leads to a much more efficient system and a lower cost basis. The development of Neutral Host networks is one of the most important trends in the broadband wireless industry today. As individual mobile carriers look to deploy their own solutions in small and mid-size venues, the cost for providing this additional coverage may not justify the benefit for the improved service. Yet, if a third party can provide one shared infrastructure, such as DAS, small cells or Cloud RAN that can support all carriers in a venue, the economics suddenly turn in favor of both the Neutral Host provider and the mobile carriers.

Exhibit 4 provides a diagram of the ip.access Viper™ virtualized small cell solution using Neutral Host controlled resource and capacity sharing spectrum obtained from one of the mobile operators. Where the regulator allows it, mobile carriers can agree amongst themselves to use a single spectrum band from one of the carriers.

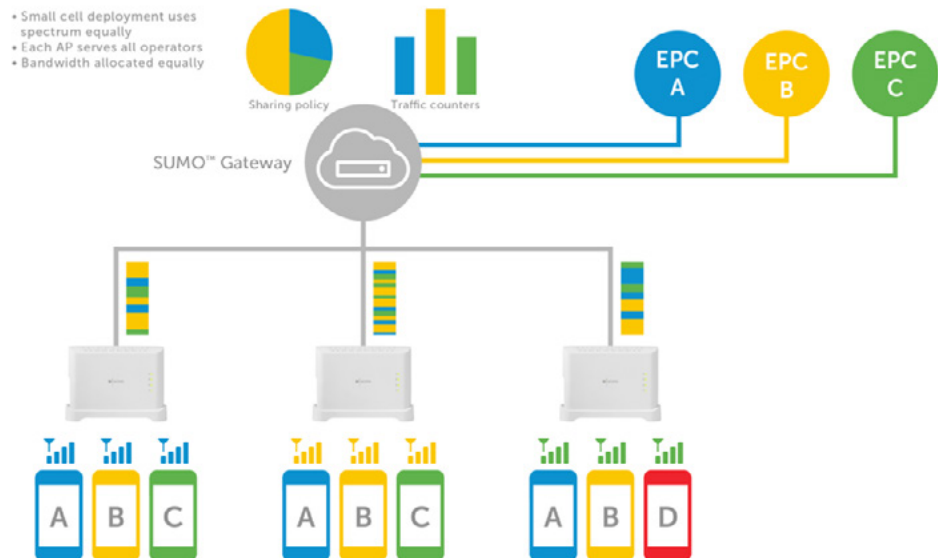


Exhibit 4
Viper™ Deployment with FairPlay
Contributed Spectrum

Source: ip.access

The new Viper™ platform also provides per-operator reporting of voice and data traffic, enabling a variety of business models for shared multi-operator RAN. It simplifies small cell rollouts by providing a single, scalable interface to the mobile operator's core network, and offloads all small-cell specific signaling to the Viper™ gateway. All small cell provisioning, configuration management, KPI reporting, and fault/alarm monitoring are performed as a fully managed service.

The cost advantages of neutral host spectrum and cost-effective RAN sharing to allow these underserved 'Middleprise' customers to determine for themselves the high quality mobile voice and broadband service their businesses demand.

The ip.access Viper™ virtualized small cell solution can be deployed using shared or unlicensed spectrum. Two industry groups are working in these areas.

- The CBRS Alliance supports a neutral host shared spectrum using 3.5GHz light-licensed spectrum. 3GPP has now formally approved band 48 for the US CBRS spectrum (3550 to 3700MHz), overlapping with bands 42 and 43 already in place (3.4 to 3.6GHz and 3.6 to 3.8GHz). This was required for both smartphone and small cell vendors to proceed with product development.
- MulteFire is consortium of industry players that support LTE in the 5GHz band, which can support the users of all wireless carriers with a single RF carrier. The MulteFire Alliance expects to publish its specification during Q1 2017, and commercial availability will be mostly driven by handsets.

FINANCIAL COMPARISON OF IP.ACCESS VIPER™ AND DAS AND OTHER SMALL CELL SOLUTIONS

Wireless 20/20 conducted an analysis of several example "Middleprise" venues to better understand the potential financial impact of ip.access's unique capability to provide a multi-carrier small cell solution. While DAS solutions have been effective at providing multi-carrier service for larger venues, they proved costly in the small to medium size venues we tested in the analysis, both for the initial CapEx, and the on-going OpEx. While in some cases single-carrier small cells provide a cost advantage in the initial CapEx, the OpEx of supporting the many deployed units can lead to a high OpEx and TCO. However, when a multi-carrier capability like that offered by ip.access's Viper™ solution with SUMO™ capability is deployed, significant savings for both the CapEx of initial deployment and the on-going OpEx, as compared to a DAS or small cell without multi-carrier capability in the same deployment venue, can be achieved for the "Middleprise" venues that were modeled.

The test venues were set up on Wireless 20/20's award winning WiROI™ Neutral Host Venue Business Case Tool. Wireless 20/20 used the tool to evaluate three types of venues.

- Tier 4 Fast Food Complex
- Tier 3 Small Enterprise Building
- Tier 2 Medium-size Hospital

Each of these venues could benefit from improved mobile coverage and capacity, and as outlined in this white paper, require support for subscribers of all of the MNOs. The venues have been modeled in the WiROI™ tool to determine the coverage needed for each venue, the subscriber population, the estimated traffic use at each location, including the impact of Wi-Fi, and potential growth in traffic demand. In each case, the analysis modeled support for 4 major MNOs that would be required.

For each venue, we have captured the initial Year 1 CapEx to deploy the network, the total CapEx required over the 10 years of the business case, and the total OpEx for the 10 years of the business case to run the network. The model includes assumptions about typical costs compiled for developed countries from numerous previous test cases for in-building network deployments. In addition to the equipment costs, the costs have been identified for installation, backhaul, testing, commissioning and on-going maintenance of the network. All applicable operating costs, both for the network, and for marketing and organizational cost have been evaluated. The site rental, transport costs, system monitoring and maintenance, and customer support, have been included in the on-going costs.

We have compiled the results considering 3 technology options:

- DAS
- Small Cells without SUMO™ multi-carrier capability
- Small Cells with SUMO™ multi-carrier capability

Each technology has been modeled after leading vendor solutions using data gleaned from real deployments.

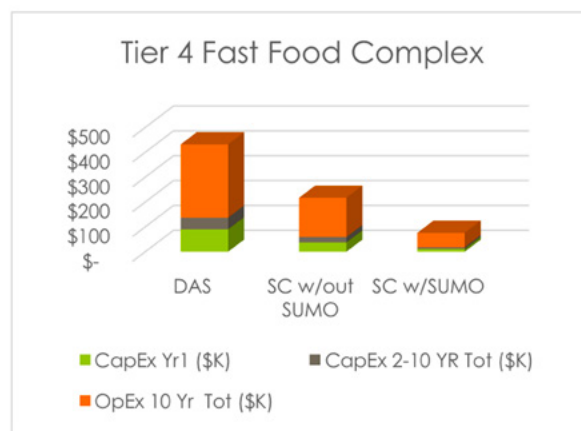
WIROI® TEST RESULTS

The analysis results show the impact of supporting each venue with each of the technology choices. In each case, these small venues could be supported in a more cost-efficient manner with small cells. According to the analysis results for the tested venues, a multi-carrier small cell solution with SUMO™ could offer a 50-80% TCO savings over 10 years.

The ip.access Viper™ platform support for SUMO™ multi-carrier operation provided several key benefits to the analysis. Far fewer small cells needed to be deployed at each venue, resulting in significant cost savings for both CapEx and OpEx. Also, the virtualized platform provided by Viper™ allowed cost savings for the required cost for deploying gateways and core network functionality, since this resource would be shared across a number of venues. As a result, each venue could achieve a better cost basis for any business model that could be pursued.

Exhibit 5 presents the analysis of a typical Tier 4 Fast Food Complex with multiple restaurants. In this particular case, there are 4 separate buildings. In this type of smaller Tier 4 venue, the overhead cost of the DAS network deployment could be onerous. Small cell solutions provide significant savings to the targeted coverage and capacity needed, for these kinds of venues. The SUMO™ capability in the ip.access solution would enable even greater savings. The WiROI™ model estimates that the neutral host would deploy 4 small cells, one in each restaurant. For this type of venue, the Viper™ virtual gateway also makes this deployment very cost effective.

These small Fast Food Complexes are very common across North America and Europe, usually situated beside a gas station, off the highway. Such venues are usually franchised and therefore must not be viewed in isolation, but considered as a significant in-building market opportunity.



Venue Statistics	Tier 4 Fast Food Complex
Total Coverage Area (square feet)	8,619
Total Subscribers	170
Venue Description	Small food complex with 4 separate buildings

Exhibit 5

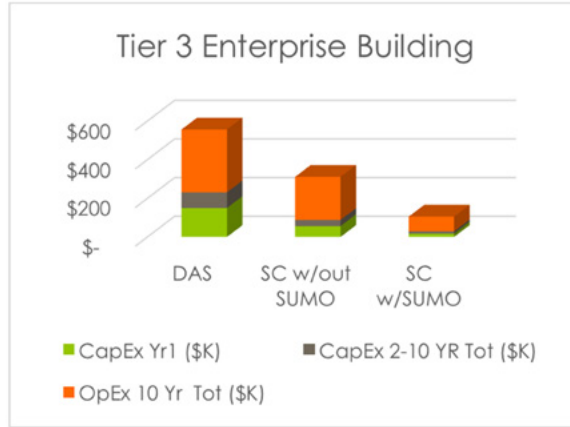
Comparison of DAS, Single Carrier and Multi-Carrier Small Cells for Tier 4 Fast Food Complex

Source: Wireless 20/20 using Custom WiROI™ Neutral Host Venue Business Case Tool

Wireless 20/20 applied the same analysis to a medium-size Tier 3 enterprise building, as depicted in Exhibit 6. This venue is a long narrow building with 3 floors. A building like this may have multiple tenants or could be occupied by one larger single tenant. The WiROI™ model estimates that 6 small cells would be needed to cover this building.

In a typical small cell solution a neutral host would need to deploy multiple sets of small cells for each MNO. The small cell solution without the SUMO™ feature can provide some CapEx and OpEx savings over the DAS solution. But the streamlined, shared infrastructure of the SUMO™-based small cell solution provides significant cost savings for both CapEx and OpEx for multi-carrier deployments. As is shown in Exhibit 2, a majority of enterprise buildings fall into the category. In almost any market, there would be many thousands of buildings that could be targeted to take advantage of such a multi-carrier solution.

Exhibit 6
Comparison of DAS, Single Carrier and Multi-Carrier Small Cells for Tier 3 Enterprise Building

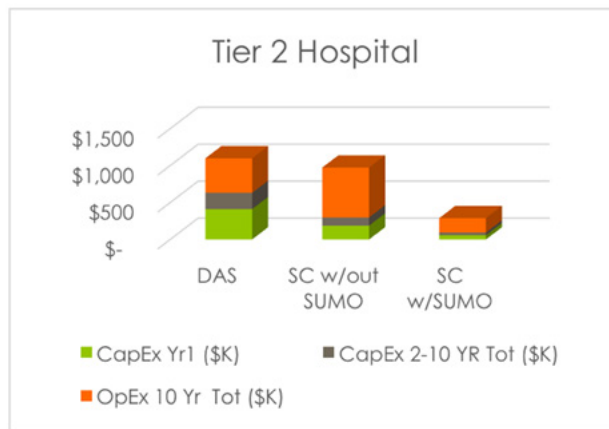


Venue Statistics	Tier 3 Enterprise Building
Total Coverage Area (square feet)	71,016
Total Subscribers	450
Venue Description	Medium size, long narrow enterprise building with 3 floors

Source: Wireless 20/20 using Custom WiROI™ Neutral Host Venue Business Case Tool

Exhibit 7 presents focuses on a Tier 2 hospital located in the US, the largest of the venues that were analyzed. As a larger, 4-story medical facility, this venue could potentially support a DAS solution. Because of the large number of staff and public that are visiting the building, multiple carrier operations is a requirement. The WiROI™ Tool estimates that 20 small cells would be spread throughout the building to provide coverage. While a typical small cell solution would be effective for 1 or 2 carriers, a larger facility such as this hospital, would have a higher OpEx since many more small cells would be deployed, leading to higher small cell rental charges from the building owner. Here, a SUMO™ solution becomes a much more favorable option versus both DAS and a non-SUMO™ small cells, providing a much lower CapEx and OpEx. This facility is typical of larger hospital facilities. Similar economics would likely apply to Tier 2 buildings of all types, including enterprise buildings, larger retail venues and hotels.

Exhibit 7
Comparison of DAS, Single Carrier and Multi-Carrier Small Cells for Tier 2 Hospital



Venue Statistics	Tier 2 Hospital
Total Coverage Area (square feet)	250,708
Total Subscribers	325
Venue Description	Major US medical facility with 4 floors

Source: Wireless 20/20 using Custom WiROI™ Neutral Host Venue Business Case Tool

CONCLUSION

As the demand for more and more capacity continues to accelerate, indoor mobile networks are required to provide cost-effective and highly scalable solutions for all subscribers in “Middleprise” venues, which make up the vast majority of commercial buildings. These small and medium size buildings demand a new solution that can extend the benefits of in-building multi-carrier networks to tenants in these smaller venues, but at a more cost-effective price point. The ip.access Viper™ solution, with its virtual core and multi-carrier SUMO™ capabilities, can provide the CapEx and OpEx savings of up to 80% that enable a successful business model for a neutral host operator to quickly capture a large market share in one of the fastest growing segments of the wireless industry.

Footnotes:

1. Coleman Parkes survey of 600 building managers, facilities managers, real estate managers and architects across the US - to explore this untapped business opportunity and consumer need. <http://www.businesswire.com/news/home/20160210005250/en/Building-Professionals-Indoor-Mobile-Systems-Increase-Property>
2. The seventh edition of the CommScope Global Enterprise Survey of more than 1,100 IT professionals from 63 nations participated in the tri-annual research. <http://www.commscope.com/NewsCenter/PressReleases/Mobility-and-Cloud-Services-Identified-as-Top-Network-Challenges-Facing-Organizations/>
3. New Approaches Needed to Unlock the Enterprise Market, Mike Collado, Principal Consultant, Wireless 20/20, December 15, 2016. <http://www.aglmediagroup.com/new-approaches-needed-to-unlock-the-enterprise-market/>
4. SOLiD's Sandfeld Looks to Change In-building Wireless Economics, J. Sharpe Smith, AGL Magazine, November 24, 2016.
5. Rocky Mountain Institute, Distribution of US Commercial Building Stock by Size, 2011.
6. Sizing the In-Building Wireless Systems Market, John Celentano, August 18, 2016. <http://www.aglmediagroup.com/tag/skyline-marketing-group/>

This White Paper was co-authored by Berge Ayvazian and Randall Schwartz, Senior Analysts and Principal Consultants of Wireless 20/20 in association with ip.access.. Wireless 20/20 helps mobile operators and their vendors develop their Wireless Network launch strategies, service offerings, marketing plans, technology roadmaps and business cases. More information about the WiROI® Neutral Host Network Venue Business Case Analysis Tool can be found at www.wireless2020.com/WiROINeutralHost/. More information about ip.access is available at www.ipaccess.com.

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