COMMSCOPE®

IN-BUILDING WIRELESS BEST PRACTICES

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CHAPTER 1

The history and future of in-building wireless solutions

The history and future of in-building wireless solutions

Bringing the outdoor wireless network indoors

Where it all began

In the 1980s, when the first wireless telephones hit the market, one of the first obstacles they met—apart from their clunky shape—was the fact that, when people sought a mobile connection, they often did so indoors. The issue was that the macro cellular network—the wide-area coverage provided by cell towers—had trouble penetrating walls and windows. As soon as the first cell phones dropped a call in a sunny, glass-walled lobby, the seeds of the first in-building wireless (IBW) solutions were planted.

To use a wireless network indoors, you must bring the network with you—or at least part of it. IBW solutions include a number of different technologies, each with their own applications. We'll briefly cover the technical distinctions of two major families of these solutions, DAS and small cells, later in this chapter and discuss them in more detail in Chapter 5. But one thing all IBW solutions have in common is that they are designed first and foremost to supplement the macro wireless network—that is, cellular service—by deploying coverage within an indoor area.

The birth of in-building wireless technology

Because they are designed to route cellular voice and data traffic onto wireless operators' macro networks—a process called backhaul—IBW solutions have evolved alongside the wireless networks themselves.

The first IBW solutions included an off-air repeater on the roof of the building, connected by coaxial cable in a passive distribution network that relayed signals from within the building to the outside, and vice versa. These were used in sprawling indoor spaces like airports.

Because these indoor systems could be expensive to deploy and optimize, they were generally only used as a niche solution in highly-customized installations. Wireless operators were the only source of such solutions, since the technology needed to interface with their macro networks. While this freed the enterprise from assuming the cost of an IBW system, it also limited the number and types of locations where IBW solutions could be practically—and profitably—deployed.

Since wireless operators had to prioritize installations based on opportunity and variable costs, they were also sensitive to regulatory requirements and other cost variables that affected the potential viability of an IBW solution. For instance, some jurisdictions require that such a solution also provide support for public safety frequencies.

As effective as they were, IBW solutions remained a niche solution with availability governed exclusively by operators well into the 1990s. The enterprise owner, manager or architect generally had little or no input to the selection process. But all that was about to change.

IBW FAST FACTS

CommScope has been a part of IBW since the beginning. We were privileged to create solutions for dozens of large venues all over the world, including:

- 24 of 31 National Football League stadiums across the United States
- 6 of the 10 busiest airports in the world
- The sprawling infrastructure of the 2012 Summer Olympic Games in London

Growing networks, growing potential

As wireless operators fully adopted 3G in the late 1990s and early 2000s, exploding demand for 3G's new Internet capabilities radically changed the playing field. Stadiums full of rabid fans who could now upload pictures, browse the Internet, and more—right from their seats—not only pushed the system to its limits, but far beyond them.

DAS deployments, once limited to venues like airports, began to appear in stadiums, designed to handle the highly variable demand spikes that came on game days. While the technical element of the problem was largely addressed, however, another challenge remained.

Because a DAS solution does not have its own RF equipment, it relies on its link to a specific operator's core network. With multiple popular operators in most markets, it seemed wise to work together to create multioperator DAS platforms that could handle traffic from fans in the seats, no matter which operator network they used.

This shift is actually quite momentous; to see why, consider the reasons people don't use rotary phones any more. It has to do with who owns the equipment and who provides the service.

- Consider the 1950s, when the telephone company owned not only the interchange lines, but the wiring into the home or business. They even owned the telephone, giving you a basic choice of either a table rotary or wall rotary model. Innovation was slow.
- In the early 1980s, things changed. You could buy your own phone, and the phone company's network would support it. You were responsible for the phone, but you could select one that suited your needs—and a lot of companies were vying for your business. This spurred a round of innovation resulting in cordless phones, one-button memory dialing and built-in answer machines. Today, we take these features granted; but in their time, they represented a dramatic departure from the prior half-century of basic dial-and-speak telephones.
- Later on, the phone company ceded responsibility for the telephone wires inside your structure as well. Again, they were happy to interface and support their operation, but management of that infrastructure became the dominion of the property owner.

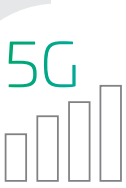
This evolution closely tracks with IBW and the move to enterprise control. Since operators cannot feasibly deploy IBW in every building, it falls to the enterprise itself to judge if an IBW solution is needed, and what kind is best for the circumstances.

By taking ownership of the infrastructure—and connecting to one or more operators' core networks—the owner, manager or architect has access to a range of options.

IBW FAST FACTS

Wireless communications have come a long way in a short time, with each evolution designated by its generation, or G for short.

- **1G** was the first widely adopted wireless standard, arising in Japan in 1979 and growing worldwide through the 1980s. 1G is an analog standard that was phased out in the late 1990s.
- **2G** was the first digitally-encoded wireless standard that arose in the early 1990s. In addition to more efficient support for voice calling, 2G was the first standard to enable cellular data communication in the form of short message service (SMS), now more commonly known as texting.
- **3G** introduced wideband digital networking in the late 1990s, and, with it, easy Internet access. While it has been largely displaced by 4G/LTE in many markets, it remains the widely used in many parts of the world.
- **4G/LTE** employs more efficient modulation to expand bandwidth, increase speed and enable new online functionality for online devices.
- **5G** standards have not been fully defined as of this writing, but 5G is expected to offer >1 Gbps speeds and low latency needed by many emerging applications such as remote surgery, driverless automobiles and Internet of Things (IoT). Experts believe that 5G will achieve significant market presence in the 2020s.



A distinct wireless technology, designed for distinct purposes

It's important to note that IBW solutions are not the same thing as Wi-Fi. While there are some superficial similarities in the functions they perform, there are radical differences in how they are designed, deployed and managed.

These differences will be highlighted throughout this book, but, as far as a wireless user is concerned, the distinction boils down to using a cellular network—such as 4G/LTE or 3G—to connect for data and voice instead of Wi-Fi which is typically used only for data and is part of the enterprise's IT infrastructure.

To better understand the distinction, let's take a look back, explore how consumer-grade wireless communications evolved from the original beige brick, and learn how wireless operators (like AT&T, Verizon and Vodafone, among many others) and enterprise owners and managers met their IBW needs.

IBW FAST FACTS

Wi-Fi networks use unlicensed and unregulated spectrum, and face significant obstacles when used as a voice traffic solution. This subject is examined in Chapter 7.

This is not to suggest that there is a choice to be made between Wi-Fi and IBW solutions, however. In fact, they are powerful complements to each other, and may even share a common physical infrastructure on Cat6A IT cabling.

Fast-forward to today's modern solutions

The IBW solutions we discuss in this book are easier to install and less expensive to operate than ever before. In fact, modern IBW solutions have improved over earlier generations as much as the latest iPhone has improved over the avocado-green rotary phone you may remember hanging in your parents' kitchen.

For enterprise owners and managers, the biggest challenge is determining what kind of IBW solutions are best for their specific needs.

- **DAS** is the better solution for larger structures with high usage. It also offers multi-operator support since it connects to multiple base stations of the same type that are used by mobile operators in their outdoor networks.
- **Small cells** work more like small-scale macro cells and offer a complete solution including a dedicated radio. They are best for smaller areas, offering exceptional service quality and less expensive installs. Some options run on IT cabling like Category 6A, allowing an overlaid Wi-Fi network to run on the same infrastructure. However, because of their integrated radio source, small cells typically connect only to a single operator.

You will learn much more about how these solutions stack up against each other in Chapter 5.

A typical IBW solution can cost less per square foot covered than installing basic industrial carpeting—and has about the same life span.

New solutions help your enterprise realize its full potential

The persistent challenge of ensuring seamless, high quality, high-speed connections where people spend most of their time living and working—indoors—continues to drive IBW innovation to this day. Of course, like every technology, IBW comes with its own advantages and challenges, which we will examine in the next chapter.

CHAPTER 1 SUMMARY

- Unlike Wi-Fi, IBW brings *cellular* data and voice connectivity indoors
- IBW's growth reflects an ongoing need to improve indoor connectivity
- Operator control is giving way to an innovative new era of enterprise control
- Modern solutions remove many barriers to entry in time, cost, expertise requirements & flexibility

CHAPTER 2

A technology defined by the obstacles it has overcome

A technology defined by the obstacles it has overcome

Wireless users view connectivity like water and electricity: a utility that should be always on, always available

In some ways, the wireless revolution of the past 20 years has been one of history's quietest innovations. Consider how quickly and effortlessly wireless users have adopted the once-fantastical notion of universal connectivity in an affordable, pocket-sized device. In less than a single generation, the world has evolved from a tethered telephone to a wireless communication device that puts the world at your fingertips—24/7, virtually everywhere.

The only things that have grown faster than wireless adoption are user expectations for instant access and reliable, fast performance. Cellular dead zones, when discovered, are regarded with surprise and disappointment. A dropped cellular call is considered embarrassing. For such a young technology, cellular communication has already cultivated a nearly universal expectation of ubiquitous, high-quality, high-speed performance, indoors and out—a trend that will only accelerate with the ascendance of the Millennial generation.

For this reason, many in the wireless industry consider in-building wireless (IBW) service as the "next utility"—that is, a modern convenience that has become as accepted and expected as electricity and running water. Users are not interested in knowing where the wires are laid or how the pipes are arranged. They simply expect the convenience of seamless, invisible, universal access and performance. So it has become for cellular service.

Distinct from Wi-Fi, in-building wireless meets different needs

It's not uncommon for many to mistakenly expect that Wi-Fi will meet all in-building wireless needs. In fact, Wi-Fi is a powerful and flexible connectivity solution, but one that requires a manual user log-in and that is optimized for data and Internet access instead of voice communications, with some limited exceptions such as Voice over Wi-Fi (VoWiFi) that we will explore later on in Chapter 7.

So, the challenge becomes one of extending outdoor wireless service to indoor spaces. The macro network is designed to cover wide swathes of outdoor space, but cellular frequencies have difficulty penetrating buildings effectively. Some construction materials, such as energy-saving Low-E window glass, are actually designed to reflect radiation away, including RF signals. We are all familiar with quality of service (QoS) issues sometimes present in underground locations like parking garages.

In short, while Wi-Fi has played a critical role in the provision of traditional indoor connectivity to date, it is simply not the same thing as an IBW solution and not currently capable of supporting cellular connectivity in a way that's comparable to IBW solutions. The two technologies are, however, powerful and effective complements. We will explore the respective roles of Wi-Fi and IBW in Chapter 7.

Because the two technologies fill such different roles, the inclusion of a IBW solution is an important priority for enterprise owners and building managers; it should be included at the architectural design stage of all new commercial, industrial and enterprise spaces.

IBW FAST FACTS

Indoor cellular coverage has traditionally been overlooked as a productivity center.

80% of wireless communications originate indoors, but…

98% of commercial/enterprise spaces do not have a dedicated IBW solution.

Customer, tenant and employee expectations

The growing need for IBW solutions is driven primarily by those who work, live and shop within buildings. Customers, tenants and employees want rock-solid cellular coverage, but building and enterprise owners have little or no recourse with local wireless operators—and even less technical expertise to know how to solve the connectivity challenge. One of the biggest IBW issues is that many simply don't know what they don't know. Lack of awareness and education invariably lead to industry myths and misperceptions; and, even for those actively seeking an IBW solution, the complicated issue of funding the system can make matters even more uncertain for small to mid-sized enterprise environments.

Attitudes are changing and the IBW evolution continues

A 2016 survey sponsored by CommScope and conducted by Coleman Parkes Research of 600 building managers, facility managers and architects in the United States, United Kingdom, France and Germany revealed some interesting insights into current IBW perceptions.

Countering this need is a prevailing confusion over how to implement a true IBW solution, however. Unlike Wi-Fi, IBW must interface with operators' macro networks—just one of many challenges.

IBW FAST FACTS

In order to clearly distinguish IBW solutions from other wireless networking technologies, this book will use "IBW" to mean a solution that provides indoor cellular service (i.e., 2G, 3G or LTE).

These solutions will include distributed antenna systems (DAS), small cell and some of their variants.

Percentage of respondents that agree with the following statements:

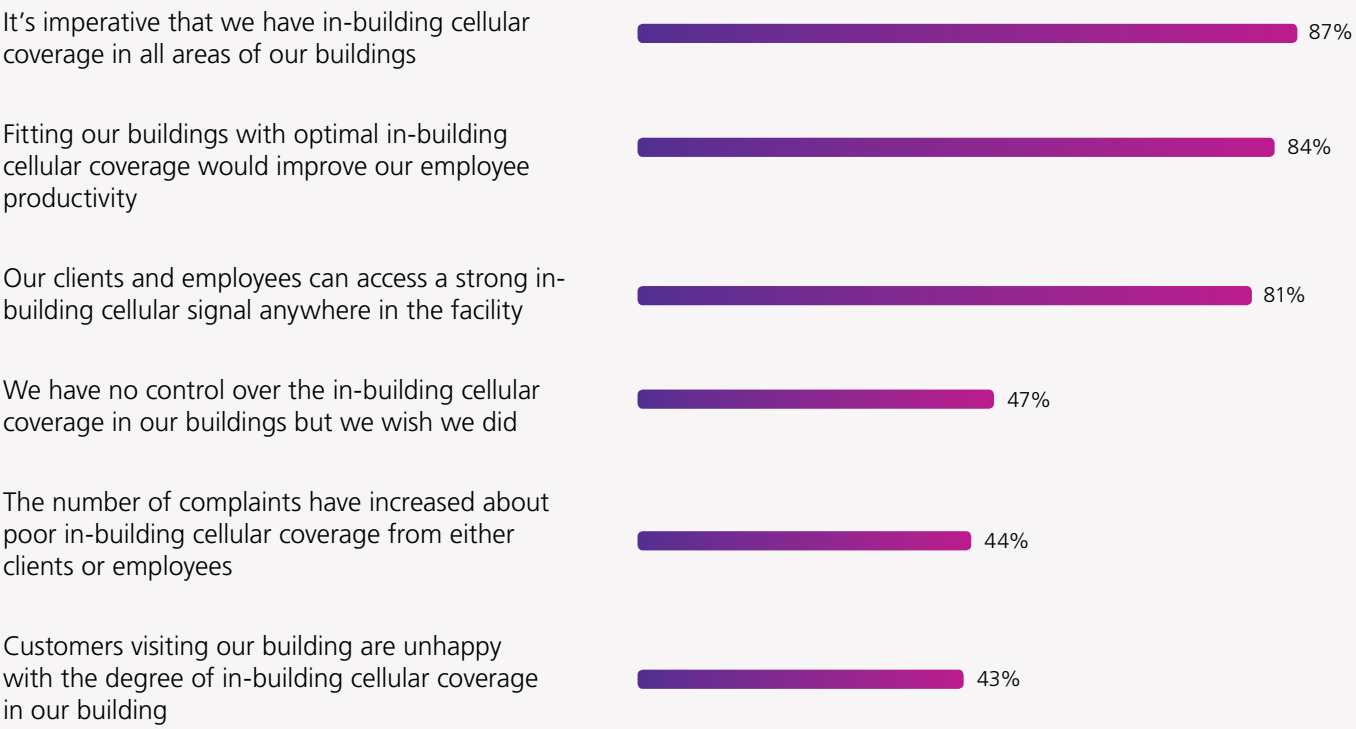


Figure 1: Top-line results survey of 600 building managers in the United States and Europe in 2016, Source: CommScope In-Building Wireless Survey Report; February 2016

Challenge: How do you make the cost/benefit analysis work?

This is generally one of the first challenges a building owner, manager or architect encounters. Even though modern solutions have simplified and reduced the cost of IBW deployments, there remain significant investments in time and money that must be justified with tenants or prospective tenants.

While quantifying the benefits of IBW coverage is difficult to achieve in the abstract, our IBW survey results (Figure 1) indicate that, on average, 84 percent of respondents believe that ubiquitous cellular coverage increases employee productivity. Architects report that the main obstacles preventing the inclusion of IBW solutions in their designs revolve around cost and complexity. A mere 16 percent cite lack of demand.

Architects on the challenges that exist when considering the installation of an IBW network:

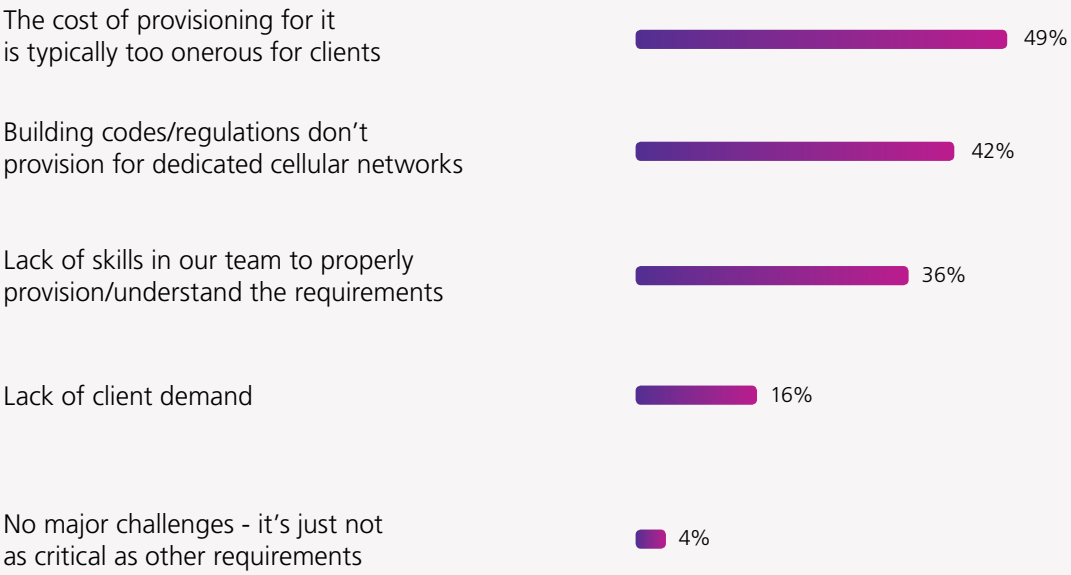


Figure 2: Obstacles to inclusion of IBW solutions, Source: CommScope In-Building Wireless Survey Report; February 2016

Whose responsibility is it?

The survey reveals that only one in five building tenants believe that the owner, manager or architect is responsible for providing indoor cellular coverage. Most believe this responsibility falls to wireless operators. Some wireless operators will provide IBW solutions to certain locations, but these are restricted to traffic running on their own network. These solutions are also only made available to the largest venues with vast amounts of traffic, where failing to provide an IBW solution would be tantamount to failing to adequately service their customers—where it is a matter of necessity as well as one of revenue.

Operator-supplied IBW solutions typically are reserved to airports, convention centers, stadiums and so forth. For smaller venues—those comprising the overwhelming majority of enterprise floor space in the world—it falls to the building owner or manager to source their own IBW solution.

How important is the provision of cellular coverage for your tenants and their visitors?

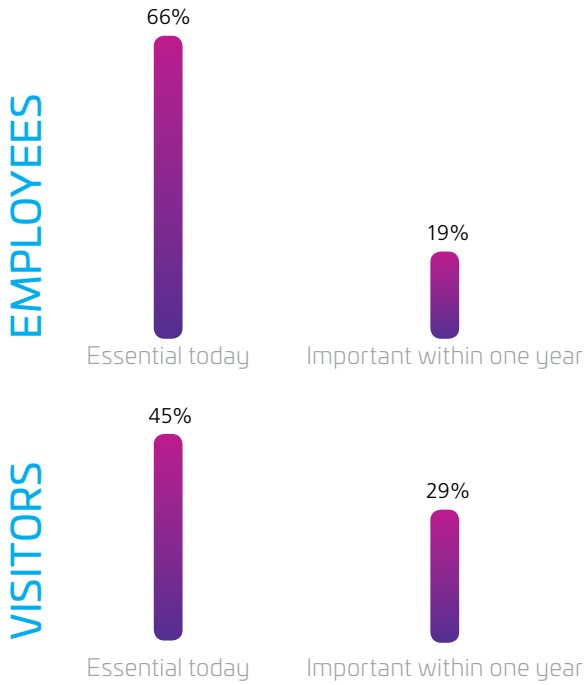


Figure 3: The importance of cellular coverage, Source: CommScope In-Building Wireless Survey Report; February 2016

Overcome the complexity

IBW deployments can be complex to provision. Because they interface with wireless operators' networks, IBW solutions must meet stringent requirements. This demands infrastructure that includes specialized RF equipment and cabling. We will explore these challenges more in Chapters 6 and 8.

Provide effective backhaul

Backhaul is a general term describing the mechanism of a network that moves aggregated cellular traffic on and off the network's backbone. In the macro network, wireless operators handle backhaul through high-bandwidth, low-latency fiber-optic cables or via directional, point-to-point microwave antennas. Neither option is economical or practical in a small-to-medium building, raising the challenge of getting all those cellular users connected to the world outside.

Recent innovations have greatly simplified backhaul, making it possible to run these vital connections to the larger network on highly economical standard IT cabling and fiber-optic infrastructure that don't require specialized labor to install. Then there are hybrid copper and fiber cables that can deliver power and data to remote devices in a single, economical cable run.

The move to standard IT cabling, such as Category 6A, for speeds of up to 10G is particularly exciting since it represents an important step toward true infrastructure convergence—the ability to run multiple networks, services and applications across a single physical layer. We will explore this and other aspects of the future of IBW technology in Chapter 3.

Thoughtful strategic planning improves implementation success

Like Wi-Fi when it first arrived in the market, IBW represents a leap forward in wireless convenience and performance. The massive reduction in wireless network latency and boost in bandwidth offered by an IBW solution—and how the resulting wireless experience more than satisfies tenants, customers and employees—will radically and positively impact property values.

This ripe potential creates a compelling case for proactive investment right now. An April 2016 report published by Mobile Experts, LLC explored a number of IBW use cases and demonstrated that IBW deployments, when properly scaled and provisioned, benefit the enterprise. Indeed, even for small to mid-sized enterprise environments, the question is no longer *if* an IBW solution should be implemented, but *what kind* and how.

As with all investments, a business-critical utility like IBW requires thoughtful strategic planning and efficient implementation to provide maximum value over the long term. Let's take a closer look at the future of IBW in the next chapter.

CHAPTER 2 SUMMARY

- Cellular connectivity is the "next
- utility"—people expect it everywhere
- Wi-Fi doesn't provide cellular connectivity—alone, it isn't enough
- The macro cellular network cannot consistently penetrate buildings
- IBW is becoming a greater priority in the U.S., Europe and worldwide
- Challenges include cost, marketability, ownership and complexity
- Significant innovations and rising property values are mitigating these challenges and making a compelling case for enterprise deployments

CHAPTER 3

The future of in-building wireless networks

The future of in-building wireless networks

Better, simpler, faster—and more necessary

It's getting crowded out there. Not only in complex enterprise spaces, where tenants come and go, desk sharing becomes more prevalent and the number of connected devices skyrockets. The spectrum driving that enterprise space is getting crowded, too. To offer reliable, efficient and (most importantly) revenue-generating enterprise connectivity, building owners, managers and architects are increasingly incorporating in-building wireless (IBW) solutions into their business strategies, and wisely so.

IBW innovation is tracking with business priorities as well. The latest solutions offer simpler setups, greater performance, more capacity and faster speeds than ever. While the remainder of this book will explore the latest IBW solutions and their ongoing evolution in greater detail, now is a good time to briefly cover the key technologies and architectures that are shaping the future of IBW solutions.

Not all situations are the same, so not all solutions are equally useful

One theme that will emerge throughout this book is the importance of understanding the enterprise space as the foundation of selecting the right IBW solution to support it. Of the many new and emerging IBW solutions we'll explore here, there is no magic bullet—no single solution that offers the best of all worlds in all situations. You will see that asking the right questions is a prerequisite to identifying the right solution.

With that in mind, here are some of the fundamentals you need to know about the solutions driving the future of IBW.

- **Distributed antenna systems (DAS).** Using licensed frequencies, this network of antennas linked to a headend allows LTE, 3G and 2G services to be carried directly to an onsite or offsite, operator-owned radio source. We explore DAS in more detail in Chapter 5.
- **Small cells.** Built like small versions of macro cell sites, this system of sectors covers an area and connects to its own base station, which is then connected to an operator's core network. We explore small cells in more detail in Chapter 5.
- **Wi-Fi and Voice over Wi-Fi (VoWiFi).** Wi-Fi uses unlicensed bands on an IP network to handle data traffic and doesn't natively handle voice calls. VoWiFi adds this capacity, though a user's device and the operator's network must both support this functionality in order for it to work effectively.
  We explore this in more detail in Chapter 6.

Solution set	Licensed/unlicensed	Multi-operator	Multi-technology (2G, 3G, LTE)
VoWiFi	Unlicensed	Varies	No
LTE-U/LAA	Licensed and Unlicensed	Yes	No
MulteFire	Unlicensed	Yes	No
DAS	Licensed	Yes	Yes
Small cell	Licensed	Typically no	Typicall no

Table 1: A summary of the characteristics of various new IBW solutions

Emerging architectures

These IBW solutions all depend on a network of copper or (increasingly common) fiber-optic infrastructure to support their antennas, access points and other interfaces. In the past, most IBW solutions have relied on RF cabling, such as coaxial cable, for its infrastructure.

However, new technologies—including most of those shown above—have simplified architectures that allow Gigabit speeds, and sometimes much more than that, over simple IT structured cabling. The advantages here are lower cost of the cable, lower costs for labor to install it, and greater possibilities for different services to share a single, convergent cable infrastructure.

Speed matters—and fiber is the future's on-ramp

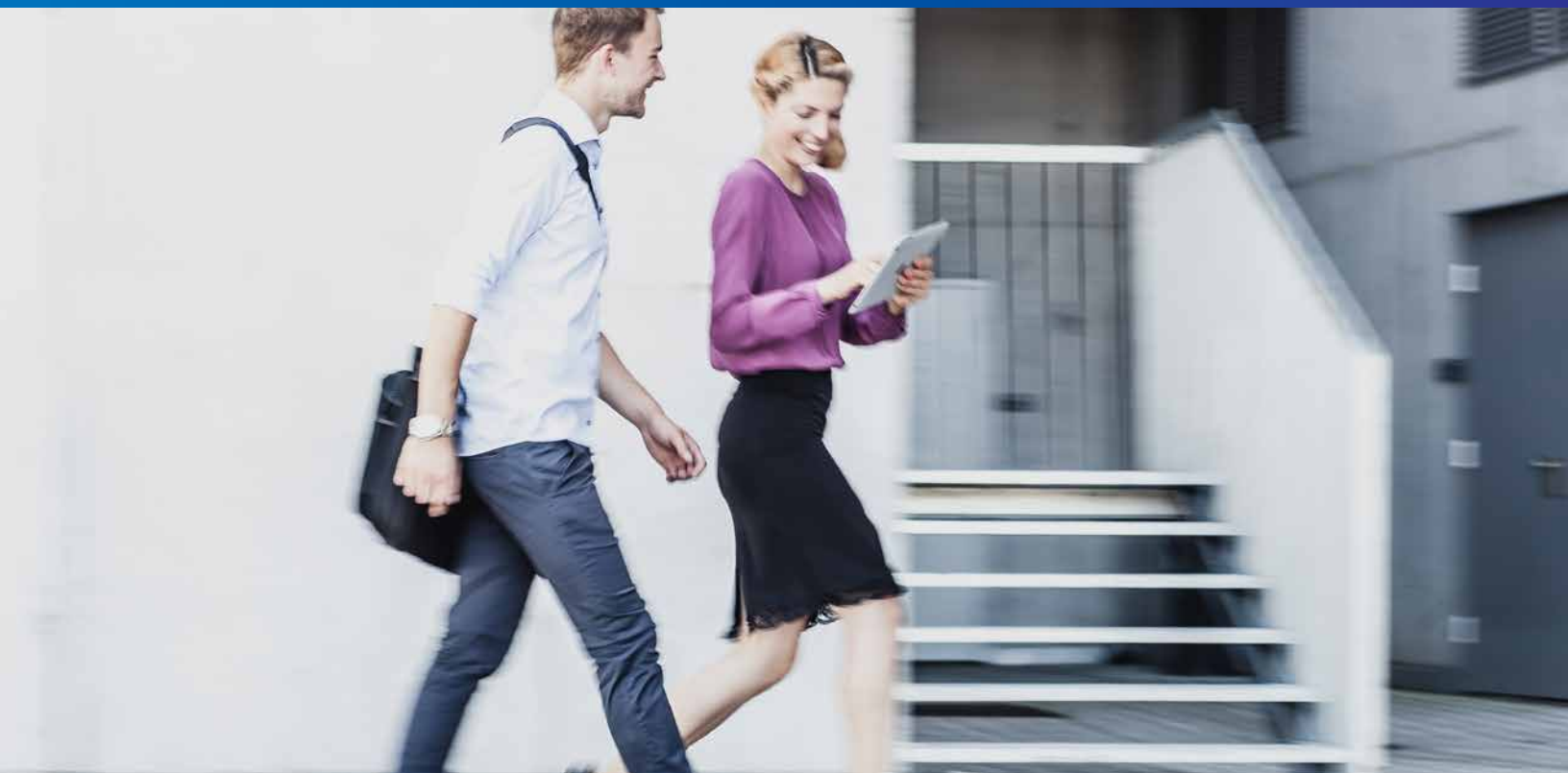
One element all IBW solutions have in common is the need to rapidly route traffic on and off the macro network of one or more operators. Since many of today's applications are data intensive, they consume a great deal of bandwidth. As a result, in most enterprise-sized deployments, this on-ramp can become very congested—very quickly.

To keep that on-ramp flowing smoothly, it's important to employ fiber as your backhaul solution. Or, if space or location won't allow, point-to-point microwave antennas to backhaul traffic onto the network. After all, it doesn't matter how fast your IBW solution is if it can't move traffic beyond your walls efficiently.

IBW FAST FACTS

With tenants moving in and out, offices changing configurations and users working in more unconventional ways and locations, how can an enterprise offer a simple, flexible way to ensure connectivity throughout a space?

CommScope offers a solution in the Universal Connectivity Grid (UCG). Built on high-performance copper and fiber solutions, it ensures that high-speed ports for wired and wireless access will be available wherever they are needed.



What about 5G?

While the IBW solutions we've covered here relate to 4G/LTE networks, it's a fair question to ask about where 5G will take us. As of this date, 5G standards have not been formalized and there is no one universal specification. However, the projected performance targets of 5G do provide some insight as to which IBW solutions will be poised to take advantage of the next generation of wireless networks.

Again, fiber-based backhaul and high-end IT cabling will figure strongly in 5G-ready solutions. CommScope's ION-E® DAS solution, for instance, operates on Category 6A cabling and supports the 1 Gbps speeds needed by 5G. Other IBW solutions are also expected to evolve into 5G-capable variants over time.

IBW FAST FACTS

5G specifications will likely focus on the reduction of power, decreasing latency and a corresponding increase in the number of applications— the Internet of Things (IoT)—from smart cities to vast fleets of driverless automobiles.

The outlook on IBW is promising

The race between demand and solutions continues to accelerate. With fiber-based architectures, 5G on the horizon and a number of ways to deploy a quality IBW solution, it seems that the technology has regained the upper hand over skyrocketing demand—for the moment.

While it's important to keep one eye on the future, there's little doubt that you need an IBW solution that is ready for today, too. A brighter future is built on smarter networks, and CommScope knows that it's our job to know what's next.

In the next chapter, we'll see how that future takes shape in your enterprise space as we explore the various technologies available right now.

CHAPTER 3 SUMMARY

- IBW solutions are becoming simpler, more affordable and more necessary
- A variety of new IBW solutions use different architectures and bands
- Fiber connectivity and an IT-convergent infrastructure will help you support future applications and standards deployments

CHAPTER 4

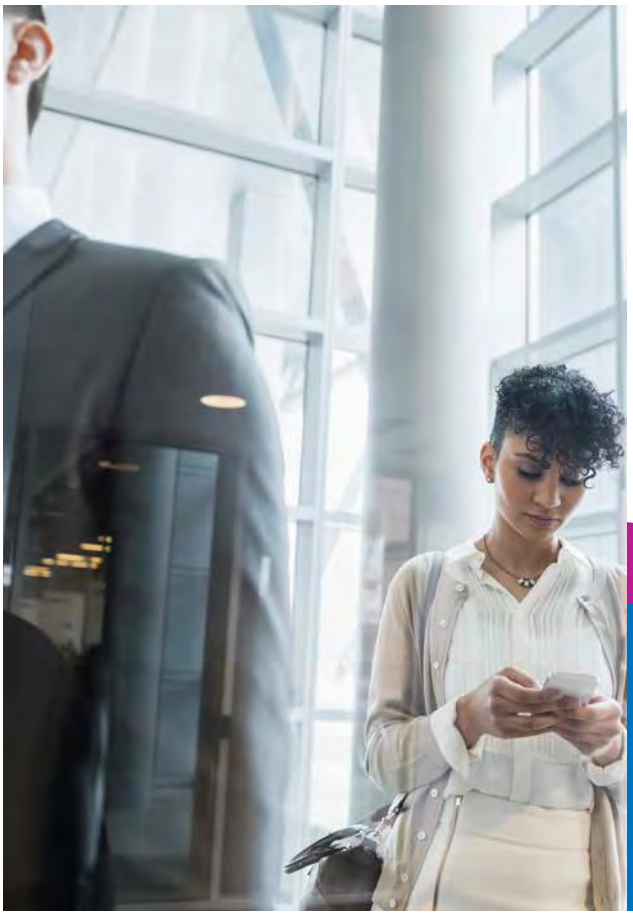
Planning your in-building wireless future

Planning your in-building wireless future

What does the right in-building wireless solution look like?

The diversity and innovation seen in modern in-building wireless (IBW) solutions puts them within reach of more enterprises than ever, as costs and complexity edge further downward. Yet, not every solution is the best choice for a given enterprise's circumstances—depending on the space and need, there's likely one option that offers the most suitable combination of efficiency and performance.

Therefore, the next step is to define what kind of technology you need, and how it should be best configured to your unique circumstances. This chapter explores the different features offered by different technologies. First, let's define these features so a meaningful comparison is possible.



Consider the space, the occupants, the demand —and future use

Let's begin with the simplest question of all: what kind of space will your IBW solution need to serve? The physical layout, size and occupancy all have a great deal to do with selecting the right technology.

CONSIDER:

- Is the space low, spread out and horizontal, or is it tall and vertical?
- Is the coverage area outdoors, indoors, or a mix of both?
- Is high tenant turnover an issue, and are occupancy levels expected to change dramatically?
- Will the space need to provide IBW access to tenants, the public, or just building management?
- Are tenants likely to be technologically driven and therefore likely to increase per-user demand?
- Is there a need to provide access to all wireless operator networks, or is one enough?
- Do local regulations require that your enterprise space support public safety networks?

Answers will come more easily if you understand how your space is used. The next page provides a snapshot of common enterprise-style environments and the specifications generally suited to each, as well as a general recommendation of DAS or small cell (SC).

Building type	Access	Venue	Multiple operators	Single operator	Dual operator	Solutions	RF power
Enterprise	Private	Multi-tenant residential buildings	✓			DAS	Low
Enterprise	Public	Hotels		✓		SC	Low
Enterprise	Private	Single tenant, Fortune 500 office buildings	✓	✓	✓	SC	Low
Enterprise	Private	Multi-tenant commercial buildings	✓		✓	DAS/SC	Medium/low
Enterprise	Public	Hospitals	✓	✓	✓	DAS/SC	Medium/low
Enterprise	Private	Government	✓		✓	DAS/SC	Medium/low
Large Enterprise	Public	Sports venues	✓			DAS	Medium
Large Enterprise	Public	Casinos	✓			DAS	High
Large Enterprise	Public	Major hotels	✓			DAS/SC	Medium/low
Large Enterprise	Public	Convention center	✓			DAS	Medium
Large Enterprise	Public	Shopping malls	✓			DAS/SC	High/medium
Large Enterprise	Public	Transportation: airports, trains stations, subways	✓			DAS	Medium
Large Enterprise	Public	Education	✓	✓	✓	SC	High

Table 1: Examples of enterprise environments, shared characteristics and common IBW solution recommendations

IBW fast facts

Single, dual or multi? The simplest solutions offer the least number of supported operators, which may be fine in cases where tenants only use company-issued mobile devices that all run on a single operator's network.

Multi-operator—that is, support for two or more operators—enables everyone to connect to their own networks. This is ideal for spaces where bring-your-own-device (BYOD) policies prevail or retail customers regularly come and go.

There can be a cost premium for solutions supporting multiple operators, however.

Supporting one, two or all operators

One of the most important distinctions among various IBW solutions is their capacity to interface with the wireless operators who run the macro networks. Some only support one operator's network, some can be expanded work with all networks right out of the box.

- Single-operator solutions may be the simplest to set up and the least expensive to operate, but they can lock you into a single operator relationship for all users. For those subscribing to non-supported operators, this can mean roaming charges or other complications.
- Multi-operator solutions (supporting two or more operators) interface with as many networks as required, though the way this is achieved varies by solution type. Some, like small cells, require additional radios for each new operator added. Others, like DAS, connect directly to more than one operator's core network without additional modification.

Most IBW solutions can be used for either of these configurations, but it is generally true that small cells are best suited to single-operator deployments and DAS is more easily used in multi-operator deployments.

Power levels and energy costs

Different IBW solutions operate at different power levels, as we briefly mentioned in Chapter 2. The efficiency and effectiveness of those power levels are determined by the size, shape and construction of the enterprise space served by the IBW solution.

Generally, the larger the inside space covered and the more walls a signal must penetrate, the more power is required to ensure a high-performance, high-reliability, high-QoS network

While it may seem intuitive that more power means a better solution, that's not always the case. In fact, power levels are subject to strict regulations that govern the placement of RF-emitting elements in human-populated areas, such as an indoor enterprise space. Also, higher-power systems naturally consume more electricity, increasing the cost of operating the IBW solution. This incremental cost can really add up in parts of the world where energy prices continue to edge upward over time.

The differences boil down to how much electricity is used, and how much signal power is delivered. Higher

powers naturally involve larger, more expensive units and higher energy costs.

CLASSIFICATIONS:

- Low power solutions:
  0.04 to 0.2 Watts,
  yielding signal power of about +16 to +23 dBm
- Medium power solutions:
  1.0 to 2.0 Watts,
  yielding about +30 to +33 dBm
- High power solutions:
  20.0 to 40.0 Watts,
  yielding about +43 to +46 dBm

Covering large, open spaces

There also exist combination IBW solutions, such as CommScope's **ION®-U DAS solution**, that overlay low- and high-power coverage for optimal flexibility and efficiency in deployment. This option is typically used for venues such as stadiums and airports that have a combination of large open spaces and smaller enclosed spaces.

Laying the groundwork—and infrastructure—for tomorrow

The latest innovations in both small cell and DAS solutions have yielded more affordable ways to deploy, optimize, operate and adapt the network. These innovations include fiber-optic cabling infrastructure, IT-convergent solutions that let the IBW solution run on everyday IT structured cabling alongside Wi-Fi or other services, and even Cloud-RAN based coverage that eliminates cross-sector interference that can otherwise reduce the quality of the user experience.

One important factor to ensuring the future-readiness of your IBW solution is the kind of transport—that is, the cabling—that carries the signals to the headend or radio. Ensuring a wide enough pipe means your space will be ready to adapt quickly to new technologies and standards. Doing so may only require a software change or swapping out a module rather than tearing out the old system and paying to install a new one.

Dynamic IBW solutions offer future-ready options for your enterprise

While many factors must be figured into your selection of an IBW solution, there also exists a significant degree of flexibility and freedom in implementing those solutions. Depending on your enterprise space and the needs of its occupants, you may opt for a single-operator, multi-operator, low-power, high-power or combined solution.

In the next chapter, we'll dig a little deeper into the actual differences between DAS and small cells, the two main solutions available to you.

CHAPTER 4 SUMMARY

- The size, shape, occupancy and bandwidth demand of your space can point you to the ideal IBW solution(s)
- Solutions may support one, two or all operators
- Power levels determine performance, but more isn't always better

CHAPTER 5

DAS and small cell opportunities

DAS and small cell opportunities

Different solutions for different applications

As mentioned in Chapter 1, this book uses the phrase "in-building wireless" (IBW) as a catchall term covering an entire class of diverse, specialized solutions that bring cellular coverage indoors. Choosing the right option requires building owners, enterprise owners, managers and architects to weigh the benefits and costs to determine the most efficient solution—and that has a lot to do with one's specific circumstances, as we saw in Chapter 4. It's imperative that the ideal solution meets not only the needs of today's tenants and users, but also offers the flexibility to serve future needs as well.

This chapter will look at two of the most significant classes of IBW solutions: distributed antenna systems (DAS) and small cells. While they share some physical and configuration similarities, they operate differently. Each offers unique advantages.

DAS deployments provide reliable coverage and capacity in environments that other solutions can't handle.

One example is the Perot Museum in Dallas, Texas. 14 stories tall and covering 180,000 square feet of display space, it features CommScope's reliably revolutionary IBW solutions to power integrated video displays, VoIP, security systems and much more.

DAS: powerful, scalable coverage for large venues

Built from a networked series of remote antennas, or nodes, DAS is one of the industry's longest-established wireless coverage and capacity technologies. DAS is an effective means of delivering uniformly high quality of service (QoS) wireless coverage and robust capacity across:

- A large indoor area
  (such as high-rise office buildings)
- A contiguous outdoor area
  (such as a stadium, open courtyard or entry space)
- A combination of indoor and outdoor environments
  (such as a college campus)

As mentioned in Chapter 2, indoor areas are covered by low-power DAS, and outdoor spaces are covered by high-power DAS. The latest generation of DAS solutions can integrate both low- and high-power networks into a single, unified platform for mixed environments.

DAS is an inherently scalable solution, which means it can be expanded to cover larger spaces and irregularly-shaped areas. For example, when cellular service is added to a subway tunnel, a sprawling sports arena or a tunneled mountain road, chances are that it's being done with DAS.

The physical infrastructure of DAS generally relies on radio frequency (RF) cable, such as coaxial cable, to link antenna remotes. It uses fiber-optic cable to connect various floors or other discrete areas. Both types of cable then connect to a central processing point, called the headend. Some more advanced DAS solutions now operate on IT structured cabling instead of coaxial, making it easier to install. IT cable also supports other networks and functions, like Wi-Fi, security systems and so forth; its broad use means that installers are relatively easy to find and to hire.

It's worth noting that DAS is just what its name describes—a system of distributed antennas. It connects to the operator's network through that operator's own base station, which allows DAS to work with one, many or all available wireless operators in the market. New operators can connect to the existing DAS infrastructure for access to high-quality, high-capacity coverage.

Each DAS installation is unique to the environment it serves, so there are no out-of-the-box DAS solutions—though there are innovate new options that simplify the process with intelligence-enabled automatic configuration (Figure 1) and alternative means of signal transport, such as via an existing IT cabling infrastructure (Figure 2).

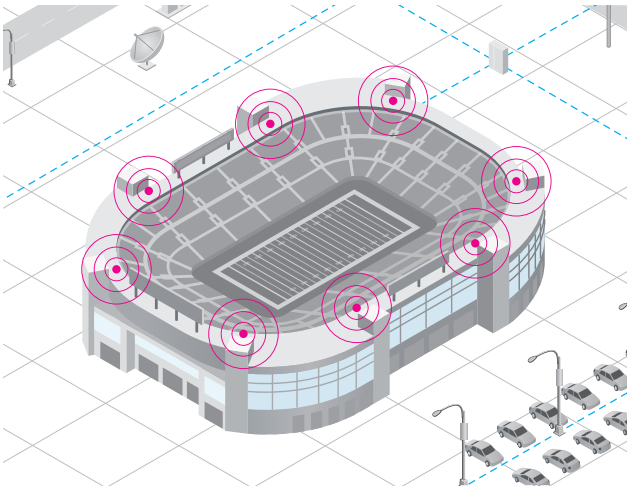


Figure 1: An intelligent auto-configuration of outdoor DAS optimizes coverage and capacity in a large stadium.

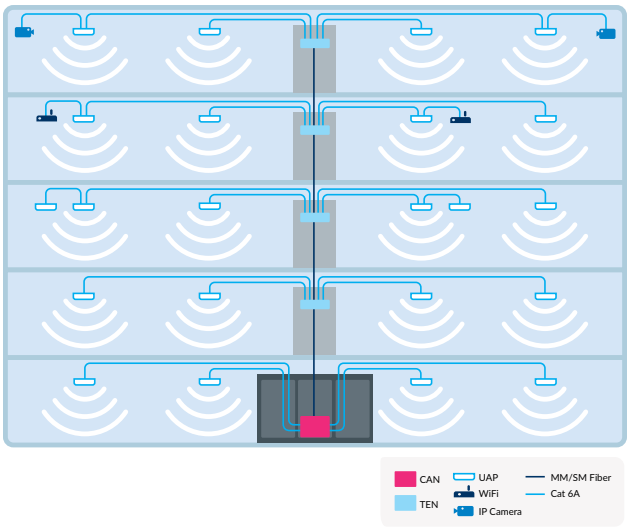


Figure 2: An IT-converged DAS infrastructure uses network cabling instead of expensive coaxial cabling.

These factors make DAS an attractive option for large venues, mixed indoor/outdoor venues, isolated locations and spaces where demand is variable, but has the potential to be extremely high. In these cases, DAS makes financial sense.

As far as DAS has come since its early days as a niche solution, it's not always an economical solution for smaller enterprise environments, though recent innovations like IT-convergent solutions that operate on network cable are lowering the cost of entry.

IBW FAST FACTS

DAS is a suitable IBW solution for:

- High-rise office buildings
- Large hospitals and hotels
- College campuses
- Shopping malls and museums
- Stadiums and sports complexes

Small cells: affordable and adaptive

For smaller indoor locations, small cells offer an economical alternative that's flexible and self-contained. Small cells are what their name implies: small versions of macro cell sites, including base station, radio and antennas, typically combined into a single physical unit. Small cells can support deployments spanning the size of a small-to-medium office building, where the distribution of users does not vary to any great extent.

Each small cell creates a discrete "cell" of coverage. Like macro cell sites, traditional small cells also create areas of overlap where their cell boundaries meet. In these areas, cellular connections suffer significant drops in service quality: reduced data rates, choppy voice, and dropped connections. This problem can be mitigated through thoughtful design and careful optimization of small cell placement and power, but it's impossible to eliminate this interference between cells entirely (until recently, that is—we will explore the latest small cell innovation in the next section).

Small cells are relatively easy to install, which makes them an attractive option for an enterprise environment. We will explore this in more detail in the next chapter.

Unlike DAS, which connects to an outside base station owned by a wireless operator, small cells include their own baseband unit, which must be integrated with operator networks—a one-time process. As of this writing, most major operators have only integrated a limited number of small cells and some have not integrated any. A given model of small cell typically only supports one operator's network.

Also bear in mind that small cells have a hard limit of coverage and capacity that may present serious challenges if the IBW solutions will need to expand significantly in the future. Small cells can typically support 16 to 64 users at a time, which may be more than adequate for many small to mid-sized enterprise environments. In addition, unlike DAS, conventional small cells cannot dynamically share capacity between access points, so large gatherings in small spaces may create bottlenecks—a phenomenon sometimes called the "cafeteria problem."

C-RAN small cells: a vision for the future of IBW

We stated above that small cells suffer from the interference between neighboring cells and that concentrations of users can overwhelm individual access points. In traditional small cell architecture, this is true. However, a recent innovation from CommScope has removed this barrier from small cell deployments, making them even more attractive for deployments of the right size. This innovative approach is called a cloud radio access network, or C-RAN small cell. Here's how it works.

The baseband unit centralizes all processing from the small cell's various radio points, creating a virtual "super cell" that combines the entire system into a single area of coverage.

This solves service quality issues and avoids dropped connections by eliminating overlap altogether (Figure 3).

As an extra bonus, this architecture operates over conventional Ethernet switches and cabling, making it easier to install and maintain without expensive or specialized expertise.

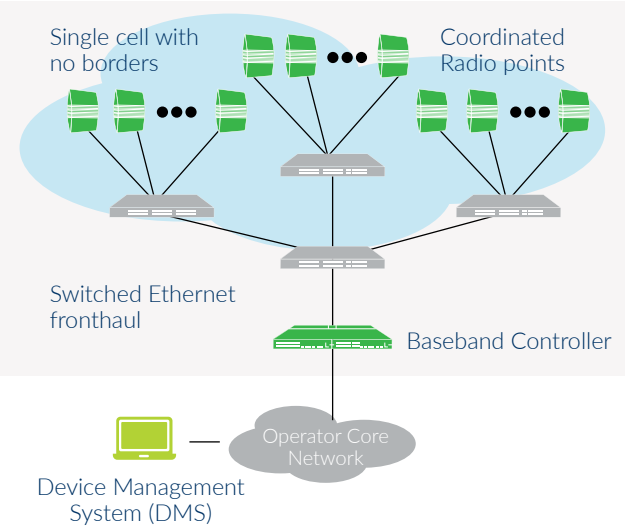


Figure 2: An IT-converged DAS infrastructure uses network cabling instead of expensive coaxial cabling.

The choice depends on the challenge

Choosing a solution for an IBW deployment involves several questions. How much space must be covered? How many people must be supported? How many operators must be supported? And, perhaps most importantly, how much will it all cost?

DAS and small cells comprise the lion's share of IBW solutions. They each have their place and purpose. By carefully identifying expectations—and thoughtfully considering the future of your business—the ideal IBW solution will become clear.

Keep in mind, however, that both DAS and small cell solutions continue to evolve and improve over time, with several key innovations hitting the market right now. Small cells are improving their scalability, and DAS is becoming more economical by the day.

This means that you—the owner, manager or architect—will have access to an ever-improving array of options as time goes on. However, this won't be your only decision point; you will also want to consider the possibilities of using licensed versus unlicensed frequencies in your IBW solution, which we will discuss in the next chapter.

CHAPTER 5 SUMMARY

- IBW encompasses several diverse technologies
- DAS and small cell are two of the most promising alternatives
- DAS is ideal for larger, mixed venues with multi-operator requirements
- DAS is not always economical for smaller areas of coverage
- Small cells are suited to small-to medium spaces
- C-RAN is a breakthrough small cell innovation that eliminates many of small cells' interference issues

CHAPTER 6

Unlicensed frequencies that unlock network potential

Unlicensed frequencies can unlock the potential of your in-building wireless network

Why is there licensed and unlicensed spectrum?

In the United States, the FCC is responsible for licensing the use of broadcast frequencies. Other countries have similar authorities that do the same thing. The reason for licensing some frequencies —not all, as we'll soon see— is that spectrum is by nature a limited resource that can't meet all the demands that the modern world would like to make of it. In order to ensure orderly and cooperative use of these frequencies, they are regulated and licensed by government authority. As new spectrum bands are released for public use, they are parceled out by an auction process. Being such a limited resource, newly available spectrum can be licensed for many millions of dollars.

For buyers—usually wireless operators, TV and radio broadcasters and the like—these licenses are valuable because they grant legally-enforceable rights to use certain bands in certain locations over a long period of time. Licenses are, in effect, a semi-permanent franchise.

However, not all frequencies are licensed or regulated. Governments also set aside certain bands for open use without licensing, for various uses that include Wi-Fi networks, Bluetooth connections and even TV remote controls. While these frequencies are unlicensed, there are still rules or best practices associated with their use.

DAS and small cell: the current licensed alternatives

Because they integrate with one or more wireless operator networks, both DAS and small cell solutions are examples of IBW solutions that rely on licensed frequencies. The actual bands used depend on the operators and the licenses they hold in a particular area. As far as the enterprise owner or manager is concerned, the frequencies themselves are a non-issue.

There is a cost associated with integrating one or more wireless operator networks in terms of the amount of traffic moving across the network, whether measured in megabytes or minutes, but the licensing of the spectrum is entirely the operator's concern. This scheme gives the operator latitude to design the in-building wireless (IBW) deployment and monitor its performance. This, in turn, helps the operator meet guaranteed key performance indicators (KPIs) since IBW is, in a very literal sense, an extension of the operator's mobile network.

IBW FAST FACTS

Just how expensive is licensed spectrum? Very.

Consider FCC Auction 97, which concluded in January of 2015. It resulted in 31 bidders securing 1,611 licenses—**at an aggregate cost of more than $41 billion.**

Consider also that Auction 97 included just 65 MHz of spectrum spread across six blocks of bands.

Unlicensed solutions in the enterprise

You probably recognized a few familiar names in the unlicensed technologies at the beginning of this chapter, such as Wi-Fi and Bluetooth. These technologies are popular even though they don't use licensed frequencies because they are comparatively simple to set up and configure. In many cases, they can self-optimize performance.

This freedom, however, comes at a cost. The possibility of experiencing interfering signals in the same bands—say, from the office across the hall, or the building across the street—means that it is up to the enterprise to find their own way to a secure, high-performance solution. This lack of control is also why applications like Wi-Fi can become congested even under moderate traffic loads. As a result it is very challenging, if not impossible, to guarantee KPIs using unlicensed spectrum.

Expanding from licensed to unlicensed—when necessary—with LTE-U

LTE Unlicensed (LTE-U) is a recent development that begins to blur the lines between using licensed and unlicensed frequencies. LTE-U operates as a standard wireless network under normal load, but has the capacity to dynamically extend its frequency range into unlicensed bands during periods of peak usage. At these times, it uses an LTE signal in the unlicensed 5 GHz band—the same band used by advanced Wi-Fi networks—to carry user traffic.

LTE-U is potentially subject to traffic jams because it shares frequencies with Wi-Fi data traffic. Depending on the deployment, either voice or data may be bottlenecked. Like LTE, LTE-U is run by a wireless network operator, but because it hasn't been specified as a global standard it is uncommon and unlikely to be a viable enterprise-based alternative in its current form.

While LTE-U solutions are only now becoming commercially available in the United States, they require users to have specially-designed phones in order to use the service. These, too, are only now seeing production.

LAA: The next evolution for LTE-U

License-assisted access (LAA) is the next planned stage in the evolution of unlicensed LTE. LAA will implement a global standardization that current LTE-U technology lacks in order to ensure that LTE traffic does not negatively impact Wi-Fi usage in the shared 5 GHz spectrum.

This will be accomplished through the adoption of a listen-before-talk (LBT) technique. LBT senses the presence of conflicting traffic on a frequency before trying to transmit on that frequency—the radio equivalent of looking both ways before turning onto a highway. LAA should allow the efficient coexistence of both kinds of network traffic in the same bands.

As operators continue to promote unlimited data and voice plans for their customers, it seems likely that LTE-U and LAA will be popular methods of offloading macro network traffic in more user-dense enterprise environments.

LTE-U and LAA both operate with what is known as a licensed anchor. That is, a connection always starts in licensed band and then extends into unlicensed bands if needed for capacity and if available to use. LTE-U and LAA never operate entirely in unlicensed bands.

The long-term view on unlicensed IBW solutions

Looking even further ahead in the development pipeline, there are other technologies that hold promise as partially or completely unlicensed IBW solutions. While years away from commercial deployments, they offer an interesting perspective on the direction of the evolution of wireless networking.

CITIZENS BROADBAND RADIO SERVICE (CBRS)

CBRS uses lightly licensed and shared spectrum, straddling the line between licensed and unlicensed solutions. Comprising 150 MHz of spectrum within the 3.5 GHz band, some frequencies can be licensed under a Priority Access License (PAL) while others, known as General Authorized Access (GAA) will remain unlicensed. Some restrictions exist, as several frequencies are still used by the military, but these are related to specific locations and times and managed by entities known as Spectrum Access Systems or SAS. Comsearch, a CommScope company, is an SAS for CBRS frequency management.

The practical upshot of CBRS is that it opens the possibility for enterprise-based "neutral host" LTE networks that can act as indoor islands somehow separate from operator's network.

The frequencies are well-suited to indoor use, expanding their possible applications. While the prospect of truly neutral small cell solutions is an exciting one to contemplate, phones will first need to add support for these frequencies, and mobile operators will need to connect to these neutral host networks in order to complete a call end-to-end.

MULTEFIRE

MuLTEfire uses an air interface to directly connect to broader networks, such as ISPs and wireless operators. It is a wholly unlicensed solution in that it does not rely on a licensed anchor band as LTE-U and LAA do.

The MuLTEfire alliance released the 1.0 specification for the technology in January of 2017, bringing it one step closer to market applications; however, it is not a 3GPP standard and no available devices currently support it. As with CBRS, for MuLTEfire to be truly useful, mobile operators will need to connect their networks to these networks for end-to-end calling.

Unlicensed solutions offer high potential in the near future

There's no doubt the next decade will bring many of these exciting technologies to market. As of this writing LTE-U and LAA are currently in early state of network deployment. Their success will mainly depend upon the actual market penetration of mobile devices supporting these technologies in the next few years. CBRS and MuLTEfire are expected to arrive in a few years, but for now, enterprises are generally best served by a licensed-frequency IBW solution.

CHAPTER 6 SUMMARY

- Licensed frequencies are regulated and purchased by mobile operators
- Growing demand is pushing IBW solutions into unlicensed bands
- LTE-U "borrows" 5 GHz bandwidth from Wi-Fi when needed; LAA will standardize this technique
- CBRS and MuLTEfire use partially and completely unlicensed bands to extend IBW coverage
- Licensed-frequency IBW solutions remain the only viable and commercially-available option for now

CHAPTER 7

Wi-Fi's role in dynamic, always-on wireless networks

Wi-Fi's role in the ecosystem of dynamic, always-on wireless networks

The right tool for the job

In many cases, Wi-Fi is just one piece of the enterprise wireless puzzle—an important piece, to be certain, but not suited to every wireless need the enterprise may have.

As we mentioned in Chapter 2, in-building wireless (IBW) requirements can sometimes be unclear to enterprise managers, building owners and even seasoned architects. But no matter how one looks at it, Wi-Fi alone cannot be considered a practical, standalone IBW solution. Even the most useful tool in the toolbox isn't right for every job.

Managing your bands

Wi-Fi is becoming truly ubiquitous. More and more shops, hotels, public parks and commercial buildings offer Wi-Fi, often with little or no restriction to visitors or employees. On the one hand, that ubiquitous nature is a phenomenal asset—the same mobile device can find connectivity just about anywhere.

On the other hand, however, the unlicensed frequencies Wi-Fi uses (the 2.4 and 5.0- GHz bands) are becoming increasingly crowded as coverage areas overlap, causing neighboring Wi-Fi networks to interfere with each other and reduce performance.

Even though Wi-Fi employs multiple channels in each band (three channels in the 2.4 GHz band and up to 14 in the 5.0 GHz band), their unlicensed and unregulated nature means conflicts with neighboring signals are more likely to occur and require an ad hoc coordination agreement between network owners to protect their own network's bandwidth and speed. In a multitenant enterprise space where multiple Wi-Fi networks operate in close proximity, these agreements can become more complicated and harder to enforce.

In contrast, an IBW solution, such as DAS or small cells, uses licensed frequency bands that are managed by the mobile network operator.

Wi-Fi applications are growing fast—but not all are fully mature just yet

One of the ways in which Wi-Fi network may appear redundant with an IBW solution—rather than a complement to it—is the emergence of Voice over Wi-Fi (VoWiFi). As its name suggests, it adds the capability to carry voice data from mobile devices over Wi-Fi bands back to the core network.

The current 802.11ac Wi-Fi standard promotes an impressive throughput rate of as much as 1.3 Gbps, but this theoretical limit does not bear up in real-world enterprise deployments. Capacity, too, is a highly variable metric in real-world deployments, depending on distribution of access points, distribution of users, and the kind of demand each one puts on the network.

Although the actual data rate of VoWiFi is very low, considerable Wi-Fi capacity is consumed by the airtime overhead associated with sending small packets in rapid repetition. The more capacity is consumed by a voice application, the less is left for all others.

The latest IBW solutions include DAS that operates over standard IT structured cabling instead of the traditional RF coaxial cable.

This not only makes it easier and less expensive to install, but also allows it to run on the same cable infrastructure used for other IT applications.

The log-on logjam

But perhaps the most significant factor to consider in a VoWiFi deployment is that of authentication. VoWiFi, like regular Wi-Fi connectivity, requires a user to log on manually to use the service. While this is only a minor obstacle for users who connect constantly—like employees or residents—it can be an inconvenience for visitors or infrequent users. Without that log-on, calls can't be connected—not even if the correct equipment and software is present.

It's also worth noting that wireless operators do not always assume responsibility for calls made on VoWiFi as they do with cellular connections. The system and the service are the responsibility of the enterprise's IT staff.

For these reasons, VoWiFi can be an effective complement, well suited to enterprises where there is tight control over who uses it, where people spend most of their time indoors, and where one occupant fills the entire space. However, without these factors on your side, VoWiFi alone will likely not provide the same level of service as a IBW solution can.

Can Wi-Fi do it alone? It depends on your current and future requirements

Wi-Fi is a given and it's virtually assured that your enterprise already sports a Wi-Fi network. Deciding whether it makes sense to supplement with a cellular IBW solution depends on the communications needs of your enterprise, and weighing them against the flexibility—and the limitations—of Wi-Fi.

In offices where there are few visitors or customers, or in which cellular connectivity for employees and visitors is of low importance, Wi-Fi alone may be sufficient. However, if your space is a hospital, hotel, retail store, professional service building, school or government building, the situation is quite different. Then, the prospect of inadequate coverage, capacity and availability becomes far more serious—even business critical. CommScope has grown to become a trusted partner of these high-demand, high-performance networks by providing the IBW solutions for the always-on networks of today—and tomorrow.

Fortunately, the decision to add a complementary IBW solution is becoming simpler and more cost effective. Some modern DAS and small cell solutions can share much of an established Wi-Fi network's existing cabling infrastructure, including Category 6A and fiber-optic cable.

IBW FAST FACTS

Voice over Wi-Fi (VoWiFi) is gaining wider adoption but is limited by several significant factors, including:

- It requires the user to connect to the Wi-Fi network, which is not necessarily automatic.
- Routing calls to Wi-Fi-connected phones using only the recipient's phone number requires specialized network equipment and mobile device software. There is currently no universally-deployed standard for doing this.
- VoWiFi calls cannot roam onto the cellular network as the user moves between Wi-Fi and cellular coverage areas—calls drop at the door.
- VoWiFi has performance and capacity limitations relative to cellular, as they are not designed to handle that kind of traffic natively. Doing so generally requires an upgraded deployment.

Consider a strategic combination

The bottom line is that, for most enterprise spaces, the best strategy is a combination of complementary Wi-Fi and IBW solutions. Each has its place, and complex enterprise environments generally need both capabilities to maintain employee productivity, customer satisfaction and tenant longevity. CommScope's newest IBW solutions leverage this shared responsibility by operating on the same kind of infrastructure, and even sharing the same data and power schemes.

In the next chapter, we will discuss what's involved in installing and integrating your enterprise's IBW solution.

CHAPTER 7 SUMMARY

- Wi-Fi is the starting point of your wireless strategy—but it doesn't have to be the end
- Unlicensed technology is easy to set up but difficult to optimize and secure
- VoWiFi shows promise under the right circumstances but currently has limitations that have prevented widespread adoption
- Combined Wi-Fi and IBW solutions deliver optimal performance, flexibility and reliability
- Modern DAS and small cell solutions can share IT cabling infrastructure with Wi-Fi or other IP devices

CHAPTER 8

Deploying bandwidth without boundaries

Deploying bandwidth without boundaries

How to fast-forward to your wireless future

Suppose you're a facilities manager for a mid-sized shared office. Or you're a building owner doing a refresh to attract new, higher-rent tenants. Or you're an architect, keen to provide your client with the best enterprise connectivity options available. Whoever you are, IBW should be on your radar. It may make sense for your situation, but your unfamiliarity with IBW has you hesitating.

The first step is to determine whether a particular space would be better served by DAS or small cell, single-operator or multi-operator, high-power or low-power, and so forth. By this point in the book, you should have some good ideas about your expectations and requirements. If not, don't worry. Your partner will be able to help guide this key decision early on.

Fortunately, no matter what IBW solution you go with, there are five general steps involved in making it a reality. Even better, there is help available to get you through these steps and beyond. Let's review them.

Step 1: Design

Implementing an IBW installation is not like designing a bridge, or even a building. It's more like designing a dynamic, living ecosystem. A good IBW design is one that covers every place you need connectivity. It's also sensitive to factors beyond your walls.

- **Work with a reputable end-to-end partner**
  The first point is the most obvious: you're not going to install your own IBW solution. It takes specialized expertise to plan, deploy and operate such a system.Most markets offer a wide selection of partners who can assist you with the process and help you plan the best system for your individual circumstances. If possible, it's recommended that you work with a company that will also handle the deployment itself, which we will explore later.

IBW FAST FACTS

Whatever your role, you're not an engineer. Fortunately, you won't have to be to integrate IBW into your enterprise space. You'll need a partner, whether it's a large national wireless operator or—more likely for smaller enterprise deployments—a third-party IBW engineering partner.

- **Get a detailed view of your enterprise environment**
  Once you've selected a design partner, they should begin by creating a virtualized, 3D model of your enterprise space in specialized indoor propagation software. This is done in order to map out where access points and antennas should be placed to provide maximum capacity and service quality for users—placing more access points where demand will be highest, and scaling power levels to overcome the macro network.

- **Keep the outside out**
  In Chapter 5, we explored the different use cases and advantages of both DAS and small cell IBW solutions. Whichever you choose, your designer's first priority is to maintain dominion of the airwaves within your walls—and keep the outside network out of your building. This means planning your IBW coverage to provide stronger signal strength than what leaks through your walls and windows from the macro network—because the macro network may not be powerful enough to deliver useful connectivity indoors, but it can be powerful enough to interfere with the frequencies your IBW solution will use. You need to make sure each access point or antenna is operating at sufficient power to drown out any stray macro network signals.

The right partner is essential

Not all design partners are equally qualified to deliver all IBW solutions. Look for a partner who is certified not only in the IBW technology, but also in the specific products they will be dealing with when it comes to installation.

Many IBW solutions manufacturers offer certification for these partners, along with continuing education on the latest solutions and techniques. The CommScope Infrastructure Academy certification program ensures that CommScope solutions are installed correctly, efficiently and reliably.

Step 2: Deployment

How you actually deploy your IBW solution depends on the size, shape and use of the space. Here is where you put into action the plans made in the design phase.

- **The power drives the solution**
  IBW solutions, particularly DAS solutions, offer various power levels suited to different environments. For small office spaces, low-power systems are adequate. For larger commercial spaces like high-rise buildings or underground areas, higher power levels are needed to penetrate the building structure.

- **Marrying communications infrastructure to physical structure**
  The deployment of an IBW solution in an existing building usually means running new cable between the headend and the various access points covering the space. For some solutions, this means coaxial cable in the horizontal (that is, a discrete area such as an entire floor of the building) and fiber-optic cable in the vertical (the backbone that connects all the horizontal layers into the system's headend). It's worth nothing, however, that there are now DAS and small cell solutions that run on ordinary IT cabling, such as Category 6A or even Category 5, that may already be installed throughout the building, or can at least be installed with minimal time and expense.

- **Smooth operator integration**
  Once the physical infrastructure is installed, the IBW solution must connect to the wireless operator network, or networks. How this happens depends on the solution used. For example, a DAS deployment does not include the baseband unit in the building—it has no radio source of its own. It must be connected an operator-supplied signal source or base station in order to operate. This means multiple operator networks can operate simultaneously on a DAS deployment, if desired. All they need to do is "plug in" their radio sources for access to the entire DAS. In a small cell deployment, the solution does include its own radio source, which must be among those approved for use by the corresponding operator in order to be integrated.

Step 3: Commissioning

So, your hardware has been installed, the connections are made, and all that's left is to flip the switch to bring it all to life, right? Wrong! Even the best-designed system will need some tweaking to ensure power levels are properly balanced and all areas are adequately covered. This is called commissioning.

- **Adjust and re-adjust**
  Real-world performance will vary somewhat from the theoretical ranges described in the design, and here is where those necessary adjustments happen. Depending on the kind of IBW solution you have, this could be either a manual or a software-managed process. In most IBW deployments, this involves RF engineers walking the covered space, measuring levels and looking for intrusion from the outdoor macro network, which interfere with the IBW solution. Then the individual access points' power levels are adjusted at the headend to compensate for these variances. The levels are rechecked and readjusted until a satisfactory network is in place.

- **Small cells have a simplicity edge here**
  As a general rule, small cell deployments are simpler and less finicky in their real-world operation than most DAS solutions. This is particularly true for small cells operating on IT cable infrastructure.

- **But DAS has a trick or two up its sleeve as well**
  Modern DAS solutions—some of which also operate on IT infrastructure—may include intelligent provisioning and commissioning capabilities that allow remote monitoring and troubleshooting in addition to more traditional features like remote power level adjustments. These new options can often be handled from anywhere through a browser-based interface. Some even have the capacity to commission themselves automatically, adjusting levels not only at installation but on an ongoing basis in response to changes in demand. CommScope is a leader in innovating these solutions, with a particularly advanced option detailed on the next page.

CommScope connects enterprise customers with trained, certified experts that can handle an IBW design, installation and operation. These experts are part of the PartnerPRO® Network, a global organization that can offer turnkey support from beginning to end—and also help ensure optimal warranty coverage of purchased CommScope solutions.

Step 4: Optimization

Once power levels are properly adjusted, it's time to optimize the IBW network by looking for areas of interference in the RF path. This is necessary to ensure high QoS and adequate capacity to all covered areas. Again, this work is best performed by certified, qualified engineers who are familiar with the solutions being used.

- **Check the uplink and downlink**
  For most DAS and small-cell deployments, interference can be measured and isolated at the headend by checking the uplink and downlink paths that connect the IBW to the core network.

- **Adjust access point antennas to reduce overlap**
  When interference does arise, it is likely from overlapping areas of coverage by adjacent antennas. This too can be a slow process, as each manual change must be made, checked, and remade until the interference is brought down to allowable levels.

This step greatly benefits from an end-to-end IBW engineering partner offering turnkey service.

Step 5: Monitoring and maintenance

IBW solutions aren't static—because demand isn't static, particularly in enterprise environments. Tenants move in, move out, expand, change operator contracts and so forth. Areas of greatest demand will require rebalancing of power levels, and changes to the outdoor macro environment will change how interference affects your capacity and QoS. As a result, IBW solutions require monitoring and upkeep.

- Bring in the experts. Don't expect that your own IT staff has the expertise to manage your IBW solution. You will likely need help from a third party—preferably an end-to-end turnkey partner capable of providing fast, professional post-deployment support.

- Don't go too far afield. Since many IBW troubleshooting calls involve physically adjusting antennas or moving access points, it's critical to work with a partner within a reasonable service radius.

- Consider budget-conscious ways to scope partner contracts. Not every IBW outage is a disaster, and not every problem requires instant attention. IBW management is usually available at various levels and degrees. Choose a service level that meets your requirements. Another way to get the most from your maintenance dollar is by choosing an IBW solution with an integrated management software solution. Such solutions can automatically detect problems, identify service disruption locations, and generate automatic alerts and troubleshooting work orders to send directly to your maintenance partner. Providing them with prompt, precise, reliable information about the problem can help expedite resolutions and reduce wasted time and resources.

IBW FAST FACTS

CommScope offers an enterprise-focused DAS solution that greatly simplify the process of commissioning, optimization and monitoring. ION®-E is an IT infrastructure-convergent solution that dynamically scales capacity when and where needed, with software to constantly monitor activity. ION-E is a prime example of CommScope's commitment as an innovator, driven to anticipate network needs and solve for challenges so that our customers in both the wireless and enterprise spaces can fully leverage every opportunity.

Zero interference small cells

Modern IBW solutions now exist that can greatly simplify this once-arduous process. In addition to the advantages of CommScope's **OneCell®** offers an innovative way to create a small cell deployment without any cross-cell interference at all.

Software dynamically monitors and adjusts all access points to create a single "super cell" that effectively has no cell borders—and hence no cross-sector interference, yielding improved signal quality and better user experiences.

How do you deploy IBW? With smarter partners.

IBW solutions have come a long way from the early days of the first DAS. Modern solutions like DAS and small cells are now more affordable, versatile, capable and easier to install than ever before. CommScope is a trusted partner in the industry precisely because we are known as a problem-solving innovator that unlocks the potential of networks.

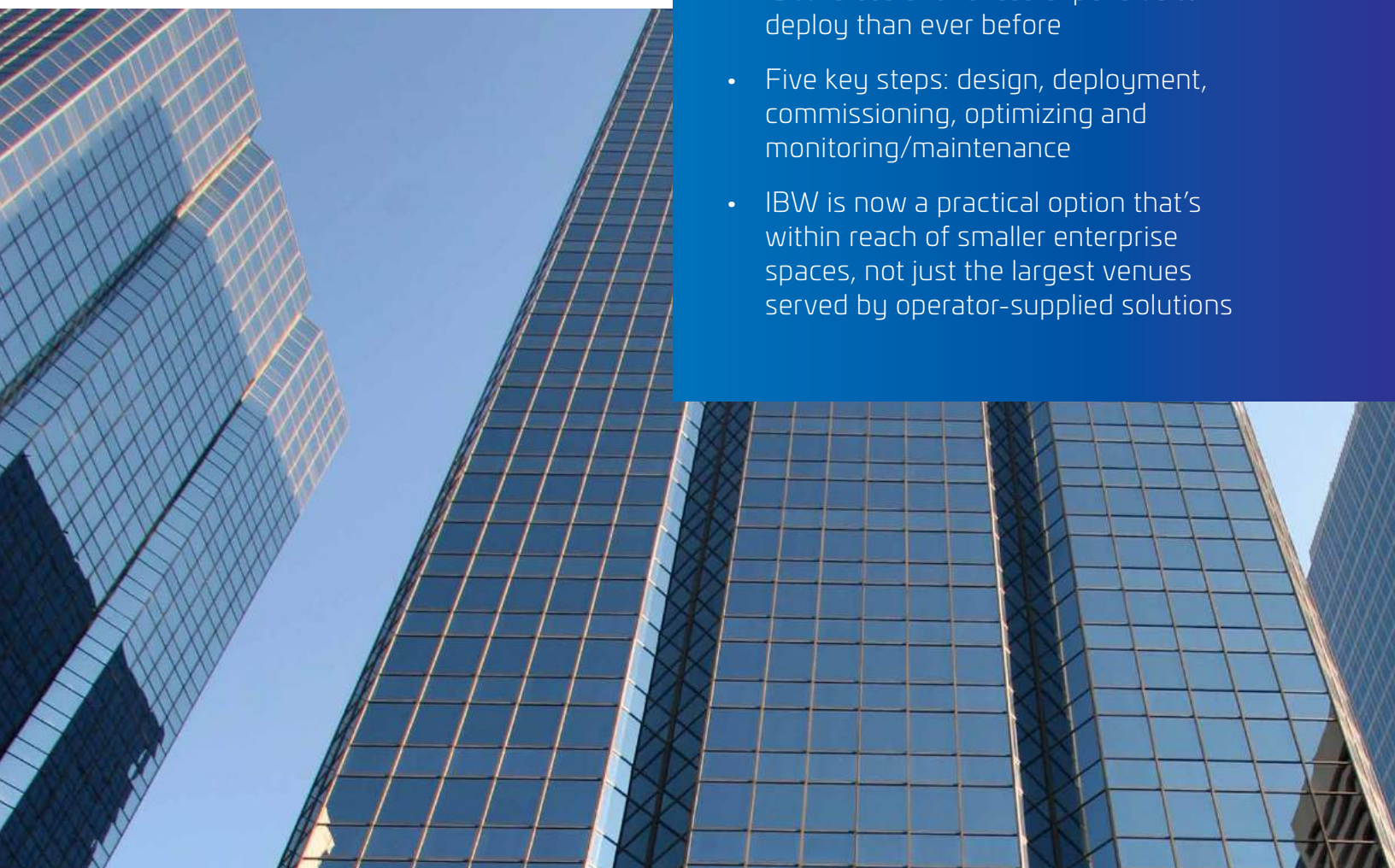
With the right partner, any enterprise can deploy an effective IBW solution. Ongoing maintenance will require your attention as well—and this leads us to our final subject: funding your IBW deployment.

IBW FAST FACTS

Among its many other DAS monitoring and management capabilities, CommScope's Andrew® Integrated Management and Operating System (A.I.M.O.S.) can automatically detect DAS problems and generate work orders for an IBW management partner, saving time and cost.

CHAPTER 8 SUMMARY

- IBW is easier and less expensive to deploy than ever before
- Five key steps: design, deployment, commissioning, optimizing and monitoring/maintenance
- IBW is now a practical option that's within reach of smaller enterprise spaces, not just the largest venues served by operator-supplied solutions



CHAPTER 9

Funding your in-building wireless solution

Funding your in-building wireless solution

Improving ROI makes in-building wireless (IBW) more accessible to enterprises

Once, IBW solutions were pretty much the exclusive domain of wireless operators, who installed them in locations where they would provide ample ROI—large venues with great amounts of revenue-generating traffic. In those days, the operator would of course pay for the deployment and operation of the IBW solution.

However, this model kept the advantages of IBW solutions out of reach of small to mid-sized enterprises simply because the operators cannot justify the expense in smaller venues. A typical metro area might have one large airport and up to three stadiums, but it will have thousands of office buildings, each containing a relatively smaller number of mobile subscribers and less usage. Mobile operators cannot justify investing in IBW systems for all the office buildings. Fortunately, the cost has come down to the point where an enterprise owner or manager can make a solid business case for deploying their own IBW solution, or sharing the cost with third-party partners under certain circumstances.

Let's look at the three main players when it comes to paying for an IBW solution in an enterprise space, starting with the most optimistic option and finishing with the most likely.

In their 2016 Global DAS Forecast document, Mobile Experts LLC predicts a 300% increase in the number of enterprise-funded in-building wireless systems is expected by 2021 to meet the needs of ubiquitous wireless coverage in the workplace.

1 The wireless operator

As mentioned above, wireless operators still deploy IBW solutions in the largest commercial spaces. This is because they provide fast, significant ROI for the operator, even where they carry different operators' traffic in addition to their own. This is of course the most optimistic possibility, as the enterprise assumes little or no cost for the system or its operation.

In some cases, operators are willing to negotiate to provide single-operator IBW solutions for enterprise spaces. The downside for the enterprise is that only one operator's network is supported, leaving users of other networks without connections. If the enterprise only intends to support company-issued devices that all run on a single network, this may be an acceptable limitation.

However, it's important to know that these arrangements are uncommon and only available under specific circumstances dictated by the operator.

2 A neutral host company

Neutral hosts are third-party providers of DAS and small cell solutions that support multiple operator networks. If the ROI justifies it, a neutral host may offer to install an IBW solution in the enterprise at little or no cost to the enterprise owner or manager, and then charge the wireless operators for the traffic that IBW solution moves onto their networks.

Again, there exists a significant ROI hurdle. The neutral host business model depends on a revenue stream from mobile operators that offsets the initial investment and ongoing operation of the DAS. For the operator, this ongoing expense is only justified where there is a large number of subscribers generating high usage. As a result, neutral host deployments tend to closely mirror the profile of operator-funded deployments: very large venues such as airports, stadiums and convention centers.

3 The enterprise itself

This is the most common way IBW solutions are now being funded. Because of recent advances in DAS and small cell solutions, the cost and complexity barriers have been reduced, making them a more practical and economical choice for a wide variety of enterprise environments.

In an enterprise-owned IBW deployment, the building owner or manager pays for the equipment and installation, very possibly leveraging the building's existing IT infrastructure. Ongoing maintenance and monitoring can be outsourced to a specialized provider.

If the solution is DAS, then the wireless operator(s) provide and maintain the RF signal source. If the solution is a small cell, on the other hand, it has its own radio—and this may be funded by the enterprise or an operator. In all cases, the enterprise will need to negotiate agreements with the operator(s) to integrate with their networks.

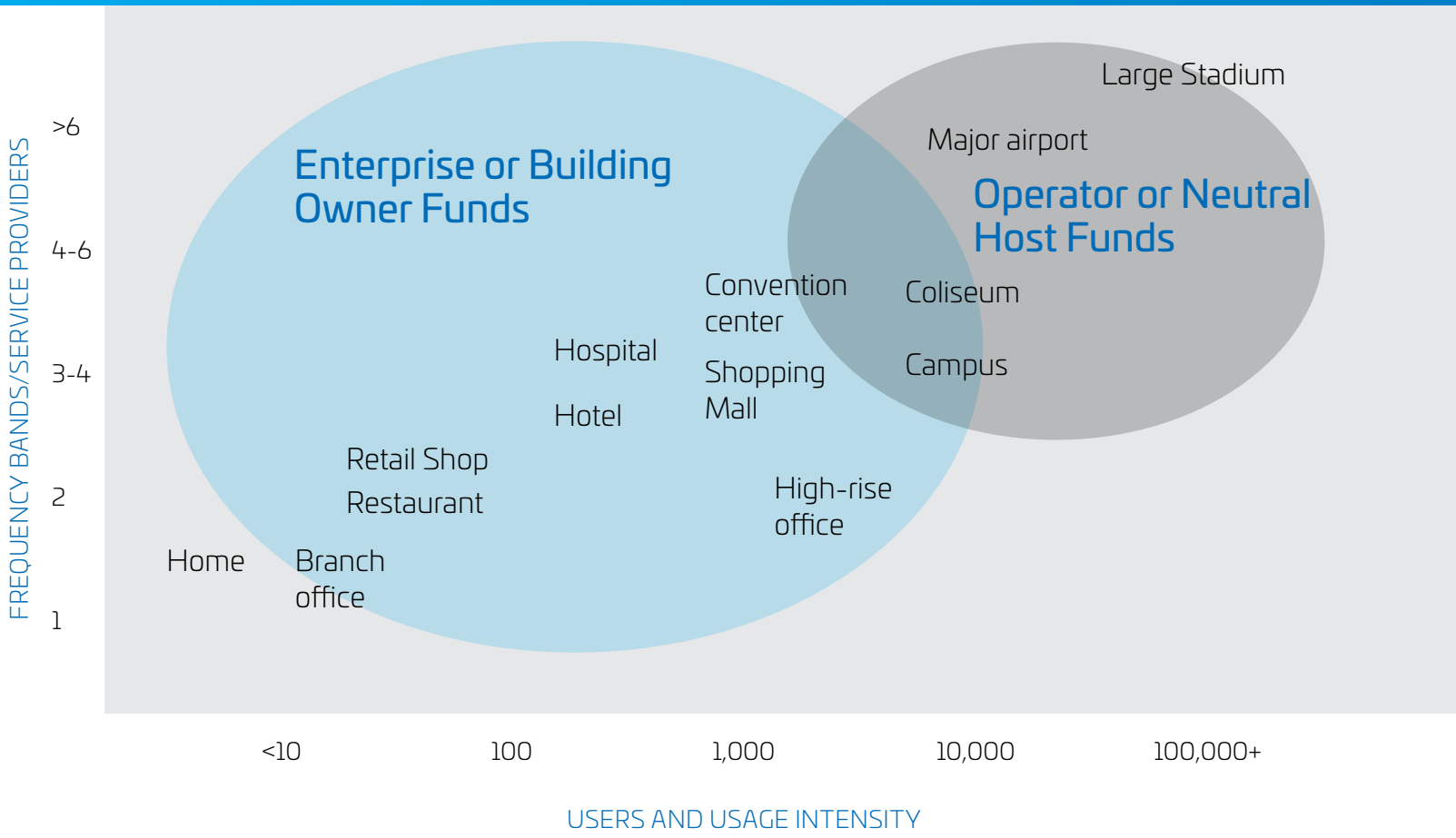
The key advantage to an enterprise-owned IBW solution is that it creates an opportunity to deliver IBW service to companies that do not meet the ROI criteria of enterprises and neutral hosts. The enterprise-funded model also provides flexibility; the system can be configured to work with as many operators as needed, a must for bring-your-own-device (BYOD) workplace environments or mixed-use retail spaces where visitors will need access to various networks.

While this funding model is the most expensive for the enterprise, it also provides the greatest freedom to customize coverage and capacity for optimized employee productivity and enhanced customer satisfaction—and again, the cost and complexity obligations continue to drop, improving ROI and making it a practical alternative for more and more enterprises, particularly those with the existing IT infrastructure to support its deployment.

In addition to these three dominant funding structures, other options exist which may include splitting ownership and responsibility of the IBW solution among two or more parties, but these combination models are uncommon and available only under specific circumstances.

Most likely, an enterprise will deal only with one of these three possibilities. The figure on the next page shows what kind of situations generally correspond to different funding models.

FUNDING MODELS MAPPED TO TRENDS IN VARIOUS VENUES AND APPLICATIONS



There are different funding models, but is there really a funding choice?

Although there are various ways an IBW solution may be funded, how it actually will be funded is generally a foregone conclusion based largely on the enterprise's size and how much wireless traffic it generates.

Under limited circumstances, a neutral host may find it practical to install an IBW solution in an enterprise environment, albeit with a contractual condition of profitability that may or may not be sustained over time. Under even more limited circumstances, a wireless operator may find it possible to deploy a single- or multioperator IBW solution, but only the largest venues will likely enjoy this support. There are even some cases where costs and ownership are split among multiple partners.

Most likely, the IBW solution your enterprise deploys will be one that you choose, purchase and install. The reductions in cost and complexity, however, make this a far less daunting prospect that delivers real ROI while remaining under the control of the enterprise itself.

CHAPTER 9 SUMMARY

- Reduced cost and complexity are shifting ROI calculations in favor of the enterprise
- IBW funding is most commonly provided by the enterprise, less often by neutral hosts and operators
- Enterprises are now more empowered to choose and manage their own IBW solutions

CHAPTER 10

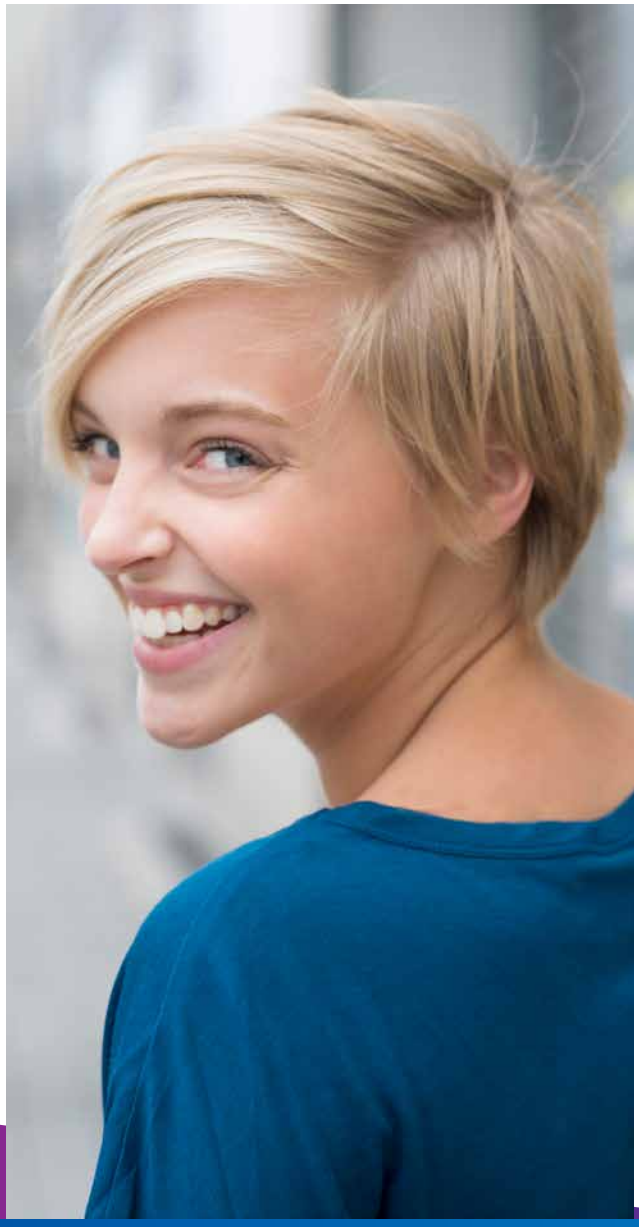
Your path to successful in-building wireless

Your path to successful in-building wireless

In-building wireless (IBW) solutions have come a long way—but the journey is far from over

Even the most optimistic RF engineers could not have conceived how far those first beige brick mobile phones would eventually take their field. From the first commercially-available wireless devices in the early 1980s to today's advanced wireless networks, the wireless revolution continues to roll on.

Where obstacles present themselves—such as interior spaces built of RF-dampening materials like concrete and low-E glass—CommScope is among the leading innovators of solutions designed to bring reliable connectivity where it couldn't be achieved before. These solutions don't rely on a single standard or architecture—they have evolved into a wide ecosystem of technologies, each striving to address specific circumstances and diverse needs. That's why CommScope is a trusted provider of solutions in DAS, small cell and C-RAN technologies, so that no matter the challenge, we can always provide a reliably revolutionary answer.



Social evolution drives IBW evolution

This book has provided you with an overview of this history, along with the science, solutions and considerations that go into choosing an effective, efficient and economical IBW solutions for enterprise spaces. We covered:

- The past, present and future of in-building wireless (IBW) solutions
- How to select the right IBW solution for your enterprise
- DAS, small cells and Wi-Fi technologies
- Licensed and unlicensed technologies
- How to fund and deploy your IBW solution

As society's demand for ubiquitous coverage became a common, everyday lifestyle expectation, IBW solutions have become a necessity for building owners, facilities managers, architects and others who are in the business of making an enterprise space attractive and functional.

CommScope is spearheading the evolution of IBW technology

At CommScope, we believe strongly in the power of sharing information and expertise to advance the wireless solutions that power our modern world of communications. We're the company that invented DAS, and 40 other incredible solutions that have become integral parts of our global communications landscape over the last 40 years.

Today, our technologies power the latest DAS and small cell options, including the self-optimizing ION-U DAS solution; the IT convergent ION-E DAS solution; the C-RAN-based OneCell small cell and C-RAN antenna system solutions; and, of course, a full portfolio of copper and fiber-optic infrastructure to connect them all to a data-hungry world. We also offer extraordinary partner support through the PartnerPRO® Network and superb training through the CommScope Infrastructure Academy because we understand that a real solution goes beyond solving your technical challenges to solve your business challenges.

CommScope invites you to contact us with any questions you may have about **our solutions** or IBW deployments. We are always happy to share our experience and insights, no matter how big your connectivity ambitions may be, or how steep your challenges.

CommScope (NASDAQ: COMM) helps design, build and manage wired and wireless networks around the world. As a communications infrastructure leader, we shape the always-on networks of tomorrow. For more than 40 years, our global team of greater than 20,000 employees, innovators and technologists has empowered customers in all regions of the world to anticipate what's next and push the boundaries of what's possible. Discover more at commscope.com

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