COMMSCOPE®

IN-BUILDING WIRELESS BEST PRACTICES

Contents

Chapter 1

IBW - What it is, where it's been and why that matters **3**

Chapter 2

IBW challenges - Why broad adoption will continue **8**

Chapter 3

The future of IBW solutions **15**

Chapter 4

Choosing the right IBW solution for your needs **20**

Chapter 5

The opportunities of using DAS and small cells **25**

Chapter 6

The role of unlicensed frequencies in IBW solutions **30**

Chapter 7

When Wi-Fi is—and isn't—sufficient **35**

Chapter 8

How to deploy IBW **40**

Chapter 9

Funding your IBW solution **47**

Chapter 10

Your IBW future **52**

CHAPTER 1

IBW

What it is, where it's been and why that matters

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 and unusual predilection for beige—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 linked 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 won't dwell too long on the differences or technical operation of various IBW solutions (we explore two major families of these solutions, DAS and small cell, in Chapter 5). But suffice it to say that all IBW solutions are designed first and foremost to supplement the macro wireless network by deploying indoor coverage within a certain area to provide seamless connectivity for people inside.

IBW isn't Wi-Fi

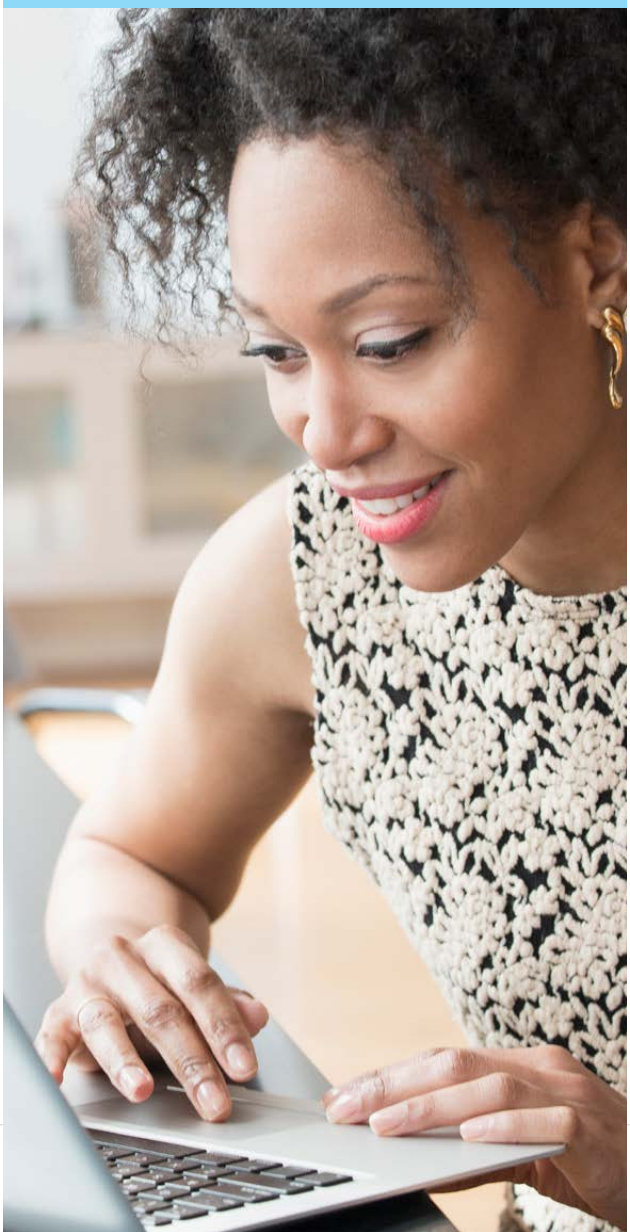
It's important to note that IBW solutions are not the same thing as Wi-Fi. While there are some superficial similarities in the functions they perform, there are radical differences in how they are designed, deployed and managed.

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—3G or, more commonly, 4G/LTE—to connect for data and voice instead of their device's Wi-Fi service.

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

Unlike IBW solutions, Wi-Fi is limited to unlicensed and unregulated spectrum. Wi-Fi is also generally not well suited as a flexible voice traffic solution such as wireless macro network-interfacing IBW solutions are. However, modern IBW solutions are now available that allow both platforms to operate on a single, shared IT cabling infrastructure. We will explore the differences—and the convergences—in detail later on.



The evolution of wireless networks and IBW

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.

It was originally expected that IBW solutions would become as ubiquitous in commercial, industrial, entertainment and other enterprise spaces as electricity and plumbing. However, since this DAS solution was difficult to optimize and expensive to install, practical applications proved to be quite limited. Initially, only wireless operators were able to offer IBW solutions. Building owners, managers, and architects had no direct control over IBW options. Fast-forward to today, and that fact has changed dramatically.

With operators being the only source of IBW solutions, they had to prioritize installations based on opportunity and variable costs. In some cases, regulatory authorities required such a system to support emergency responders' frequencies. In other cases, the financial benefits were not enough to recover the operator's investment and requests had to be denied.

Over the years, IBW deployments continued to go online here and there, but financial, legal and contractual challenges limited their appeal as a practical solution—as an operator-supplied solution. It seemed that IBW would never achieve the critical mass it needed to make a real difference in the market.

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 and remained in wide use in the United States until about 2010. It is still in wide use in other parts of the world.
- 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 the United States, it remains the most widely used standard in Europe.
- 4G/LTE employs more efficient modulation to expand bandwidth, increase speed and enable new online functionality for online devices. Ironically, one of the services it doesn't generally serve is voice communication.
- 5G standards have not been fully defined as of this writing, but it 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) devices. Experts agree that 5G will achieve significant market presence in the 2020s.

IBW finally gets to play ball

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.

When load grew too heavy, the 3G network couldn't cope. Coverage in the area would crash, resulting in outages that would last hours—sometimes days. The outages would continue long after the game was over, the stadium was empty and the actual demand had diminished to nearly zero. The perfect business case for IBW emerged.

DAS deployments 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, a solid business case remained elusive. Because DAS does not have its own RF equipment, it must link out directly to an operator's core macro network in order to operate—that is, a specific operator's core network.

With multiple popular operators in most markets, it seemed wise to work together to create multi-operator DAS platforms that could handle traffic from fans in the seats, no matter what operator they subscribed to. A group of national operators put this initiative forward in 2010, but contractual and practical challenges caused the alliance to fall apart in 2014 as other business priorities took precedence over IBW.

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

Fast-forward to the present

Why you don't actually dial a phone any more

As far as wireless operators are concerned, IBW solutions are no longer a core part of their business models. They continue to deploy them in limited circumstances, and establishing a long-term multi-operator arrangement can be an arduous process. In the meanwhile, however, growing demand following the adoption of LTE and increased concentrations of users in indoor spaces has only accelerated. The problem has grown faster than operators' capacity to deal with it.

Thanks to new solutions that simplify deployments, optimization and operation, IBW is rapidly becoming an enterprise initiative as building owners, managers and architects step in to fill the void. 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 to emerge.
- 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 a chance to suit your needs.
- 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 deploy IBW in every building they serve, it falls to the owner 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

A general rule of thumb captures the actual cost factor of installing a modern IBW solution:

A typical IBW solution like DAS or small cell costs about $1 per square foot, with an expected operational life span of 10 years.

Compare this to low-cost industrial carpet, which costs about $3 per square foot, and also has roughly the same useful life span.

IBW's past can power your enterprise's future

Born of the need to supply wireless connectivity everywhere, IBW solutions have grown up in the shadow of cellular technology, yet never far behind it.

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.

New solutions make the numbers add up

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 an iPhone 7 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 highly variable demand. It also offers multi-operator support since it does not have its own radio source; no integration means less lengthy operator approvals.
- 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 quality of service (QoS) 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 dedicated radio source, integration with multiple operators can be harder, so small cells are best suited to single-operator deployments.

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

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
- A rocky history of 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

IBW challenges

Why broad adoption will continue

Wireless users view connectivity like they view the availability of water, power and gas

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 emergence of the Millennial generation.

For this reason, many in the wireless industry consider IBW 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.

Wi-Fi alone isn't enough

A common misconception is that IBW is just another name for Wi-Fi. After all, one of the first things a wireless user does when entering a building is to check for an accessible Wi-Fi network. Generally speaking, Wi-Fi is not built to carry cellular network traffic (with some exceptions, as we will see in Chapter 6). Voice is still generally handled by the macro cellular network. While Wi-Fi may help web pages load quickly on a smartphone, it won't address those aggravating cellular dead zones that occur indoors.

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 some 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, as future capacity demands rise, it will prove insufficient to meet said cellular requirements. That's why the inclusion of a dedicated 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.

We will explore the right balance of Wi-Fi and IBW in Chapter 7.

IBW fast facts

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

- 80 percent of wireless communications originate indoors, but…
- 98 percent of commercial/enterprise spaces do not have a dedicated IBW solution.

Customer, tenant and employee expectations

The growing need for dedicated 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, but IBW challenges remain

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.

Percentage of respondents that agree with the following statements:

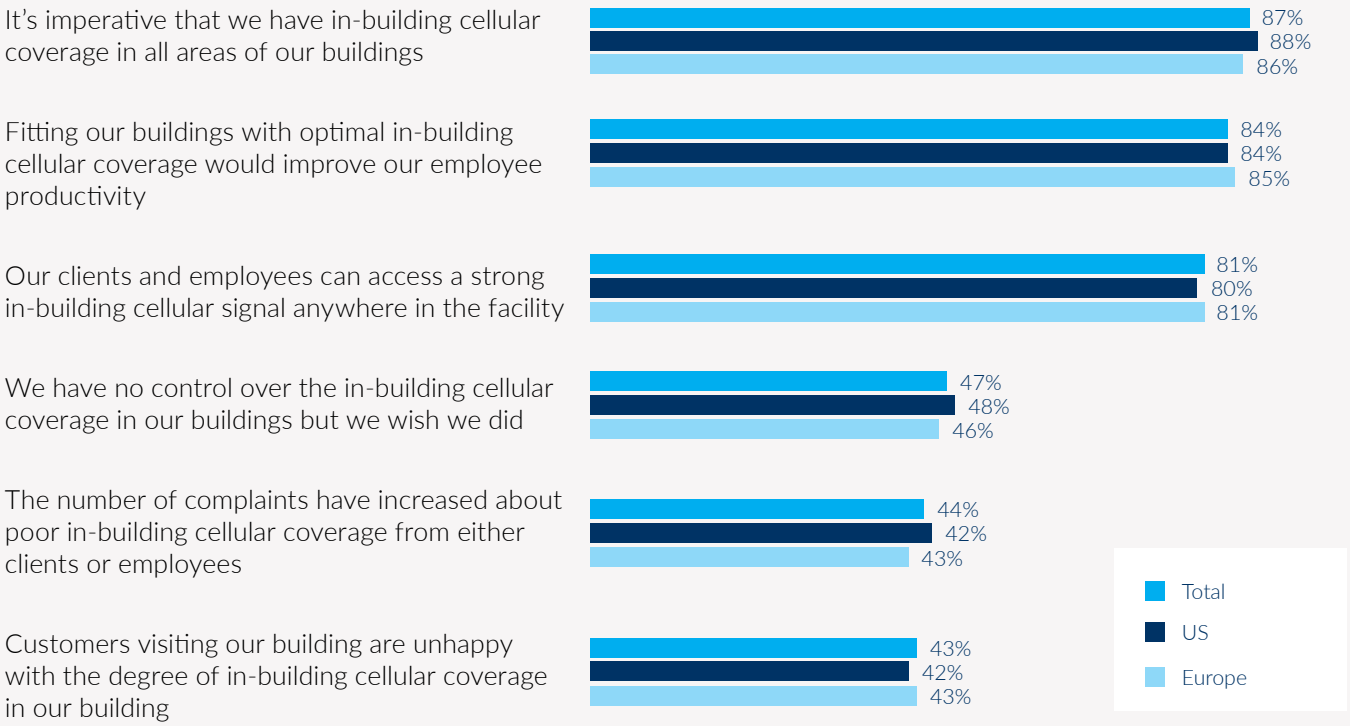


Figure 1: Top-line results of a 600-person survey in 2016, Source: CommScope In-Building Wireless Survey Report; February 2016

Challenge: making 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:

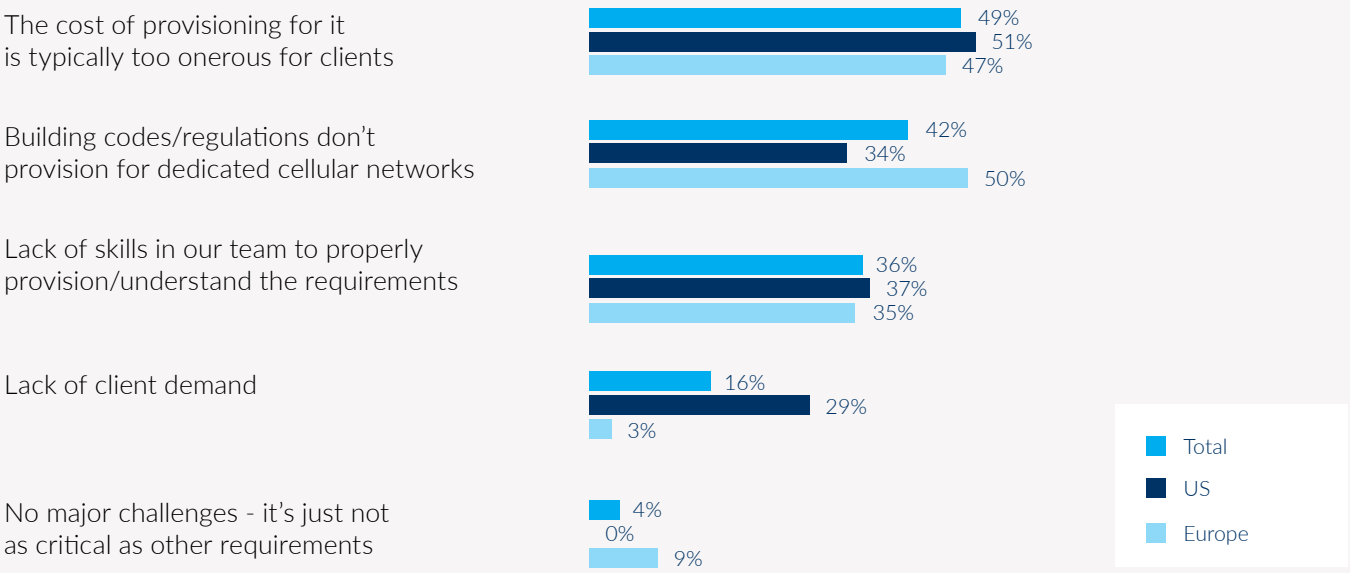


Figure 2: Obstacles to inclusion of IBW solutions, Source: CommScope In-Building Wireless Survey Report; February 2016

Challenge: who's in charge?

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 offer and support limited IBW solutions, but these are restricted to traffic running on their own network. Since there are many global wireless operators with tens of millions of customers, this solution isn't feasible in the long term.

As awareness of the problem grows, more pressure will be brought to bear on building owners, business leaders and architects who maintain other aspects of building design, operation and usage. Third-party providers are gaining importance as an intermediary between tenant needs and wireless operators because they can facilitate multi-operator connections. To remain cost-effective, however, their services are best employed only for larger environments.

In small-to-medium deployments, the costs simply don't justify the benefits, leaving the owner, operator or architect to build their own solutions capable of interfacing with multiple wireless operators. We'll explore this in greater detail in Chapter 4.

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

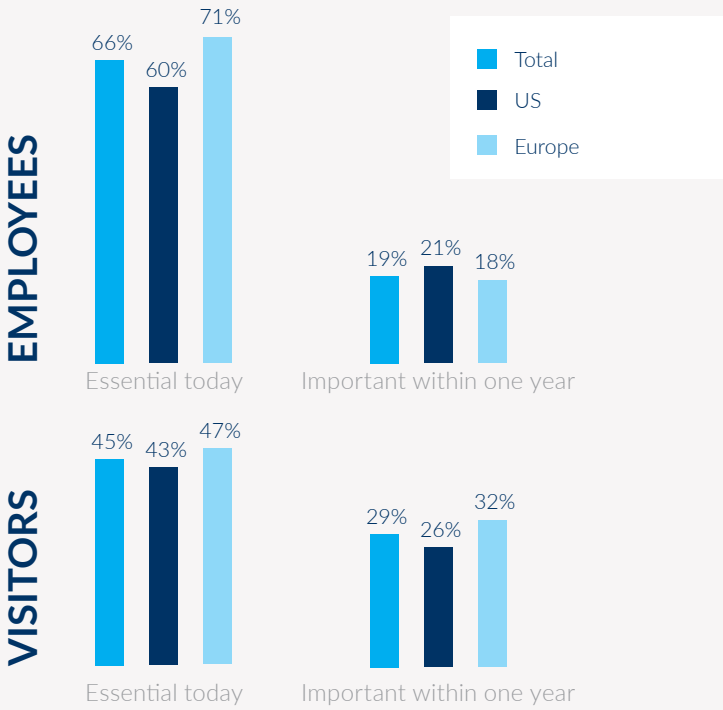


Figure 3: The importance of cellular coverage, Source: CommScope In-Building Wireless Survey Report; February 2016

Challenge: overcoming complexity

Wi-Fi deployments are generally plug-and-play solutions that use unlicensed frequencies and require little skilled labor to install. In contrast, IBW deployments can be complex and difficult to provision. Because they interface with wireless operators' macro networks, IBW solutions must meet more stringent requirements and use licensed frequencies. This demands infrastructure that includes specialized RF equipment and cabling, and requires expensive, highly-skilled labor to install.

In addition, each building tenant will likely maintain his or her own IBW expectations and requirements. Evolving wireless network standards also introduce uncertainty over future compatibility. For example, with 5G networks on the horizon, the limiting factor of complexity becomes even more significant. We will explore these challenges in more detail in Chapters 6 and 8.

Challenge: providing 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 standard IT cabling infrastructure, or even via more economical fiber-optic solutions 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.

The bottom line: IBW stands to be a technological game-changer

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 more than the wireless operators. Indeed, even for small to mid-sized enterprise environments, the question is no longer if a dedicated IBW solution should be implemented, but what kind and in what manner.

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—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 IBW solutions

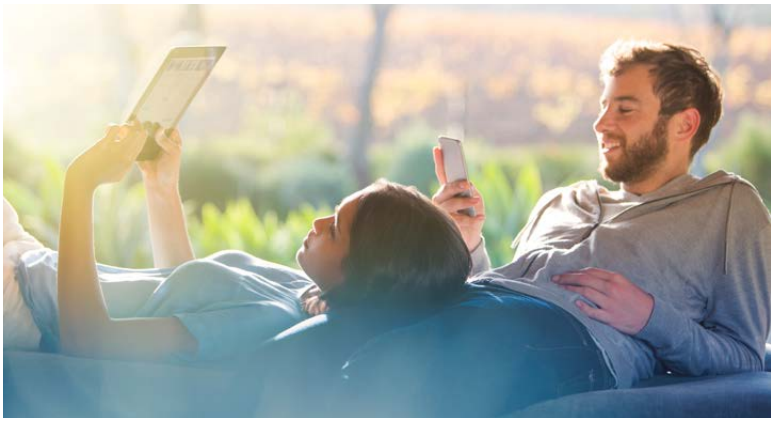
Better, simpler, faster, and more necessary

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 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.

IBW fast facts

Many jurisdictions now require enterprise spaces of a minimum size to support licensed public safety frequencies so police, firefighters and paramedics can communicate indoors in the event of an emergency.



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.

- **Voice over Wi-Fi (VoWiFi).** VoWiFi offers an unlicensed-band alternative to traditional LTE-based IBW solutions. It uses the IP network to route voice calls with acceptable quality. A user's device must be designed to connect to this kind of network, and these devices are now entering the market in greater numbers. We explore this in more detail in Chapter 6.
- **LTE unlicensed (LTE-U) and LAA.** LTE-U uses the 5 GHz unlicensed band used by Wi-Fi to move traffic on the network. In order to get the LTE-U signals onto the licensed macro network bands, it must be aggregated via licensed-assisted access (LAA) to separate it from purely Wi-Fi data signals and move it onto a licensed operator's network. We explore this in more detail in Chapter 6.

- **MulteFire.** This unlicensed solution will not require the same integration processes as VoWiFi and LTE-U, as it moves unlicensed IBW traffic to the macro network via an air interface.
- **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 integrated into an operator's network. We explore this in more detail in Chapter 5.
- **Distributed antenna systems (DAS).** Using licensed frequencies, this network of antennas linked to a headend allows LTE bands (as well as other technologies like 2G and 3G) to be carried directly to an onsite or offsite, operator-owned radio source. We explore this in more detail in Chapter 5.

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

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

Emerging architectures

These IBW solutions all depend oWn a network of copper or (increasingly common) fiber-optic infrastructure to support their antennas, access points and other interfaces. In the past, most true 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.

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.

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

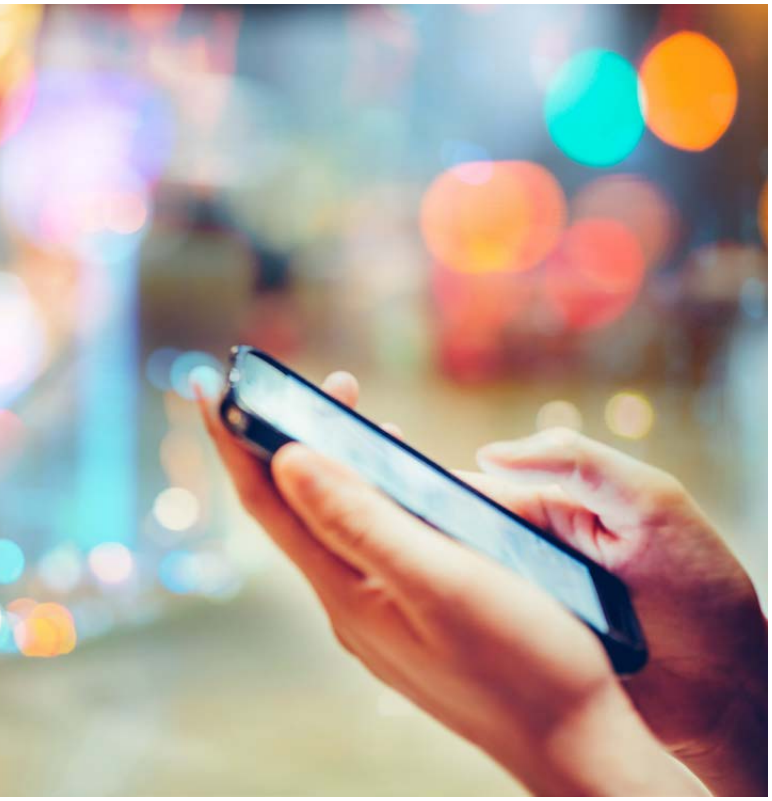
One element all IBW solutions have in common is the need to rapidly route traffic on and off the macro network of one or more operators. Since many of today's applications are data intensive, they consume a great deal of bandwidth. As a result, in most enterprise-sized deployments, this on-ramp can become 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. Multi-gigabit speeds are absolutely critical, and will only become more important as time goes on.

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 remote-controlled surgery to vast fleets of driverless automobiles.

The future of IBW is looking good

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. In the next chapter, we explore the various technologies available to help you cover the wireless gap in your enterprise space.

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

CHAPTER 4

Choosing the right IBW solution for your needs

If a dedicated IBW solution is in your future, what should it look like?

If one truth has emerged from this ebook so far, it's that there is no one-size-fits-all IBW solution that's equally efficient and effective for all kinds of enterprise spaces. While some unlicensed technology (like Wi-Fi) may be a simpler solution, its many limitations make it unsuitable as a standalone solution in many, if not most, enterprise environments—a topic we will explore in Chapter 7.

Assuming your enterprise space is among those suited to the flexibility, reliability and profitability that a licensed IBW solution can provide, 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 the future

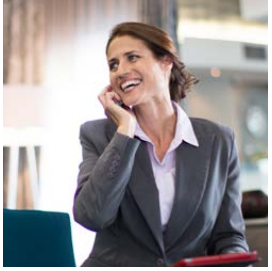
Let's begin with the simplest question of all: what kind of space will your IBW solution need to serve? The physical layout, size and occupancy all have a great deal to do with selecting the right technology.

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?

These answers will come 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

One operator, two operators or multiple 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 to connect with two or more, and some work with all networks right out of the box.

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.

A dual-operator solution provides coverage for the vast number of users in markets where two operators may account for 90 percent of subscribers. Multi-operator enables everyone to connect to their own networks—ideal for spaces where bring-your-own-device (BYOD) policies prevail or retail customers regularly come and go.

- **Single-operator solutions** may be the simplest to set up and the least expensive to operate, but they can lock you into a single relationship for all users. For those subscribing to non-supported operators, this can mean roaming charges or other complications.
- **Dual-operator solutions** enable the comingling of two operators' traffic on the same frequencies, separating them with dual-band LTE radios. This can help expand accessibility, but may reduce the amount of throughput available on each network.
- **Multi-operator solutions** interface with as many operator 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.

While most solutions can be used in any of these configurations, it is generally true that small cells are 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 enterprisespace 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, some municipalities have strict regulatory requirements governing how much RF power may be used in human-populated areas, such as an indoor enterprise space.

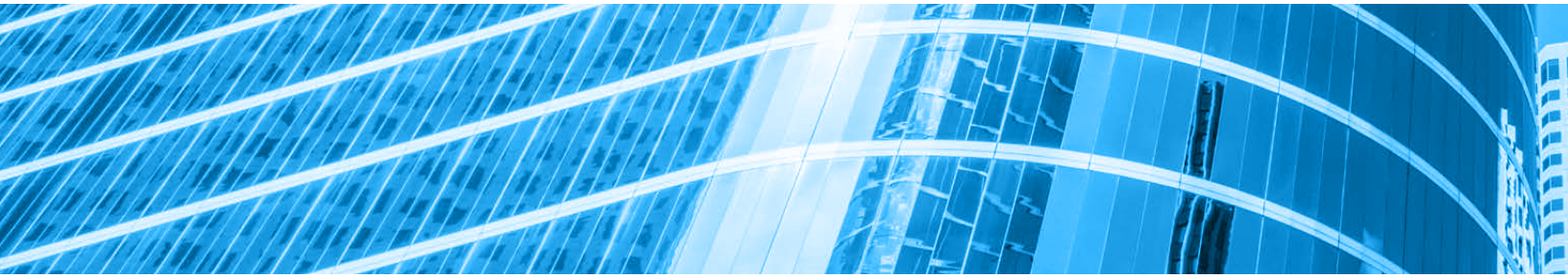
Also, higher-power systems naturally consume more electricity, increasing the cost of operating the IBW solution. This incremental cost can really add up in parts of the world where energy prices continue to edge upward over time.

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

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 also has the advantage of consolidating both systems in a single headend, reducing floor space requirements and energy costs.



Are you prepared for the future?

The latest innovations in both small cell and DAS solutions have yielded more affordable ways to deploy, optimize, operate and adapt the network, up to 5G specifications and beyond. 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 QoS for the end user.

The single most 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.

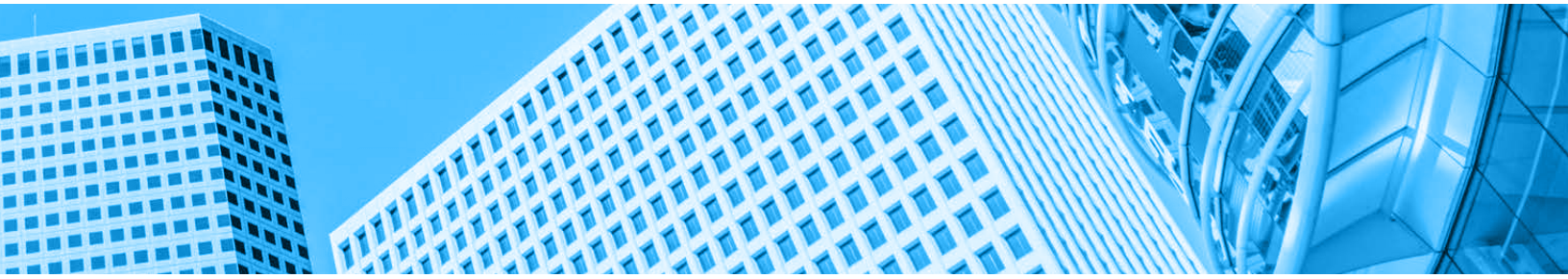
A solution for everyone

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
- Modern IBW solutions provide the headroom to adopt emerging technologies like 5G



CHAPTER 5

The opportunities of using DAS and small cells

Meet the diverse family of IBW technologies

The phrase "in-building wireless" is a catchall term that covers an entire class of diverse, specialized solutions that require enterprise owners, managers and architects to carefully weigh the benefits and costs to determine the most efficient solution. It's imperative that the ideal solution meets not only the needs of today's tenants and users, but also offers the flexibility and agility 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.

IBW fast facts

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 solutions to power integrated video displays, VoIP, security systems and much more.

DAS: powerful and 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 building)
- 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 awkwardly-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 RF cable (i.e., 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 inexpensive to hire.

It's worth noting that DAS is just that—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 instant 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).

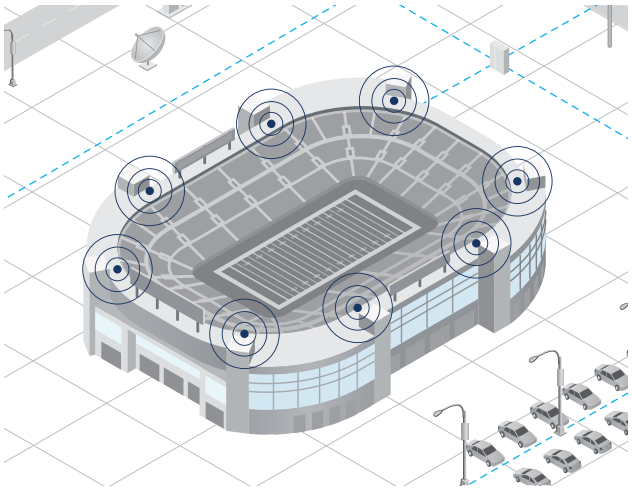


Figure 1: An intelligent auto-configuration of outdoor DAS optimizes coverage and capacity in a large stadium.

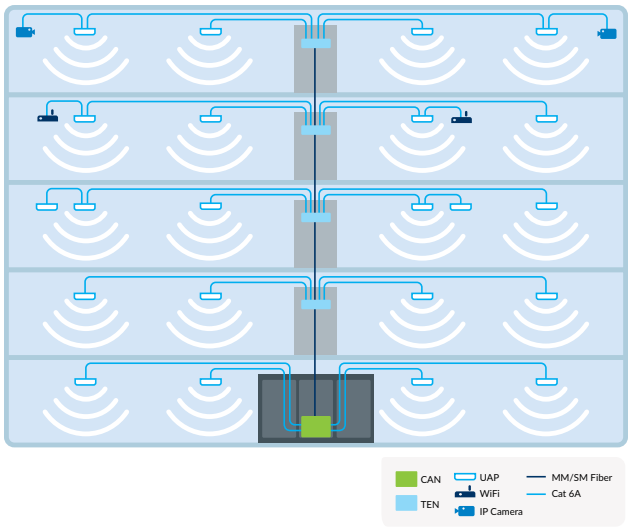


Figure 2: An IT-converged DAS infrastructure uses network cabling instead of expensive coaxial cabling.

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

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.

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 are able to support deployments spanning the size of a small-to-medium office building, where demand levels are relatively consistent from one day to the next, distribution of users does not vary to any great extent, and demand is not expected to spike to extreme levels.

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 cross-sector interference 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. This situation is improving, but slowly. A given model of small cell typically only supports one operator's network.

Also bear in mind that small cells have a hard upper 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 reliably 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: the best of both worlds?

We stated above that small cells suffer from the same cross-sector interference that sometimes plagues the macro cell network 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 base band 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 eliminates QoS issues and 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.

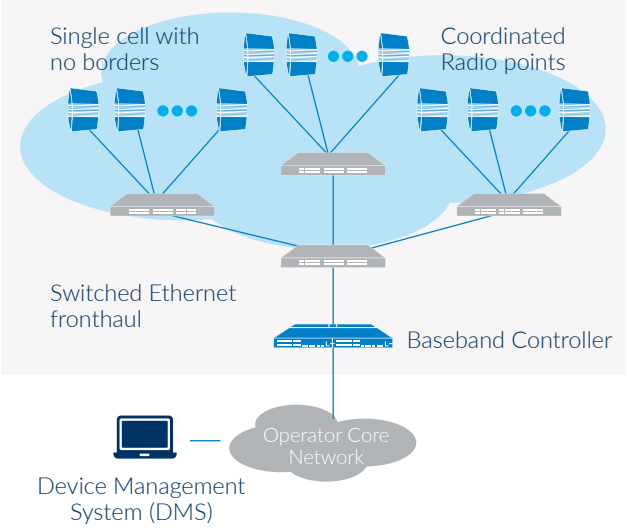


Figure 2: An IT-converged DAS infrastructure uses network cabling instead of expensive coaxial cabling.

DAS or small cell? It depends on the job you need it to perform.

Choosing a solution for an IBW deployment involves several questions. How much space must be covered? How many people must be supported? How much will the coverage and capacity demand change from one day to the next? 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 highly variable coverage and capacity requirements
- DAS is not always economical for smaller areas of coverage
- Small cells are suited to small-to-medium spaces with consistent demand
- Small cells offer similar benefits and drawbacks of the macro cell network
- C-RAN is a breakthrough small cell innovation that eliminates many of small cells' QoS limitations

CHAPTER 6

The role of unlicensed frequencies in IBW solutions

Welcome to the wild west of the airwaves

It may surprise you to learn that, in an industry as heavily regulated as wireless communications, there exist several commonly-used technologies that use unlicensed—that is, unregulated—parts of the RF spectrum. Choosing to put part of your IBW solution on these unlicensed bands can be an economical way to extend coverage quickly, but they do come with some significant limitations. In a full IBW deployment, unlicensed bands still require a method or roaming agreement to connect with the licensed bands used by wireless operators.

The emergence of unlicensed spectrum solutions

First, a bit of context. While standard Wi-Fi and DAS solutions have co-existed in larger enterprise spaces for many years—with the former serving data needs and the latter primarily supporting voice communications—the rapid rise in demand has taken all the spectrum these solutions were designed to give. Their once-distinct frequencies of operation began to converge as each borrowed more and more unlicensed spectrum until they began to conflict with one another.

Their functions, too, have begun to merge as the solutions become faster and more efficient. Let's take a look at some of these unlicensed solutions now.

Voice over Wi-Fi (a.k.a. Wi-Fi calling)

One of the main advantages DAS holds over unlicensed solutions is the ability to interface with all kinds of wireless operator networks, multiple technologies (such as LTE, 3G and so forth), and virtually universal compatibility with wireless devices, making it a must for getting voice traffic on an off the core network.

Voice over Wi-Fi (VoWiFi) offers an unlicensed alternative that uses the IP network to route voice calls with acceptable quality.

To use VoWiFi, one must have a compatible device and the enterprise environment must be outfitted with Hotspot 2.0 coverage (see sidebar). Major manufacturers are introducing these wireless devices now, but the opportunities to use VoWiFi on these devices remain hard to find.

IBW fast facts

VoWiFi deployments are few, but slowly growing—powered by Next Generation Hotspot (Hotspot 2.0).

Hotspot 2.0 can essentially turn an indoor space into its own wireless operator. It can integrate with national wireless operators via a roaming agreement, just as national operators have with each other.

While the technology is well established, these contractual roaming requirements have prevented Hotspot 2.0 from becoming a more frequently-used solution—for now.

The downsides of VoWiFi

VoWifi does have significant limitations, however, many of which are common to all Wi-Fi applications, as we will discuss in greater detail in Chapter 7. A few of these limitations include:

- Potentially unreliable QoS. Since VoWiFi traffic may not be prioritized highly enough on the network, quality can suffer. This is particularly true in high-traffic environments where users come and go. In these areas, user identification and policy application are challenging, possibly adversely affecting bandwidth.
- Adding sufficient access points to support users can reduce available throughput. As more access points are added to a Wi-Fi network, the amount of throughput at any given access point decreases. This introduces delays and jitters in voice calls.
- Calls drop at the door. While VoWiFi can offer good connectivity within the enterprise space, it cannot smoothly hand off the call to the macro network when the caller leaves the covered space—and the call will drop. This is also true in reverse: the call cannot be handed off from the macro network to VoWiFi when entering the covered space.
- Unlicensed frequencies mean you're on your own when it comes to interference. As we will explore in detail in the next chapter, shared spaces and multi-tenant buildings introduce the possibility of interference between neighboring Wi-Fi networks. Sometimes these can be resolved by informal agreements between the affected parties, but no established legal or regulatory recourse is available in cases of conflict.

For these reasons, VoWiFi is 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. For other situations, there are other unlicensed solutions available that may be better suited to the circumstances.

IBW fast facts

The push into unlicensed frequencies is driven by the delicate balance between technology and business. Even as more frequencies are made available at auction, the incredible rise in demand is still forcing the cost per bit of data to skyrocket, particularly in densely-populated markets.

LTE-U and LAA

LTE unlicensed bands (LTE-U) operate a bit like the ride-sharing service of wireless communications. LTE-U uses an LTE-style signal in the unlicensed 5 GHz band—the same band used by advanced Wi-Fi networks—to carry data and (to a lesser extent) voice traffic.

However, like a ride-share, it's also subject to traffic jams because it shares frequencies with data traffic. Depending on the deployment, either voice or data may be bottlenecked.

LAA: bringing standardization to unlicensed bands

In some cases, the LTE-U specification allows the voice traffic to take control of the frequencies, regardless of what other traffic may be trying to cross the network at the same time. Where it is aggregated through licensed-assisted access (LAA), a "listen before talk" scheme checks to see if the frequency is clear before proceeding to connect.

This arrangement is becoming the global standard. In some countries, it is a regulatory requirement. In either instance, however, a certain kind of traffic is allowed at the expense of another. LAA is a formally standardized way for an operator to add data on unlicensed bands to an existing LTE band. For IBW solutions, this means a local integration of LTE and Wi-Fi infrastructure to carry data and voice over parallel systems, with similar speed and latency.

Licensed-band network integration

It bears repeating that, for any unlicensed IBW solution, the enterprise must integrate with the licensed bands used by wireless operators in order to connect with the outside world, though alternatives are emerging that may change that requirement (see sidebar).

Also worth consideration is the rapid approach of 5G, which is poised to redefine what is possible from wireless networks and, by extension, IBW solutions. LTE will be in play for many years to come, but it will not be the only option.

IBW fast facts

MulteFire is an unlicensed solution that does not require the same integration processes as LTE-U, but integrates seamlessly with the macro network as VoWiFi does.

While not fully standardized as of late 2016, MulteFire uses an air interface to directly connect to broader networks, such as ISPs and wireless operators.

The bottom line: an enhancement, not a replacement

The realities of business have driven an incredible amount of innovation in the use of unlicensed bands to provide indoor connectivity. Affordable and easy to deploy, unlicensed-band IBW solutions like VoWiFi and LTE-U offer an effective way to economize budgets—both financial and spectral.

However, the inherent limitations of operating in unlicensed bands mean that, for most enterprise environments, these solutions alone are not enough to provide high-performance, high-reliability, high-QoS connectivity throughout the space. For the moment, a licensed-band IBW solution is also needed to move this traffic on and off the operators' core networks. In the next chapter, we will take a closer look at the complex partnership between IBW and Wi-Fi networks to see how coexistence is not only possible, but profitable.

Chapter 6 summary

- Increased demand has driven IBW solutions into unlicensed bands
- VoWiFi offers multi-operator support, but suffers from performance limitations
- LTE-U shares bands with Wi-Fi but can slow down data networks
- LAA offers a way to aggregate licensed and unlicensed traffic in the channel
- Both VoWiFi and LTE-U require integration into operator networks
- MulteFire holds the potential to interface directly with the macro network
- Most enterprise IBW deployments can benefit from a combination of licensed- and unlicensed-band networks

CHAPTER 7

When Wi-Fi is—and isn't—sufficient

In many cases, Wi-Fi is just one piece of the puzzle

As we mentioned in Chapter 2, there is a good deal of confusion among enterprise managers, building owners and even seasoned architects over what a sufficient IBW solution really is—and it's a question not easily answered. But one fact remains true, no matter the size or configuration of the space you're trying to cover: Wi-Fi coverage alone does not constitute a complete IBW solution.

Like all the options we've explored—small cell, DAS and others—Wi-Fi has a definite seat at the table when it comes to providing wireless connectivity for tenants. But, in the majority of circumstances, Wi-Fi is not enough by itself. Even with the greater functionality afforded by the latest Wi-Fi standards and applications, it is not a substitute for an overlaid LTE or 5G network.

Sharing bands (and why dedicated spectrum costs billions)

Wi-Fi coverage is assumed in many enterprise environments, and for good reason. You can't go to a coffee shop or stay at a hotel without being offered free Wi-Fi. But the very thing that makes Wi-Fi so easy to set up can also severely hamper its performance, particularly in an enterprise-style, SLA-defined deployment—the fact that Wi-Fi uses unlicensed, unregulated frequency bands in the 2.4 and 5.0 GHz ranges.

What does it mean to use unlicensed bands? It means you have the freedom to set up a network quickly and without regulatory overhead. But it also means that, ultimately, you have no control over network efficiency, security or reliability. IBW solutions that use licensed, allocated bands give a building owner or manager rights to their chosen spectrum, and legal recourse against other parties should conflicts over a common band arise. Wi-Fi, being unlicensed and unregulated, offers no such assurances or rights.

Wi-Fi remains the "Wild West" of wireless connectivity. Here's why:

1

You don't own your Wi-Fi channels.

In fact, you're not even first in line.

The number of Wi-Fi channels in the lower 2.4 GHz band is limited to three in most global regions but the higher capacity 5 GHz Wi-Fi band offers up to 14 channels. This allows multiple networks to operate in proximity to each other without interfering.

However, the lack of oversight means that conflicts can and often do arise with neighbors—oftentimes, neighbors with more watts behind their signal than yours. It then becomes a matter of creating an ad-hoc agreement with those neighbors to coordinate channel selections to avoid interference. In an enterprise environment, tenant turnover is one common way for this problem to arise.

Another challenge is the fact that Wi-Fi shares spectrum with Doppler radar, used by airports and weather stations. If such interference is detected by a Wi-Fi network, it automatically defers to the radar source—voluntarily surrendering those channels and potentially reducing network performance. While this is generally not too difficult to avoid during initial setup, it's not unheard of for mobile Doppler units to interfere in networks that had been previously deemed clear of conflicts.

So it is that Wi-Fi's unlicensed, unregulated nature can be a dual-edged sword. It can be a boon in some cases, yet introduce unforeseen challenges in others.

IBW fast facts

It's worth noting that many enterprise environments do not require higher levels of performance, security and reliability than Wi-Fi can provide.

In retail or mixed-use spaces where Wi-Fi is provided as a convenience rather than a business asset, expectations and performance can align without a dedicated IBW solution.

2 Everyone's using it. So who's keeping it secure?

Wi-Fi is easy to install and configure, but keeping it secure is an entirely different matter. Coffee-shop access point spoofing has become the stuff of IT security legend, where a malicious user establishes his own Wi-Fi hotspot and mimics the open Wi-Fi access point nearest to him. When other users connect—thinking his hotspot is your Wi-Fi network—he can intercept everything those other users send across their connections, including passwords, financial information and more.

Identifying and shutting down these threats is often difficult, if not impossible—and it's certainly something most enterprise IT departments don't have the time to handle. Dedicated IBW deployments make it much easier to keep track of connected devices and quickly spot security threats.

3 Wi-Fi applications are growing fast—but not all are ready for prime time.

One of the ways in which a Wi-Fi network may appear redundant with an IBW solution 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.

While this is a useful feature, it comes at a significant cost to performance because each small VoWiFi packet of information must be preceded with a slowly transmitted header. At the normal packet repetition rate of 50 times per second, the cumulative header overhead from each call consumes a substantial amount of airtime—an inefficient use of Wi-Fi's limited capacity even under ideal circumstances.

The current 802.11ac Wi-Fi standard promotes an impressive throughput rate of as much as 1.3 Gbps, but this theoretical limit bears little relation to the actual speeds an enterprise user experiences. 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.

IBW fast facts

Wi-Fi, by its nature, is poorly suited to provide effective VoWiFi. Smooth-sounding voice requires a high repetition rate of refresh packets, each of which includes a substantial amount of overhead airtime that can easily overtax limited capacity.

For this reason, VoWiFi can realistically only handle about 25 simultaneous voice connections per channel at this stage of development.

In contrast, a DAS solution can support 200 or more simultaneous connections per channel, using more standardized, field-tested solutions.

4 How many "nines" do you really need?

Operator-grade IBW solutions are generally built to deliver "five nines" of availability and reliability; that is, a given access point will be available 99.999 percent of the time. To put that into more relatable terms, that equates to approximately five minutes of downtime per year.

Even the best Wi-Fi solutions, properly installed, optimized and managed, rarely achieve "three nine" or 99.9% availability. While this seems to be a modest difference, three nines means you can expect almost nine hours of downtime annually.

The more common 99 percent ("two nines") yields a staggering 83 hours of downtime per year—enough to cause minor annoyance to a retail customer checking his email, but a potential disaster for a bank, hospital or other connectivity-critical enterprise. In these cases, downtime can lead to lost revenue—or worse.

Know what you need, and what you can live without

It really comes down to understanding the communications needs of your enterprise, and how Wi-Fi can or cannot meet them. The expectation of nearly-ubiquitous Wi-Fi access is only getting stronger, so inclusion of an 802.11ac network is virtually a given for most building owners, managers and architects. The question really is, "How important is it for your wireless connectivity to exceed what Wi-Fi—in its real-world state—can reasonably and reliably offer?"

Considering the kind of traffic Wi-Fi is best equipped to manage, and in what concentrations, it may be perfectly suited to an enterprise environment where Wi-Fi is provided to guests, customers, visitors or other non-business-critical users. It also offers an economical complement for environments that are largely dependent on wired Ethernet connections.

However, if your space is a hospital that requires medical telemetry or some other situation that comes with rigorous SLAs or other regulatory requirements, the prospect of inadequate coverage, capacity and availability becomes far more serious—even business critical.

The good news for building owners, managers and architects is that, while Wi-Fi is a given, it's by no means exclusive to other platforms designed to serve the applications Wi-Fi isn't suited to handle. Overlaying multiple wireless solutions not only better equips an enterprise space to deal with the diverse needs of its tenants, but it also prepares for the changing needs of new tenants.

When it comes to offering low-cost, secure data-driven access, Wi-Fi will get the job done. But for handling indoor voice communications, or to offer authentication-free data access to visitors, a dedicated IBW solution offers clear advantages, since it doesn't require a login and allows a cell phone to operate just as it would outdoors in the macro network. It's also worth noting that an IBW solution also provides a sometimes-crucial redundancy for users who are unfortunate enough to be working during the Wi-Fi network's nine (or perhaps as much as 83) hours of expected unavailability per year. All it takes is a quick tap from Wi-Fi to 4G/LTE (or, soon, 5G) and work can continue uninterrupted.

IBW fast facts

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.

This new technology achieves the long-pursued goal of "IT convergence" on a unified infrastructure.

So…when IS standalone Wi-Fi enough?

It's a question only you can answer, and that answer depends on your understanding of what Wi-Fi is truly capable of, what it's designed to do—and what it isn't. New standards and evolving technologies are moving the platform forward, but it remains a bit of a gamble in the enterprise space as a standalone solution.

As with so many technologies, its strengths are also its weaknesses. Unlicensed bands make it easy to set up, yet vulnerable to interference; emerging applications expand its capacities while simultaneously highlighting its limitations; and its easy availability on a store shelf balances with its two to three nines of availability that can mean hours or days of downtime per year.

In most enterprise spaces, the best strategy is a mix of Wi-Fi and IBW solutions. Each has its place, and, in complex enterprise environments, you'll likely need both to keep tenants happy and productive. In the next chapter, we'll explore how to install and integrate an IBW solution.

Chapter 7 summary

- Wi-Fi is everywhere—and that's what people expect
- Unlicensed bands allow quick setup but can introduce performance problems when interference from neighbors or Doppler radar arise
- It can be hard to detect fraudulent hotspots or other security risks
- VoWiFi easily overtaxes limited Wi-Fi capacity with excessive overhead at the expense of other traffic
- Wi-Fi is getting faster, but theoretical performance is still virtually impossible to achieve in real-world deployments
- Reliable enough for some uses, but not for all
- Wi-Fi/DAS overlay networks provide optimal flexibility, performance and reliability

CHAPTER 8

How to deploy IBW

Deploying IBW is simpler than ever. Here's how to make it happen.

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 anything other than Wi-Fi has you hesitating. After all, even the most advanced IBW solution can't match the out-of-the-box simplicity of a Wi-Fi network. Then again, you likely need more than a Wi-Fi network can provide alone.

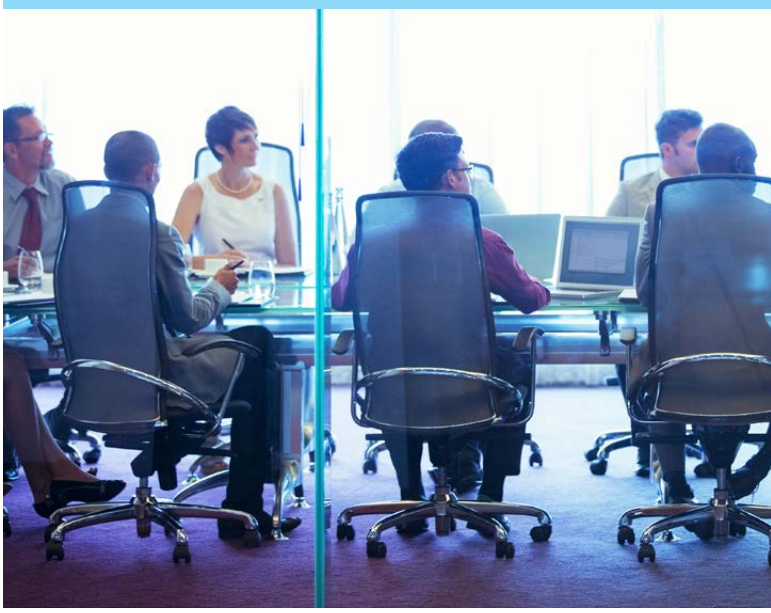
The first step is to determine whether a particular space would be better served by DAS or small cell, single-operator or multi-operator, high-power or low-power, and so forth. By this point in the book, you should have some good ideas about your expectations and requirements. If not, don't worry. Your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

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.



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 with minimal overlap between serviced areas. 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.

- **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 quality of service (QoS) 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.

IBW fast facts

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. For instance, CommScope operates the CommScope Infrastructure Academy, an online, on-demand certification program to ensure that those installing CommScope solutions are doing it 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 offices 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 innovative new DAS and small cell solutions that run on ordinary IT cabling, such as Category 6A or even older 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 to the macro network 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 instant access to the entire DAS.

  In a small cell deployment, the solution does include its own radio source, which must then be integrated with the operator's network via a backhaul solution. These integrations can be tricky, since operators enforce their own specifications before allowing integration. It also means that a typical small cell deployment will only support one operator network.

IBW fast facts

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 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 two significant examples shown here.

IBW fast facts

CommScope offers two noteworthy DAS solutions that greatly simplify the process of commissioning, optimization and monitoring.

ION-U® is a traditional RF-infrastructure solution equipped with built-in intelligence that virtually eliminates the need for RF specialists in these phases.

ION-E® is an IT infrastructure-convergent solution that dynamically scales capacity when and where needed, using its own software to constantly monitor activity.

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, since it can be particularly difficult to perform.

IBW fast facts

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

Software dynamically monitors and adjusts all access points to create a single, virtualized "super cell" that effectively has no cell borders—and hence no cross-sector interference—for instant optimization.

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 failure is a disaster, and not every problem requires instant attention. IBW management is usually available at various levels and degrees. Depending on how your enterprise space uses its IBW—such as the availability of a secondary layer like Wi-Fi—you may be satisfied with lower-cost plans that don't guarantee same-day response.

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

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.

How do you deploy IBW? With the right 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.

With the right partner, any enterprise can deploy an effective IBW solution. IBW isn't an out-of-the-box solution like Wi-Fi, so it's critical to understand and budget properly. Ongoing maintenance will require your attention as well—and this leads us to our final subject: funding your IBW deployment.

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 within reach of enterprise spaces that are left out by highly selective wireless operator installations in only the largest of venues

CHAPTER 9

Funding your IBW solution

You've got the plan in place. Now, it's time to find the funds.

Creating an IBW plan is only half the battle. You've made the business case; now you need to make the financial case—to justify the investment for your tenants, and perhaps also to yourself. Funding an IBW solution may seem like a steep mountain to climb, but there's often more than one path to the summit.

This chapter explores the three most common funding models for IBW solutions, as well as some of the ways they can be combined to create even more appealing options.

We'll begin with the most optimistic model for small to mid-sized enterprise spaces. As always, your local circumstances may vary, so don't forget to investigate them all. It never makes sense to leave money—or options—on the table.

1

Funding by wireless operators.
As discussed in Chapter 2, wireless operators have made IBW a part of their business model since the late 1990s. Over time, funding for these initiatives has been diverted to other business priorities. As a result, wireless operators now typically only extend this support to large venues such as stadiums. This is because they provide fast, significant ROI for the operator, even where they carry different operators' traffic in addition to their own.

In other cases, operators are willing to enter into negotiations to provide single-operator IBW solutions for smaller, less lucrative enterprise spaces. The downside is that only one operator's network is supported. Customers using other operator networks are left in the dark. For some enterprise scenarios, such as where only company-issued devices (all running on the correct network) are supported, this remains a viable option. However, this is a small minority of all enterprise scenarios.

Successfully using the operator-funded model for IBW in small- to mid-sized enterprise environments is rare—and getting rarer—as tight competition forces operators to allocate expenses to more business-critical initiatives.

2

Engaging with a neutral-host company.
Neutral-host companies are third-party providers of DAS and small cell solutions that support multiple operators, and bills those operators for IBW access. In other words, they install the IBW solution and then charge the cellular networks for the traffic that crosses that IBW.

Again, there exists a hurdle in the amount of ROI the neutral host can realize from the installation and operation of the IBW solution. That is, they can't build the highway where there aren't enough vehicles to make it worthwhile.

This limitation is reflected in contracts with such third parties, where there is often a clause defining a positive ROI as a requisite condition of continued operation and rights to control the physical infrastructure of the IBW solution.

In spite of this hurdle, the relatively low enterprise CapEx and OpEx involved make this an attractive option for enterprise environments.

3

Internal funding by the enterprise. In this model, you buy it, you install it and you can outsource the maintenance and monitoring. The operator maintains responsibility for the RF signal source unless you're deploying a small cell, in which case the radio is part of your infrastructure and may be funded by either you or the operator.

Enterprise-owned IBW can be built to support as many carriers, technologies and bands as needed. This is particularly helpful in situations where your IBW must support many different kinds of devices on multiple operator networks, such as bring-your-own-device (BYOD) workplaces or retail spaces where visitors expect to access your IBW solution on their personal devices.

When figuring out costs, it's worthwhile to consider that the latest IBW solutions can be integrated into an enterprise's traditional IT infrastructure, using high-end network cable instead of more expensive coaxial cable for horizontal runs. In many cases, the building may already be wired with the requisite IT cable, greatly reducing CapEx. This cost advantage can tip the budget argument in your favor.

Overall, this model clearly incurs the greatest CapEx and OpEx obligations. The enterprise may have to commit to funding operator agreements to approve their DAS source; install a base transceiver station or repeater; or to integrate their small cell radio directly into their networks. However, there do exist opportunities to recoup some of the costs in a mixed funding model—the option we'll now explore.

Mixed-funding models

Considering all the ways an IBW solution can be carved up into its operational components, connections and functions, spreading around ownership and responsibilities of these parts can help. Sometimes the most practical solution doesn't fit exactly one of the three main models already described, and mixed-funding models can be used to find the right balance.

Typically, the mixed model arises from funding three different areas:

- The active IBW equipment
- The passive transport of the signal
- The RF signal source for the DAS, or the integrated radio for the small cell

Whether the IBW solution is a DAS or a small cell, keep in mind that, at its core, it's merely an extension of the operators' radio network and must therefore be provided with an RF signal source. DAS requires a base station or off-air repeater to connect to the macro network; small cells have their own radio sources, which must be integrated into the macro network via a fiber-optic or point-to-point microwave backhaul solution.

In scenarios where a base transceiver station (BTS) or off-air repeater is the signal source for a DAS, the operator will generally assume the cost for that part of the network while the enterprise owns the internal distribution infrastructure. This assumes that the operator expects to generate positive ROI in its BTS or repeater investment.

Another possibility is the idea of a neutral-host company investing in the IBW infrastructure and contracting with multiple operators to handle traffic, with no ownership, responsibility or investment on the part of the enterprise.

However, considering the revenue conditions that would have to exist for such an arrangement, it isn't surprising that this scenario is highly uncommon. Other combinations exist as well (Figure 1).

Enterprise Funded

Advantages:

- Helps ensure the system will be multioperator
- Full ownership of the DAS by Enterprise
- Enterprise ensures technology updates

Disadvantages:

- Enterprise carries the DAS costs
- Enterprise or third party to perform DAS operations and maintenance

Neutral Host Driven

Advantages:

- Helps ensure the system will be multioperator
- Little or not CapEx investment
- Ownership in the passive (ceiling) installations

Disadvantages:

- Lack of ownership by the Enterprise
- Long-term contract imposes limitations
- ROI for the carriers must be higher than the Enterprise-funded model to allow this model

Operator Funded

Advantages:

- Little or no CapEx investment
- Ownership in the passive (ceiling) installations

Disadvantages:

- Need to ensure system is multioperator, leading operator to drive
- Lack of ownership by the Enterprise
- Long-term contract imposes limitations
- ROI for the carriers must be high

Figure 1: Different funding combinations between enterprise, neutral host and operators; a successful model must provide positive ROI for all involved.

The golden rule of funding: consider the alternatives

IBW solutions are indeed an investment, but, under the right circumstances, the enterprise doesn't have to shoulder it alone. Though operators have scaled back on their initial ambition to provide virtually universal in-building coverage and capacity to venues of all shapes and sizes, there still exist opportunities to enter into mutually-beneficial agreements that take some of the burden off the building owner, manager or architect. Neutral-host companies also provide the potential for cost-effective, even cost-free, IBW connectivity—if the conditions are right and the deployment is profitable.

The most important idea you can take from this discussion is that a great number of IBW funding alternatives exist. It can pay enormous dividends to properly investigate them before you determine how best to fund yours.

Chapter 9 summary

- IBW funding can be handled many ways
- Operator-funded may cost the enterprise nothing, but is only offered to the most profitable of large venues
- Neutral-host companies can provide a low- or no-cost IBW connection if they can realize sufficient ROI
- Enterprise-funded IBW offers optimal control, but also the steepest costs
- Combinations of IBW solution funding and ownership also influence deployment funding

CHAPTER 10

Your IBW future

IBW solutions have come a long way—and come by more than one route

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—new solutions arise to bring reliable connectivity where it couldn't be achieved before. And 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.

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 at the leading edge of IBW solutions—and expertise

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 Cloud RAN-based OneCell small cell solution; 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. It must also solve your business challenges.

As far as IBW solutions have come, the journey is not over yet. CommScope invites you to contact us with any questions you may still have about our solutions in particular or IBW deployments in general. We are always happy to share our experience and insights, no matter how big your connectivity ambitions may be, or how steep your challenges.

Chapter 10 summary

This book has covered:

- The history of wireless technology and the need for IBW solutions
- Common challenges facing IBW deployments in the field
- The future potential of IBW solutions
- How to choose the right technologies
- The differences between DAS and small cell, and how each has its place
- The merits of both licensed and unlicensed frequencies
- The cases when Wi-Fi is sufficient by itself, and when it isn't
- How to implement an IBW solution
- How to fund an IBW solution

Everyone communicates. It's the essence of the human experience. *How we* communicate is evolving. Technology is reshaping the way we live, learn and thrive. The epicenter of this transformation is the network—our passion. Our experts are rethinking the purpose, role and usage of networks to help our customers increase bandwidth, expand capacity, enhance efficiency, speed deployment and simplify migration. From remote cell sites to massive sports arenas, from busy airports to state-of-the-art data centers—we provide the essential expertise and vital infrastructure your business needs to succeed. The world's most advanced networks rely on CommScope connectivity.

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CO-110744-EN (02/17)