



HetNetForum

A large central teal circle is surrounded by several smaller circles in various colors: dark blue, yellow, light green, and teal. The circles are arranged in a way that they appear to be connected or overlapping, creating a network-like structure.

**DAS and Small Cells Evolve to
Meet Today's and Tomorrow's
Future Connectivity Needs**

**The HetNet Forum
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Table of Contents

Introduction	1
Distributed Antenna Systems (DAS) and Small Cells Defined	2
Emerging Architectures	5
Typical Use Cases	7
The Evolution of Spectrum	9
The Role of Fiber	10
Wired Backbone Considerations	12
Conclusion	13
About the Authors	14
Footnotes	15

Abstract

Technology advances increasingly blur the lines between the capabilities of Distributed Antenna Systems (DAS) and other small cells. Many DAS networks have become less complex (at least easier to install) while small cells have become smarter. Building upon its 2013 report, the HetNet Forum has drafted this report to focus on how DAS and small cells are deployed in venues today, the role of spectrum in future deployments and what fifth-generation (5G) technology means for DAS and other small cells.

Introduction

Wireless operators are experiencing continued rapid growth in mobile broadband traffic, driven by unlimited data plans and the growing ecosystem of Internet of Things (IoT), smart-city and automotive applications. According to a report from telecom equipment manufacturer Ericsson, smartphone usage in North America reached 8.6 Gigabytes (GB) per month per smartphone by the end of 2018. That number is set to reach 50 GB per month by the end of 2024. On top of that, wireless networks are expected to support about 29 billion devices by 2022,¹ many of which will be installed or used indoors.

As wireless operators race to keep up with exploding demand for mobile voice and data connectivity, in-building wireless solutions are assuming an increasingly important role within the broader network. Two of the most prevalent in-building technologies — Distributed Antenna Systems (DAS) and small cells — have provided a way for operators to supplement coverage and capacity for indoor spaces not adequately served by the outdoor macro network, and relieve pressure and congestion from outdoor data demands.

Cellular telephony originally was conceived as a mobile technology with a focus on outdoor usage, with base stations and antenna equipment designed to operate at high power over long distances. Now, the intrinsic benefits of mobility and the advent of smartphones have combined to make mobile phones the preferred medium for indoor communications as well. It's held that up to 80 percent of cellular traffic occurs indoors, where the network may have more difficulty reaching, depending on the nature of the building and the position of nearby wireless infrastructure.

With the continued proliferation of wireless devices and mobile applications, plus new ones falling under the broader IoT label, and the evolution to 5G, the amount of traffic that originates indoors is positioned to explode, both as a percentage of overall traffic and in absolute terms. The macro network has been and continues to be effective in reaching inside buildings in most cases. But outside-in approaches can be hindered by the advent of energy-efficient building practices, such as Low-emission (Low-E) glass, which has been shown to reduce radio signal strength by as much as 15 decibel-milliwatt (dBm). This means that the signal is only 1/32 its original strength after it passes through the glass — roughly equivalent to passing through a 1-inch-thick sheet of concrete.

DAS and small cells are two technologies that can supplement the macro network with indoor coverage and capacity that may be delivered directly within a building or venue. Deployed outdoors, DAS and small cells also have the same effect of bringing the network closer to the end user.

Distributed Antenna Systems (DAS) and Small Cells Defined

As its name suggests, a DAS takes the radiofrequency (RF) signal from a standard third-party cellular base station and conveys it through a series of active and passive network elements via fiber, copper or coaxial cabling to an array of relatively low-power antennas throughout a building, venue or campus. Because the transmitting antennas may be located inside the building, they may deliver stronger signals than neighboring macro towers, whose transmissions must penetrate exterior and interior walls of the structure. The DAS base station also provides its own capacity, so intensive indoor use — for example in an airport or convention center — does not “rob” capacity from the surrounding macro network.

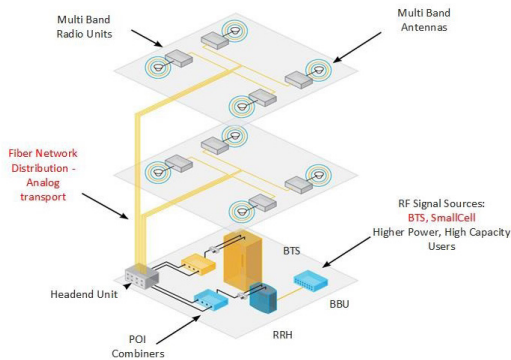


Figure 1: Analog DAS Deployment Model

Traditionally deployed outdoors to supplement the macro network, small cells recently have been deployed for specific indoor and venue applications as well. These small cells are smaller, low-power versions of the larger “macro” base stations with their own radios and antennas that can be deployed indoors or around a building where coverage is needed. The term “small cell” is now used to refer to anything less than a full-power macro base station — ranging from residential devices that serve a single household through enterprise-class systems and all the way up to outdoor streetlamp-mounted units that act as an adjunct to the outdoor macro network. For purposes of this paper, we focus on “small cells” that refer to indoor or venue-centric solutions that serve an enterprise, building or campus.

Small cells come in several types, but they can be grouped loosely into two categories, standalone and distributed. With standalone small cells, each access point is a fully self-contained base transceiver station (BTS) including baseband unit (BBU), radio and antenna. With distributed small cells, the baseband processing is mostly centralized for a large group of radio and antenna units distributed around the building.

Small cell types include microcells, picocells, femtocells and standard base stations with coverage ranging from 1 mile to 22 miles. Microcells and femtocells are smaller and are less expensive to build and maintain. Today small cells are being deployed in different enterprises of all sizes due to their ability to be deployed rapidly.

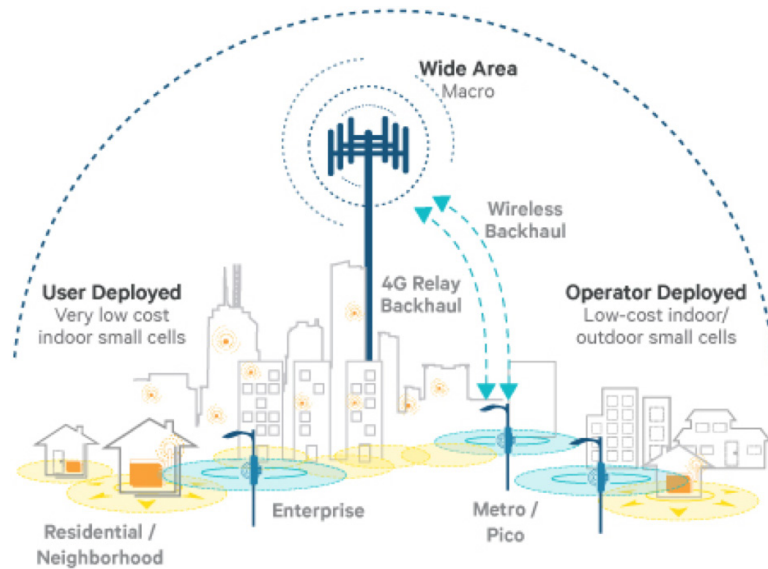


Figure 2: Small Cell Deployment Model

Functionally, DAS and small cells solve the same problem, but their different architectures have important implications. The most important difference is that the DAS uses a third-party signal source while the small cell provides its own. This is significant because base-station integration into operator networks is a complex, one-time process that can take a year or more to complete. Unless the small-cell vendor has completed this process with all the leading operators in a region, the small-cell installation is likely to support only one or two operators.

A DAS, however, attaches to a third-party base station, so it can take advantage of Original Equipment Manufacturer (OEM) base stations that are already integrated into the operator's network. Moreover, a DAS can act as a shared resource for multiple base stations from different operators. As a generalization, it's fair to say that DAS is inherently multi-operator while small-cell solutions have the potential to be multi-operator.

With both DAS and some distributed small cells, the baseband processing and resource scheduling are performed centrally. This allows the system to allocate resources to different users and prevents interference within the cell — an inherent function of the central baseband scheduler. By contrast, with standalone small cells each access point acts as its own independent cell, with no scheduling coordination between the cells. In border areas this will create interference, leading to poor signal quality in the form of slow data, choppy voice or even dropped calls. In smaller deployments with just a few small cells, this may not be an issue, but with larger numbers of standalone small cells, it can become a problem quickly. One U.S. operator is known to have a policy by which any site that contains more than three standalone small cells must be designed and approved by the operator's RF engineers.

Both DAS and small cells have now been in use for some time and as each evolves they have taken on the advantages of the other. Distributed small cells are more DAS-like in that they centralize the baseband processing and distribute the radio resources. Some DAS deployments, for their part, have begun using small cells as the RF signal source. In cases where the power and capacity of the small cell meet the venue's requirements, small cells as a signal source can prove more cost-effective than DAS.

Emerging Architectures

As DAS and small cells have proliferated, new network architectures have emerged.

Digital DAS networks transport digital signals directly from the headend to the radio head or remote antenna unit (RRU), eliminating attenuation of the signal and allowing it to be simulcast to remote antennas. Digital DAS provides multi-band and multi-operator support with low system noise, lower interference and improved power amplifier efficiency. Capacity and coverage growth can be addressed through flexible sectorization. Wi-Fi access points or small cells can be added at the edge.

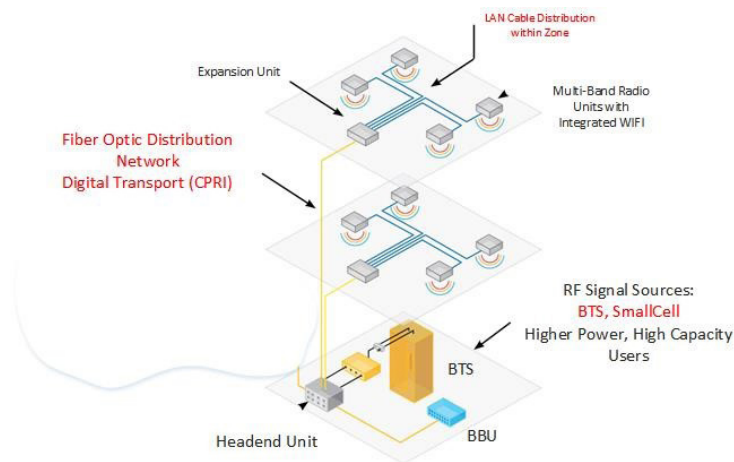


Figure 3: Digital DAS System

A distributed small-cell architecture is primarily a single-operator solution although recent configurations support dual operators simultaneously. This model supports radio access network (RAN) sharing and uses single small-cell resources to support multiple carrier core networks. Distributed small cells are well suited for enterprise applications where single operator deployments are the norm and where combined Local Area Networks (LAN) plus cellular communications on the same cable infrastructure is desired.

Deploying a distributed small cell is similar to deploying Wi-Fi access points. Power for each small cell typically is delivered over the LAN cable and it adopts a self-organizing network approach. This model is ideal for adding capacity and dense coverage.

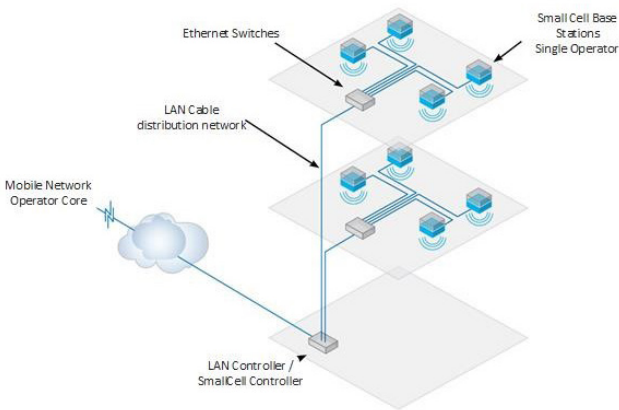


Figure 4: Distributed Small Cell System

The centralized-RAN (C-RAN) model is generally applied to outdoor macrocells, but it can also be applied to small cells that provide distributed coverage across a large indoor space. C-RAN creates a single cell that coordinates the functions of multiple radio endpoints using standard IP Ethernet LANs for fronthaul.

The C-RAN model provides many of the same benefits of small cells while eliminating the interference created at the borders of overlapping small cells when densely deployed. In traditional deployments, small cells use a central service controller to assist with handovers and backhaul aggregation but each cell still interferes with neighboring sites, and multiple independent cells generate frequent handovers referred to as “ping-ponging.” To eliminate cell borders, it is necessary to centralize the scheduling of users across all radio points. Capacity is pooled in the central Baseband Controller and allocated dynamically to wherever the usage is at any given moment.

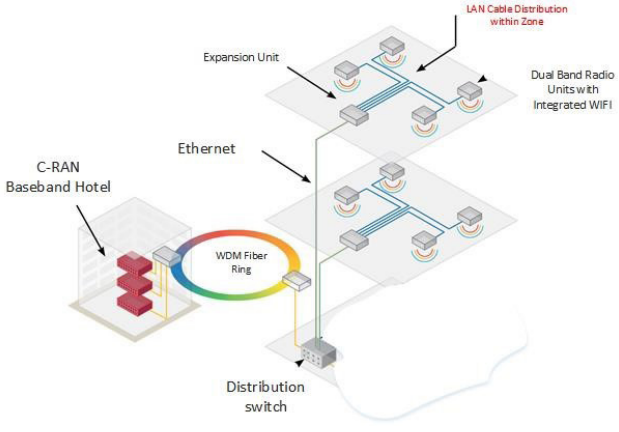


Figure 5: C-RAN Distribution Architecture

Typical Use Cases

The deployment of 5G technology is expected to transform a wide range of businesses. New businesses like Uber and Airbnb, for example, did not take off until mobile network operators built fourth-generation (4G) LTE networks to support new business models and use cases. The same types of transformations are expected once 5G networks are deployed. While it is not yet known exactly how people will innovate with 5G technology, it is clear that 5G has many use cases for both outdoor and in-building coverage. Some examples include connected vehicles, remote health care and smart-city services as well as mobile and fixed broadband services, which cost less per megabit and enable higher speeds for a wide array of indoor use cases, such as enterprise collaboration and virtual reality/augmented reality (VR/AR) applications.

Small cells are often considered the best option for building connectivity infrastructure, but when it comes to larger multi-carrier integrations, it is not always the most cost-effective approach. Multiple small cells are needed for each carrier in a building or venue, which can make it pricier than alternatives. DAS can also be used concurrently with small cells to save space and create an economical solution.

Small cells are typically deployed to enhance coverage over limited ranges and are relatively inexpensive individually and widely available. For this reason, it's the latest technology used by carriers to provide cellular service inside small buildings. Small cells connect directly to the carrier network over an internet connection to generate a high-quality signal across multiple distances, ranging anywhere from 10 feet to several hundred, depending on a range of factors. Even for those with a more extensive coverage range, small cells can become costly for large venues and when multiple carriers or frequency bands are required as cost and complexity increase for these types of installations. (Figure 6) Instead of requiring numerous small cells, using only a few as a signal source for a DAS can significantly improve the coverage area as long as the small cell has an internet connection. Users can enjoy a high-quality signal, and distributors and enterprise owners can reap the benefits of 5G with fast deployment and low costs. (Figure 7)

With a DAS and small cell connectivity infrastructure, resources can be targeted to the areas needing the most signal, and capacity can be shifted to different parts of the DAS network as the location demands change. According to the Advantage Business Media Market Monitor Research Series, more than 84 percent of engineers believe that small cell technology will be a major player with its connection to DAS as they are perhaps the best option for highly trafficked venues and for overcoming signal problems.² As such, 5G capability can extend its reach and remain modular regardless of network and influx of users, offering greater quality and user experience.

DAS and small-cell technological advancements are making networks faster and more efficient, leading the future of 5G to a successful implementation. Until 5G arrives in its full capacity, the wireless industry will push solutions that are flexible in adapting to the current needs of users by providing the bandwidth required for the ease of wireless use.

	SMALL CELLS	DISTRIBUTED ANTENNA SYSTEMS (DAS)
Pros	<ul style="list-style-type: none"> - Use standard Cat-5, 6 or 6A cabling - Inexpensive - Widely available 	<ul style="list-style-type: none"> - Can support multi-carriers and multi-frequencies in one system - Newer generations use standard Cat-5/6/6A cabling - Multi Radio Access Technology support; 2G, 3G and 4G, SISO and MIMO - Variations of output power and form factors - Amplifiers at the antenna point means zero “loss” - Easy to upgrade if modular system is used - Active systems use fiber cabling and installation is easier and less expensive - All frequency bands are supported including public-safety bands
Cons	<ul style="list-style-type: none"> - Does not support a multi-carrier in a single system - Does not support multiple frequencies in a single system - May require large number of antennas - May be difficult to design properly for overlapping coverage area - Cost and design complexity increase to support multiple carriers 	<ul style="list-style-type: none"> - More expensive than small cells - More difficult to install compared to small cells - Requires experienced and certified installers

Figure 6: Pros and Cons of Small Cells and Distributed Antenna Systems (DAS)/ADRF

	SMALL CELLS	DAS	SMALL CELLS & DAS COMBINED SOLUTIONS
Best Use Case	Small-sized venues with both small number and relatively fixed base of users who require a single carrier or few frequency bands; such as retail stores, warehouses.	Large-sized venues with both large number and continuously changing base of users who require multiple carriers and/or frequency bands; such as stadiums, airports, large hospitals, college campuses, large hotels/casinos, large shopping malls, Class A commercial real estate.	Medium-sized venues with small number but continuously changing base of users who require multiple carriers and/or frequency bands; such as individual CRE tenants, high schools, small hotels, clinics, industrial facility.

Figure 7: Best Use Cases for Small Cells, DAS, and Combined Solutions/ADRF

The Evolution of Spectrum

Both DAS and small cells typically operate in licensed spectrum, that is, frequency bands that have been acquired by mobile network operators for exclusive use. For this reason, the operator must directly or indirectly approve each DAS or small-cell deployment. For illustrative purposes, Wi-Fi is the best-known example of unlicensed spectrum; anyone can purchase and operate a Wi-Fi access point.

The spectrum situation is evolving, however, with the result that new models are emerging between licensed and unlicensed spectrum. For example, with Licensed Assisted Access (LAA) technology, an operator can temporarily use a combination of licensed and unlicensed (Wi-Fi band) spectrum to augment their capacity. Rules and protocols are being established to ensure that such practice does not impair Wi-Fi usage of these frequency bands. Another example is Citizens Broadband Radio Service (CBRS) in the United States. The Federal Communications Commission (FCC) has set aside 150 megahertz of CBRS spectrum in the 3.5 GHz band previously reserved for government purposes and made it available commercially through a more dynamic allocation process. Regulators in other countries are watching the U.S. policy develop and considering adopting similar models.

Technically, the ability to support the necessary frequency bands and to interact with the CBRS spectrum allocation server (SAS) is a base station function, so a DAS can support CBRS as long as it supports the frequency band. Small cells, since they incorporate the base station, must be developed specifically for these functions, and companies are developing this equipment.

As “neutral” spectrum not dedicated to any one operator, CBRS has been considered as a form of neutral host in-building solution whereby users in the building would connect to the CBRS radio, operated by the building owner or neutral host provider, and connect to their own mobile service provider via a roaming arrangement.

For this to take place, two conditions (at least) must be met: a) the user device must support the CBRS band and b) the in-building network owner must have roaming agreements with the major operators. Some device chipset manufacturers have announced support for the CBRS band, but it will take time before the handsets are available and a majority of in-use handsets have turned over to achieve critical mass. As of this writing, mobile operators have not publicly stated their intentions about establishing roaming agreements with in-building network providers.

The Role of Fiber

Extending fiber to buildings, neighborhoods and city blocks is crucial for maximizing the efficiency and quality of DAS and small cells. Further densification of fiber networks is needed to support next-generation wireless applications. While fiber networks already span the globe, connecting communities that are continents apart, deeper penetration of fiber into communities to support the higher number of wireless network access points, wireless devices and end users is necessary. These fiber networks, which serve as the high-speed freeways on which the next generation of data travels, will require an extensive buildout to match the buildout of infrastructure and antennas. Everything from 5G capabilities, IoT, smart-city applications and end user demands will require small-cell densification at the fiber infrastructure level.

Many legacy fiber backhaul networks were typically built with relatively low fiber capacity that is heavily multiplexed with dense accessibility (e.g., fiber-to-the-home networks), or high fiber capacity and sparse accessibility (e.g., enterprise fiber networks). In addition, backhaul networks are traditionally designed for lateral splice locations every thousand feet and weren't meant to be fragmented and accessed every couple hundred feet, which will be necessary to support the demands of the wireless carriers that are densifying their networks.

Existing fiber infrastructure will remain critical to manage backhaul needs of connecting edge data centers to the mobile operator core, but there's an entirely new complementary fiber network that needs to be built to solve the new problem of capacity and accessibility. A new type of fronthaul network, which connects the radio access network to the remote radio units, will provide high fiber capacity as well as easy accessibility, allowing for lateral splices every few hundred feet or less. Such a fronthaul network must also provide relatively short links to interconnect the baseband processing to the distributed RF interface and edge data center locations to meet stringent latency requirements.

The new fronthaul network architecture primarily differs from legacy backhaul architectures due to the density of fiber lateral splice points that interconnect DAS and small cell locations to the internet and the number of dedicated fibers required to serve each end point. To visualize the difference between backhaul topology and the fronthaul network topology, think of the backhaul network as an expressway with sparsely spaced onramps and the fronthaul network as the local roadways with an edge collocation facility acting as the interface between the two network topologies. This model offers an analogy with the legacy central office topology where large voice switches are replaced with baseband processing cloud equipment and the 2,400 pair copper trunks are replaced with 1,728 or greater fiber-optic cables (3,456 fiber cables are shipping today).

The problem is that legacy backhaul networks aren't forward compatible and can't be retrofitted to become the new, necessary fronthaul network. The backhaul network is an important piece of the overall infrastructure, but the fronthaul network is a parallel network that providers need to build in a new way to support the densification of DAS and small cells. In order to enable the new network model, innovative techniques for ducts, cables and fiber splicing must be considered to support the unique nature of wireless fronthaul access topology.

Wired Backbone Considerations

The convergence of in-building networks and the proliferation of Power over Ethernet-powered IoT sensors and devices connected to the same enterprise network are transforming workplaces and building environments with a focus on sustainable efficiency and cost effectiveness. As wireless connectivity indoors becomes prevalent, a robust wired backbone is needed to support backhaul transmission. Wired networks leverage new and existing fiber as well as twisted-pair and coaxial cabling to connect buildings as well as larger edge devices such as Wi-Fi access points, surveillance cameras, small cells and DAS.

Leading-edge in-building wireless systems require fiber or copper connectivity to the access point. Backbones in buildings have traditionally been designed to exceed the horizontal requirements by a factor of 10. As 1 Gbps (billions of bits per second) gives way to 2.5, 5 and even 10 Gbps horizontal standards for many networks, backbone infrastructure may need to support speeds of up to 100 Gbps.

In a smart building, the infrastructure for communications networks consists of two basic segments – backbone cabling and horizontal cabling. Structured cabling for a converged network – comprising one Ethernet or fiber backbone carrying voice, data, video and wireless traffic – is the foundation of smart buildings.

New standards for IT structured cabling include Category 6A copper, OM5 multimode and single-mode fiber-optic cable. The ability for in-building wireless solutions today to employ ordinary Category 6A cable – instead of the more complicated coaxial cabling – has streamlined installations and expanded applications. DAS and small-cell solutions now share the same Category 6A and fiber-optic infrastructure used by Wi-Fi, which many enterprises have deployed, for better efficiencies.

OM5 wideband multimode fiber (WBMMF) is becoming a preferred technology providing backhaul and fronthaul bandwidth to support 802.11ac Wi-Fi systems and high-density 5G radio networks. The advantage of OM5 cabling is its ability to support low-cost shortwave wavelength division multiplexing (SWDM) applications, which enable 40 and 100 Gbps data rates using just two fibers rather than the eight fibers required for comparable parallel fiber-optic solutions. With OM5, customers can retain the use of familiar duplex LC connector circuit administration while providing the density, accessibility and flexibility to support multiple applications needed for the future.³

Conclusion

A variety of technologies and solutions are needed to take advantage of coming business use cases that will arise as 5G technologies and CBRS spectrum are adopted. DAS and small-cell solutions continue to evolve to meet today's needs as well as future needs. Along with wireless infrastructure, a strong mix of fiber and other wired equipment are essential to meeting the exploding demand for accessing content and connections on wireless devices.

About the Authors



ADRF is a leading Original Equipment Manufacturer (OEM) of in-building wireless solutions that ensure reliable connectivity in venues of any size, shape and location. Established in 1999 in Burbank, California, ADRF prides itself on having a customer-centric focus, designing solutions that meet each customer's unique needs, while providing a pathway to scale for the future. The company serves some of the world's leading enterprises, system integrators, public safety entities, neutral host operators, and wireless service providers.



Boingo helps the world stay connected to the people and things they love. The company builds Wi-Fi, cellular (DAS) and small cell networks at big venues like airports, stadiums, military bases, and commercial real estate properties, and monetizes those networks with a number of unique products and services.



In the ground, in buildings or through the air, CommScope understands that networks must be robust and reliable. The company's solutions are built with products and systems that are modular, cost-effective and easy to install and maintain. For more than 40 years, CommScope has been innovating the network infrastructure of the future. Developments such as the Internet of Things, seamless connectivity and 5G introduce new requirements and demand creative thinking. With its expertise in copper, fiber and wireless infrastructure, CommScope enhances and migrates networks to outperform today and be ready for the needs of tomorrow.



ZenFi Networks is dedicated to meeting the growing demand for next generation network access in the New York and New Jersey metro region with the most innovative communications infrastructure solutions delivered with unmatched support, problem solving and expertise. The company's 800-mile fiber network currently connects more than 2,000 sites and is growing month by month.

Endnotes

1. Ericsson Mobility Report 1
2. Advantage Business Media Market Monitor Research Series. Designing Distributed Antenna Systems (DAS).
3. CommScope: Maximizing the Potential of Smart Buildings



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