INDUSTRY INSIGHT

STREAMLINING INDOOR CONNECTIVITY

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dense air

Acknowledgement

This paper was written by Stephanie Atkinson on behalf of Dense Air Networks to provide an independent overview into the changing face of the telecoms industry as new deployment, ownership and service models take hold.

While the ideas and principles outlined incorporate extensive research and conversations with experts, this paper serves only as a moment in time outlook.

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1.0 Introduction

In today's hyper-connected world, robust cellular connectivity within buildings is not just an amenity it's a fundamental pillar of modern infrastructure, vital for enhancing productivity, safety, and tenant and guest satisfaction.

Cellular connectivity is increasingly becoming a must-have for venue owners, property managers, tenants and guests, reflecting our modern reliance upon a seamless voice and data experience. Properties spanning offices, hospitals, hotels, multi-family residences and retail stores now must ensure quality wireless across their premises to remain competitive.

In nearly every industry, cellular is used for connecting assets and operations, people and devices. We increasingly require a working cellular connection all the time, wherever we are. The requisite cellular experience is seamless outdoors and indoors, regardless of the building, the elevation (top of a high rise or deep underground in a parking garage), or population density. Poor user experiences such as dropped calls or failed data sessions result in increased user frustration, and in some cases, lost revenue for venues spanning hotels, hospitals, commercial real estate and retail stores.

While cellular carriers such as AT&T, T-Mobile and Verizon are focused on building outdoor 5G networks, indoor cellular connectivity solutions have not kept up with the growing demand; this is particularly important as 80% of cellular data is generated indoors.[1]

Deploying carrier networks within buildings has historically posed difficulties, as cellular signals must navigate through frequency deflecting walls to reach a high concentration of users and devices. Structures that commonly present challenges for indoor connectivity include multi-story office or residential buildings, underground facilities like parking garages, and venues featuring thick concrete walls or multi-layered glass.

While the telecom industry has been faced with indoor connectivity issues for several decades, the problem is dramatically worsening. Modern sustainable building materials, such as low-E glass with metallic coatings, deflect signals preventing the higher frequencies used in 5G to penetrate effectively indoors. As 5G rolls out and we use more sustainable building materials while consuming more data, indoor connectivity will suffer.

With businesses increasingly depending on cellular solutions and the demand for specialized services like private networks growing, key questions emerge: What solutions and partners are available to wireless carriers and venue owners to help them enhance coverage, increase capacity, and finance networks?

This paper explores the barriers to achieving ubiquitous multi-carrier inbuilding connectivity and examines the various solutions, including traditional approaches such as Distributed Antenna Systems (DAS) and Wi-Fi, as well as disruptive neutral host small cell (NHSC) technologies. This paper will analyze how the features and benefits of these solutions vary in providing a seamless cellular experience and the various implementation partners available to a building owner.

80% of all cellular data is generated indoors.[1]

1 Ericsson Mobility Report (2024)

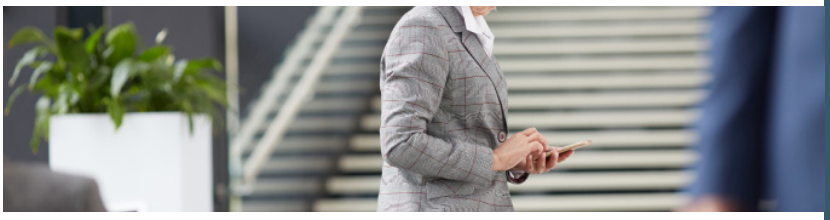
2.0 Our Growing Reliance on In-Building Cellular

Lack of coverage indoors is a growing issue for venue owners and enterprises, and demands improvement, particularly as the roll out of 5G threatens to aggravate the issue. During the pandemic, individuals grew accustomed to the mobility of cellular networks as they adapted to more flexible work routines. Today, workers expect to maintain work calls from home, during commutes, in parking areas, or while riding an elevator.

Commercial Real Estate

In commercial real estate, cellular connectivity is essential to support a variety of business operations and employee needs. Employees depend on mobile devices for seamless communication, collaboration, and access to cloud-based services, regardless of their specific location within a large office building.

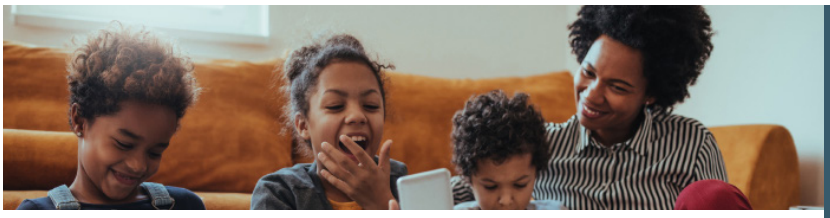
Strong cellular signals ensure that calls and data services are reliable, which is crucial for business communications, especially for visitors or employees who may not have immediate access to the office Wi-Fi. Furthermore, robust cellular connectivity is indispensable for emergency communications and for enabling modern IoT-based office systems, such as smart thermostats and security devices. Property owners, managers, and developers recognize the crucial role of cellular coverage in enhancing the lease value of properties.



Hospitality

In hospitality, hotels need to deliver a secure, connected work experience for business travelers while enabling vacationers to surf the web and make calls back home. Large events and conferences can massively increase cellular traffic, compounding the problem for discrete periods of time. A hotel therefore needs a network that can handle high peak capacity and many different users moving in and out of the premises.

Residential



In residential settings, especially multi-floor or multi-dwelling units (MDUs) managed by property management companies, there has traditionally been a focus on fixed-line connectivity. However, the rise in remote work has made all-day cellular connectivity a necessity for many tenants while smart home technologies such as smart locks, thermostats, and security cameras require a wireless connection. Quality cellular connectivity can significantly enhance resident satisfaction and make a property more attractive to potential renters or buyers.

Retail

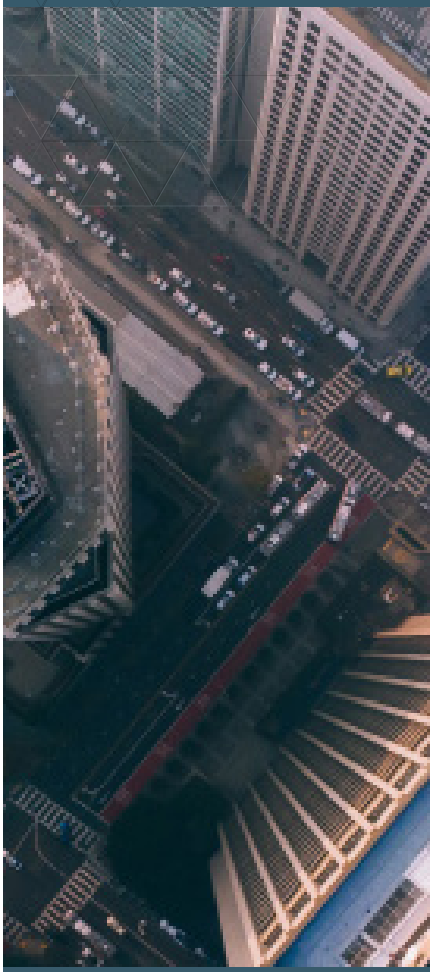
In retail, particularly in large stores, cellular connectivity has become crucial. Consumers use it to check online offers while shopping in-store and to access retail-specific applications, and store managers and IT(Information Technology) staff use it to manage front-of-house displays and demonstrations. As consumers increasingly rely upon their cellphones to support their shopping, retail stores without quality connectivity may lose customers and sales.

Healthcare

Cellular connectivity is vitally important in healthcare to ensure seamless communication throughout the facility. In the fast-paced environment of a hospital, doctors, nurses, and other healthcare professionals rely heavily on mobile devices to communicate quickly and efficiently about patient care, access medical records, and receive real-time updates. Strong cellular signals are crucial for maintaining connectivity, especially in buildings with complex layouts and dense materials that might obstruct signals. Additionally, patients and visitors benefit from reliable cellular service to stay in touch with loved ones and manage personal affairs during hospital stays. This connectivity is not just about convenience; it's a critical component of modern healthcare operations and patient safety, facilitating better outcomes and enhancing the overall hospital experience.

Parking Garages

In parking garages, cellular connectivity is crucial for safety, convenience, and operational efficiency. These structures, which are often underground and enclosed, can interfere with mobile signal reception, making it difficult for users to make calls or use data services. Enhanced cellular connectivity ensures that drivers and pedestrians can contact emergency services if needed, receive mobile payments, and use navigation apps seamlessly. For parking management, strong signals support the integration of smart parking solutions, such as real-time space availability updates and automated access controls, improving the overall user experience and optimizing garage operations.



Across various industries, there are notable similarities and differences in needs and challenges. Primary stakeholders of structures, buildings, and venues must identify the right solutions for several crucial reasons:

- **Mobile connectivity is vital for operations such as transactions, communications, and data access. Inadequate cellular service can result in lost productivity and revenue and potentially harm the reputation of the facilities.**
- **Seamless cellular connectivity serves as a competitive advantage, helping to attract customers and differentiate establishments from their competitors.**
- **Dependence on cellular operators for connectivity solutions can lead to delays and limited control, potentially causing stakeholders to lag in adopting modern technologies.**
- **Proactive investment in infrastructure and technology can future-proof businesses, keeping them abreast of evolving customer expectations and technological advancements.**

Cellular connectivity serves as the foundation for innovation and digital transformation across industries. To provide further context for the growing demand of indoor cellular, let's examine use case examples in hospitality, commercial real estate, and multi-dwelling buildings.

2.01 Example Use Case: Hospitality

The hospitality industry primarily aims to deliver exceptional guest experiences to enhance revenue retention, increase occupancy, and foster repeat business or loyalty. Establishments like hotels, casinos, and resorts face the challenge of providing consistent connectivity both inside and outside their premises.

Venues often host various events like conferences, business meetings, weddings, concerts, and sporting events. Particularly in urban areas, large venues can experience network congestion due to the high volume of attendees using their mobile devices. The goal for venue owners and managers is to ensure a high-quality experience for attendees from the moment they arrive until they leave.

Wireless connectivity is crucial in enhancing this experience, facilitating various guest interactions including services, food ordering, payments, entertainment, mobile app usage, and access to key amenities. Increasingly, guest services are migrating to smartphones, with many venues offering mobile apps that streamline the guest experience by integrating multiple services.

Consider a scenario where you attend an event in downtown:

Driving through the city, you depend on a reliable cellular connection for navigation and to direct you to the proper parking garage. Once parked, you might use a phone app to pay for parking. As you walk to the venue, you might need to locate your friends, access your digital ticket or reservation, make purchases, and find your seating or room — all relying on robust wireless services both outside and inside the venue. If security is a concern, you might opt to avoid public Wi-Fi and use your smartphone for all these activities.

Other crucial guest experiences reliant on mobile communications include:

- Charging electric vehicles (EV)
- Taking calls or working in a restaurant, bar, or café
- Arranging rideshares or food deliveries
- Navigating from your hotel to a destination

Equally important is the employee experience, which directly impacts guest services. Employees place added demands on cellular networks to ensure they can provide seamless and high-quality service.

Key areas where wireless connectivity enhances the venue experience include:

- Parking garage management
- Point of Sale (POS) systems for kiosks or merchandising carts
- Access control or patron screening
- Security camera systems
- Mobile transactions by on-site staff
- Management of on-site equipment and venue assets

2.02 Example Use Case: Commercial Real Estate

The commercial real estate industry has faced substantial challenges in recent years, especially during the pandemic, which led to lease losses and non-renewals, causing declines in occupancy rates and lease prices and affecting the sector's financial performance.

Currently, the U.S. Class A office market is undergoing a transition known as "flight to quality," where tenants are migrating to newer offices with amenities and equipped with innovative technology and strong security systems.

To bounce back from the pandemic's impacts and effectively adapt to the present economic conditions, real estate stakeholders need to focus on providing high-quality experiences for tenants and customers. Essential to this is seamless connectivity, which allows employees to choose between wired and wireless connections for their daily operations. Ensuring comprehensive wireless and cellular access within and around office buildings is crucial.

Employees depend on uninterrupted connectivity for a range of activities, including calls, chats, training, collaboration, and meetings. According to the NAIOP, the Commercial Real Estate Development Association, connectivity is the second most important criterion for office space tenants, preceded only by location (NAIOP Summer 2021).

Connectivity is the second most important criterion for office space tenants, right after location.[1]

1 NAIOP, (Summer 2021)

Real estate owners and managers are thus compelled to offer modern and secure facilities with attractive office amenities to draw and keep tenants. In a competitive market, such amenities are crucial differentiators that significantly affect tenant satisfaction and retention.

The following office activities rely on cellular communications:

- Occupant communications
- EV charging stations in parking lots
- Security and surveillance (cameras, access control, facial recognition)
- Parking garage access
- Conference and AV rooms
- Common areas (lunch and break areas)
- Building systems and management (BMS, HVAC, lighting, energy)
- Connected building assets (digital signage, occupancy sensors, hot desking solutions)

2.03 Example Use Case: Multi Dwelling

During the pandemic, multi-dwelling units (MDUs) became critical spaces as many tenants worked from home and adhered to quarantine measures.

This shift resulted in increased demands on building infrastructure and services, as tenants used these systems extensively for both work and leisure. Like hotels, MDUs and residential facilities often include adjacent or underground parking garages for employees and residents. There is also mounting pressure to ensure seamless cellular connectivity both indoors and outdoors. Effective cellular coverage and services are often highlighted as amenities to attract residents and influence lease agreements.

The following activities rely heavily on wireless:

- Security and surveillance (cameras, access control, facial recognition)
- Kiosks and front desk services
- Amenity access or services
- Building systems and management (BMS, HVAC, lighting, energy)
- Connected building assets (voice activated assistants, smart smart security systems and applicances)
- Occupant communications
- EV charging stations in parking spots

Cell phone coverage is the third most important factor for movers, ranking above cost of living and proximity to work for most Americans.[1]

1 whistleOut (August 2023)

3.0 Carriers are Not Funding In-Building Cellular Modernization

As cellular use and networks evolve, questions arise as to who will finance the incremental infrastructure needed to modernize.

Carriers are conducting cost-benefit analyses to decide whether to pursue infrastructure projects, balancing the potential for less-than-ideal customer experiences against economic realities. For in-building extension projects, carriers typically prioritize large marquee venues, such as stadiums, airports, and convention centers, and forsake investing in sub-1MM sq. ft buildings such as offices, hospitals, hotels, retail stores, and multi-family residences.

Even if a carrier does choose to invest in a property, it is likely only to build the network for its own use case, rather than one that can support its competitors. Building owners should be wary of working with just one carrier if they want a system to support all service providers.

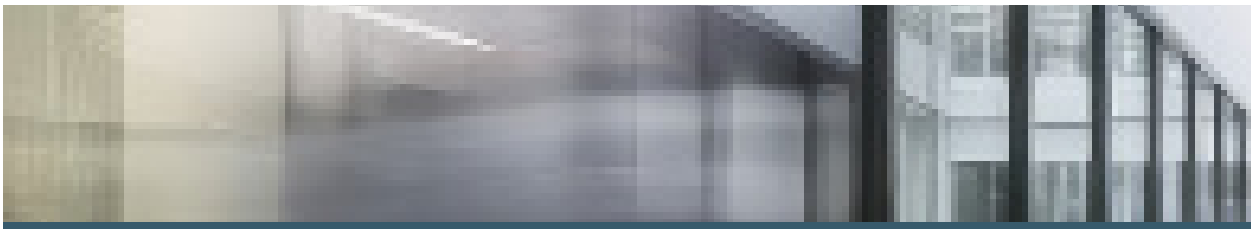
The owners of these smaller properties have traditionally hesitated to invest in cellular infrastructure improvements themselves, deterred by a lack of technical expertise and concerns about costs, while expecting network operators to shoulder the financial burden.

Furthermore, many stakeholders may not recognize the full scope of connectivity challenges or their detrimental effects on customer experiences and business operations. Thankfully, there are affordable and flexible solutions available. Building owners and property managers, as key stakeholders, are well-positioned to lead efforts to enhance network connectivity, improving the experience for all involved.

Before discussing these solutions, it is important to understand the challenges in greater depth.

4.0 Cellular Connectivity Should be SEAMLESS

The challenges facing the industry to provide a seamless experience are complex. Let's explore these eight variables that significantly impact the success or failure of indoor cellular experiences.



S Signal Penetration Issues

No cellular coverage= frustrated customers & employees

E Equipment Proximity

Proximity to the radio access network (RAN) is critical

A Accelerated Data Usage

Data usage is expected to double over the next 6 years

M Massive Traffic

High traffic and densly populated areas strain the nework

L Latency & Legacy

Delays & lags in data transmission due to aging hardware

E Expertise & Skillset Gaps

IT teams lack the time or skillset to manage new cellular solutions

S Secure Connectivity

Robust security is essential for data protection and privacy

S Single Carrier

A network that supports multiple networks is paramount

4.01 Signal Penetration Issues

As we transition from LTE to 5G, signal penetration becomes more challenging. 5G signals, with their higher frequency and shorter wavelength compared to 4G/LTE, struggle to penetrate physical structures like building walls. A weak outdoor signal follows users indoors, leading to an unsatisfactory indoor experience that fails to meet consumer and operational requirements. This presents significant challenges, as poor cellular connectivity hinders business operations. It's simple: no cell service or weak cell service means employees become less effective, less productive, and more frustrated.

Employees need reliable phone access for both business and personal purposes. The quality of calls or video streaming can significantly affect the perception end-users have of the network and the building or company. Additionally, many enterprise assets are monitored, tracked, and managed using cellular communications, both public and private.

4.02 Equipment Proximity

As we expand our mobile footprint and increase remote working, the distance between radio equipment, signals, and end-users becomes a critical factor in ensuring seamless connectivity.

The core infrastructure, transport, and radio access network (RAN) are vital for delivering 5G services. Proximity to the RAN or cell towers significantly affects signal strength and reliability. 5G cell towers typically have a range of 1 to 3 miles in low to mid-band radio areas. However, obstructions such as buildings, walls, and floors can further degrade signal quality. As the reliance on remote work and mobile connectivity grows, it's imperative to address these challenges, and bring the RAN closer to the end-user to ensure quality performance and user satisfaction.

4.03 Accelerated Data Usage

Voice and data demand and consumption have increased, and with this comes the expectation for reliability and accessibility of data for everyday consumer and workforce applications. This puts growing demands on the cellular network and drives network congestion.

Ericsson reports that average mobile data usage per smartphone globally is projected to increase from 21 GB in 2023 to 56 GB by 2029[1]. This figure escalates when considering the expanding demand for non-smartphone data applications, including robotics, vehicle fleets, machines, equipment, and other physical assets. This increasing data consumption worsens the strain on cellular networks, affecting the overall connectivity experience.

End-users rely on data communications for both leisure and work-related activities. For leisure, this includes streaming movies, social media, video chatting, and online gaming. For work, data communications support collaboration, virtual meetings, simulated training, asset tracking, digital signage, kiosks, digital commerce, and more. The continued stress to the network with the growth of data usage will need to be considered when thinking about indoor cellular coverage.

Global mobile data traffic consumption per smartphone is expected to reach

56 GB per month at the end of 2029.[1]

56 GB

1 Ericcson Mobility Report (June 2024)

4.04 Massive Traffic

As discussed in #4.03, the industry is experiencing a supply-demand problem, and this becomes even more cumbersome as we enter high-traffic or dense areas. In heavily populated urban areas, as well as events that bring an increase in pedestrians and visitors in concentrated locations, the degradation of cellular signals worsens.

On healthcare and college campuses, the high density of end-users and connected assets creates a substantial demand for robust network solutions to improve cellular experiences. Similarly, hotel guests often face poor communication quality on the most crowded days due to high traffic.

These frequently visited locations require advanced solutions to enhance signal strength and provide redundancy, ensuring improved reliability and throughput. Network congestion remains a significant challenge for businesses, hotels, hospitals, and campuses, requiring dedicated efforts to maintain seamless connectivity and meet user expectations.

4.05 Legacy & Latency

Cellular latency refers to delays or lags in data transmission, often caused by outdated or degraded hardware components within the network infrastructure. Older buildings may also lack the equipment to properly set up and install the solutions needed. As equipment ages, it may struggle to process data efficiently, leading to slower response times and increased latency for users. This can negatively impact various activities such as video streaming, online gaming, or real-time communication, resulting in a less satisfactory user experience.

Upgrades, and technology refreshes can help alleviate latency issues and improve overall network performance. Professionals in-house or hired will need to perform a complete analysis of all wired and wireless connectivity installed within a building, to provide recommendations and implement solutions that work across all methods of both voice and data communications.

4.06 Expertise & Skillset Gaps

IT departments may lack the in-house expertise to modernize their wireless networks. Generally, legacy IT employees have a strong understanding of wired communications, traditional networking, telecommunications, and Wi-Fi, but they lack complex cellular networking expertise and/or cannot manage relationships with the large carriers. Traditionally, IT departments have relied on third-party vendors, partners, and integrators to address connectivity challenges. However, the cellular landscape is changing rapidly. Network improvements and upgrade cycles are becoming more frequent, and hardware and equipment options are evolving at a fast pace.

Keeping up with these evolving solutions, ensuring seamless 4G to 5G migration, and meeting the demands of end-users and business performance can be both costly and time-consuming. Adapting to these changes requires continuous investment and effort to maintain optimal connectivity and performance.

4.07 Secure Connectivity

In today's digital era, the security of cellular connectivity is paramount for both personal and business communications. With the widespread adoption of 5G technology, which supports everything from mobile devices to Internet of Things (IoT) applications, the network architecture introduces significant complexities and potential security vulnerabilities.

Consumers expect robust security measures to ensure their data remains protected and private, which is crucial for supporting personal privacy, business integrity, and national security. The expansion of connected devices heightens these security risks, requiring stringent protections across all network endpoints.

As 5G continues to evolve, maintaining strong security protocols — through robust encryption, continuous monitoring, and collaboration among industry stakeholders — is essential to ensure safe and reliable connectivity.

4.08 Single Carrier

Ensuring that a network supports multiple carriers is paramount to providing quality cellular connectivity for all tenants and guests, who likely subscribe to different providers. However, creating a multi-provider system is challenging due to the technical and logistical complexities involved.

- Each carrier has its specific requirements and frequencies, which means a solution must be carefully designed to meet these varied specifications without interference.
- Additionally, the negotiation process with multiple carriers can be intricate and time-consuming, as agreements must be reached that satisfy all parties involved, often requiring extensive coordination and significant upfront investment, as well as pre-existing familiarity and relationships with the carriers.
- Most importantly, the carriers may not prioritize the same venues: while one building might receive investment from a carrier with many customers as tenants, other carriers might choose not to participate in the system.

A single carrier solution is not a solution at all.

5. Solution Review

Now let's explore some of the solutions to address the problem of in-building connectivity. A comparison of three solutions to improve user access is demonstrated below: Wi-Fi, Distributed Antenna Systems (DAS), and Neutral Host Small Cell (NHSC).

Solution Comparision	Wi-Fi	DAS	Neutral Host Small Cell
Multi carrier inclusive	Passpoint required to support all	Pay per carrier onboarding	Included as standard
Carrier onboarding	No (passpoint required)	9+ months	Day 1
Uninterupted calls	Intermittent	Yes	Car door to office door
Cost to build/own	$$	$$$$	$$
Speed to deploy	6-12 weeks	6-18 months	6-12 weeks
End-to-end support	Minimal	Yes	Yes
Security	Minimal, requires additional requests	Carrier grade as standard	Carrier grade as standard
Scalibility	Yes	No	Yes

5.01 Wi-Fi

Wi-Fi enables seamless access to the internet and internal networks, fostering productivity and collaboration among customers and employees. However, relying on Wi-Fi for wireless connectivity can have its drawbacks. Guests must have a password for access, making network entry time-consuming and sometimes challenging. Users expect continuous connectivity as they move throughout a building – from their car to the building, up the elevator, and into their office. With capacity constraints and coverage limitations, Wi-Fi networks cannot guarantee a seamless connection, resulting in dropped connections and user frustration.

Features

- Wireless Access: Access to Internet and local networks, eliminates need for cables
- Multiple Device Support: Supports wide range of devices
- Scalability: Easily expanded with added access points to cover larger areas
- Ease of Deployment: Easy to install and set up compared to wired networks
- Variety of Standards: Based on speed, range, and capabilities
- Flexible Configuration: Configure networks for guests, business, public

Benefits

- Convenience and Flexibility: Connect from anywhere within reach
- Cost-Effective: Less expensive installation/maintenance than wired networks
- Ease of Use: Minimal setup, making it user-friendly
- Scalable: Add access points as you grow or upgrade to newer Wi-Fi standards.
- Compatibility: Compatible with a wide range of devices and operating systems

Drawbacks

- Voice Capabilities: Struggles to support calls particularly when device is mobile
- Security Vulnerabilities: Access, data interception, and cyber-attack risk
- Interference: From devices, networks, and obstacles causing performance issues
- Limited Range: Limited range/coverage in multi-floor buildings & older structures
- Network Congestion: High volume of devices or users can overload the network
- Bandwidth Limitations: Lower bandwidth compared to wired networks
- Access Control: Risky environments in public spaces or large events
- Maintenance: Ongoing maintenance and updates for security and performance

5.02 Distributed Antenna Systems (DAS)

A DAS improves carrier signals by distributing them to where they are needed, and then broadcasting them to devices using multiple smaller, less powerful antennas in various locations. DAS is especially suitable for large-scale, complex environments where a large area needs to be covered, such as airports and stadiums. DAS is theoretically carrier-neutral, making it a flexible solution for venues hosting users from different network providers. This technology is crucial in large or complex structures where conventional wireless networks might struggle due to interference or distance. By bolstering signal strength and reducing dead zones, DAS improves productivity, customer satisfaction, and operational efficiency.

Features

- Signal Distribution: Strategic placement of antennas to distribute cellular signals
- Scalability: Scale from small to large footprints including campuses or stadiums.
- Multi-Carrier Support: Supports multiple carriers and frequencies

- Customizable Coverage: Per specific requirements and usage in the building
- High Capacity: Adaptable to high volume of users/devices simultaneously
- Seamless Handoff: Seamless connectivity as users move through coverage area

Benefits

- Enhanced Coverage: Improve weak signals or dead zones
- Improved Signal Quality: Reduce dropped calls and improve data speeds
- Multi-Carrier Support: Users from different mobile networks supported
- Increased Capacity: Enhance high user density for venues and buildings
- Future-Proof: Support upgrades to new frequencies and technologies (5G)
- Customizable: Tailor needs to building, facility, and usage

Drawbacks

- High Initial Cost: Significant upfront costs for equipment, design, and installation
- Complex Installation: Greater planning and coordination, disruption to the environment
- Maintenance: Ongoing maintenance for performance optimization
- Long Deployment Time: Due to carrier integration delays
- Interference and Capacity Management: Requires greater skillset and coordination
- Carrier Agreements: Multi-carrier agreements require complex negotiations and each carrier bringing separate circuits

5.03 Small Cell and Neutral Host Small Cell (NHSC)

Small cells are low-powered radios that fill in the cellular coverage gaps in hard-to-reach places, including densely populated areas and in multi-floor buildings. Small cell technologies can operate in licensed and unlicensed spectrum that provide a range of 10 meters to several hundred meters. They ensure comprehensive coverage by mitigating the shorter range and poor indoor penetration associated with higher frequencies. NHSC does all of this, while supporting more than one carrier.

Features

- Low-Powered Radio Access Nodes: Enhance cellular coverage/capacity in localized areas
- Neutral Host Capability: Supports multiple carriers at the same time
- Flexible Deployment: Indoor and outdoor application to fill coverage gaps and enhance network density
- High Data Throughput: Low Latency, suitable for data-intensive applications
- Integration with Existing Networks: Works with macrocell networks for seamless coverage
- Scalability: Add more small cells to cover larger areas as you grow

Benefits

- Enhanced Coverage: Improves indoor environment connectivity and urban canyons
- Cost-Effective: More cost-effective for improving coverage and capacity in specific areas
- Supports Multiple Operators: Supports multiple carriers at the same time
- Increased Capacity: Reduce congestion in high-traffic, dense areas
- Low Latency: Helps real-time data transmission
- Flexibility: Adaptable to offices, hotels, shopping malls, and urban areas
- Reuse existing assets: can use existing building data circuits (DAS requires carrier provided circuits)
- Building Analytics: provides coveted footfall and heatmap data of cellular users in the building

Drawbacks

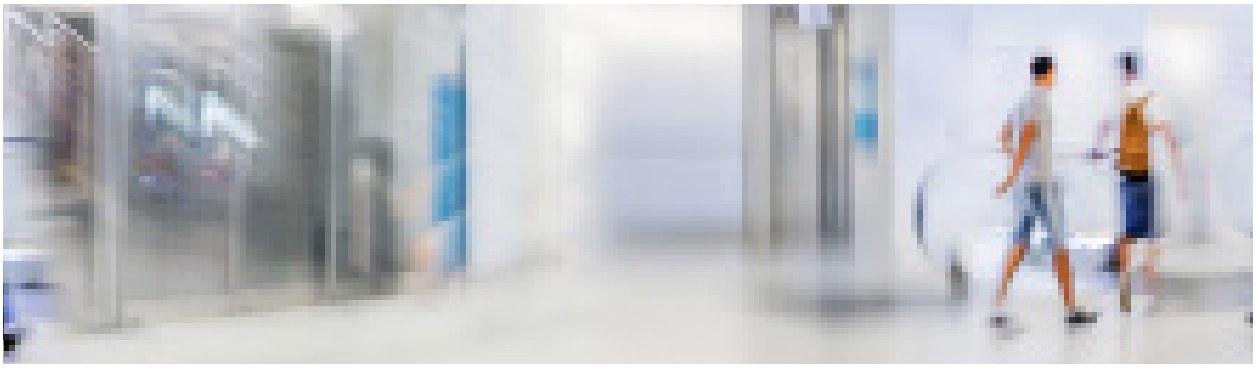
- Complex Coordination: Multiple carrier coordination brings complexity
- Initial Deployment Cost: Upfront costs required, though less than macrocell
- Interference Management: Requires skillful planning and expertise
- Backhaul Requirements: Needs robust backhaul connectivity to ensure high performance
- Limited Coverage Area: Reach limitations compared to macrocells
- Ongoing Maintenance: Requires ongoing maintenance and monitoring

6.0 Working with the Right Partner

When a venue owner decides to install an in-building system, there are several partnership models to consider: in-house, carrier-deployed, system integrator, and third-party operator (3PO). Each model has its benefits and drawbacks depending on the specific needs and capabilities of the building owner.

While some building owners with large IT teams may choose to task their in-house teams with creating the in-building system, most lack the capabilities to do so and look to partners to build the network and bring the carriers on as tenants.

Building owners may work with IT integrators who construct the in-building system but lack the relationships or technical sophistication to bring even a single carrier onto the network. This leaves the building owners with a stranded investment and a chronic connectivity problem. Alternatively, owners may turn to third party operators (3PO) who can build and own the network and work to bring the carriers on; however, many 3POs overstate their ability to attract multiple tenants, requiring owners to be skeptical of upfront claims.



Selecting the right partner for implementing and installing a seamless cellular solution is crucial for ensuring optimal performance, cost-efficiency, scalability, and multi-carrier capability.

In-House: Building and managing a system in-house requires significant IT expertise and resources. While it offers the highest level of control over the system, it also involves substantial risks, including the complexities of carrier coordination and the technical challenges of system management. This option is usually not feasible for most building owners due to the high initial investment and ongoing operational requirements.

Direct to Mobile Network Operator (MNO): Going directly to an MNO might seem like a straightforward approach, but it typically results in a system that supports only that specific operator's network. This could significantly limit the system's utility for occupants who subscribe to different carriers, thereby reducing the system's overall value and appeal.

System Integrator: System integrators can provide customized solutions by integrating various subsystems and ensuring they work together seamlessly. While they are highly skilled in the technical aspects of DAS installation, their focus is more on the hardware and software integration rather than ongoing operations or carrier relationships. This can be a limitation for building owners looking for comprehensive service management and certainty on attracting multiple carriers.

Third-Party Operator (3PO): A 3PO specializes in managing the entire lifecycle of an in-building project, from design and installation to operation and maintenance. The most compelling argument for choosing a 3PO is their ability to design a DAS with the needs of multiple MNOs in mind. This is crucial for ensuring wide coverage and compatibility. Furthermore, 3POs are experienced in negotiating with various MNOs, acting as an intermediary that can effectively manage relationships and expectations on behalf of the building owner. This reduces the complexity for the owner and ensures a DAS that is optimized for performance and profitability, with potentially faster deployment times and minimized operational hassles.

Given these options, partnering with a 3PO often makes the most sense for building owners. A 3PO not only alleviates the burden of technical and managerial challenges but also brings expertise in dealing with multiple carriers, ensuring that the DAS meets the broadest possible needs and maximizes both service quality and revenue potential. This model provides a balance of technical proficiency, operational management, and carrier negotiation that is difficult to achieve with other partnership models.

Ultimately, however, a partner is only as good as the technology deployed. Most 3POs deploy DAS, which requires each carrier to bring its own separate radio, creating friction and uncertainty of multi-carrier deployment. When deployed as part of the right platform, the NHSC alleviates this carrier uncertainty and solves the cellular connectivity problem quicker.

cellShare™

by dense air

7.0 cellShare™

cellShare™ by Dense Air is a unique solution that offers turnkey services to identify connectivity gaps, install hardware, implement software, and offer full-service management of cellular connectivity improvements.

Dense Air provides the equipment, manages deployment, ensures security, provides ongoing maintenance, and monitors traffic to simplify improving cellular connectivity in building.

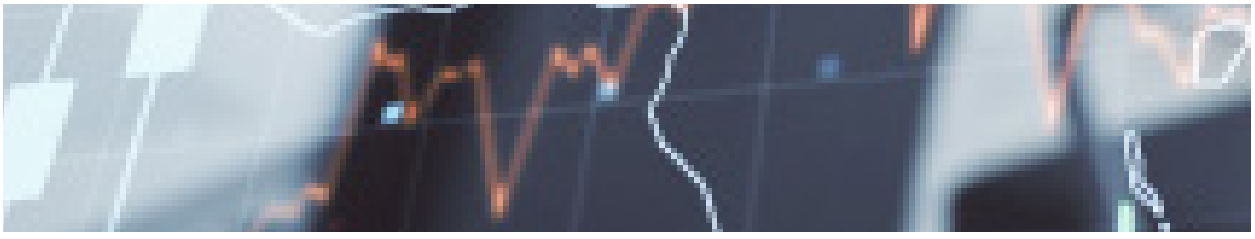
Primary features of the cellShare™ solution include:

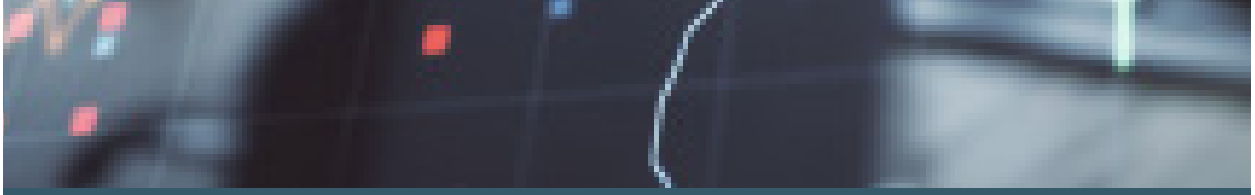
- Enabling multiple carriers at the same time, in the same location, without waiting months or years after deployment
- Cost efficient, minimal footprint, and easily integrated into the existing buildings.
- Rapid installation (weeks) compared to traditional solutions (months and years)
- Security, continuity, and reliability of your cellular connection
- Fully managed as a turnkey service

Dense Air incorporates neutral host (or multi-carrier) small cells to solving the issues of poor connections, dropped calls, and poor cellular experiences with its cellShare™ solution. The solution can be installed space by space or floor by floor for multi-floor buildings, which allows for a customized solution that targets trouble areas and quickly improves end user experiences.

To identify where coverage and capacity gaps exist, cellShare™ uses big data analytics with a proprietary software tool called denseWare™ that gathers insights across multiple operators and end-user activity. Dense Air designs customized solutions and rapidly deploys small cells only where needed, using existing infrastructure to limit the cost expenditure.

Once cellShare™ is deployed, consistent, reliable 24/7/365 performance monitoring is enabled, and maintenance and upgrade support are provided as needed. Through denseWare™, Dense Air provides the software and APIs (Application Programming Interfaces) needed to fully integrate with existing systems, provide user and network insights, and present dashboard visibility for managers or IT teams.





Key benefits offered via the cellShare™ solution include:

- Increased throughput of signal for optimal experiences
- Reliable turnkey and white-glove service
- Scalable and secure connectivity
- Budget-friendly solution with a lower TCO (Total Cost Ownership), flexible opex, and/or capex funding
- Less complex and faster installations
- Integrates with top carriers simultaneously
- Public and private wireless friendly
- Network coverage mapping and analytics platform

As businesses digitally transform and automate, cellular remains a critical foundation for innovation. While cellular is enhancing customer experiences, it is also being used to augment, improve, or provide redundancy in enterprise or business networks. Cellular connectivity can be used to extend or supplement businesses' primary networks, augment an existing DAS network, and extend key guest or customer services to hard-to-reach indoor and outdoor locations.

cellShare™ by Dense Air provides reliable, uninterrupted cellular connectivity for a fraction of the cost of other options, while improving overall guest and employee satisfaction, loyalty, and tenant retention — ultimately maximizing the value of your property.

For more information on cellShare™ please contact Dense Air at:

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cellShare™ by dense air