



Wireless Without Limits

*The Advantages of Outdoor-Based Wireless
Local Area Networks for Carrier-Class Applications*

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Summary

The current evolution of wireless local area networking (WLAN) from small hot spots to large-scale enterprise deployments is changing the requirements of WLAN infrastructure. Wireless networks initially served small, primarily indoor areas (“hot spots”) only, where performance was knowingly sacrificed for convenience and where scale was not a concern. Today, WLAN solutions that offer greater coverage and performance are needed to enable the evolution of WLANs from small indoor deployments to carrier-class applications.

This paper establishes the requirements for carrier-class WLAN deployments, and then briefly describes current indoor, outdoor and hybrid WLAN solutions – including their primary uses, advantages and drawbacks. The discussion concludes with an overview of BelAir Networks outdoor-based, carrier-class WLAN solution, which successfully resolves the challenges of large-scale Wi-Fi networking.

Beyond Hot spots

Today, the wireless local area network (WLAN) is growing beyond the modest interconnection of several computers in an office or home setting, and into the realm of vital business infrastructure. Service providers are looking to wireless networks to extend the reach of existing infrastructures, while enterprises are turning to wireless deployments as a means of facilitating productivity and untethered access for increasingly mobile workforces across large campuses.

To date, wireless networks have served small, primarily indoor, “hot spots,” where performance is knowingly sacrificed for convenience and where scale is not a concern. These solutions are usually complicated and costly. Multiple access points, endless feet of cable to and from switches and routers, security issues and maintenance requirements create obstacles that complicate and increase the cost of deployment.

The reason is that the majority of indoor solutions are constrained to coverage on single floors because penetrating reinforced concrete is challenging. To provide coverage to other areas, multiple units per floor are required. Since every indoor unit requires power and LAN connectivity, the complexity of the deployment increases.

Outdoor solutions and hybrid solutions have been proposed to address these issues. But each presents its own advantages and drawbacks and neither completely eliminates the complexity associated with current WLAN deployments for medium and large venues.

To enable the evolution of WLANs to carrier-class enterprise and service provider applications, WLAN solutions need greater coverage and performance than current solutions can provide. Next generation WLANs must be able to serve medium and large diverse environments effectively, they must be easy to deploy and maintain, and they must be profitable for service providers and cost-effective for enterprises.

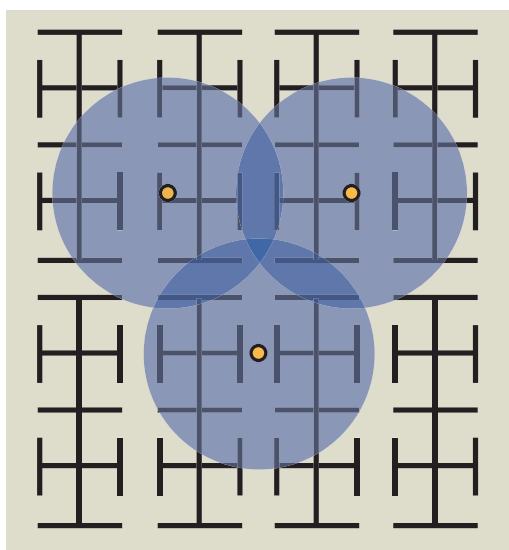


Figure 1: Example Indoor WLAN:
Three Omni-Directional APs

Indoor Solutions Complex and Costly

The most basic unit of WLAN coverage is a single access point (AP). Generally, these indoor networks are deployed with omni-directional antennas, which radiate power equally in all directions (see *Figure 1*) and typically provide coverage to a 100-foot radius.

When deployed in small areas on a single floor, these solutions provide sufficient wireless connectivity for small hot spot applications such as small office/home office settings; they are simple and cost-effective—the AP is simply plugged into an existing LAN.

As an omni-AP network grows, however, AP-to-AP interference impacts network performance in a continuing cycle as noise levels in the AP receivers increase throughout the network. This, in turn, reduces the coverage of each AP, and users in marginal areas (i.e. at the outer periphery of the antenna's reach) may find that their service slows or becomes intermittent. More APs are required to cover these areas, further decreasing the coverage of each AP and escalating the cost of deployment.

Another common scaling issue in indoor WLAN configurations is channel sharing. This occurs because the network's channels often need to be reused due to the limited spectrum available for WLAN deployment.

For all intents and purposes, just three channels in the spectrum are available for network use, so if more than three APs are required, channel sharing must occur. Further complicating the deployment is the close proximity of the APs, which will result in a capacity reduction as co-channel APs wait for their "visible" neighbors to complete transmission before they get a chance to transmit their own data.

Duplication is also an issue that must be considered with multi-floor deployments. Current indoor wireless LANs are wireless only to the PC. Each AP must be wired to the Ethernet for access, as well as to a costly T1 or DSL for backhaul. Therefore, in multi-floor deployments,

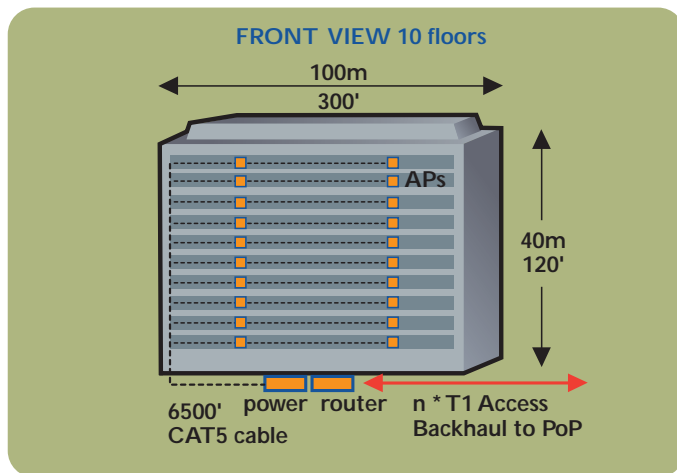


Figure 2: Current Multi-Floor WLAN Deployment Example

conventional indoor systems require a substantial duplication of the network its cost, and its inherent problems on each floor where coverage is required (see Figure 2). In structures with many interior walls the duplication problem is even more acute. In open-concept environments such as cubicle arrangements or manufacturing facilities, there is typically sufficient unobstructed space to allow substantial energy propagation. However, the presence of hard walls and structural obstructions such as stairwells and elevator shafts leads to substantial "shadow" (marginally covered) regions. The solution is to add yet more APs to improve coverage, which duplicates the cost and inherent problems associated with indoor solutions.

Proposed Outdoor Solutions: Adaptations of Indoor Options

Compared to traditional indoor systems, outdoor solutions promise many advantages over indoor solutions for medium and large deployments. They promise to:

- Simplify deployment with fewer required units/cables.

- Provide greater incremental capacity with each AP added to the network by using directive antennas. Directive antennas mitigate AP-to-AP interference by controlling the angle of energy emitted by each AP.
- Maintain isolated coverage and reduce the interference received from user stations in adjacent areas.
- Serve the needs of more than one application.

But the currently proposed outdoor solutions are merely adaptations of conventional indoor options that have been enhanced or patched together and moved outdoors. Unfortunately the reality of these patchwork solutions is inconsistency of coverage. Because most are designed for very specific applications, they don't provide the kind of consistency required in diverse situations. This includes campus applications where users move from indoors to outdoors.

Hybrid Solutions Combine Best of Both Worlds But Increase Cost

For some deployments a combination of outdoor and indoor solutions is required.

In a convention center, for example, interior areas are typically surrounded by thick walls and may include sound proofing materials. An indoor solution is ideal for these areas. But to serve the large common areas of such a space, an outdoor solution will provide the greatest coverage.

No single solution exists to meet both needs optimally and cost-effectively. Therefore, the same scalability and cost challenges associated with indoor and outdoor solutions apply to these situations, due to the number of wired APs required to sufficiently cover the space. (see *Figure 3*).

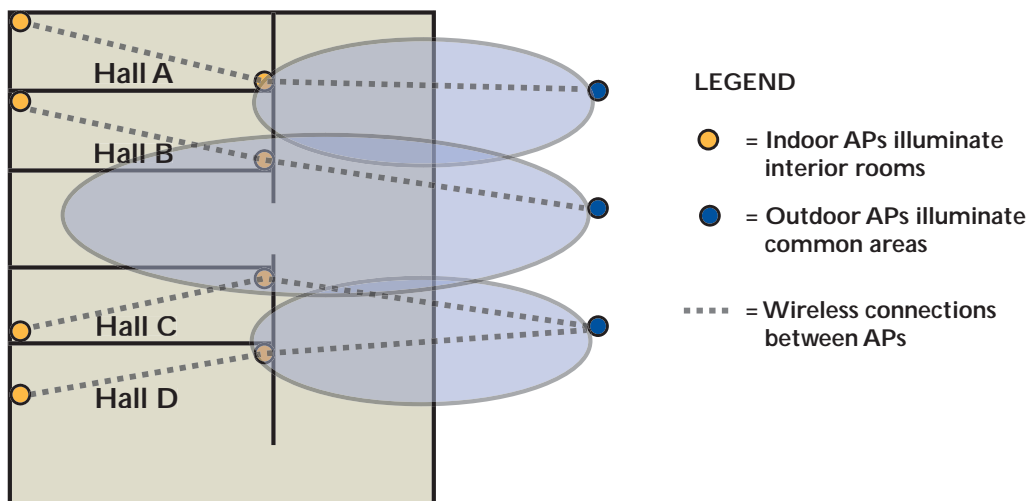


Figure 3: Hybrid Solution

Toward a Carrier-Class WLAN Solution

If current indoor and outdoor solutions are not adequate for medium and large deployments, what are the characteristics of an optimal carrier-class WLAN solution that addresses the needs of these venues?

There are five key criteria that must be met in order for any solution to adequately address the needs of medium and large public and private WLANs:

- **Outdoor deployment**
- **Scalable architecture**
- **Minimal cabling**
- **Maximum coverage**
- **Antenna diversity**

Let's look at each in detail.

Outdoor Deployment

To meet the majority of today's larger-scale WLAN requirements, an outdoor-based solution is needed to achieve the coverage required in diverse indoor and outdoor spaces, and to overcome limitations of interior building structures.

The ideal outdoor solution is, therefore, one designed for outdoor operation and based on an architecture that is very scalable. In addition, the WLAN equipment must be optimized for outdoor operation, in tune with relevant environmental standards, and subject to relevant stress testing.

Scalable Architecture

The ideal WLAN infrastructure design must be scalable, both to enable very large deployments and also to support incremental and cost-effective growth of the network.

The solution must be designed such that very few new APs need to be deployed as the network grows. This reduces capital costs and minimum incremental costs as the number of users or size of the covered area increases.

Minimal Cabling

The architecture of an ideal solution must minimize the need for cabling between access points (AP) to allow the network to scale cost-effectively. Additionally, it must avoid or minimize the need for costly, complex wired connections from the AP to the Internet (i.e. backhaul).

The ideal outdoor solution should, therefore, integrate backhaul into the system. It should exploit the wireless network to avoid wiring by wirelessly connecting APs to each other and to the backhaul. The backhaul should be provided for on a medium other than the medium that clients are using, as transmitting backhaul on the access medium reduces overall network capacity. (See BelAir Networks white paper "*Beyond The Hot Spot: Wireless For Profit*")

Maximum Coverage

In an optimal, carrier-class WLAN solution the APs and antennas must provide coverage in a three-dimensional space. An outdoor-based WLAN solution improves overall coverage and can take advantage of directional antennas to isolate the energy transmission as required. But, the solution must address two particular coverage challenges: power limitations and interference issues.

802.11b and other unlicensed spectrums are restricted in the amount of power they are able to transmit. APs thus need to be deployed close to the target building using a wide beam width antenna, or far away with a high gain antenna. In either case, the total transmit power is restricted and the power arriving at the building is reduced with greater distance. Thus, a solution located close to the target building is typically ideal.

Outdoor-based WLAN solutions must also be designed so that interference is minimized. Because WLANs operate in the unlicensed spectrum, frequencies from outside networks can interfere with deployment. Interference may include man-made noise sources, such as microwave ovens or other wireless LANs, or may include line-of-sight obstructions. This probability increases as the AP is moved further away from the illumination target.

These considerations mean that antenna design must minimize the antenna's response to energy outside of the intended coverage region. Location of the solution is also important.

To address these challenges, the optimal balance between the equipment's proximity to a building and the interference between antennas must be achieved. As an access point is brought closer to the building, its angle to higher floors increases rapidly, while available openings on higher floors (where the bulk of the power enters) become very small when projected back onto the sight line to the access unit. To avoid interference and obstructions, the solution must be located in close proximity to the building.

For capacity-limited situations, additional access units are required and, with conventional solutions, must be deployed close together using directional antennas to minimize interference between the access points.

Antenna Diversity

For medium and large-scale WLAN deployments, where the WLAN provides primary infrastructure, the solution must be robust enough to provide availability, reliability and carrier-class performance.

The primary technique used to improve link robustness is antenna diversity, which buffers against signal variations taking advantage of the fact that different paths will have different power statistics. Most commercial chipsets support simple switch diversity schemes, in which the receiver "sniffs" the incoming RF during packet preamble and determines which of the two antenna inputs is strongest, then locks the receiver to that input for the duration of the burst. This process is executed on each received packet to ensure that the environment has not changed in the intervening time.

In indoor solutions, diversity is provided by two small receiving antennas separated by $\sim 1/4$ of a wavelength. This approach works well indoors because, with energy bouncing off many surfaces, there are generally many paths by which the signal may arrive at the user device. Outdoors, however, there are fewer paths – usually paths through windows.

An alternative to spatially separated antennas that is more appropriate for outdoor applications is the use of polarization diversity. Rather than relying on large separations to differentiate the paths to antennas, orthogonally polarized antennas are used, with little or no spacing needed between them.

Polarization diversity works well in typical 802.11 scenarios because the signals from clients tend to bounce several times off various parts of the interior structure prior to leaving the building; this randomizes the polarization angle of the energy.

Using polarization, the orientation of the user relative to the AP can affect the polarization that is radiated from the client. Dynamic effects on different paths include movement within the environment: opening and closing of doors, traffic flows, and, when dealing with a laptop, even the subtle motions of an end user on a keyboard and small body movements can affect the end path because of proximity to the antennas.

With a strong diversity scheme in place, it is unlikely that both diversity antennas will experience a fade (degradation), thereby increasing link robustness. The technique has also been found to improve throughput in both directions because the likelihood of receiving a successful acknowledgement (ACK) message improves and reduces retransmissions that would otherwise result from missed ACKs.

BelAir Networks and Carrier-Class WLANs

Based on the realities and requirements for carrier-class WLAN implementations, BelAir Networks has designed an optimal solution designed for outdoor operation and true scalability. It combines the best of WLAN and cellular technologies to overcome the limitations associated with traditional hot spot WLANs.

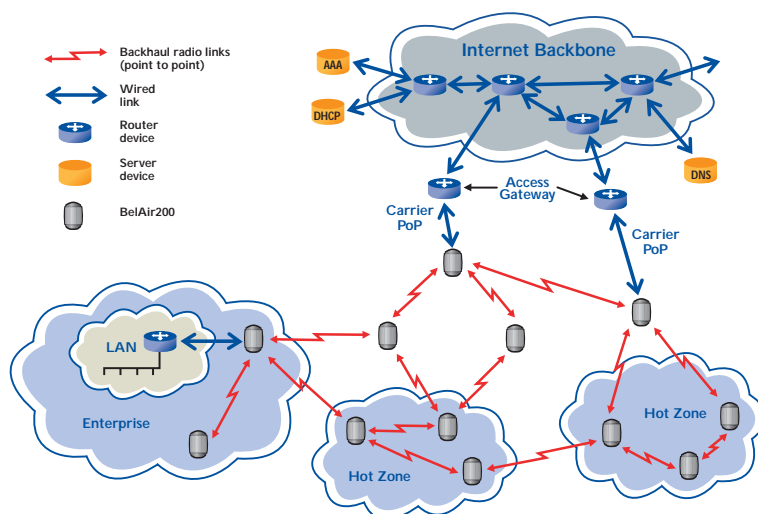


Figure 4: BelAir Multi-Point-to-Point Mesh Architecture

The BelAir Networks solution provides exceptional indoor and outdoor coverage with multi-service platforms that are designed and packaged for outdoor environments. It is based on a patented, multiple-point-to-point mesh architecture that uniquely integrates wireless access and backhaul, thereby simplifying WLAN infrastructures and eliminating the crippling costs of T1 and DSL backhaul.

Like a cellular network, this architecture is designed for outdoor deployment. It provides wide area coverage and long reach, and enables the creation of cell-based networking solutions. And like a WLAN it incorporates an open IP architecture and standards-based Wi-Fi technology that enables the deployment of cost-effective private and profitable public cellular LAN networks.

To create the mesh, BelAir Networks has designed outdoor multi-service platforms that beam signals into buildings from the outside. These can cover buildings, outdoor scenarios of all types, and can connect to an existing hybrid solution.

Multiple radios in each platform are configured point-to-point with directional antennas. Each platform can connect to multiple others and the combined connections form a wireless mesh. At the same time, the BelAir Networks solution makes use of robust point-to-point links.

This design takes full advantage of wireless networking by connecting units to each other and to the backhaul without cabling. This architecture is optimized for carrier-class scalability, as it can be organically extended and grown to provide coverage anywhere and at any time, interconnecting any number of hot zones. At the same time, the BelAir Networks solution takes advantage of directional antennas to minimize interference and control coverage in any application.

Built for Outdoors

The **BelAir200** cellular LAN platform is a network-in-box, mobile networking solution designed to beam signals into buildings from the outside. It implements the patented BelAir Networks mesh architecture that, for the first time, integrates wireless access and backhaul. The electronics of the BelAir200 are encased in a compact, environmentally hardened outdoor package that allows for a variety of mounting options. It can be mounted on any type of pole or readily attached to the side or roof of a building (see Figure 5).

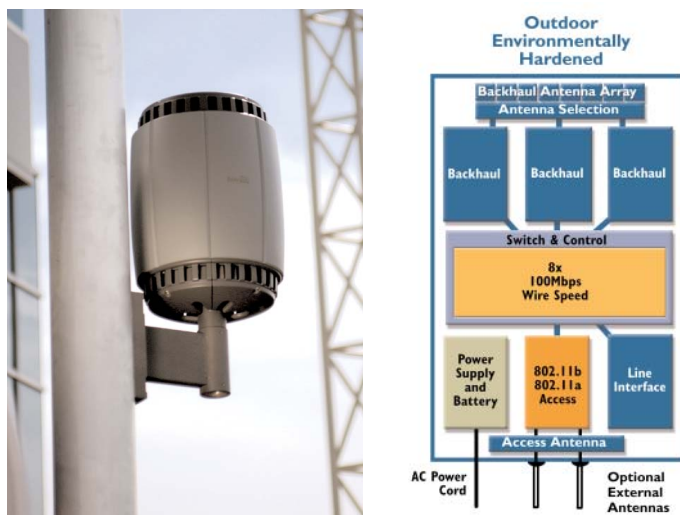


Figure 5: BelAir200: Environmentally Hardened Design

There are no extra switches, routers or cables required to connect multiple BelAir200s. Each unit's power supply is connected to a pole's external outlet to receive the required AC power.

Integrated Design

The BelAir200 is built around a high-performance network processing core, multiple Wi-Fi access and backhaul modules and an open embedded software environment.

The processing core provides 100 Mbps, Fast Ethernet wire speed routing capability per module. The software provides operator-class, network level operation, administration and maintenance (OAM) capabilities and a wealth of security, mobility, management and accounting services. Combined, the processing core and software allow network operators to quickly and easily access to applications and services, such as:

- E-mail,
- Web surfing
- Corporate VPN access
- File transfer
- Instant messaging

Eliminates Deployment Hassles

The BelAir200 can be easily deployed within line of sight or near line of sight of a building, at which point the radio waves penetrate the building windows to illuminate the interior. In this way, a single BelAir200 can cover multiple floors at once.

With a BelAir200 a typical 10-floor mid-sized building 234ft wide by 72ft thick by 144ft high can easily be covered with two to four BelAir200s located outside the building.

To provide the same coverage with an indoor solution would require a minimum of 20 indoor access points (i.e. a minimum of two per floor), with 1000s of feet of associated wiring.

An added advantage is that deploying a BelAir200 eliminates the need to have access to the building for installation. BelAir200 platforms can be readily deployed on existing infrastructure such as light poles and adjacent buildings.

The same BelAir200 can also be used to cover very large, near line-of-sight areas as well, at distances of three-quarters of a mile or more.

Integrated Multiple Radios Improve Coverage and Ease Deployment

What makes the BelAir Networks solution so effective is the ease of deploying access where it is needed. This has been uniquely enabled by BelAir Networks integration of multiple Wi-Fi access and backhaul radios in a single compact package.

In traditional solutions, when a nearby radio transmits, the other receivers are significantly desensitized due to the coupled power into their antennas.

BelAir Networks has reduced the coupling between integrated antennas to enable the co-location of radios. Further enhancements to key parameters of the backhaul radios ensure that each can receive at their sensitivity limit while the other radios are transmitting at full power.

Each of BelAir Networks backhaul radios delivers industry-leading receive sensitivity and increased transmit power compared to standard solutions. This creates an increase in reach.

BelAir Networks radio enhancements also include industry leading receive sensitivity and transmit power, and full cross polarization antenna diversity for the best possible performance in outdoor to indoor deployments.

The integrated access antennas provide a directional pattern suitable for the majority of deployments, from low-rise suburban office buildings and campuses, to high-rise urban towers.

Cellular LAN Solution: Best of the Best

Change demands change. With wireless local area networking growing beyond hot spots and into the realm of vital business infrastructure, the requirements of WLAN infrastructure are changing. Today's WLANs require high availability, performance, throughput, redundancy and very broad coverage – all at reasonable cost.

BelAir Networks has mapped those needs to requirements for radios, antennas and overall product design. The result is the BelAir 200, an innovative WLAN solution truly designed for outdoor operation that takes full advantage of wireless to integrate both access and backhaul capabilities.

In so doing, BelAir solutions:

- Eliminate the need for cables, extra switches and routers to interconnect wireless nodes
- When used for indoor applications, reduce access points by five to ten times compared to conventional indoor solutions
- Eliminate disruptive, in-building network deployment
- Reduce WLAN capital expenditures by up to 70%
- Reduce WLAN operating expenditures by up to 90%
- Eliminate T1, DSL and other backhaul costs
- Provide five times more capacity and distance compared to traditional wireless mesh architectures.

About the Author

Eric Johnson is a radio systems architect and a 15-year veteran of antennae and radio solutions. He began designing space-based radio applications, remote sensing and communications systems antennas. Later, during his seven-year tenure at Nortel Networks, Johnson designed cellular systems, including TCMA, CDMA, GSM and UMTS. Today, he is a radio systems designer for BelAir Networks, responsible for radio coverage and antenna solutions.

About BelAir Networks

BelAir Networks is a wireless infrastructure supplier that provides advanced, multi-service, mobile networking solutions optimized for medium and large public and private cellular LAN networks.

Combining the best of WLAN and cellular technologies, BelAir Networks solutions go beyond basic Wi-Fi to overcome the limitations associated with traditional WLANs. They are built on a patented multiple point-to-point mesh enabled by outdoor platforms, indoor nodes, and network management software. Together, the mesh and the products that enable it are designed to simplify wireless infrastructures, reduce capital and operating expenditures, and deliver ubiquitous high capacity data, video and voice services where and when needed.

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