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WHITE PAPER

Beyond the Hot Spot: Wireless for Profit

The Benefits of a Multiple Point-to-Point Mesh Network

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Summary

Wireless technology is sufficiently exciting that today both service providers and enterprises are looking to wireless networks as infrastructure solutions on campus-wide scales. Unfortunately, network operators are discovering that today's wireless networks don't scale well.

The current approach to networking wireless access points is to wire between the many required units. This is expensive, time consuming and complex – and can be difficult in many buildings and outdoor environments. Furthermore, wiring between access points requires the use of a T1 or DSL wireless backhaul, which can impose crippling costs. In essence, current wireless networks are problematic because they depend on too many boxes and too many wires.

This paper explores the pros and cons of the four solutions currently used to network WLAN access points, including pure wired networking, point-to-point, point-to-multipoint, and multipoint-to-multipoint systems.

The paper then introduces a new approach from BelAir Networks that resolves the problems of cost and complexity in conventional wireless networks. The BelAir Networks patent-pending multiple point-to-point solution is described, along with how it enables mobile networking—without limits.

The Search for True Wireless Freedom

Freedom is the new driving force in telecommunications. With access and speed now table stakes, consumers want to connect to the wired world without wires. Service providers are, therefore, focused on wireless networking to extend the reach of existing infrastructures. Likewise, enterprises are turning to wireless deployments as a means of facilitating productivity and providing untethered access for increasingly mobile workforces. Public and private 802.11 Wireless Local Area Networks (WLAN) are widely deployed today and "Wi-Fi" is a buzzword on the lips of executives, students, airport managers and coffee shop barristas alike.

Wireless LAN networking has, in a word, arrived. Its early years reflected the technology's infancy, with ad hoc deployments in small "hot spots" like lounges and cafeterias. The technology is sufficiently exciting that today both service providers and enterprises are looking to wireless networks as infrastructure solutions on a broader scale, including:

- **Hot zones**, such as business districts, office parks, airports, hotels, conference centers, recreation areas, and shopping malls
- **Campuses**, corporate offices, manufacturing centers, universities, hospitals, research parks, municipal centers and more

But, the problem with scaling the conventional "wireless" LAN networks to these proportions is . . . *too many boxes and too many wires*.

Too Many Wires Spoil the Profit

Current approaches to networking wireless access points (AP) together is to wire between units. Multiple APs, endless feet of cable to and from switches and routers, security issues and maintenance requirements create costly deployment nightmares in applications that require more than a handful of APs. Furthermore, current methods require the use of a T1 or DSL wireless backhaul, adding crippling costs.

Following the expense and complexity of current wireless networks, the cost of connection to the Internet is often prohibitive. Connections are typically made to small venues and charged to the venue operator based on traffic. But, $400 a month for a high-speed connection into a coffee shop offering WLAN access is hardly sustainable.

In light of these challenges, solutions that enable cost-effective sharing of point-of-presence across multiple venues are highly desirable. The current solutions to networking WLAN access points include:

- Pure wired networking
- Point-to-point
- Point-to-multipoint
- Multipoint-to-multipoint

But all of these solutions present their own challenges and none completely address the problems associated with deploying medium and large public and private wireless networks. A new solution is required that simplifies the process, eliminates the complications, and addresses service provider and enterprise needs.

Pure Wired Networking: Tied Down by Complexity

Traditional wireless LANs are constructed from individual APs, each of which has a wired Ethernet connection. The APs may leverage existing LAN infrastructure or may have a dedicated set of connections. Depending on the scale of network growth, switches and routers may be required to provide the desired connectivity.

An advantage of wired systems is that the capacity of the links between nodes is well understood, as is the network's availability and reliability. This is useful in building the wireless backhaul system, which must be optimized to address capacity, throughput, latency and reach concerns.

But although wireless networks are intended to provide portable data services, as the network grows so does the complexity of wiring the APs. Each AP requires both power and data connections to enable access, thus filling wiring closets with switches and routers. Power over Ethernet (PoE) is often used to alleviate the need for additional AC power wiring, but results in yet more boxes in the closet.

Over time, therefore, wires become dominant in this conventional "wireless" network. This is not economically scalable, and using wired connections between APs negates many of the advantages of wireless networking. While it is the obvious choice for a single AP, such as a small hot spot (just hook it into a DSL modem or port on the existing LAN switch), using wires in a network of APs soon becomes unmanageable.

To overcome some of the limitations of this approach, systems may incorporate dedicated, purpose-built switch/routing engines into the wiring closet to connect the APs (*see Figure 1*). While segregating the WLAN from the wired LAN offers administrative and management advantages, this approach further increases the wired infrastructure.

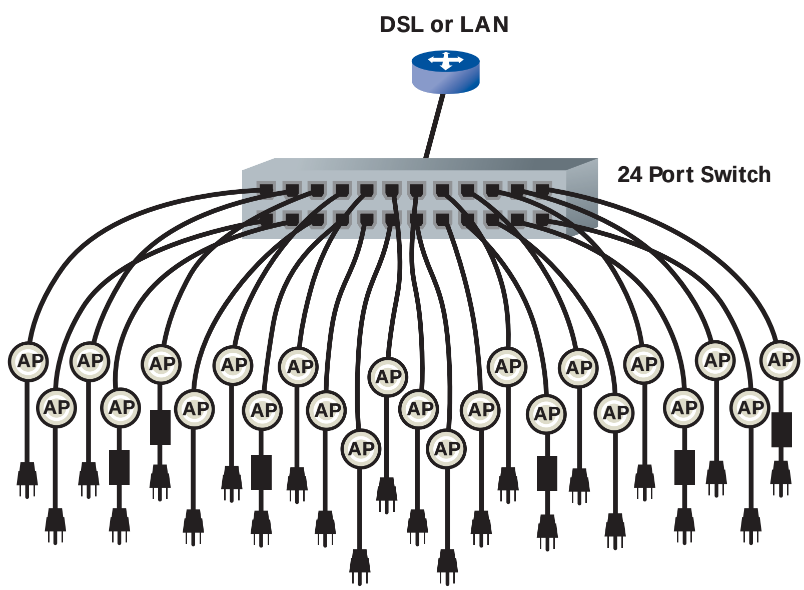

Figure 1: Basic Wired WLAN Infrastructure

Further complicating deployment is the fact that the locations of APs are determined by building layout. Suitable locations are often not near existing wired infrastructure, meaning that new power and data cabling must be pulled, at considerable cost and disruption to the work environment. In older and heritage buildings this can be difficult or impossible.

Traditional Point-to-Point: Low Availability

The most mature wireless backhaul solution is the point-to-point radio. Rather than sharing the medium, point-to-point systems use a defined link (one-to-one) between nodes and can thus rely on more deterministic capacities and latencies. This provides network operators with clear metrics for link availability and enables them to make service level agreement (SLA) commitments to their clients.

Extensively deployed in licensed RF bands, point-to-point microwave has been used to connect private enterprises, cellular base stations, and traffic monitoring and control systems to core telecom networks (SONET over radio). In these scenarios, one backhaul radio is deployed at each end of a radio link, with multiple hops deployed in a relay over longer distances. In recent years, Wi-Fi-type technologies have been used in this architecture to take advantage of unlicensed bands.

Point-to-point systems can also take advantage of directional antennas, which have greater gain because their energy is focused in a particular direction rather than dispersed over a 360º radius. Directional antennas thus improve the link budget at both ends (both transmit and receive), as well as improving overall reach. However, directional antennas require pointing – often resulting in considerable installation challenges and, therefore, additional costs.

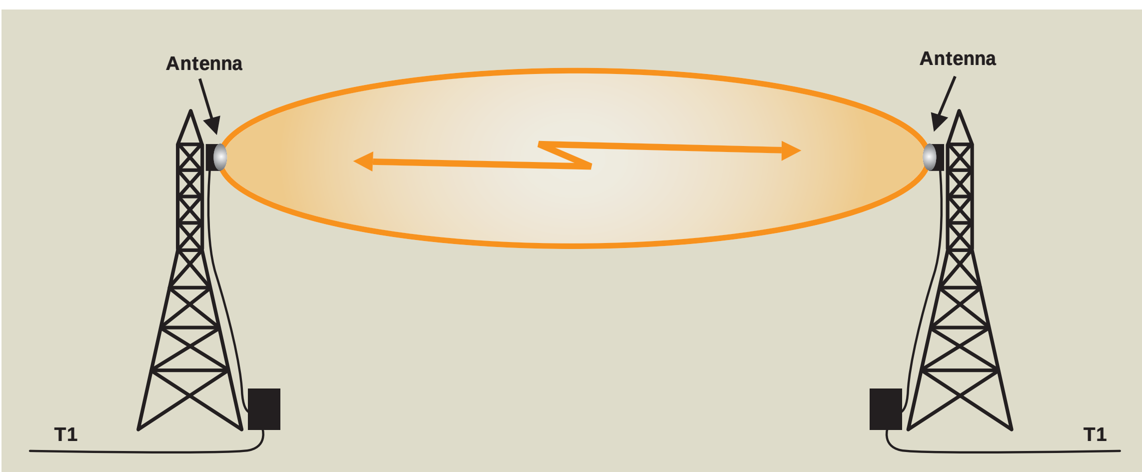

Figure 2: Typical Point-to-Point WLAN Design With Directional Antennas

But the primary issue with traditional point-to-point wireless networks is that they have no redundancy and thus the overall availability of the system can be low. In traditional microwave backhaul, availability is typically enhanced by deploying a second network for redundancy, but this doubles the amount of equipment at any site.

Point-to-Multipoint: Low Throughput, Short Reach

In a point-to-multipoint system, a central base station connects wirelessly to numerous "child" nodes in a one-to-many configuration. This is the basic mode of operation of the access portion of a wireless LAN, where a single AP connects multiple wireless clients (laptops, PDAs etc.) to the backbone. This approach has also been extended from the point of access to the wireless backhaul (*see Figure 3*).

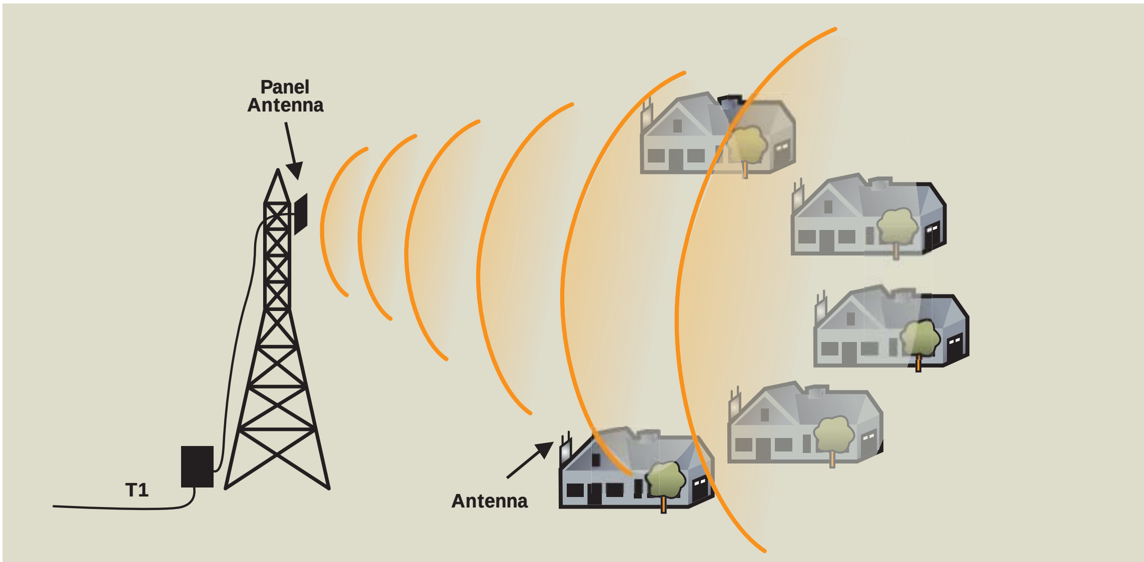

Figure 3: Typical Point-to-Multipoint WLAN Design

In some systems the nodes are fixed, as in broadband wireless access (BWA), where a central base-station connects to multiple customer premises equipment (CPE) attached to the outside of a building. The CPE then has an Ethernet connection to the inside of the building. In situations of fixed-data use—such as residential applications where the user is stationery in the building—these CPEs are located inside the building, with an antenna external to the building.

Using this approach, a single AP can serve the wireless needs of a large population of mobile clients. However, for the purposes of backhaul, point-to-multipoint has few redeeming characteristics due to the use of a shared medium to backhaul multiple nodes. The network's channels often need to be reused due to the limited unlicensed spectrum. In practice, just three or four channels in the 2.4 GHz spectrum are available for network use, so if more than three APs are required, channel sharing must occur.

In these cases, the usual interference crosses experienced on the access network now impact the backhaul network. APs on the same channel are unable to transmit at the same time, and during transmission, the coverage of each node decreases, reducing the useable throughput of each node (the good-put) and increasing delays in data transmission. These difficulties can be alleviated by using Time Division Multiplex (TDM) or polling techniques to allow the nodes to more gracefully share the spectrum. However, the fundamental issue of sharing a single channel between nodes remains.

The shared medium also limits scalability of the network, as the client node-to-master-node ratio must be kept low to ensure performance and to achieve acceptable levels of service. To cover multiple nodes, the central base station must use a wide-beam width antenna, trading off for lower gain and subsequently lower reach. To increase the range, highly directional antennas are sometimes used. These require pointing, which increases installation complexity and cost.

Of greater concern, perhaps, is that a point-to-multipoint network is vulnerable to a single point of failure. Where a single node subtends many other nodes, its failure removes them all from the network.

Multipoint-to-Multipoint: Big Appetite

In a multipoint-to-multipoint system, each node in the wireless network can "talk" to many other nodes in a many-to-many configuration. Network contention is obviously a concern in these networks, which must provide very high capacity to accommodate the traffic.

A common rendition of such a system is the peer-to-peer ad hoc network, or mesh network often deployed informally by technically savvy home users. Such systems have been proposed for larger, infrastructure-scale applications where a network of multiple fixed nodes are deployed, each of which is able to communicate via its radio to multiple other nodes (*see Figure 4*).

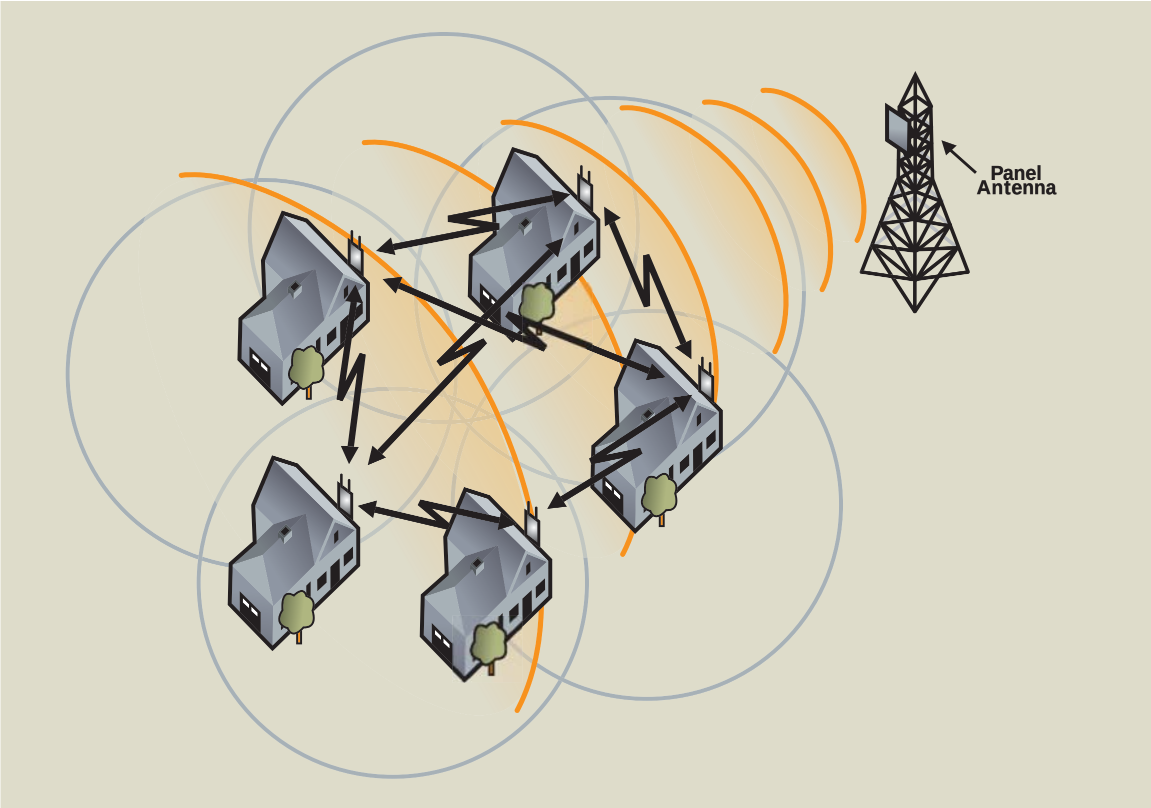

Figure 4: Typical Multipoint-to-Multipoint WLAN Design

Multipoint-to-multipoint wireless networks are attractive because the mesh provides redundancy and increased availability. However, the problems of the shared medium associated with point-to-multipoint systems are increased here. With even more nodes competing for access to a shared medium, good-put drops further. Polled, or TDM, systems may be used to mitigate these inherent challenges, but they are complicated, requiring synchronization and arbitration algorithms to resolve the contention in a multipoint-to-multipoint system.

In addition, multipoint-to-multipoint systems do not provide the performance that network operators require. Using CSMA/CD (Carrier Sense Multiple Access, Collision Detect) techniques, such as those captured in 802.11, enables multipoint-to-multipoint systems to work, but total capacity of the system drops as the medium fills and collisions become more frequent.

Just as with point-to-multipoint systems, to see many other nodes, antenna beam widths must be wide. The tradeoff is low antenna gains (i.e. less emitted energy) with correspondingly short reach, although in this case antenna pointing is less of a challenge.

While transmission power can be raised to partially offset low antenna gain, this has its own drawbacks: increased power consumption, increased interference between nodes and significantly increased cost.

Multiple-Point-to-Point: More Capacity, More Coverage

A new and unique approach to solving the WLAN networking challenge is the patent-pending, multiple point-to-point mesh architecture developed by BelAir Networks.

The unique multiple point-to-point architecutre integrates wireless access and backhaul in a single mesh, combining the best aspects of WLAN and cellular technologies while avoiding most of the drawbacks described above. It simplifies WLAN infrastructures and eliminates the crippling T1 and DSL backhaul costs, which have so far stifled the deployment of economical public Wi-Fi systems.

In a BelAir Networks mesh, unique outdoor multi-service platforms 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 in a point-to-point format with directional antennas. Each platform can connect to multiple others and the combined connections form a wireless mesh (*see Figure 5*). At the same time, the BelAir Networks solution makes use of robust point-to-point links.

This design gives network operators significant advantages:

- **Eliminates backhaul costs:** the system uses independent connections between nodes in point-to-point design. This is highly efficient and ensures that network capacity is determined by the two points and the efficiency of the access medium. Capacity is unaffected by other nodes or number of users on the system; thus, an operator knows what the network's performance will be and can rely on the system to achieve the

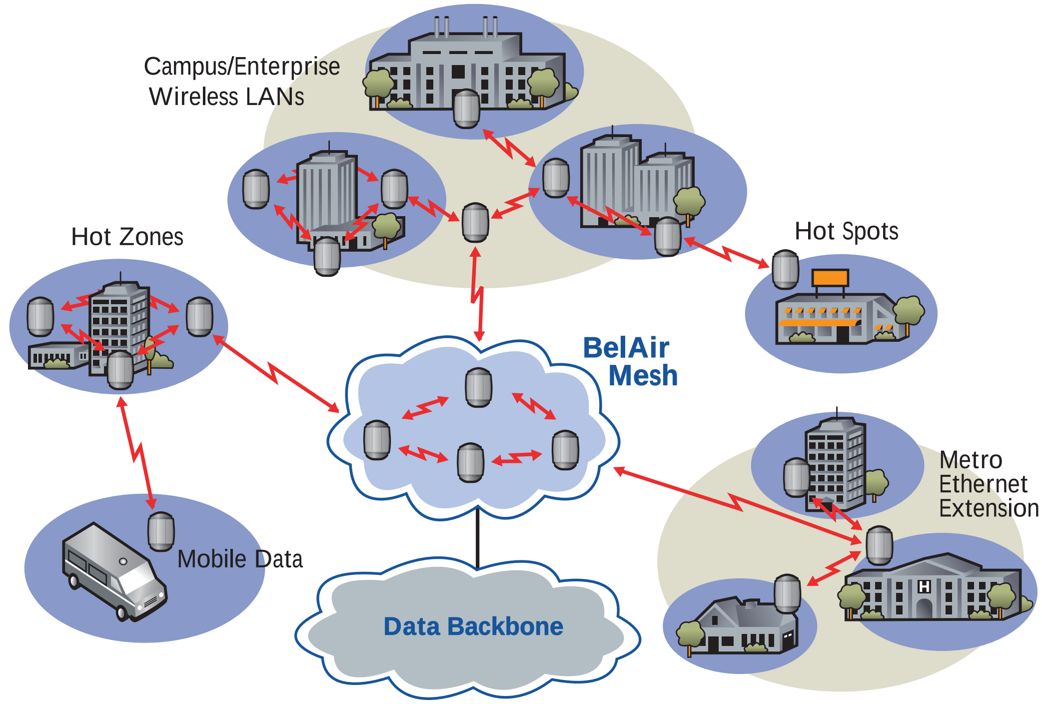

Figure 5: Multiple Point-to-Point Mesh Architecture

required backhaul performance. Throughput and latency can be accurately planned for, without costly T1 or DSL lines.

- **Reduces expense:** the solution eliminates the need for up to 70% of the capital expense associated with conventional solutions, and up to 90% of the operating expenditures traditionally involved in installation and maintenance. These gains are due to the integration of backhaul and access, as well as overall simplification of a true wireless network in which wires between APs are eliminated.
- **Simplifies infrastructure and deployment:** no extra switches, routers or cables are required to connect multiple nodes. The fully meshed backbone provides redundancy to ensure service availability without operator intervention and makes interconnecting nodes much simpler and more cost effective than conventional point-to-point mesh architectures.
- **Frees up greater capacity:** overall capacity of a mesh of nodes between five and 10 times higher compared to alternative architectures because the medium is not shared. More access points can be supported by the spectrum allocated for the backhaul.
- **Enhances reach:** directional antennas can be used to enhance reach while eliminating interference problems encountered with omni-directional antennas.
- **Achieves high availability:** load balancing and alternate paths enhance system availability and provide a self-healing network.

The key to successfully deploying a multiple point-to-point mesh architecture lies in the radio design. The radios must be integrated together in a small space, and in such a way that they will not suffer from self-interference problems.

The BelAir Networks mesh architecture overcomes the radio design challenge. Each BelAir Networks node has three independent point-to-point links with a sophisticated routing engine at the heart of the node. Advanced radio and antenna techniques enable three radios to operate in close proximity without degradation of performance. And, an integrated access radio allows for full Wi-Fi point-to-multipoint access at every node (*see Figure 6*).

To obtain the same benefits while avoiding installation challenges, the BelAir Networks architecture integrates antenna beam selection on the backhaul. Each of the three backhaul radios can automatically connect to any one of eight backhaul antennas. This is done via BelAir Networks patent-pending auto-antenna selection algorithms. Each antenna has a 15dBi gain and a 45º horizontal beam width, which, together with enhanced radio performance, significantly extends antenna reach.

As mentioned before, point-to-point radios with directional antennas provide clear metrics for link availability with enhanced reach. The access radio operates in point-to-multipoint mode, leveraging the huge population of standardized Wi-Fi clients for WLAN terminals. BelAir Networks radio enhancements include improved sensitivity and transmission power together with full antenna diversity for the best possible access performance.

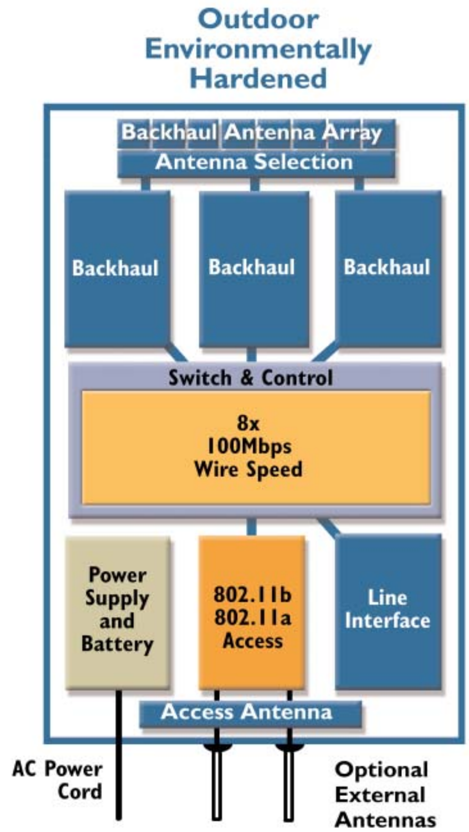

Figure 6: BelAir Networks Multi-Service Platform Modular Design

Innovative Availability Techniques

System availability is kept high in the BelAir Networks solution by a combination of techniques. The first of these is dynamic power and data rate techniques. The radio environment is constantly changing, so the radios must be smart enough to shield the mesh algorithms from the signal variations. Dynamic power and data rate changes on individual radio links absorb effects in the radio path – such as fast fading (created by radio propagation effects) and shadowing (the result of physical obstructions).

Second is radio-aware routing algorithms. These choose the best route for traffic through the mesh based on a number of radio-relevant metrics, such as available capacity, latency and radio link performance. Where standard routing approaches chase changes in the radio environment, the BelAir Networks mesh adapts itself to maintain stable traffic flow.

Third is load balancing. To increase system up time and minimize traffic outages, traffic from each node is balanced across a minimum of two routes to reduce the impact of link congestion and failure. Alternate paths are continuously calculated and refreshed so that seamless re-routing of traffic can occur with minimal packet loss in the unlikely event of link failure. The mesh topology is continually updated, enabling it to self-heal if a node stops functioning, and to allow for new nodes to be incorporated easily.

Finally, the BelAir Networks mesh architecture is designed for high scalability. A mesh can be deployed with a single egress point (point of presence) upon first installation, and as usage increases, additional egress points can be added for greater capacity and redundancy. Full multi-homing support provides for dynamic traffic re-routing in the event of a egress point failure, and also balances the load between points of presence for enhanced availability. This enables operators to scale the network as appropriate for the service level.

Unwiring the Wireless LAN

As freedom of access becomes the driving force in telecommunications, wireless networking is a major focus of enterprises, carriers and service providers. The push to deploy public and private Wireless Local Area Networks (WLANs) has revealed the strengths and limitations of various approaches to wireless LAN networking.

One of the biggest challenges associated with public and private WLANs is the networking of access points. The conventional approach of wiring between units is expensive, time consuming, and not easy in many buildings and outdoor environments. In addition, conventional approaches make costly wireless backhaul between access points necessary.

Of all available solutions, only the new multiple-point-to-point mesh architecture offered by BelAir Networks addresses the major issues impeding infrastructure-scale deployments of wireless LANs.

With BelAir Networks, profitable public and cost-effective private wireless infrastructures can be deployed. That means service providers can make wireless LAN networking profitable, while enterprises can cost-effectively deploy it across campuses for truly untethered productivity.

About the Author

Dave Park has 15 years experience designing wireless systems. Prior to joining BelAir Networks, he held progressively senior engineering and management positions with Marconi Communications, STC technology, Bell Northern Research, and Nortel Networks. He has worked on most of the commercially successful wireless standards of the last decade and has designed and engineered cellular base stations, pico-cellular systems, in-building wireless systems and fixed wireless access terminals. He holds a Master of Electrical Engineering from the University of Surrey in Guildford, England, and has three patents with four pending in wireless and optical systems.

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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