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In-Room Technology Workgroup

A Hotelier's Guide to Converged Wireless Systems using DAS Technologies

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1 Introduction

1.1 Document Purpose & Contents

This paper is intended to educate hoteliers and hospitality technology management organizations recommending and supporting hotel properties on the fundamentals of Distributed Antenna Systems (DASs) This guide includes an overview of the alternative systems available and their strengths and weaknesses, as well as design, installation, and ongoing support considerations. This paper is intended to provide the hospitality IT or telecom manager with a complete overview from business case to post-installation support to business model options. It describes the basic architecture and explains the process that hundreds of businesses have undertaken. The information is presented in an uncomplicated manner so that it may be quickly grasped for a high-level understanding, while still providing enough depth to support a complete understanding of the technologies, issues, and concerns.

This paper outlines how a property implementing a Distributed Antenna System: the potential issues, concerns, considerations, benefits, and costs.

1.2 DAS Usage & Compatibility

In-building wireless Distributed Antenna Systems (DASs) are designed and implemented to improve coverage for wireless devices, including public-safety radios, cell phones, pagers, personal digital assistants, wireless LAN (WLAN), telemetry, and building automation within buildings and related structures such as basements, parking garages, and maintenance facilities. DASs utilize antenna technology strategically placed throughout a building to facilitate the propagation of radio frequency (RF) signals, generally in the 400 MHz to 5 GHz frequency range. DASs can support a wide variety of technologies, such as TDMA, CDMA, WCDMA, GSM, UMTS, and services such as PCS/ cellular, paging, iDEN, E911, RFID, VoIP, POS, building automation, and 802.11 a/b/g Wireless LAN. Technically, DASs are not, in and of themselves, a complete solution, as they do not include RF sources or carrier electronics.

1.3 DAS & Carrier Participation

An in-building system is very different from a carrier's cell site. Carriers or authorized representatives may actually approach a hotel when the rooftop is the perfect height and location for installing a rooftop cell site. This is what carriers refer to as a macro site, which is designed to serve the general public and provide desired outside and in-car coverage. A hotel is generally offered a monthly site lease agreement, and the carrier offers to pay a monthly rental fee. A rooftop cell site does not, in any way, guarantee in-building penetration. Additionally, hotels should not deploy in-building DASs in anticipation of receiving revenue from carriers (i.e., cell site lease revenue). In-building DASs serving the hotel and its guests are a very different business model for the carriers. It is highly unlikely they will be willing to pay for the DAS without a guaranteed revenue stream back to them.

1.4 Business Case

Traditionally, the primary reason hotels install Distributed Antenna Systems (DAS) is to improve in-building wireless coverage. There are primarily two user communities who stand to benefit from the deployment of a DAS and related equipment: guests and hotel staff.

1.4.1 Guests / Public

The driver behind most DAS deployments is guest/ revenue loss prevention, as well as guest convenience and satisfaction. Today, business travelers -- especially conference goers -- have come to depend on their cell phones as their primary means of communication while staying in a hotel.

Ideally, the DAS solution also wirelessly enables guests and could provide wireless Internet access throughout the hotel property. This converged solution derives the most financial benefit in a new property, as most properties have already accounted for the cost for their High Speed Internet Access (HSIA) systems.

1.4.2 Hotel Staff

Though most DASs are installed to accommodate guests, deploying a DAS provides many benefits for hotel staff, as well, especially once the infrastructure is in place. Such advantages include:

1.4.2.1 Two-way Radio

For some carriers -- notably Sprint/ Nextel's iDEN -- the traditional two-way radio infrastructure may be replaced with a multi-functional-based solution that incorporates radio communication. The key hotel departments that rely on two-way radio communications are those with responsibilities for safety and security, including maintenance and security personnel and most department heads.

1.4.2.2 Technology Consolidation

Several carriers offer hotels the opportunity to consolidate technology onto a single handheld device for two-way radio, paging, cellular, and data services. This allows the hotel to activate the combination of services that is optimal for each individual hotel staff member.

1.4.2.3 Data Applications

This is one area where hotels can expect to see explosive growth in terms of available applications, which leverage in-building cellular technology and DAS deployments. Some of the most common online data services are work-order management (for maintenance and housekeeping), bar-code scanning, and food and beverage.

1.4.2.4 802.11 Wireless LAN

A widely recognized wireless protocol, 802.11, may be able to share some providers' in-building DAS infrastructure to deliver WiFi and VoIP, as well as specific wireless applications. 802.11 supporting data and voice communications may be deployed in key areas or throughout the hotel. When deploying 802.11, hoteliers should consult with a qualified resource to determine hotel and guest needs, as well as applications to be supported, since these drive required coverage areas, number and location of antennas, and capacity.

1.5 Sample Business Case I

Following is a sample business case that illustrates a real-life scenario in which a hotel justified the implementation of a DAS by retaining convention business that would otherwise have been lost.

Setting	
Customer	Premier Hospitality
Facility	Multi-building campus
Size	Approximately 2 million square feet; 1,300 guest rooms
Installation Type	Retro-fit; fully operational during install
Desired Services	Multi-carrier, Wireless LAN, Wireless Point Of Sale
Reason for Request	Resolution of number-one customer complaint

Acela Technologies was contacted by a hotel with a customer that was so disappointed with the cellular coverage on the property that he threatened to take his business' annual conference to a competitor if the property did not provide a specific mobile-phone service for its executives to stay in touch with key clients. The loss of this customer would have resulted in the hotel's losing over five-million dollars in revenue over the span of one week each year for an unspecified number of years. The customer turned to Acela with a short deadline to get the system installed and working for its client's scheduled conference date.

Acela installed and tested the MobileAccess DAS in time for the client's annual conference. The client was so pleased with the performance of the new wireless services that the president and CEO of the Fortune 500 Company personally praised the hotel's wireless services. The coverage in the guest rooms, conference areas, and even poolside areas provided wireless mobility to the thousands attending the conference. Subsequently, the hotel upgraded the facilities for all four major carriers and WLAN so that all other conference attendees and guests would have a pleasant and productive wireless/ mobility experience.

The DAS solution, which cost less than half of the revenue for this particular client's one-week conference[1], provides a high-quality wireless mobility experience for all of the hotel's clients for years to come. Since the WLAN can be controlled by the hotel, it provided an additional revenue source for services. As a result, this property minimized cost and gained the potential for new customers by implementing the converged Wireless DAS, providing reliable high-speed Internet access throughout the property. For this hotel, the return on investment (ROI) was less than one week.

[1] Actual cost of DAS installation was approximately $1.30/ square foot.

1.6 Benefits of DAS

Benefits	Without the DAS	With the DAS	Approx. Gain
$5 Million Annual Customer	Lost Revenue	Retained Revenue	3 year gain of $15 Million
Verizon Wireless Services	Spotty Coverage	Excellent Coverage	Minimum $2 M Annually
Cingular Wireless Services	Spotty Coverage	Excellent Coverage	Minimum $2M Annually
Sprint Nextel Staff Services	Fair Coverage	Excellent Coverage	Minimum $2M Annually
T-Mobile Wireless Services	Poor Coverage	Excellent Coverage	Minimum $2M Annually
Wireless LAN Guest Rooms	Non Existent	Very Good Coverage	New Customers
Wireless Point of Sales	Restaurant Only	In/Outdoor Public Spaces	Approx. $200k Annually
Wireless AP Service/Maint	Ceiling Mounted	Centralized in Closets	Approx. $100K Annually
Voice over WiFi Capable	Non Existent	Infrastructure in Place	Approx. $300K
WiMAX Capable	Non Existent	Infrastructure in Place	Approx. $250K
Public Safety Capable	Non Existent	Infrastructure in Place	Approx. $250K
Wireless Guest Access	Non Existent	Infrastructure in Place	Approx. $700K

2 Architecture Overview

Wireless Service Providers (WSPs) -- like Verizon, Sprint/ Nextel, and AT&T -- support thousands of mobile customers by constructing cellular base transmit stations (often called cell sites). These are most often recognized by the antennas mounted to a tower or building. Each cell site serves a predefined area based on the traffic (number of customers) and the range of RF signal. When the range or capacity is exceeded, another cell site must be strategically installed.

However, mounting public dislike of the antennas and towers, along with the high cost of these facilities, are making it increasingly difficult for the WSPs to solve coverage problems inside buildings with the traditional cell sites. Additionally, on some level, each cell site interferes with the next one. This interference reduces the efficiency (traffic and range) of all surrounding cell sites, in effect, diminishing returns. In-building DAS solutions allow the WSPs to improve coverage inside buildings without the high costs and interference of additional cell sites deployed outside.

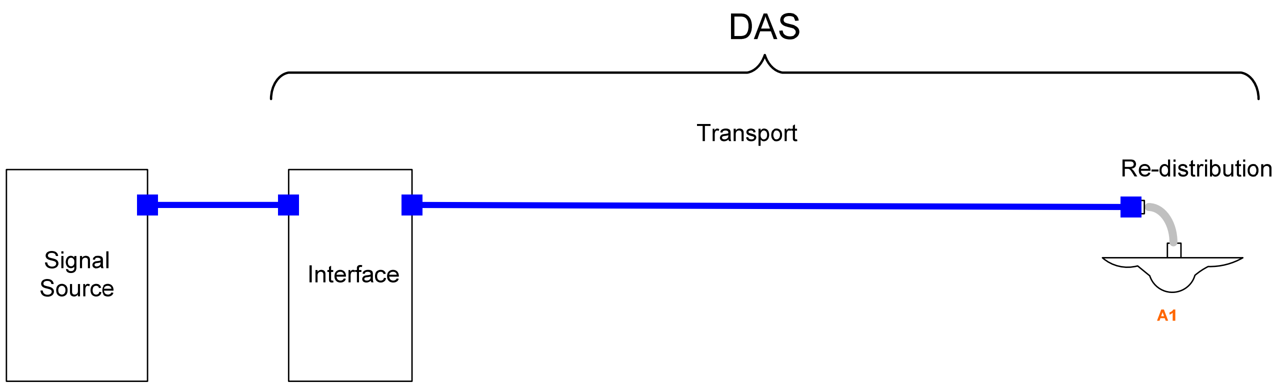
A multi-carrier or neutral-host solution can be a big incentive for convention business, particularly for repeat business. In fact, ubiquitous cell coverage for all carriers is becoming an expected amenity, much as high-speed Internet access has become. Part of the reason for this is that most guests do not understand that cellular coverage is engineered for street-level and car RF penetration and not in-building coverage. While a property may experience some coverage, it most likely will vary by carrier. Additionally, coverage varies throughout the property.

There are many factors that contribute to coverage penetration throughout the property. While proximity to a carrier's tower is a major factor, a property's size and physical structure (e.g. steel, reflective glass, etc.) also impact RF signal penetration, as does the technology used by the carrier. Generally, signals rarely penetrate below ground levels, above seven stories, or deep within the center of a large building. Even if one carrier has some coverage, not all wireless networks are designed to perform at the same level.

Section 2.2.4 -- Comparison of Technology Alternatives -- contains more detailed information.

2.1 Basic DAS Structure and Elements

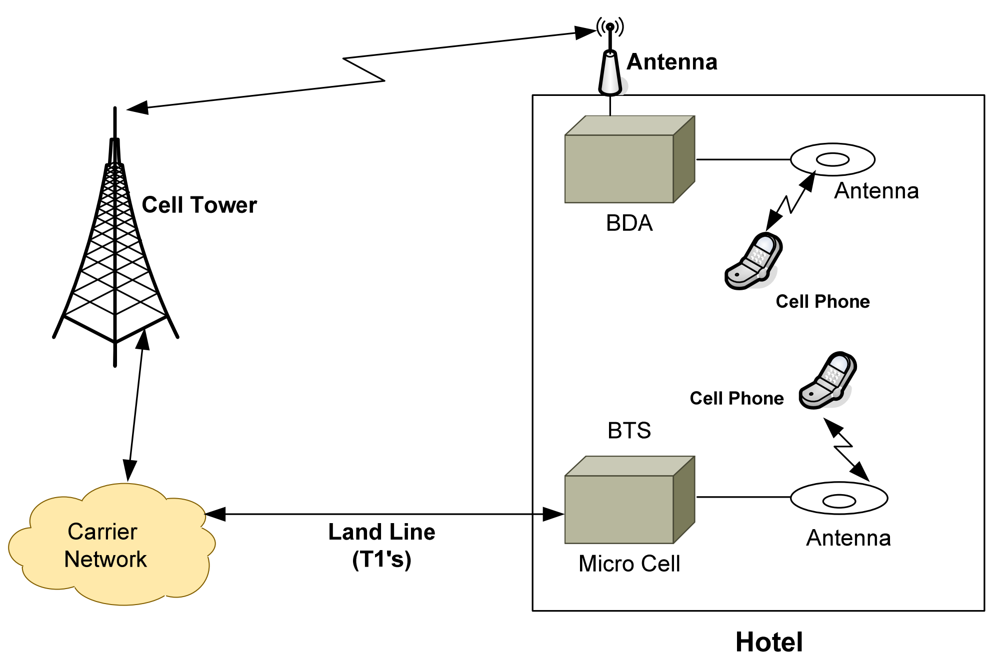
For cellular services, the basic elements of a DAS are a radio frequency (RF) interface, signal transport network, and re-distribution point as shown in the diagram below. (Wireless LAN will be covered later in this document). A signal source that is provided by each wireless service provider (WSP) is needed to provide signal to the DAS. This is a key and influential part of the solution.



2.1.1 Comparison of Wireless Service Provider (WSP) Connectivity

Section 2.2.4 -- Comparison of Technology Alternatives -- summarizes the pros and cons of each of the DAS methodologies: active, passive, and hybrid.

The following diagram illustrates the two most common methods of WSP connectivity: the bi-directional amplifier (BDA) and mini-base station (micro-cell).



The signal source provides the link to the WSP's system or network. Typically supplied and maintained by the WSP, equipment can be classified in two categories: bi-directional amplifiers (BDAs) and mini base stations (or micro-cells).

Bi-directional amplifiers, as the name suggests, repeat signal from an outdoor cell site, thereby sharing the capacity of the outside cell site. BDAs typically communicate with the outdoor cell site via a directional antenna mounted on the roof of the building. RF signals from the donor cell site are received by the antenna and passed to the BDA via a coaxial cable. The signals are amplified by the BDA and then passed to the distribution system. Likewise, the return signals are passed by the distribution system back to the BDA, where they are amplified for transport back to the cell site outside the building.

Micro-cells come in various sizes and capacities but are typically larger and more expensive. They require a T1 backhaul to the WSP's call-switching center and more HVAC resources than BDAs. These, in essence, act as miniature cell sites, providing dedicated capacity to the facility.

BDAs are lower in cost and typically much smaller than micro-cells. However, they share capacity with the donor cell site, so if the donor cell site is loaded with traffic outside the building, the ability to get a signal may be limited. In contrast, the BDA transports all the advanced services available at the outdoor cell site, which a micro-cell may not be able to offer. BDAs with an off-air interface are also more susceptible to interference and to causing interference. These are issues that the local WSP engineer should consider when deciding upon the type of signal source to use for any given installation.

Note: An off-air interface is almost always used to communicate with the public safety network. These are relatively un-complex for public safety in the 800 MHz band, but may be quite complex and expensive for public safety in the 150 or 450 MHz band. The risk of BDA interference is greater in the 800 MHz band.

2.1.2 Distributed Antenna System (DAS) Components

The distribution antenna system consists of an interface to the signal source, the transport medium, and re-distribution element(s) or antennas. The DAS interface places the RF signals from the source(s) into a format suitable for transport over the specific type of medium used in the DAS. The re-distribution element(s) are connected to the transport. Re-distribution can be accomplished with a small in-building antenna (about the size of a smoke alarm) or a type of coaxial cable called a radiating coax.

½" Plenum Rated Coaxial Cable

Omni-directional Ceiling Mount Antenna

Typically, RF is transported in one of the following ways:

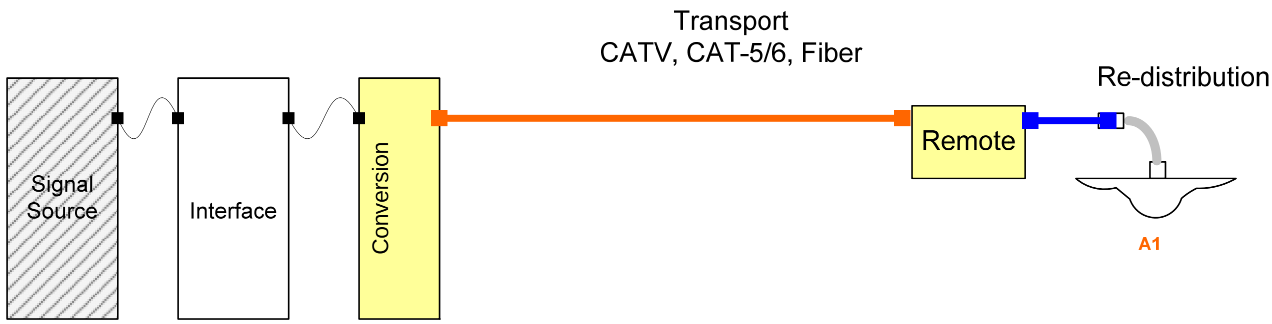
- Coaxial cable
- Native RF
- Manipulated RF

Each method has both advantages and disadvantages

Coaxial cable, usually a half-inch in diameter, is expensive to install relative to other transport mediums like CATV or CAT5, but because of the larger diameter, it presents less RF signal loss . As such, it may be used for distances up to 250 feet without any conversion (electrical) or re-amplification of the RF signals. A major advantage of half-inch coax is the broad bandwidth. It can support high throughput and a wide variety of RF signals and, thus, multiple services.

Native RF typically uses single-mode optical fiber for transport (thus, electrical to optical conversion is required). Single-mode fiber is similar in cost to coaxial cable and requires active components to convert the RF signals. As such, this method is the most expensive type of transport. However, it provides the greatest flexibility with bandwidth of coax at distances greater then 6,000 feet.

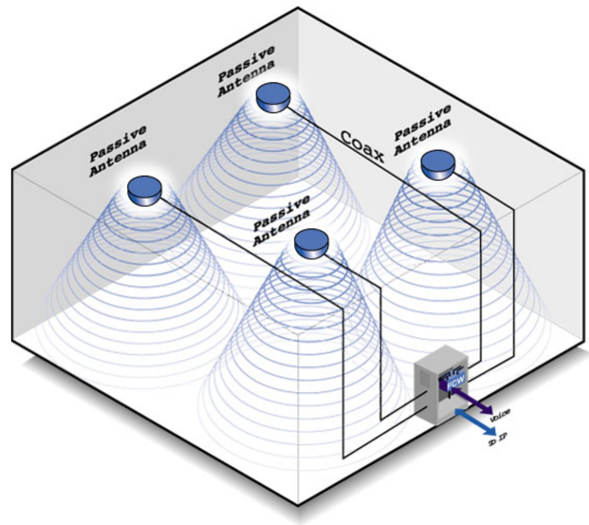
CAT5, CATV and Multimode fiber are cheaper to install than ½" coax but present high loss to the RF signal and require "**Manipulated RF**." The RF signals are manipulated (usually down converted) in active devices in the DAS that allow the use of these mediums. These active devices increase the cost of the DAS but also allow for use of the lower coat mediums over longer distances, up to 1,000 feet. The trade-off is very limited bandwidth in this method, so multiple services may require multiple or parallel systems. [2]



From the remote location, antennas, or radiating coax are connected to redistribute the RF signals. These devices are passive and very low cost. Radiating coax, often called leaky coax, is cabling with slots cut into the outer shield that allows RF signals to leak out along the length of the cable. The best analogy is a garden hose with holes cut along the length. As water flows, it leaks out. Radiating coax has a wide frequency range and provides very consistent coverage. It is widely used in transportation tunnels. However, deployment in buildings and/ or with WLAN tends to be higher in cost and requires careful engineering.

[2] This active transport requires a method of conversion from electrical to optical, for example. The conversion process is designed to have minimal impact on the integrity of the RF signal and requires a conversion back to RF at or close to the re-distribution element(s) in what is called a remote unit or remote hub**.**

Antennas cover an area of about 20,000 to 30,000 square feet, depending upon the power of the DAS, obstructions in the coverage area, and the pattern of the antenna. Both directional and omni-directional antennas may be used, with omni-directional being most common. As shown in the diagram on the right, **directional antennas** focus the signal strength in one direction and work well for narrow hallways or large rooms, where a ceiling-mount omni-directional may not work well. **Omni-directional antennas** provide consistent signal levels in all directions and are generally mounted in the ceiling.



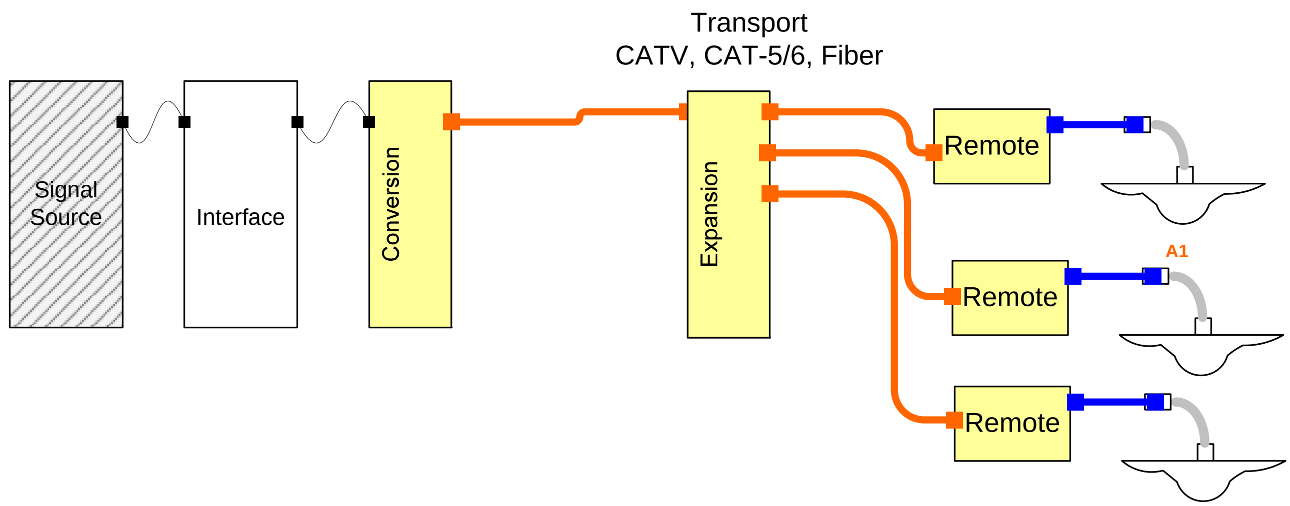
2.2 DAS Technology Alternatives

The terms, active, passive, and hybrid have become an industry standard method of categorizing DAS solutions. These terms refer to the primary method of signal distribution in the system. Passive, as the name suggests, is non-powered distribution, usually using half-inch diameter (or greater) coaxial cable. Signals simply pass over the coaxial cables to the re-distribution component. Active systems tend to have a very high level of active or power components, where, as described earlier, the radio signals are converted for transport and un-converted close to the re-distribution component. All of the DAS solutions available utilize a mixture of active and passive methodologies. For this reason, these terms are intended to refer to a particular solution's primary methodology. A hybrid system comes closest to a 50-50 mixture of active and passive methodologies.

DAS designs offered by different vendors vary in capabilities, flexibility, and complexity. Generally, capabilities and cost are traded off by the different technologies. Some are optimized for specific wireless service providers and do not support convergence of other services, but all vendors have methods of supporting the primary wireless service providers and wireless LAN as discussed below. In some instances, the wireless LAN DAS is actually an overlay facility.

2.2.1 Active Systems

Active systems utilize a higher level of active components in the system and tend to be specific to a WSP or limited grouping of WSPs. Typically, the RF signals are converted for transport through the building on a medium such as Fiber, CATV, or CAT5/6. In an active DAS, there is very little half-inch coaxial cable in the system. To increase the number of remote amplifiers for larger buildings, the active DAS may use an expansion hub in the transport as illustrated in the following diagram.

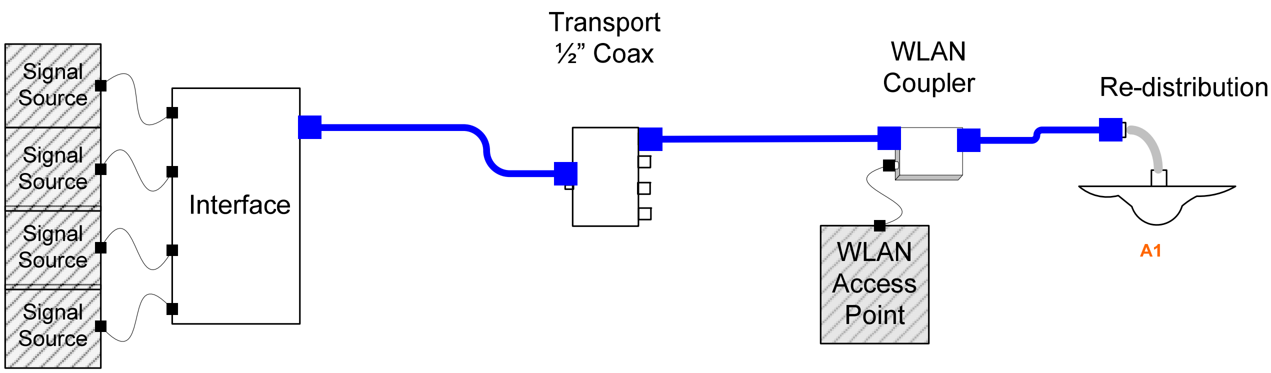


Active systems may have several expansion hubs feeding multiple remote hubs, but, typically, each remote hub feeds only one antenna. These systems are generally used to improve cellular coverage for only one WSP at a time and, thus, can be less expensive for single WSP installations. In some instances, active systems require "parallel" networks, as shown in the following diagram. For example, Verizon uses a spectrum in the 800 MHz band, often referred to as the cellular band. Nextel, now Sprint, also uses a spectrum in the 800 MHz band but it is referred to as the SMR (Specialized Mobile Radio) band. Combining these wireless service providers into a common antenna is difficult for a highly active DAS. In this case, there would need to be two complete systems, each with its own interface, conversion, transport, remotes, or expansion hubs and associated antennas.

WLAN deployment with an active system usually takes a traditional approach. As discussed in subsequent sections, the overlay of WLAN in passive and hybrid systems takes advantage of the existing antenna via the half-inch coax. The active system uses very little coax, so there is little or no benefit to overlay the WLAN on the DAS. The following is a diagram of an active DAS with WLAN provided by LGC.

2.2.2 Passive Systems

Passive systems consist primarily of half-inch coaxial cable. Passive devices, such as splitters or couplers, are used to distribute the RF signal to different areas of the building or coverage area. Passive systems are the least expensive type of system in smaller facilities. However, for larger facilities, they require a full engineering design, due to installation complexities.



Since the coaxial cable has broad bandwidth, there are no active components that can limit which RF signals are amplified. The interface equipment may combine RF signals from several services, all of which are re-distributed over a common antenna or radiating coax – this is the fundamental benefit of a passive system. The catch is that the power of the RF signal input to a passive DAS needs to be stronger than in an active or hybrid DAS. This may increase the cost of the signal source the WSP has to provide, which, in turn, may inhibit participation by the WSPs and prevent them from coming on the system. The higher power levels typically required to plug into this type of system exponentially increase the likelihood of interference and intermodulation.

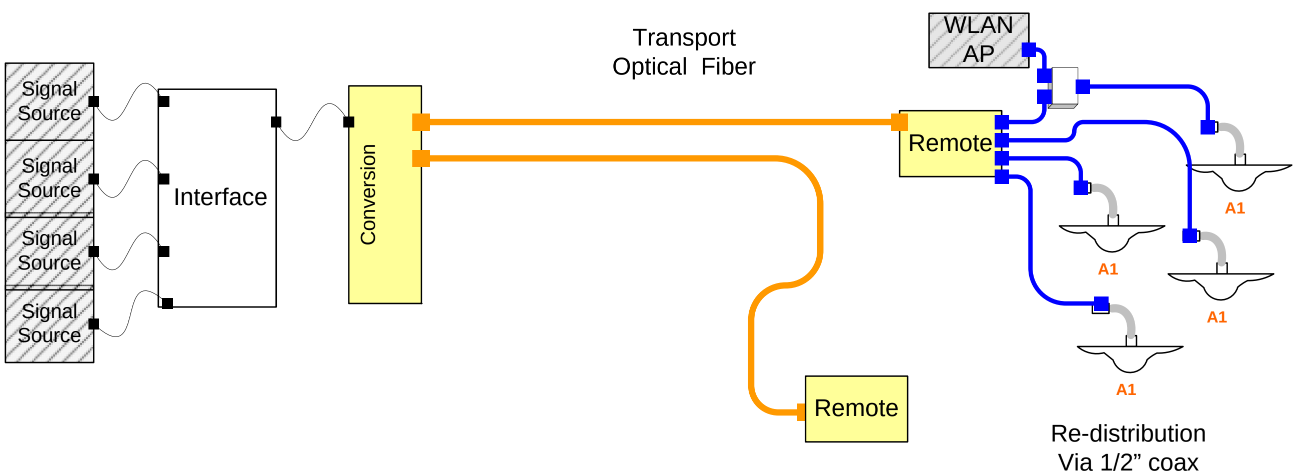
Integration of wireless LAN over a passive system is achieved by passively coupling the output of a Wireless LAN access point onto the distribution coax. The WLAN services then share the antenna or radiating coax with the cellular services. This is done after the last splitter and within 150 feet of the antenna, as the losses in the splitter and coax diminish the WLAN performance. This approach allows the WLAN access points to be located in a more convenient location.

There are also methods by which multiple WLAN access points can be combined for service over a single antenna or a run of radiating coax. However, this requires that the WLAN deployment be engineered and fully provisioned to support advanced WLAN features. As always, any WLAN deployment other than the traditional approach described in section 2.2.1 Active Systems, should be discussed with the WLAN access point provider.

2.2.3 Hybrid Systems

Hybrid systems combine active and passive elements, typically using very low loss optics in the "transport" part of the network and taking advantage of the broadband nature of coax for the "distribution" part of the network. Like an active system, the hybrid system uses a remote hub before connecting to multiple antennas for re-distribution. However, at this point, the active and hybrid system differ. The goal of the hybrid system is to leverage the best features of the passive and active systems into one solution.

The hybrid system does not use an expansion hub like the active system described earlier; rather the hybrid system uses a higher output power remote unit. From the remote hub, coax is deployed to support multiple antennas. From each antenna, all wireless services can radiate simultaneously if the solution chosen has the required interference mitigation and is approved by all service providers. The remote hubs are typically installed in telecom closets or IDFs for easy access.

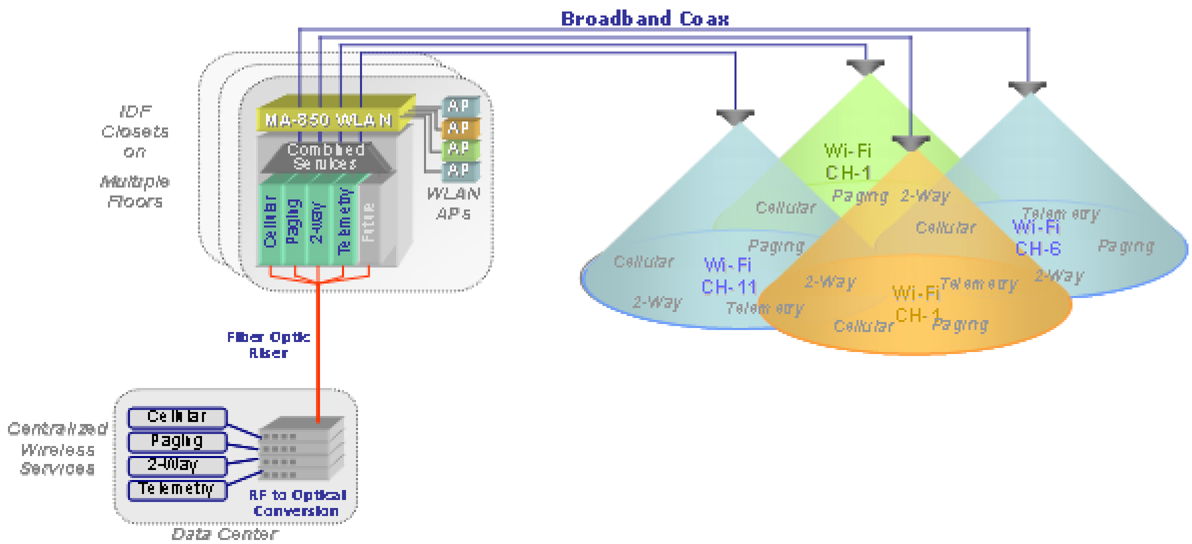


Like the active system, the hybrid system utilizes low–loss, fiber-optic transport and supports low-input power from the WSPs. This is a highly desirable feature, since it lowers the financial barrier for the WSPs. The passive part of the system supports the combining of various services at the remote hub location so that multiple services can be provided over a shared antenna. Some services still require a separate interface and conversion like the active system, but only one set of antennas will have to be installed.

Hybrid systems can integrate WLAN access points at the junction point between the low-loss fiber transport and the broadband distribution part of the network. In this architecture, the access points can be located in secure, easily accessible telecom closets for easy access while maintaining advanced WLAN features (RTLS[3], Rogue detection, power control, etc.) and ensuring the support of many WLAN access point manufacturers, including Cisco, Colubris, and Aruba.

[3] Real Time Location Services

The following diagram[4] displays how a hybrid system supports multiple services, including WLAN.



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4 Courtesy of MobileAccess Networks

2.2.4 Comparison of Technology Alternatives

The following table outlines the pros and cons of in-building wireless solutions:

	Active	**Passive**	**Hybrid**
Pros	Pro-active monitoring	Typically does not rely on power past the input point	Pro-active monitoring and interference mitigation
	Adjustable signal and power	Limited failure points	Integrated WiFi support in some systems
	Widely accepted by wireless service providers	Provides all services; no future expansion needed	More flexible; modular systems easily expanded for future service needs
	Low cost for single wireless services	Able to add any 802.11-compliant device	Widely accepted by wireless service providers
Cons	Parallel networks required for new service additions	High-loss system; restricted to shorter cable lengths	Multiple equipment locations requiring space, power, and cooling
	Multiple equipment locations requiring space, power, and cooling; multiple failure points	Difficult to design and to make changes after initial deployment	Amplification of 802.11b/g but not 802.11a (future); careful design required for balanced performance
	Active components (antennas) must be installed in ceiling spaces	Requires very high-power service inputs from wireless service providers	Active components could require network monitoring
	No wireless LAN support	Difficult to troubleshoot problems; no surveillance, error detection, or alarms	

3 Design Considerations

3.1 Summary of Desired Services and Coverage: Planning Ahead

One of the first steps in planning a DAS solution is to take an inventory of what is required. Most of the technology alternatives have been discussed so far, but it is always good to have the current vendors provide a presentation of the current range and capabilities of their products.

If the primary purpose is to support guest cell-phone usage, then a shopping list of WSPs desired to be a part of the DAS should be prepared. A DAS to support one WSP costs less. However, for small increments in cost, additional WSPs can be included. Additionally, services like WLAN may be added to the DAS, which will increase the cost, but the incremental increase may be less than the cost of traditional WLAN deployment.

Ideally, this list of desired services should be made available to vendors before presenting product solutions, allowing vendors or contractors to focus their presentations on a solution that meets the needs of the facility. Desired services may include:

- Building automation
- Maintenance or security radio service
- Paging
- 802.11
- Multiple cellular carriers, including Sprint, Verizon, AT&T, etc.

As with the list of desired services, it is important to consider the areas that need coverage. If a full set of floor plans is available with details on which areas do or do not require coverage, it will greatly improve the process of estimating the cost and complexity of a solution. Additionally, it is important to consider which services are needed in specific areas. Most vendors/ contractors can save costs by implementing only the needed services in specific areas. While many DAS vendors guarantee coverage for cellular service, this is not the case for WiFi. In fact, a hotel may not have full coverage for WiFi.

It is important to ensure that equipment monitoring may be performed locally by the hotel or remotely by a provider, so that when system failures are detected, service and maintenance personnel may be automatically dispatched.

3.2 Site Survey and RF Analysis

With the information identified above, a vendor can provide a much more accurate survey and RF analysis. This process could be done by a third party prior to requesting proposals, or the site survey can be conducted as a group with several vendor/ contractors attending.

The person(s) doing the survey will be looking at building dynamics, as well as existing coverage and/ or perhaps how well signals will propagate in the building(s).

From the RF analysis viewpoint, the level of coverage already existing for the desired services is an important consideration. It is not uncommon to find that a service is already sufficient in some areas and does not need additional coverage. Some services may need coverage in an area where other services are adequate. Additionally, some WSPs may want to capture the entire facility with the DAS to reduce traffic on the outside system.

A vendor may also conduct an analysis of how well a test signal distributes (propagates) in some areas. This is usually done with a low-power test transmitter and signal-strength meter. There is no potential danger involved with this process, as the levels are typically less than normal outdoor signal levels.

The output of a site survey should yield detailed notes on the floor plan regarding levels and areas of needed coverage.

Naturally, as the size of the property increases, the cost of the DAS increases, but layout may also increase costs over a smaller property. Typically, it is much easier and costs less to cover small floors that stack than the same amount of square footage on a single level, especially if the telecom closet or IDF is centrally located on the floors.

Long, narrow areas, like hallways and walkways, are difficult to cover, as well as areas where the ceiling is high and open. Small buildings not physically connected to the main building and/ or parking garages may require an incrementally higher cost to support. Obstacles like these add to the complexity of the project.

3.3 Cabling and Antenna Considerations

Given the fact that all DAS architectures solve in-building RF propagation challenges, it is easy to overlook the cable plant design, installation, commissioning, and documentation process necessary to support all wireless applications within a given facility. As indicated earlier in this document, the RF application requirements, coupled with the building size and scope, can easily influence the type of DAS technology architecture employed (e.g. passive, active, hybrid, etc). Likewise, the DAS technology architecture employed determines the type of cable plant necessary per manufacturer's equipment specifications. This can include any/ all of the following medium: fiber (single mode or multi-mode), coax (various forms), and twisted pair.

During the site-survey process, a complete audit of the facility is necessary to identify clearly both horizontal and vertical cable paths necessary to support the DAS technology. Typically, intermediate distribution frames (IDFs) or telecom closets are centrally located on each floor within a facility and become a wiring medium management point between horizontal cable runs to antenna points on the floors and vertical cable runs to the master distribution frame (MDF). The MDF is typically co-located in the basement level of a facility within a telecommunication/ server room and becomes the wiring demarcation between multiple IDFs located throughout the facility and the RF signal sources or data application servers.

Floor space and/ or wall space must be provisioned in the IDFs/ MDF to accommodate cable terminations and interconnects. In most cases, and to systematically support and manage the cabling infrastructure, various sizes of telecommunications equipment racks are employed in the IDFs/ MDF to support: the various active/ passive equipment; AC/ DC powering equipment; cable termination hubs; wireless service provider bi-directional amplifier or micro-cells; emergency power backups; telecommunications interfaces, etc.

For cable installation purposes, adequate horizontal and vertical cable pathways must be clearly identified and readily available to support the targeted DAS technology. Commonly, vertical cable conduit is employed between floors to support the interconnection and homing of multiple IDFs to a single MDF location. Depending on the cable medium utilized, ample space must be readily available via conduits to support the vertical cable plant. Further, if fiber is being employed in the conduit between the MDF and IDFs in support of the DAS technology, additional innerduct within the conduit to protect the fiber against future potential cabling installation damage must be considered.

Likewise, horizontal cable runs must be clearly identified in order to obtain precise antenna locations for optimal RF propagation. Horizontal cable pathways must be clearly identified and unobstructed in order to ensure cost-effective installation of the cable plant from the IDF to the antennas on the various floors.

In all cases, thorough link budget analysis must be performed to ensure adequate signal strength to all appropriate end points for both uplink and downlink within the respective DAS technology solution. Throughout the cable plant installation process, fiber/ coax/ copper cable sweeps can be performed on all cable to ensure appropriate performance to validate propagation characteristics. Various forms of handheld telemetry equipment are readily available to perform these sweeps and guarantee the integrity of the cable plant.

Cabling should be designed and installed by someone certified by the following organizations:

- Building Industry Consulting Services, Inc. (BICSI)[5]
- Registered Communications Distribution Designers (RCDD)

Whenever possible, it is recommended that certified design/ engineers (RCDD) and BICSI-trained installers be utilized to ensure that the current best price practices are employed for a cable plant and DAS technology installation. Contractors must ensure that all cabling is appropriately labeled and that a complete set of cable plant documentation ('as-builts') is made available to the client as a permanent record and for future reference. Any federal/ state/ local regulations must be recognized and incorporated into the design to ensure compliance.

Finally, the expense of site survey, design/ engineering, installation, and commissioning of a DAS can vary dramatically between an existing facility (retrofit) and a new building ("greenfield"). If planned well in advance and in conjunction with building construction, a greenfield installation is the most cost effective in which to install the cable plant. Typically, existing and experienced onsite construction trades can be engaged to physically install the cable plant at appropriate, scheduled times during the infrastructure build-out. Installation personnel should be certified to work with the medium type being installed. Close coordination and schedule flexibility with the building general contractor and building trades is vital and can offer a very cost effective cable plant installation.

[5] BICSI (Building Industry Consulting Service, Inc.) is a professional association supporting the information transport systems (ITS) industry with information, education, and knowledge assessment for individuals and companies. It is these individuals and companies that provide the fundamental infrastructure for telecommunications, audio /video, life safety, and building automation systems.

Building retrofits can offer some unique cable plant challenges from a design/ engineering and installation perspective, such as:

- Lack of adequate riser facilities between floors to support vertical cable plant
- Lack of adequate horizontal pathways from IDFs to antenna locations
- Drywall ceilings with little to no access panels
- Lack of adequate AC/ DC power and cooling in IDF/ MDF to support active equipment
- Fire-rated partitions
- Outdated, inaccurate, or non-existent blueprints depicting potential cable pathways and potential obstacles
- Elaborate trim and hallway/ room decorum requiring re-establishment after cable plant installation
- General lack of facility knowledge/ history with current staff and construction trades
- Coordinating rolling room/ floor blocks for system installation
- Union versus non-union labor
- Standard versus non-standard work hours

While a thorough site survey, peer review, construction trade review, and detailed project plan can help minimize the aforementioned challenges, contingency plans and change orders should be expected with cable plant installations in building retrofits.

3.4 Redundancy Requirements

Redundancy most often takes the form of a battery backup or backup generator for the system. All vendors can support redundancy, even to the point of two fully functional systems, but rarely do the benefits justify the cost. A backup generator, rather than a battery, should be utilized as the emergency backup system, since a generator can provide continuous backup for an extended period of time.

Additionally, reliability of the system should be considered. Passive components, splitters, coax, and antennas tend to have very high reliability. For active components reliability is quantified by industry standard as MTBF, or mean time between failures. The higher the MTBF, the less likely a component will fail over time. The industry standard for MTBF used by most manufacturers is the Bellcore Reliability Prediction Model B332 - Issue 6. While a high MTBF is no guarantee a system will not have service interruptions, tends to be a good indicator.

3.5 VoIP Considerations

Voice over IP using a WiFi signal has started to find its way into the hotel industry as an administrative/ staff application, primarily in use with the different operating departments within a hotel property. The guest services staff has discovered that the Voice over WiFi communications systems are useful in replacing, supplementing, or augmenting commonly used staff communications devices (pagers, analog two-way radios, cell phones, etc.). The advanced feature set of these WiFi voice communication devices allows for more effective communication, and, therefore, condenses operational workflow, which in turn can lead to a more responsive hotel employee and a better guest experience.

Voice over WiFi communication generally requires a denser coverage design and a more powerful reception level when compared to the RF requirements of other common WiFi applications in a hotel environment. As an example, a guest-facing WiFi broadband network can operate at a coverage level that provides reasonable QOS, but this same coverage density, in many instances, would not be sufficient if VoIP was introduced as an application to that same network. A properly engineered DAS solution has the capability to meet these more aggressive VoIP network coverage characteristics. In addition, DAS can typically achieve this using a reduced switch infrastructure, fewer access points (APs) and minimized power requirements when compared to a traditional RF site design for WiFi. DAS has the ability to saturate a building or group of buildings with even and complete coverage, which is important for IP-based voice communications that utilize WiFi.

The following chart incorporates best practices for the various services listed when WLAN is implemented over a DAS. It takes into consideration typical losses associated with the DAS and the effect on the WLAN AP coverage. However, these are typical and provided for reference only. Each facility requires a full evaluation to determine the best solution based on the desired services.

Service	RSSI Target	Typical Distance
802.11b/g Data	-75 dBm	60' open space 45' office space
802.11b/g Voice	-70 dBm[6], -65 dBm[7]	40' open space 30' office space
802.11a Data	-75 dBm	40' open space 25' office space
802.11a Voice	-67 dBm	25' open space 15' office space

[6] Cisco, Spectralink
[7] Vocera

4 Installation/ Facilities Considerations

4.1 Access for Installation

Hotels are unique with regard to DAS installation. They do not have down time like public venues, airports, or convention centers. Access may be a challenge, and installation may be restricted due to hotel occupancy or security issues. Night work may be the best option for common areas, but will often not work in the guest areas. Additionally, WSPs require access to install and commission the equipment and for ongoing maintenance as discussed in section 5: Post-Installation Considerations.

Most vendors take this into consideration, but restricted access should be specified in the request for quote, including times that certain areas will be open for installation.

While most DASs require only a few workers to deploy, consideration must be given to access for these workers and the typical access restrictions unique to hotels.

4.2 Space, Power, and HVAC

The DAS itself requires very little AC power and space and, therefore, generates very little heat. For example, the DAS equipment needed to cover a half-million square feet may fit in half of a standard telecom rack in the MDF (head end) and consume less than 200 watts of power. However, the RF sources provided by the WSPs require additional space, power, and HVAC. The amount of resources required for the WSP depends on the signal source they select for the installation.

Remote hubs used in the active and hybrid systems require additional power that can be centralized in the same room as the head end equipment via a remote power feed or provided locally in the IDFs.

The BDAs or BTS equipment used to provide signal for the DAS typically requires more space and depends on the device used. BDAs range from the size of a remote hub to half of a standard telecom rack. A BTS may require several full racks. Power and HVAC needs also vary depending upon the device.

Passive systems use no power in the DAS and occupy less space. However, a passive approach requires more power from the WSP to cover the facility sufficiently.

4.3 WSP Infrastructure Backhaul Considerations

4.3.1 Off Air

As mentioned briefly in the architecture description, an off-air interface for a BDA requires that an antenna be mounted on the roof or comparable location. Half-inch-diameter coaxial cable is run from the antenna to the location of the BDA. Ideally, this can be accomplished in existing riser and roof cores and does not require any building penetrations. The roof-mounted antennas tend to be less than five pounds with very little wind loading.

4.3.2 Micro-Cell

A micro-cell, or mini BTS, requires a T1 for backhaul and may require a GPS antenna to be mounted on the roof. These elements are part of the WSP consideration when determining the best device to use.

4.4 Subsystem Requirements

4.4.1 Overview

In a perfect environment, building design architects and building owners have allocated appropriate space for distributed antenna subsystems during design and funding phases. Key locations for space allocation include IDFs and the MDF. Building retrofits may not afford ample or appropriate IDF/ MDF space for equipment placement. If MDF/ IDF locations are not readily available, great care must be given to determining a secure location for all equipment placement. Consideration must also be given to powering, grounding, servicing space, cable access and dressing, security, access, etc.

Building geometry and wireless application requirements dictate whether DAS equipment is required in each IDF, on every floor, or on every other floor. Co-location with other facilities' IT equipment within the IDF determines whether dedicated telco racks should be used or if wall-mounting considerations must be made. If IDF space is readily available, one should consider utilizing a telco rack to properly rack-mount all DAS equipment and power and dressing all appropriate cables (fiber, CAT5/6, coax) ingress/ egress to the telco rack. Rack placement must accommodate manufacturers' specifications related to environmental considerations, service space allocation, powering, grounding, cable access, fiber patch panels, Ethernet hubs, etc. If IDF space is a premium, wall-mounting of equipment or deployment of smaller wall-mounted swing racks may be considered. Wall spacing must take into account manufacturers' equipment wall-mounting specifications, cable dressing, fiber patch panels (if required), WLAN access point co-location, CAT5/6 Ethernet hubs, equipment grounding, AC/ DC converters (if required), etc. The amount of DAS equipment typically located in the MDF may require multiple telco racks to support both the DAS head-end equipment.

Consideration for Wireless Service Provider (WSP) BDAs and/ or BTSs must also be made.

In most cases, dedicated quad AC outlets are adequate to power all equipment to the DAS within the IDF. If multiple outlets are not available, then a multi-outlet power strip may be utilized to provide sufficient power to all DAS equipment within the IDF. The amount of power required for MDF equipment is determined by the amount of DAS equipment and associated WSP head-end equipment to be placed in the MDF. In all cases, proper equipment grounding must be afforded in both the IDF and MDF. In a perfect environment, dedicated building grounding bars are preferred. When grounding bars are not readily available, grounding to building mechanical infrastructure can suffice. In all cases, All DAS equipment within the IDF/ MDF should be supported by emergency power back-up for the building, as this equipment may be critical for emergency situations. When emergency power is not readily available, independent battery backup subsystems can be employed in each IDF and MDF.

4.4.2 Antenna Placement

The least complicated DAS design provides separate in-building distribution and antenna systems for each carrier/ frequency being deployed. Though simple, this can lead to the property's having an undesirable and unsightly "antenna farm" appearance. To reduce both the cost and number of antennas, a common alternative design broadcasts multiple frequencies on a single DAS infrastructure. Antenna placement for multi-frequency systems is normally designed based on the "worst-case" propagation, usually the highest frequency to be transmitted. Multiple methods can be employed to make in-building antenna installations more aesthetically pleasing. Antennas can be colored to blend with surrounding areas or located above suspended ceilings, for example. Electronic down-tilt antennas are frequently specified for mounting above ceiling tiles.

4.4.3 Additional Design Considerations

Building Codes – Local codes dictate cabling requirements for a building. Items such as fire stops, plenum locations, and cable loading vary by locale. DAS designs and associated costs may differ accordingly.

FCC Compliance - All equipment included in the DAS design must comply with FCC regulations for the equipment type. RF sources must be certified for use on the carrier network and not pose an operational hazard for other frequencies.

Link Budget – The link budget for each carrier must provide sufficient signal for satisfactory user service levels. DAS system gain/ loss should be carefully documented and periodically checked to ensure consistent performance. Link budget should be considered for both uplink and downlink transmissions.

Frequency - Where multiple frequencies will be utilized, specification of filters must be sufficient to prevent interference from neighboring channels.

Power Levels – The aggregate power emanating from any antenna should not exceed levels recommended in the FCC OET Bulletin 65 Standards for Maximum Permissible

Exposure for the safety of those in close proximity. RSSI minimum requirements should be clearly documented for all covered areas.

Plenum Locations – Any equipment or cables installed in a plenum location should be manufacturer-rated for that purpose.

Inter-modulation – When multiple frequencies are passed through a non-linear device, such as an antenna, additional harmonic waves are generated. The third harmonic generated is so close to the original frequencies that in-band RF noise and interference levels are significantly raised. This can create a multitude of operational problems, including "cell deafness" for the RF carrier equipment if not properly mitigated. When operating at power levels of 1 watt and below, which is common for in-building designs, inter-modulation problems are infrequent, but the potential issue should not be disregarded. The most common mitigation technique for inter-modulation is geographic separation of the antennas.

IDF (and other types of maintenance closets/ locations where equipment can be deployed) – Each of these locations must account for wall space and cooling requirements.

Power - For all locations, how many outlets are required and at what voltage (110/ 220V)?

Communications Infrastructure - What is required to support the applications (for example, Ethernet cabling, fiber, etc)? Are multiple Ethernet drops needed (home-run to the head-end)? If this is not possible, is additional Ethernet equipment such as a switch required?

4.5 Cellular System Wiring Requirements

As indicated earlier in this document, the two predominant methods of obtaining a WSP's signal source to the DAS are via off-air BDA and micro-cells. Each method requires different considerations about wiring, space, power, access requirements, etc.

For off-air solutions, BDAs are typically collocated in the designated MDF along with all other associated DAS equipment. Each BDA employed requires ample power (to include backup power), rack-mount or wall-mount space to comply with manufacturers' space-allocation specifications, environmentals, and cable pathways for access to both the DAS head-end equipment and the rooftop antenna. In most cases, short coax cable runs and potentially diplexers are required between the BDA and the DAS RIU. These cables can be easily installed, dressed, and labeled.

From access between the BDA and a rooftop antenna, ample cable vertical pathways are required. Cable riser space must be planned and allocated for each BDA employed in the DAS. Typically half-inch coax cable is the norm. However, in some cases where RF link budgets may be borderline or exceeded, thicker cables, such as five-eighths-inch coax, may be required. Though not necessary, various forms of armored cable are available, further protecting the integrity of the cable from damage.

Micro-cell or pico-cell solutions, like the BDA's listed earlier, require ample power; rack-mount/ wall-mount space to comply with manufacturers' specifications; environmentals; and cable pathways for access to the DAS head-end equipment (Radio Interface Unit [RIU]), telco access facilities, and rooftop access for a GPS antenna. Like the BDA, short coax cable runs are required between the micro-/ pico- cell and the DAS RIU. The micro-/ pico-cells are serviced by communication links (T1s, Ethernet [DSL/ cable]) to/ from the facility and typically require some form of twisted pair cabling from the building telco demarcation to the micro-/ pico-cells. Finally, a GPS antenna may be required on the rooftop or similar location to service the micro-/ pico-cell. This, too, requires a half-inch cable via a dedicated or shared vertical pathway from the MDF to the rooftop.

Close coordination with the various WSPs ensures that proper planning has been undertaken to accommodate all cabling requirements as they relate to the micro-/ pico-cell equipment.

4.6 Wi-Fi System Wiring Requirements

As mentioned earlier, not all DAS vendors' equipment is architected to support 802.11 a/b/g WLAN over the same infrastructure. During the site survey phase of the project, incremental applications for the enablement of Voice over WiFi (VoWiFi), Wireless point of sale, wireless data (hotel staff, back office, guests), etc. need to be uniquely specified and considered, as they may add incremental costs to the DAS. As an example, best engineering practices dictate a stronger Receive Signal Strength Indicator (RSSI) level in support of VoWiFi versus best-effort wireless data services (WLAN). In effect, the antenna density and associated prerequisite equipment, labor, cabling, etc. in support of VoWiFi may increase, as well. Further, various WLAN applications may only require coverage within certain locations of the facility.

Security is yet another consideration in the design of a DAS to ensure that all property and guest data is secure and free from vulnerabilities. As such, each wireless application has a prerequisite cause/ effect on design considerations for the DAS.

Given the complexities of supporting a multitude of frequencies over the same infrastructure, a DAS may not provide 100% WLAN application coverage as dictated by targeted applications. Additionally, it may not be cost effective to provide 100% WLAN application coverage in all cases. As a result, hotels need to understand the tradeoffs between the technical requirements and business objectives of a WiFi system supported on a DAS. Therefore, a hybrid approach may make the most sense. In this scenario, discrete WLAN Access Points (APs) would be strategically placed to complement the WLAN support provided via the DAS infrastructure. In some cases, a total stand-alone WLAN infrastructure may be warranted. However, careful consideration to the economic, technical, and ongoing lifecycle maintenance requirements must be carefully weighed.

5 Post-Installation Considerations

5.1 Acceptance Testing

Acceptance testing usually consists of injecting a signal (from a test transmitter) into the DAS and measuring the level of the signal at several areas in the property. Most vendors or DAS contractors propose an acceptable method of testing in their quote. A key consideration here is to include WSP commissioning in the DAS quote. An independent group should do the Acceptance Test Plan (ATP) to show the best- and worst-case readings. The installation vendor or contractor who sells and installs the DAS should be present, so they can be reached quickly if there are issues with coverage for a specific SWSP.

5.2 DAS System Monitoring & Ownership Responsibilities (Troubleshooting, Support and Preventive Maintenance)

5.2.1 System Monitoring

In today's enterprise environment, cellular, wireless, and applications services from the multi-service DAS have become mission critical and require real-time monitoring. A DAS today must effectively monitor:

- its own health
- signals from each of the services it handles
- service-provider signal
- amplifier status
- physical cable connectivity (all the way out to the antennas in the ceiling)

Since enterprises today have many locations, the DAS must be capable of real-time monitoring of multiple sites from a Web-based terminal. The components of the DAS should also provide flexible connectivity options that align with the demands of a dynamic enterprise network environment, including Ethernet IP, dial-up, and local connectivity. The DAS must be able to proactively send alerts out when faults are detected, as IT personnel are typically too busy to monitor the system proactively.

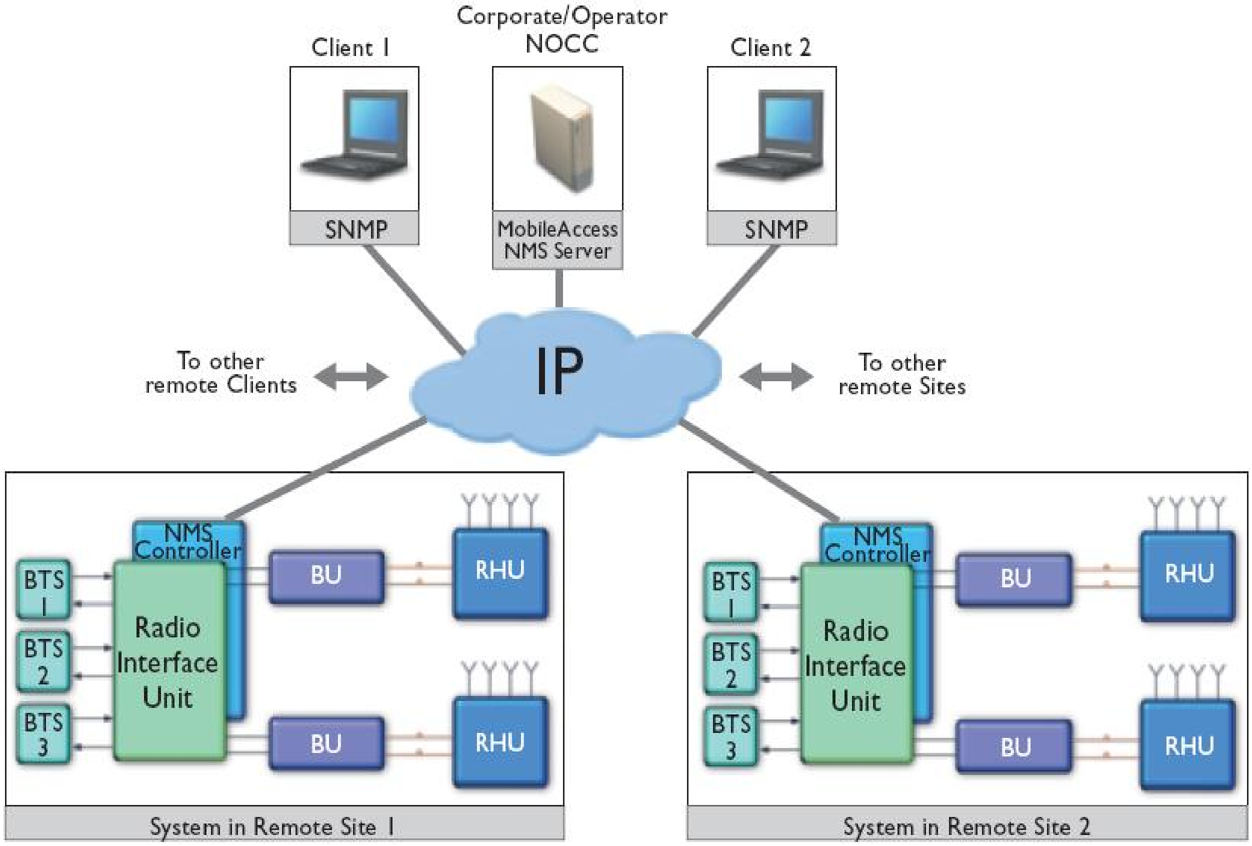
Active, passive, and hybrid technologies all require monitoring, ideally to the antenna. However, active and hybrid systems also require management capability to set up and optimize the system. DAS vendors offer integrated or add-on system management elements and software that vary somewhat in capability but provide the essentials for good system management.

From a network-level perspective, enterprise distributed antenna management systems offer an application that enables the user to monitor all of the remote system controllers simultaneously via IP connectivity. This server is typically Web based, allowing equipment monitoring to be done locally by the hotel or remotely by a provider so that when system failures are detected, service and maintenance personnel may be automatically dispatched.

On the individual site level, the enterprise distributed antenna management systems monitor provider signal levels on a per-provider basis. The systems also monitor equipment health, including the status of the amplifier, fiber, and antenna connectivity.

Generally, this functionality is handled in-band over the same fiber as the DAS, so no additional network infrastructure is needed.

The following diagram is an example of one vendor's Network Management System (NMS):



5.2.2 Ownership Responsibilities for DAS-Carrier, Owner or Third-Party Vendor

As previously discussed, Multiple options are available for funding, management, and control of distributed antenna systems. However, ownership of the DAS does carry certain responsibilities, regardless of the business model. Primary among these are spectrum stewardship, interference mitigation, performance monitoring, and network protection. As network carrier diversity increases, so, too, does the complexity of DAS management.

Spectrum stewardship is taking responsibility for the RF sources that are being distributed within the building. When multiple RF sources are broadcast, certain frequency parameters must be adhered to by each source. Frequency, filtering, power levels, channel usage, and guard-band requirements should be clearly defined for each source. Identification of such violations and proper remediation are the responsibility of the DAS owner. With neutral host systems, carrier demarcation occurs at the RF source.

Interference mitigation is required when the performance of one or more RF sources is negatively impacted by external sources. With neutral host systems, the most common interference sources are other carriers and inter-modulation generated at the antennas. Identification of interference sources and corrective action are the responsibility of the DAS owner.

Performance monitoring involves verifying that all RF signals are being distributed throughout the building(s) at a sufficient level to provide adequate service to users. Reduced signal strength may be the result of interference, DAS component failure, environmental changes, or problematic RF sources. Identification of performance failures, issue resolution, and notification of affected carriers are the responsibility of the DAS owner.

Network protection normally involves providing physical security for RF source equipment and electrical isolation, if required. Any DAS component failure that negatively impacts carrier equipment is the owner's responsibility.

6 DAS Installation Considerations

6.1 Assurance of Coverage

As established earlier in the document, a vendor that provides a comprehensive site survey and design document usually renders a comprehensive and complete solution that exceeds the performance criteria established in the initial requirements document. A good DAS solution provider commonly samples system performance measurements as the solution is being installed to ensure that RF coverage requirements are being adequately met. RF sources can be easily injected into the cable plant and associated antennas (on a sample basis) and verified via RF measurement equipment as the solution is being built out. Typically, one can quickly hone in on challenging coverage areas within the property and determine if adequate coverage can be provided for all wireless applications.

Once the solution is completely installed, activated, and "tuned" appropriately, similar measurements can be easily ascertained to ensure that adequate coverage exists throughout the targeted coverage areas for all wireless applications. Results of the measurements should be documented and stored for future reference purposes.

6.2 Training

Like any Information Technology (IT) solution in operation at the property, training is paramount to handle day-to-day operational requirements that may arise. In many cases, after the initial system turn-up and final documentation of the solution is rendered, basic hands-on and/ or formal classroom training should be considered. While it is not necessary to thoroughly understand all aspects of the system, basic system surveillance and management techniques, level-one troubleshooting scenarios, and ongoing periodic maintenance procedures should be well understood by a number of members on the staff. Likewise, good system documentation and reference guides should be provided with the solution and be readily available to reinforce any information covered in a training curriculum. Most distributed antenna systems have various forms of remote management capabilities that can enable remote assistance from either the solution provider and/ or original equipment manufacturer should the need arise. Training for use of the system-management tool should also be provided.

6.3 Financing

If a hotel property's client satisfaction scores indicate a strong demand for ubiquitous wireless coverage, and their planning and budget cycles do not support a capital purchase such as a DAS at the time, various financing options are available from many reputable industry institutions that can tailor a financial package to coincide with your funding requirements and minimize the impact of a capital purchase such as a DAS to your business. Depending on the total expense of the project, it is conceivable to obtain financing packages that range anywhere from a one- to five-year term. Further, some financing companies allow the labor costs of a project to be underwritten in a financing package, which is beneficial. While financing a project such as this may not be appropriate for every situation, it should be used as a tool to parlay a capital cost into an operating expense that can coincide with the operating cash flow of the property. It is imperative to ensure that the financing company is reputable, possesses excellent references, and has the financial staying power to withstand changes in market and other unforeseeable conditions. It is of utmost importance to ensure that the financial institution regularly deals in the hospitality marketplace and thoroughly understands the business.

6.4 References

The lowest bid is rarely the most complete and comprehensive solution. Taking the time and energy to call and/ or meet a cross section of a vendor's previous clients is paramount and can possibly save a lot of project aggravation in the long run. Some basic questions one should ask when performing reference checks include:

- Does the vendor commonly provide solutions such as this to other hospitality venues? Does the vendor understand the hotel business, adhere to company business ethics? Has the vendor proven to be accommodating in working around daily facility operational challenges?
- Does the vendor issue a high number of project-change orders after the project is underway? If so, this could be a warning sign that the lowest bid may not be the best (or lowest cost) bid.
- Does the vendor provide complete turnkey and life-cycle maintenance support or do additional contracting specialties (and costs) need to be considered?
- In the past, did the vendor keep all trade payables current with any/ all participating trades on the project?
- Have previous projects come in on time and on budget? If not, what were some of the lessons learned?
- Were jobsites kept orderly and safe? Were local safety regulations and building codes adhered to during the project?
- How thorough was the initial site survey and did the end solution meet the design goals stated in the initial design document?

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It is ideal to verify bank references and check with major suppliers to anticipated vendors Visiting one or two clients for whom the vendor installed a solution similar in size and scope is also a good idea. Not only will this provide relevant feedback from a current client but can assimilate many "lessons learned" for the project, as well.

6.5 WSP Participation

Deployment of a DAS solution does not automatically guarantee signal source from Wireless Services Providers (WSPs) that operate. In many cases, if the property is capitalizing the cost of the DAS, then the probability is very high that signal source from the WSPs will be obtained. However, to increase the probability of WSP participation, the selected DAS solution provider should be able to assist in contacting the appropriate local WSP resources to ascertain their ability and willingness to provide signal source to the DAS. This should be performed after the design phase and prior to the contracting phase. Many times, the WSPs reserve the right to thoroughly review the DAS design plan to ensure that their signal source is managed appropriately on the DAS and that it adheres to each WSP's operating standards. Naturally, it is advantageous to utilize a DAS vendor that has an excellent working relationship with all WSPs and has a proven record in gaining a high degree of WSP participation on past projects. Hoteliers should also take into consideration whether or not they want to take on the responsibility of obtaining WSP participation. This is typically not part of a hotelier's core skills, and many clients prefer to use an experienced, independent third party who already has a good working relationship with the WSPs.

6.6 Economics

To assist in the planning process, the following chart provides some general economic guidelines for capital planning purposes for a turnkey DAS installation as highlighted section 6.7: The Process. It is important to note that each property is unique in nature and must be individually qualified in order to provide an accurate capital cost. Price ranges are delineated in price-per-square-foot of coverage area. The figures in the chart below were put together for a perfectly symmetrical building with boilerplate floors, drop ceilings, etc. In most cases, such a perfect building does not exist in the hospitality industry, so actual cost may vary from that described here.

Building Type	1-2 Frequencies	3-4 Frequencies	5-6 Frequencies
New Construction / Renovation	$.35 - $.85[8]	$.65 - $1.20	$1.00 – 1.85
Retrofit	$.45 - $.95	$.75 - $1.35	$1.10 - $2.00

Additional factors that may affect pricing include, but are not limited to:

- Occupancy
- RF signal source designation
- Number of high-band/ low-band signals requiring coverage
- Designated work hours
- Building geometry, construction material, furniture, fixtures
- Legal agreements
- Building age and ability to support structured wiring
- Specialized cabling requirements
- Campus with outdoor coverage requirement
- International standards/ compliance (where applicable)
- Local building standards
- Union versus non-union labor
- Carrier participation
- IDF/ MDF space considerations
- System powering/ backup power requirements
- Wireless applications supported
- Emerging wireless standards/ frequencies

6.7 The Process

Qualified DAS vendors will have developed and implemented time-tested and proven Methods of Procedure (MOPs) for the design, engineering, project management, installation, testing and certification, and ongoing maintenance of various forms of wireless/ mobility solutions, including Distributed Antenna Systems (DASs). These MOPs ensure measurable, manageable, and repeatable steps necessary for a successful project. Hotels should seek a vendor who can provide a turnkey solution that meets and

[8] Note: WLAN enablement – add $.06 to $.12 per square foot to figures listed here.

exceeds the wireless/ mobility demands of discerning clients. The following sections outline the various phases necessary for a successful, converged wireless implementation.

6.7.1 Phase 1 - Site Survey

A detailed site survey should be conducted and should include the following tasks:

- Evaluate building construction and proposed equipment location
- Evaluate equipment closet and riser
- Validate coverage objectives of client
- Set up test transmitter to collect signal-strength data
- Optimize propagation predictions
- Identify potential problem areas
- Generate guidelines for installation of cabling
- Pre-qualify subcontractor(s)
- Prepare subcontractor's scope of work
- Update cost estimates
- Update project scheduling
- Develop CAD drawings
- Complete site survey report

6.7.2 Phase 2 - System Design & Engineering

System design documentation should be prepared per customer specification and should include the following information:

- Description of design methodology and assumptions
- Description of the demarcation point
- RF plots
- Equipment locations
- Cabling runs
- Power-system design
- Alarm-monitoring design
- Proposed-to-build drawings

6.7.3 Phase 3 - Project Management

A detailed project plan should be generated for the management of all the associated tasks to ensure project objectives are met. The project plan should incorporate the following details:

- Coordination building access, work-area access, security checks, and safety training with facility management
- Coordination of receiving and staging logistics with facility management
- Assessment of work area's adherence to safety standards
- Review and signoff of proposed-to-build-drawings
- Review and signoff of proposed project schedule
- Management of DAS equipment shipping logistics
- Management of third-party equipment shipping logistics
- Quality assessment of incoming DAS materials
- Management of wiring subcontractors
- Management of system commissioning

- Confirmation and implementation of selected sparing option
- Coordination of system acceptance and signoff

6.7.4 Phase 4 - Installation

The wireless system should be installed in accordance with proposed-to-build drawings, taking into account the following:

- Broadband coaxial cabling attached per manufacturer's specification and in accordance with all EMR (occupational health and safety) and EMC/ EMI standards
- Type N RF broadband coaxial connectors installed per manufacturer's specification
- (Optional) single-mode fiber installed in innerduct
- Single-mode fiber cabling attached per manufacturer's specification and in accordance with all EMR (occupational health and safety) and EMC/ EMI standards
- SC/ APC fiber connectors attached per manufacturer's specification
- All cabling labeled
- All cabling tested
- All racks installed in accordance with local standards
- All equipment rack- or wall-mounted in accordance with the installation guidelines
- All fire stops repaired in accordance with local regulations
- All antennas installed in accordance with manufacturer's specification
- Power connectivity (local or central)
- As-built cabling documentation
- Optional: power drops, core drilling, or conduit runs installed in accordance with local regulations

6.7.5 Phase 5 - Commissioning, Testing, and Verification

The wireless system should be tested to confirm that the design requirements are met. Typical design requirements include coverage, received signal strength, maximum power level, and signal "roll-off" outside the building. The commissioning, testing, and verification should consist of the following:

- Final configuration of integration module (i.e., attenuation) and measurement of incoming power level
- Measurement of EIRP at remote hub unit antenna port
- Antenna orientation, if applicable
- Comprehensive "walk test" to measure received signal strength at pre-determined locations, including perimeter window, building core/ elevator, basement/ garage, and street-level outside building
- Handoff into and out of in-building network
- Talk-in and talk-out testing, if applicable
- Closeout documentation, such as coverage maps, as-built drawings, and acceptance results
- Signoff/ customer acceptance

6.7.6 Phase 6 - Ongoing Maintenance Support

A comprehensive maintenance plan should be designed and implemented based on the hotel's specific needs. Considerations for the plan should include:

- Technical-assistance center/ help-desk function
- Network Operations Center (NOC) monitoring function
- Dispatch and troubleshooting function
- Sparing program

6.8 Business Model Options (Uncovering the Costs, Funding & Deployment Options)

This section is intended to present a high-level overview of the business-model options available to hotels deploying multi-carrier or neutral host DAS solutions. It is important to note that hotels should expect to retain some level of outside consulting services unless they have RF expertise in house. For several of the options below, the DAS solution becomes a hotel asset and should be considered accordingly if the property is sold.

By FCC mandate, carriers must retain control of the RF source, whether a repeater, a bi-directional amplifier (BDA), or a micro-cell base station. Most hotels do not require a micro-cell base station, but if they do, the carrier should provide the T1 access at no cost to the hotel.

6.8.1 Shared Cost Model (SpectraSite, for example)

In this model, a carrier or vendor goes into a hotel and builds out the infrastructure and takes on the responsibility of getting each carrier to connect to the network. The cost is divided evenly among the connecting carriers.

Pros

- Lowest cost to hotel
- Possible source of revenue (may be minimal)

Cons

- Typically only multi-carrier cellular service provided (does not include 802.11)
- To avoid unforeseen costs, the hotel should ensure that the vendor has incorporated a fee for ongoing support. If not, the hotel may need to hire and pay for a neutral third party to perform this function.
- Risk that no carriers will connect to the network, since it can be a very expensive proposition for each carrier. In fact, it is highly unlikely that a hotel will get all carriers to connect.
- Most carriers will not agree to this model unless there is a guaranteed revenue stream from the hotel
- Expensive model to support and smaller, less-established vendors have gone out of business. While hotels could take over, it is typically not their core expertise to solicit and manage the carriers.

6.8.2 Hotel-Funded Model (InnerWireless, for example)

In this model, a hotel covers the cost of the DAS and the electronics required to support a multi-carrier or neutral host solution.

Pros

- Hotel is in direct control of network decisions, including what is supported (800 MHz, 900 MHz, 802.11)
- Most likely model to obtain agreement from carriers to attach to the network, and therefore the lowest risk
- Many financing options are available through hotel resources (lease purchase, etc.)

Cons

- High cost, especially for larger properties (the larger the property, the higher the cost for each carrier to connect to the network)
- Carrier has to provide RF source (FCC mandate) and needs an installation agreement to attach to the network, which must be negotiated by the hotel or its representative
- Hotel has to decide who is going to pay for the up-front bill for the electronics (the hardware in the head-end required to support the various RF frequency options needed by each carrier since the carriers do not typically fund this)
- Hotel needs a third party to provide ongoing support (a neutral third party is required to support the DAS server and infrastructure)

6.8.3 Outsourced Model (Sprint Custom Network Solutions – CNS, for example)

In this model, a carrier or vendor covers the cost of the DAS infrastructure and related equipment. In exchange, the vendor requires a commitment from the hotel in terms of guaranteed monthly revenue or partial payment to offset the cost.

Pros

- Reduced up-front cost
- Carriers are stable and reliable vendors
- Carrier may pay for a portion of the infrastructure
- Least involvement required from hotel
- Guaranteed coverage, typically to -85dBM, contractually

Cons

- Hotel may still need to solicit carriers or obtain a third party to do so
- Hotel still covers the cost of maintenance for the ongoing service and support of DAS infrastructure
- Carrier may retain DAS and/ or head-end ownership.
- Carrier typically requires a three- to five-year commitment. The capital amount a carrier is willing to contribute is dependent upon hotel contractual commitment and the carrier's associated revenue stream.

7 Available Vendor Solutions

7.1 Andrew Corporation[9]

Andrew Corporation (NASDAQ: ANDW) designs, manufactures, and delivers innovative and essential equipment and solutions for the global communications infrastructure market. The company serves operators and equipment manufacturers from facilities in 35 countries. Andrew, headquartered in Westchester, Illinois, is an S&P MidCap 400 company founded in 1937. Their complete line of tested, active and passive RF distribution systems delivers coverage solutions for road tunnels, train tunnels, metros, buildings, stadiums, and dense urban areas. Andrew offers design and installation services, as well as management of large, complex RF distribution systems for metropolitan railways, building owners, and public mobile radio and telephone operators throughout the world.

7.2 InnerWireless[10]

Founded in 1998 in Richardson, Texas, InnerWireless is a leading provider of comprehensive in-building wireless distribution systems that provide a shared wireless broadband infrastructure. The InnerWireless system has been adopted by a growing number of companies in a variety of venues, including corporate campuses, hospitals, hotels, office buildings, and sports/ entertainment venues. These include Children's Memorial Hospital in Chicago, the three-million-square-foot Time Warner Center in New York City, and the Charlotte Bobcat Arena in North Carolina. The wireless solutions implemented by InnerWireless for these customers are broadband and support a full range of wireless applications and services, including those from every nationwide wireless provider, paging services, two-way radios, and wireless LAN applications.

InnerWireless' headquarters is in Richardson, Texas, and the company has a regional presence throughout the United States. In addition, the company has a growing international business, with installations in Beijing, Singapore, and Hong Kong. InnerWireless is privately held and has many of the country's leading venture capital funds as its investors: Sevin Rosen Funds, Massey Burch Capital Corp., Technology Associates, and Centennial Ventures.

7.3 LGC Wireless, Inc.[11]

LGC Wireless began in 1996, when two University of California - Berkeley PhD students, along with their professor, came up with a novel way to adapt fiber-optic technology to improve wireless communication. With this idea the company was launched in 1997. With more than 5,500 deployments worldwide, LGC Wireless is a leader in extending scalable, high-performance wireless coverage and capacity inside buildings and public facilities. LGC offers design, installation, end-to-end monitoring and management, and

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[9] Andrew Corporation, Worldwide Headquarters, 3 Westbrook Corporate Center Suite 900; Westchester, IL 60154 USA; (708) 236-6600 Phone; www.andrew.com

[10] InnerWireless, 1155 Kas Drive, Suite 200; Richardson, TX 75081 USA; (972) 479-9898 Phone; (972) 479-9625 Fax; www.innerwireless.com

[11] LGC Wireless In-building Systems, 2540 Junction Avenue; San Jose, CA 95134-1902 USA; (408) 952-2400 Phone; (408) 952-2410 Fax; www.lgcwireless.com

easy integration of emerging wireless technologies. LGC Wireless is based in San Jose, California USA and is privately held. LGC's products enable high-speed wireless voice and data communications in dense urban areas, as well as inside public and private structures. LGC currently ships product to more than 41 countries and supports all major wireless access standards, including TDMA, CDMA, GSM, iDEN, 1xRTT, Ev-DO, GPRS, W-CDMA, UMTS and 802.11.

7.4 MobileAccess Networks[12]

MobileAccess Networks is an enterprise wireless innovator that provides a universal platform for connecting the people and applications that drive business. The MobileAccess universal wireless network is the key to widespread wireless connectivity in hotels, hospitals, office buildings, public venues, and other large-scale facilities. The company's intelligent, in-building infrastructure delivers business-quality performance, scalability, security, and signal reliability to more than 1,000 customers, including hotels and casinos, like Peppermill Casino; JW Marriott Grand Lakes; Fortune 1000 companies, such as Lehman Brothers and Hearst Corporation; leading healthcare facilities, like Northwestern Memorial and Clarian Health; and many public-sector customers, such as ALLTEL Stadium, American University, and the Oakland International Airport.

MobileAccess works through channel partners who specialize in specific vertical markets. In the hospitality market, Acela Technologies, Inc. -- a leading design, engineering, and consulting company headquartered in Frederick, MD -- specializes in complex, turnkey convergence solutions with emphasis on: indoor/ outdoor wireless mobility; optical networking; IP telephony; IP video; and wired/ wireless security. Acela Technologies has successfully addressed a broad range of voice/ data/ video application requirements to selected vertical markets, including hospitality, education, healthcare, federal government, state/ local governments, and wireless service providers. Acela Technologies provides a complete spectrum of services to include: requirements analysis; site surveys; design/ engineering; technology assessment; information assurance; network systems prototyping and integration; and installation, test, commissioning, final documentation, and lifecycle maintenance services. Additional information on Acela Technologies can be found on www.acelatechnologies.com.

7.5 Powerwave Technologies, Inc.[13]

Powerwave Technologies (NASDAQ: PWAV) is a global supplier of end-to-end solutions for wireless communications networks. Powerwave designs, manufactures, and markets antennas, boosters, combiners, filters, repeaters, multi-carrier RF power amplifiers, tower-mounted amplifiers, and advanced coverage solutions: all for use in cellular, PCS, and 3G networks throughout the world.

Founded in 1985 and headquartered in Santa Ana, CA, USA, Powerwave provides advanced wireless and end-to-end wireless infrastructure solutions, including antenna,

[12] MobileAccess, 8391 Old Courthouse Road; Vienna, VA 22182 USA; (866) 436-9266 Phone; (703) 848-0280 Fax; www.mobileaccess.com

[13] Powerwave Technologies, Inc., 1801 East St. Andrew Place; Santa Ana, CA 92705 USA; (714) 466-1000 Phone; (714) 466-5800 Fax; www.powerwave.com

base station, and coverage systems. Their product portfolio covers most major frequency bands and air interfaces and is coupled with operational and engineering expertise, including single-carrier and multi-carrier power amplifier products, base-station antennas, tower-mounted amplifiers (TMAs) , coverage solution products, and various filter products, along with a wide range of repeater products.

7.6 ADC[14]

The ADC (NASDAQ: ADCT) Digivance Indoor Coverage Solution (ICS) is used to extend coverage to specific areas within a building or multiple buildings or throughout a campus environment. This digital distributed antenna system (DAS) solution features unique, patented technology that allows it to distribute wireless coverage digitally over optical fiber, making the Digivance ICS the best choice for signal quality, flexibility, and overall performance. ADC's Digivance family offers service providers a flexible and scalable platform to improve customer retention and offer enhanced services to meet increasing subscriber demands.

ADC provides the connections for wireline, wireless, cable, broadcast, and enterprise networks around the world. ADC's innovative network infrastructure, equipment, and professional services enable high-speed Internet, data, video, and voice services to residential, business, and mobile subscribers. ADC has sales into more than 130 countries.

8 System Compatibilities and Supported Standards

8.1 Frequency Considerations

In the United States, the most commonly used frequencies for public voice and data communications are:

- 800/ 900 MHz – SMR Band
- 800 MHz Cellular Band
- 1900 MHz – PCS Band
- 2.4 GHz – 802.11 b/g WiFi
- 2.5 GHz – Broadband Wireless Service (WiMAX)
- GHz – 802.11 a

[14] ADC, 13625 Technology Drive; Eden Prairie, MN 55344 USA; (952) 938-8080 Phone; (952) 917.1717 Fax; www.adc.com or www.adc.com/productsandservices/wireless/

Broadcasts in the 2.4 GHz range and the 5 GHz range do not require the operator to hold license for use. A graph showing spectrum holdings of prominent U.S. carriers by frequency is shown here.

Carrier	Frequency Band(s)	Technology
Alltel	800 MHz Cell	CDMA
AT&T/ Cingular	800 MHz Cell, 1900 MHz PCS	TDMA, GSM
Sprint/ Nextel	800/900 MHz SMR, 1900 MHz PCS	iDEN, CDMA
T-Mobile	1900 MHz PCS	GSM
Verizon	800 MHz Cell, 1900 MHz PCS	CDMA

The differing wavelength of these frequencies results in significantly different propagation characteristics among the bands. In general, the lower frequencies (800/ 900 MHz) tend to travel farther and provide better penetration of solid barriers, such as exterior walls, doors, etc. As the frequencies get higher, wavelengths grow shorter, thus having a lesser range and becoming more easily deflected. In dense, urban environments, this can create a more indirect propagation pattern or a "bounce" effect. An effective DAS design requires consideration of known frequency characteristics and power levels when planning antenna placement.

There are significantly more international carriers, and while most in Europe and Asia are GSM, each country -- and sometimes various regions within a country -- have different carriers. A good reference for international carriers and the spectrum they utilize is http://en.wikipedia.org/wiki/List_of_mobile_network_operators_of_the_Asia_Pacific_region.

As to DAS in Asia, carriers may install the cable/ antenna systems at their own expense, and pay a 'rental fee' to the building. In most countries this means there are two to three separate and distinct infrastructures just for this application. For example, in the case of Singapore, there are three GSM operators, and none of them share any infrastructure but do allow inbound roaming from other countries.

8.2 Scaling for the Future[15]

8.2.1 Accommodating New Technologies (FMC, IMS and LBS)

Fixed-mobile convergence (FMC) is the trend towards seamless connectivity between fixed and wireless telecommunications networks. The term also describes any physical network that allows cellular telephone sets to function smoothly with the fixed network infrastructure.

[15] The information in this section was obtained from research performed by Burton Group and Gartner in January 2007.

The ultimate goal of FMC is to optimize transmission of all data, voice, and video communications to and among end-users, no matter what their location or device. In the more immediate future, FMC means that a single device can connect through and be switched between wired and wireless networks.

FMC also utilizes a framework called IP Multimedia Subsystems (IMS) to deliver IP multimedia services to end users. Due to the complexity and cost of deploying IMS, this framework will most likely be deployed by one or more of the major carriers. For example, one of the services that could be provided by this framework is location-based services (LBSs,) which would provide a hotel with the ability to track associates on and off property locations.

In the hotel environment, for example, through the use of FMC, mobile (cellular) phone users could automatically be switched to a wireless local area network whenever the user moves within close proximity of a WLAN access point (inside the hotel) and then have the call routed over the fixed wireline network. In this case, the property-based IP PBX would provide all call control and routing of the call. In particular, a property may use this technology as another revenue opportunity by offering guests the add-on service of full voice services, such as wireless VoIP phones for guest use or extended wireless coverage through the use of the guests' cell phones.

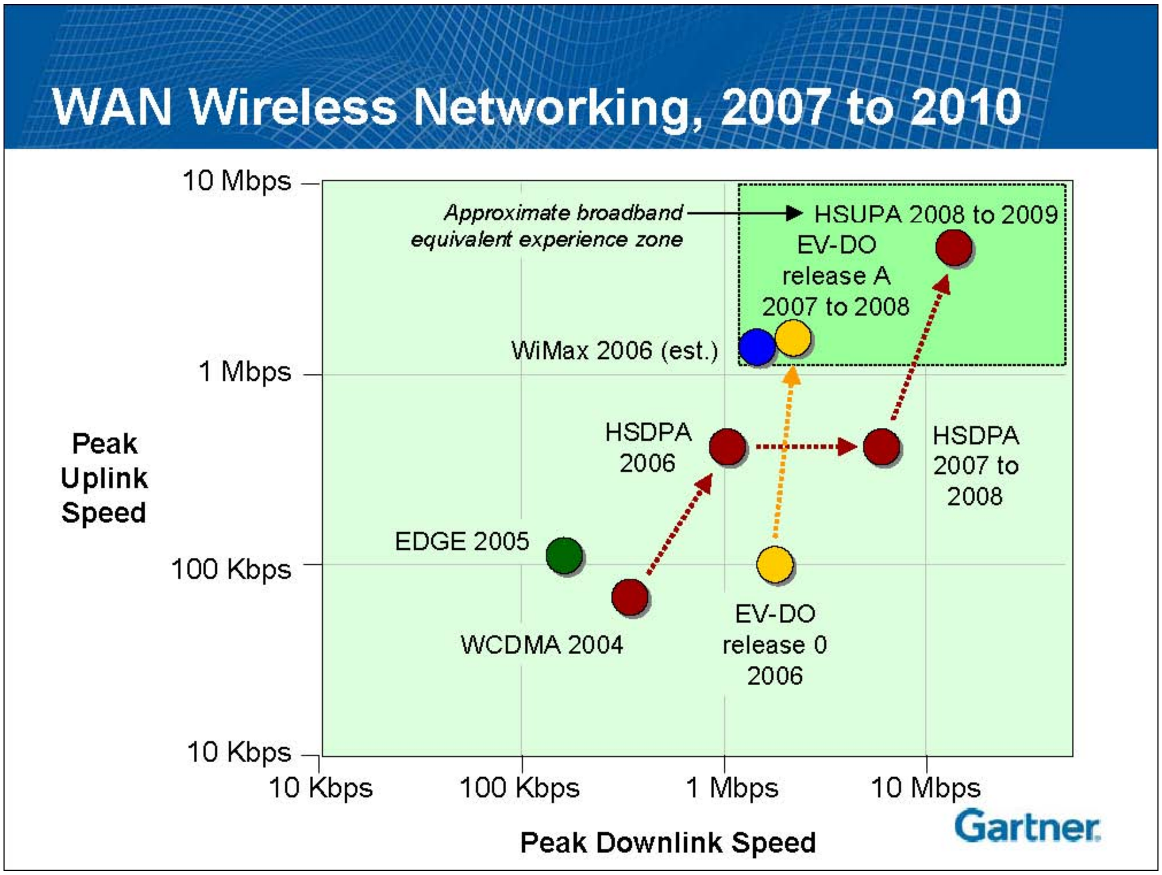
Finally, FMC can also provide multimedia (e.g. video and messaging), as well as just voice communications to hotel guests and associates.

8.2.2 Accommodating New Wireless Standards[16]

Wireless technology is experiencing a rapid change. In order to provide the reader with some insight into how to plan for this change, information on the timeframes for the delivery of future WiFi (802.11), WiMAX (802.16) and Bluetooth technologies is presented here.

[16] It should be noted that the information presented in this section was presented in January, 2007 at Gartner Wireless Summit conference.

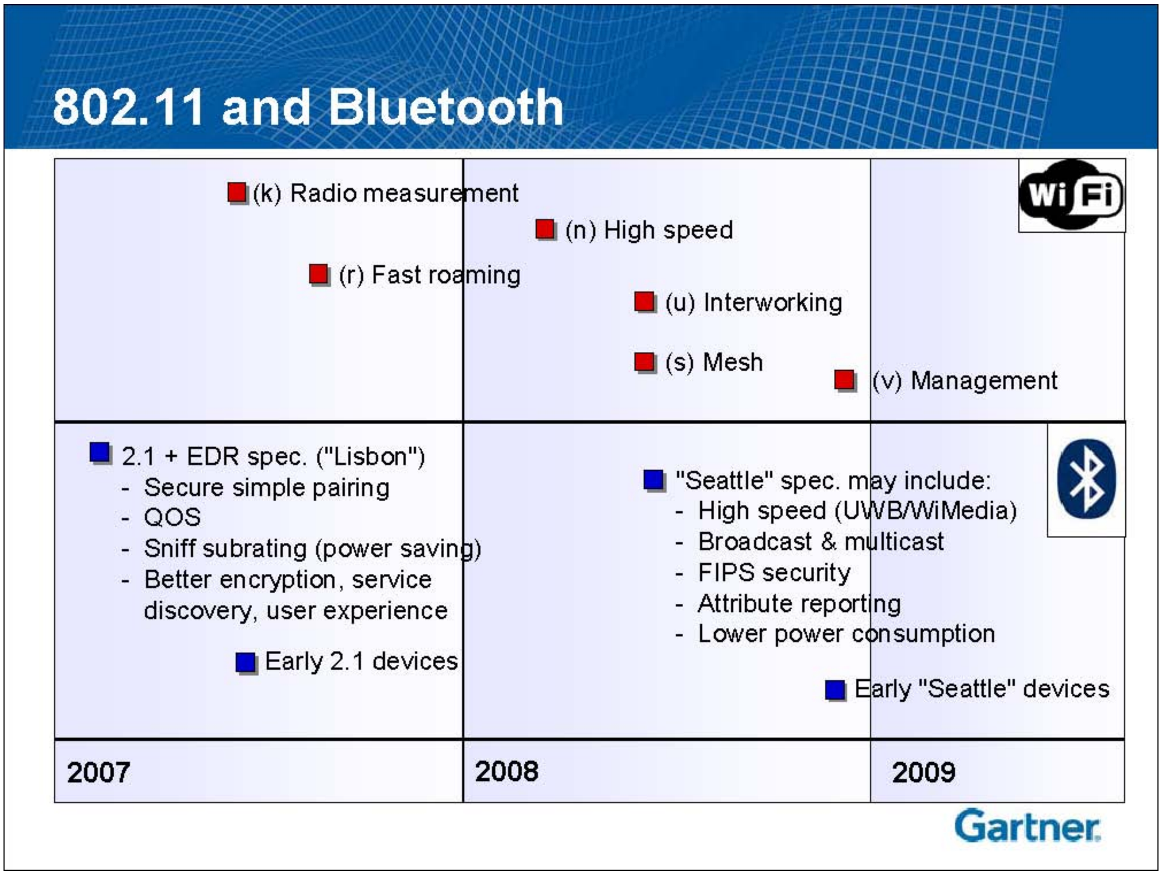
The following diagram depicts the current wireless technology trends through 2011 for wireless broadband (cellular) and WiMAX.



Cellular networks are evolving through 3G and 3.5G in most regions of the U.S. The details vary depending on local technology but target with 12 to 24 months in a megabit or two in each direction, with higher peak speeds. Cellular evolution will continue through 3.75G (for example long-term evolution [LTE]) in the GSM technology toward an eventual 4G (which will not arrive before 2012).

Metro wireless broadband is being delivered through several technologies. These include WiFi and WiFi mesh. More recently, a few operators, such as Sprint/ Nextel in the U.S., have started to show interest in WiMAX. It is currently anticipated that the deployment of WiMAX will remain small through 2010.

The following diagram depicts the current and future of WiFi and bluetooth technologies.



WiFi continues to evolve and a number of key extensions are planned through 2009. The major planned extensions include (1) fast roaming (802.11r), (2) high speed - around 100 mbps (802.11n), and (3) mesh networking standards (802.11s).

Bluetooth is broadening to incorporate additional wireless bearer technology, including WiMedia ultrawideband for high speed. Improvements are also planned in the areas of pairing, quality of service, power saving, and user experience.

8.2.3 Migration to Smart Phones (Cellular to WiFi VoIP)

Some organizations following the IP telephony route are considering the new generation of sophisticated IP desk phone, which can run applications and make video calls, as well as support other business applications. This concept is misguided for two reasons: (1) Most desktop computers have a better application platform and (2) a WiFi smartphone is a better choice for an office handset since it is more sophisticated and flexible.

Although it is technologically possible to use a cell phone as a back-office phone, it is likely to remain merely a niche activity through 2010 (for financial, contractual, and technical reasons).

VoIP over WiFi and unlicensed mobile access (UMA) are becoming increasingly viable; however, VoIP over WiFi challenges battery life, and most hotel WiFi networks still do not offer any quality of service or coverage to support the needs of both the associates and the guests.

However, WiFI-enabled smartphones will become good VoIP platforms and will provide hotels with value-added features, such as presence. It is therefore recommended that hotels start selecting devices and infrastructure to support VoIP over WiFi.

9 Case Studies

9.1 Innerwireless[17]

Mandarin Hotel, New York, NY

- Property layout: 251 rooms, five-star hotel located in top 20 floors of the 2.8-million-square-foot Time Warner Center
- Implementation: Installed DAS for guest safety and seamless cellular coverage (inclusive of elevators, garages, and stairwells); first-responder two-way radio integration; and customized, guest-facing wireless applications
- Benefits: Realized increased efficiency of hotel operations and enhanced guest service

9.2 Acela Technologies[18]

JW Marriott Ritz-Carlton Grande Lakes, Orlando FL

- Property layout: 1500 guests, spa, golf course, and 100,000 square feet of meeting space within this 4-million-square-foot property
- Implementation: Installed multi-carrier DAS, WLAN, and a future-proof network
- Benefits: DAS allows hotel to seamlessly add future wireless services and realize a competitive advantage while providing guests ubiquitous cellular coverage throughout the property

9.3 Sprint/ Nextel[19]

Borgata Hotel Casino and Spa, Atlantic City NJ

- Property layout: 2000 rooms, 125,000 square feet of gaming, 11 restaurants, 11 retail boutiques, and 70,000 square feet of event space
- Implementation: Installed a multi-carrier system for property-wide cellular coverage and consolidated devices (cell phones, pagers, PDAs, two-way radios) and custom data applications, such as a jackpot slot technician device that reports the specific machine and amount won so winnings may be delivered immediately to the guest.
- Benefits: Reduced communications devices for employees provide property-wide cell coverage for both guess and staff and increased customer satisfaction

9.4 MobileAccess[20]

Peppermill Casino, Reno NV

- Property layout: 1100 guest rooms, 14 bars/ lounges, 8 restaurants, multiple gaming venues, 860,000 square feet of coverage, and a planned expansion of 560 square feet
- Implementation: Deployed cellular and WLAN coverage for guests and staff in a multi carrier environment that was aesthetically pleasing and non-disruptive to the guests

[17] Appendix A: Innerwireless Case Study contains more information.
[18] Appendix B: Acela Technologies Case Study contains more information.
[19] Appendix C: Sprint/ Nextel Case Study contains more information.
[20] Appendix D: MobileAccess Case Study contains more information.

- Benefits: Ensured guest retention; property may easily and cost effectively expand the system, and all managed components are in secure telecom closets out of public view

10 Glossary of Acronyms & Terms

1xRTT	3rd generation
3.xG/ 4G	3rd generation / 4th generation mobile phone services
802.11 a/b/g	Very common wireless LAN standards, also known as Wi-Fi
802.16	Family of standards known as WiMAX
AC/ DC	Alternating current / Direct current
AP	Access Point
APC	Manufacturer of uninterruptible power supplies
ATP	Automatic Transfer Protocal
Backhaul	Transport of voice or data communications between distributed sites in a telecommunications network
BDA	Bi-Directional Amplifier - RF device used to receive and amplify RF signals in both the base-to-mobile and mobile-to-base directions
BISCI	Building Industry Consulting Service International
Bluetooth	Wireless standard for short range
BTS	Base Transmit Station in wireless cellular network
BU	Base Unit
CAD	Computer Aided Design
CAT5/6	Category 5 or 6 cable used to network computers
CATV	Term for low cost coaxial cable often use for cable TV.
CDMA	Code Division Multiple Access
CEO	Chief Executive Officer
DAS	Distributed Antenna System
dBm	Decibel relative to one milliwatt – measure of RF power
DSL	Digital subscriber line
E911	Wireless 911
EIRP	Effective Isotropic Radiated Power
EMC/ EMI	Electromagnetic compatibility or interference is low level radiation, which is emitted by electrical circuits as a by-product of their normal operation and causes unwanted signals (interference or noise) to be induced in other circuits
EMI	Electro Magnetic Interference
EMR	Electro Magnetic Resonance
Ev-Do	Wireless radio broadband data standard
FCC	Federal Communications Commission
FMC	Fixed-Mobile Convergence
GHz	Giga Hertz – measure of frequency
GPRS	General Packet Radio Service –protocol associated with GSM
GPS	Global Positioning System
GSM	Global System for Mobile communications
Head-end	RF terminology for the entry or primary location of a network, often where the network management is centralized
HSIA	High Speed Internet Access
HVAC	Heating Ventilation Air Conditioning
IDF	Intermediate Distribution Frame - A distribution point for multi-pair cables from the main distribution frame (MDF)

IMS	IP Multimedia Subsystems
In-Band	Electrical term used to describe radio frequency signals that are in a particular band of operation
Interference Mitigation	Effort to reduce interference
IP PBX	Internet Protocol Private Branch Exchange
Link Budget	All of the gains and losses from the transmitter, through the medium (free space, cable, waveguide, fiber, etc.) to the receiver in a telecommunication system
ICS	Iranian Cheetah Society
iDEN	Integrated Digital Enhanced Network – wireless protocol
IP	Internet Protocol
IT	Information Technology
LGC	Manufacturer of DAS
LTE	Long Term Evolution
MDF	Medium Density Fiberboard
MHz	Mega Hertz – measure of frequency
Micro-Cell	A cell in a mobile phone network served by a low power cellular base station, covering a limited area
MOP	Method Of Procedure
MTBF	Mean Time Between Failures
Multi-Carrier	DAS term used to describe multiple service providers
Neutral Host	A distributed antenna system that is not specific to an individual wireless service provider but can serve multiple services
NMS	Network Management System
NOC	Network Operations Center
OET	Office of Engineering Technology - FCC
PBX	Private Branch Exchange
PC	Personal Computer
PCS	Personal Communications Service
PhD	Doctor of Philosophy
Pico-Cell	Term used to describe a small area in wireless network
POS	Point of Service
QOS	Quality Of Service
RCDD	Registered Communications Distribution Designers
RF	Radio Frequency
RFID	Radio Frequency Identification
RHU	Remote Hub Unit
RIU	Radio Interface Unit - A device that provides an interface to the radio equipment provided by the wireless service provider
ROI	Return on Investment
RSSI	Receive Signal Strength Indicator - A measurement of the received radio signal strength
RTLS	Real Time Location Systems
SC/ APC	Subscription Channel/ Angle Polished Connector. A standard optical fiber connector type with specific physical characteristic which is known for its audible click locking mechanism

SMR	Specialized Mobile Radio
SNMP	Simple Network Management Protocol
T1	Trunked interoffice
TDMA	Time Division Multiple Access – wireless protocol
Telecom	Telecommunications
TMA	Tower Mounted Amplifier
Type N RF	Connector type
UMTS	Universal Mobile Telecommunications System
V	Volt
VoIP	Voice Over Internet Protocol
W-CDMA	Wide Band – Code Division Multiple Access
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WiMedia	Industry Association
Wireless LAN or WLAN	Wireless Local Area Network - Linking computers in the home or office network (often to the internet) without wires

11 Appendix A: Innerwireless Case Study

innerwireless

Customer Success Story

The 5-Star Mandarin Oriental, New York

Objective

To increase guest safety and enable the use of wireless applications and devices throughout the entire hotel, which includes 251 guest rooms, more than 7,000 square feet of meeting space, and a 14,500-square-foot spa.

Business Gains

- Increased guest safety
- Efficient and improved staff communication
- Enhanced guest services and amenities
- Increased guest satisfaction

The Mandarin Oriental, New York, Increases Guest Safety and Amenities with its Wireless Infrastructure

Background: The 2.8-million-square-foot Time Warner Center houses the Mandarin Oriental, New York. The 5-star hotel occupies the top 20 floors of the Center's two towers and includes 251 guest rooms. Whether for business or pleasure, the hotel offers many amenities including floor-to-ceiling views of Manhattan, an exclusive 14,500-square-foot spa, and a total of 7,000 square feet of meeting space that includes a spacious ballroom. The Mandarin Oriental, New York, caters to more than 225,000 guests annually. Services include twice-daily maid service and VIP check-in.

The Challenge: The Mandarin wanted to provide wireless communications to all of its guests, regardless of the purpose of their stay. The hotel's goal was to offer uninterrupted wireless service throughout the building, including in elevators, parking garages and stairwells. Additionally, to ensure the safety of their guests in the event of an emergency, the Mandarin wanted to enable first responder contact with seamless two-way radio communication.

However, the materials used to construct large structures like the Time Warner Center and Mandarin Oriental can distort radio frequency (RF) signals and interrupt wireless communication, thus hindering the use of Wi-Fi, cellular phones and the radios used by first responders and security staff.

The Solution: When Dave Heckaman, regional director of IT during the hotel's construction, was charged with implementing a wireless communication infrastructure, emergency preparedness and the safety of thousands of people was his top priority. Heckaman needed a wireless system that acted as a utility capable of distributing a wide range of standard protocols seamlessly throughout the building.

To meet this need, Heckaman's team selected InnerWireless' Wireless Utility, a strategic shared wireless broadband infrastructure, which supports a full range of wireless devices and applications, including cellular/PCS, wireless PDAs, BlackBerry® devices, wireless LANs, two-way radios, pagers, and more.

InnerWireless worked closely with Heckaman and his team to design and engineer a system that would meet their needs. InnerWireless brought in experienced RF engineers to conduct a comprehensive site survey, taking into account building construction materials and coverage requirements.

InnerWireless' team of experienced project managers oversaw every aspect of the system design, procurement, installation, testing and acceptance, working closely with all involved parties to ensure a quality installation with minimum disruption to the building's construction timeline and opening.

"With the InnerWireless system operational since October 2004, the hotel staff says the benefits of having InnerWireless are immeasurable solely because of the enhanced guest safety," said Heckaman. "What began as an insurance policy against wireless communication failure soon materialized into a remarkable amenity for the Mandarin and its guests."

"What began as an insurance policy against wireless communication failure soon materialized into a remarkable amenity for the Mandarin and its guests."

Hotel operations are more efficient as guest services are enhanced by the pervasive wireless coverage. For instance, prior to check-in, a VIP guest can request that hot tea arrives in his suite shortly before he does. While the guest is checking in, the front desk can notify the member of the catering staff in charge of that room via their hotel-issued PDA, so by the time the guest reaches his room his tea is ready and waiting for his enjoyment.

The Mandarin Oriental Hotel sought to provide its guests with seamless wireless coverage for their use and, most importantly, their safety, and in the process, took a large leap forward in becoming a true 21st century facility.

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innerwireless

12 Appendix B: Acela Technologies Case Study

Grande Lakes Resort Creates a First-Class Guest Experience with Pervasive Wireless Coverage

Situated on 500 acres of premier Florida Everglades real estate, the $600 million, 4 million square foot Grande Lakes resort re-defines the Orlando experience for business and leisure travelers. The resort has built a reputation of excellence by providing all of the luxury amenities that travelers have come to expect from the Ritz-Carlton and JW Marriott brands.

Grande Lakes' executives recognized the growing importance of providing reliable wireless communications for clientele, who expect the convenience of mobility as a part of their travel experience. As they discovered, wireless connectivity was no longer a 'nice to have' service, it had become essential to maintaining the resort's competitive position as a high-end destination. "Our customers demand world-class service and amenities and we've recognized that robust wireless communications are high on their list of expectations." said Steve Contos, vice president and managing director, Grande Lakes Orlando.

Hired by the resort's executive team, Acela Technologies, a turnkey wireless infrastructure provider, determined that Grande Lakes Orlando needed wireless coverage for multiple wireless operators, devices and technologies, covering 1,500 guest rooms, the 40,000 square foot spa, poolside areas, restaurants, shops and the 18-hole championship golf course. More importantly, wireless had to work wherever guests expected it to work. Conference attendees had to stay connected during events, families wanted to communicate with each other and hotel guests paying for premium, high-speed internet access could also benefit from an always-on WLAN connection.

As another primary goal, the Grande Lakes management team wanted to avoid labor-intensive maintenance activities, as this could disturb guests and drive up operating costs. It was also important to keep exposed fixtures to a minimum in order to maintain the aesthetics and ambience. Wireless infrastructure had to blend in and go unnoticed.

Lastly, everyone agreed that the resort needed to address future wireless needs, today. Much like the hotel industry, the wireless industry is changing rapidly and the resort's executives wanted the freedom to adopt future mobile applications that could one day improve operations and maximize return on investment. Ideally, they wanted staff to have the ability to activate new wireless services anytime, without the need for re-wiring or installing new infrastructure.

Knowing the resort's critical list of requirements, Acela and the Grande Lakes executive team focused on finding a wireless solution that addressed all of the resort's current and future requirements.

The Company

The $600 million JW Marriott Ritz-Carlton Grande Lakes Orlando resort is a 4 million square foot complex housing 1,500 guest rooms, an exclusive spa, championship golf course, shops and 100,000+ square feet of meeting space.

Challenges

- Improve guest convenience by providing wireless communications anywhere on the resort
- Maintain resort 'look and feel' and avoid disturbing guests
- Seamlessly add future wireless services, anywhere and at anytime
- Generate future business with cutting-edge amenities

Benefits

- Single platform delivers multiple wireless services over a common cabled infrastructure
- Wire-it-Once™ infrastructure supports future wireless services without parallel networks and service disruptions
- All managed elements are kept in wiring closets to preserve aesthetics and optimize management

Grande Lakes Orlando

Making Wireless an Indoor State of Mind

The Solution

After thorough analysis, the Grande Lakes team selected the MobileAccess Universal Wireless Network solution. With a strong track record in large scale venues, the MobileAccess solution delivers the pervasive wireless coverage needed to address of the resort's challenges and requirements. The innovative MobileAccess Universal Wireless Network simultaneously delivers robust wireless coverage for all of the resort's wireless services, devices and applications over a common fiber/coaxial cabled infrastructure. While competing systems require parallel cabled systems to support multiple service offerings, the unified MobileAccess infrastructure supports cellular/PCS services for PDAs, laptops, mobile phones and seamlessly provides WLAN coverage that integrates with the resort's iBAHN broadband IP-based network.

With the MobileAccess solution, staff and guests can reliably use WLAN services, delivered transparently over the same cabled infrastructure used for other wireless offerings. And unlike conventional WLAN approaches, the resort can subsidize the costs of the resort's WLAN with other wireless requirements. In addition to meeting the resort's existing wireless requirements, the MobileAccess Wire-It-Once™ architecture allows IT staff to add virtually any combination of wireless services anytime, simply by adding the appropriate service module in wiring closets. With its modular architecture, the Wire-It-Once™ solution clusters all intelligent network components securely in wiring closets instead of on ceilings. This preserves the 'look and feel' of interiors, prevents disruption to existing services and keeps routine maintenance away from public areas so that guests are unaffected. The result is a future-proof network that evolves as guests' needs evolve.

Leveraging the MobileAccess Universal Wireless Network as the foundation of its communications infrastructure, Grande Lakes Orlando resort not only met its short-term goals but can continue to meet guests' future demands, keeping its competitive advantage as a first-class Florida destination.

"Whether they're traveling for business or pleasure, guests want to stay connected to their families, friends, clients and colleagues. With our state-of-the-art wireless network, our guests will be able to do just that anywhere at the resort."

Steve Contos,
Vice President and Managing Director,
Grande Lakes Orlando

About MobileAccess

MobileAccess Networks is an enterprise wireless innovator that provides a universal platform for connecting the people and applications that drive business. The company's intelligent, in-building infrastructure solution is the key to mainstream wireless connectivity in hospitals, office buildings, public venues and other large-scale facilities. The MobileAccess Universal Wireless Network delivers business-quality performance, scalability, security and signal reliability to more than 1000 customers, including Aladdin Resort and Casino, ALLTEL Stadium, American University, Clarian Health Partners, Hearst Corporation, Lehman Brothers, Northwestern Memorial Hospital, Oakland International Airport, SeaMobile and The Homer Building. For more information, visit www.mobileaccess.com.

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13 Appendix C: Sprint/ Nextel Case Study

Nextel® Choices

Hospitality/Entertainment Solution

NEXTEL IN-BUILDING SOLUTION BY SPRINT FOR ATLANTIC CITY HOTEL

As the only "super casino" in Atlantic City and the largest hotel in New Jersey, Borgata Hotel Casino and Spa's staff has to manage and maintain 2,000 guest rooms and suites, 125,000 square feet of gaming, 11 restaurants, 11 retail boutiques, a relaxation spa and 70,000 square feet of event space for hosting conventions, trade shows and concerts.

To create a nimble operation that can quickly attend to any number of daily challenges, Borgata made the strategic decision to outfit their staff with a singular communication device that handles all of their needs.

"Our relationship with Nextel goes back several years to the construction phase of the property," explained David Farlin, vice president of information technology at Borgata Hotel and Spa. "We used Nextel Walkie-Talkie, and while the project grew, we realized the need to expand the relationship in order to address what would become our in-house communications system."

Since Borgata is partly owned by the MGM MIRAGE where the Nextel Custom Network Solutions (CNS) group at Sprint has delivered a custom wireless digital voice and data network to all five of their Las Vegas properties, Farlin was able to interview their executive staff and get feedback on the Nextel Solutions implementation.

"I was able to get answers to questions regarding reliability and downtime, and then made the decision to go with Nextel to build our in-house communications system. One area that became a great selling point for us in terms of luring convention business, is the fact that the multi-carrier system that Nextel provides allows the casino to handle traffic for any wireless carrier," explained Farlin.

A crucial element in Borgata's communication system is the ability to set rules based on custom data applications. For example, when someone hits a jackpot on a slot machine, an alert is sent directly to the handset of a slot technician who is then able to look up the code, based on over 1,000 different combinations, and know exactly which slot machine needs a payout and for how much money.

> Situation:

Largest hotel in Atlantic City needed heightened wireless coverage and integrated devices to increase productivity of hotel and casino operations.

> Solution:

System designed and built that handles traffic for any wireless carrier along with handsets and devices running custom-made data applications.

> Success:

Reduction in communication devices needed for each employee, ubiquitous coverage throughout hotel to better serve guests and improve customer service.

NEXTEL® from Sprint

Nextel® Choices

Not only does this maximize the uptime for the slot machine, it helps enhance the overall customer experience because the slot technicians can respond to the winning machines in a matter of minutes.

"What's more, we need to have a redundant communication system for our slot operations with radio devices that serve as a backup in case of an outage on the Nextel network. To date, we have not had to use the emergency radios, which speaks for itself," Farlin added.

"From housekeeping to food and beverage to maintenance, we are using a variety of Nextel devices," remarked Farlin. "Whether it is the ruggedized handsets that we used during the construction phase or our IT and marketing staff increasing their accessibility and productivity due to the Nextel BlackBerry 7510, we have been able to continue to deliver our high standards of customer service to our guests. In addition, our VP of Food & Beverage is experimenting with ways that a cell phone with a built-in camera can assist in our daily operations."

> "From housekeeping to food and beverage to maintenance, we are using a variety of Nextel devices... to continue to deliver our high standards of customer service to our guests"
>
> – David Farlin, vice president of information technology, Borgata Hotel and Spa

Another advantage Nextel solutions offer to Borgata is in the area of security, a critical component of any casino operation. "We are evaluating how the i810 camera phone could aid in our on-going assessment of our security system, as well as the possibility of going with a total Nextel solution in the future," Farlin said.

By choosing Nextel as its wireless provider, Borgata has been able to avoid the costs of separate cell phones, pagers, PDAs and two-way radios for their staff. "Prior to opening, we had to decide if we would purchase an in-house radio solution. Prevailing wisdom in our industry nearly mandated one as part of the communications infrastructure. Had we purchased the radio-only system we would then need to additionally layer on a cellular contract and a pager contract. That meant that an employee would conceivably wear three devices, which is something we wanted to avoid if at all possible," Farlin explained.

He went on to say that, "For approximately the same cost as a radio-only system, we engaged Nextel to deliver an in-house system that supports radio, cellular phones and BlackBerry devices. We no longer needed three contracts to achieve all three objectives (cell, radio, and messaging). The ROI for Nextel was easy at that point. We got all three systems/contracts for the price we would have normally paid for just one."

For more information visit us at sprint.com/cns.

Contact
Rep
Email
Phone
Etc.

NEXTEL from Sprint

14 Appendix D: MobileAccess Case Study

mobileaccess

Making Wireless an Indoor State of Mind

Peppermill Hotel Casino

Luxury Casino Raises the Bar with Wireless Connectivity

Located in the heart of Reno's newly-built retail, entertainment and restaurant district, Peppermill Hotel Casino is a premier property, featuring over 1,100 guest rooms, 14 themed bars and lounges, 8 restaurants, and multiple gaming venues. With its array of world-class guest services, the casino is ranked as one of the "Top Ten Casinos in America" by MSN Citysearch.

As a world-class facility with all of the modern luxuries that guests have come to expect, wireless access was more than a 'nice to have' for Peppermill Hotel Casino. Casino executives understood that wireless voice and data connectivity were essential for enhancing the overall experience of their guests and for boosting the efficiency of their internal security and operations teams.

Toward that end, Peppermill sought a wireless coverage solution for delivering WLAN and cellular phone services from multiple operators, including Cingular, Sprint and Verizon Wireless, throughout its 860,000 square foot complex. The solution needed to meld seamlessly with Cisco WLAN equipment and provide reliable support for SpectraLink Voice over WLAN (VoWLAN) telephony services.

With plans for a 560,000 square foot high-rise addition on the table, Casino decision-makers were determined to find a scalable wireless architecture that could cost-effectively expand to cover the new space without disturbing or re-engineering the initial deployment. Along those same lines, the Casino recognized the need for a flexible solution that would allow them to activate new wireless services at any time without disrupting hotel operations or compromising their guests' experience.

The Solution

Peppermill Hotel Casino selected the MobileAccess Universal Wireless Network for its superior ability to support all of the Casino's required wireless services over a single, highly flexible network infrastructure. With its unique Wire-It-Once™ architecture, the MobileAccess solution was a much more cost-effective approach than parallel networking alternatives in which separate cabling systems must be deployed for each individual wireless service.

The Company

Reno, Nevada hotel and casino complex housing over 860,000 square feet of gaming venues, restaurants, luxury hotel rooms, lounges and spa facilities.

Challenges

- Provide reliable wireless coverage throughout the facility for guest convenience and staff productivity
- Must expand cost-effectively to include a planned 570,000 square foot addition
- The wireless solution must be aesthetically pleasing and non-disruptive to the guests' experience

Benefits

- Single infrastructure cost-effectively delivers WLAN and cellular services from multiple operators
- Modular architecture gracefully expands to new coverage areas and accommodates new wireless services without disruption
- All managed elements are located in secure telecom closets; system adjustments occur out of public view

Peppermill Hotel Casino

Making Wireless an Indoor State of Mind

The MobileAccess solution is highly adaptive, which enables Peppermill to seamlessly add new wireless services to the system simply by adding new modules to the existing deployment. With this flexibility, the Peppermill Hotel Casino can easily take advantage of emerging wireless technologies, applications and services in the future, without the need for forklift upgrades, parallel networks or costly overhauls. In addition, the MobileAccess solution houses all managed components in telecom closets, satisfying Peppermill's desire for a secure and aesthetically pleasing wireless platform. Moreover, this approach keeps the operation of the wireless infrastructure hidden from guest view; Peppermill can add new wireless services at any time without disturbing the ceilings and walls of public spaces.

"We are committed to providing our guests with the highest level of luxury and convenience. Central to this mission is ensuring they can use the latest wireless technology as easily and reliably inside our world-class facility as they have come to expect outside," said Bill Hughes, Director of Marketing Operations at Peppermill Hotel Casino. "The Universal Wireless Network allows us to enhance our guests' experience by offering seamless access to wireless voice and data services and, by improving our own internal communications, it enables our staff to offer the highest level of service and security."

Not only did Peppermill Hotel Casino meet its short-term connectivity goals by selecting the MobileAccess solution, the casino also gained a long-term competitive advantage and status as a world-class destination.

"The Universal Wireless Network allows us to enhance our guests' experience by offering seamless access to wireless voice and data services and, by improving our own internal communications, it enables our staff to offer the highest level of service and security."

Bill Hughes, Director of Marketing Operations, Peppermill Hotel Casino

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Cisco Compatible

The MobileAccess MA-850 WLAN Module has tested compatible with the Cisco Unified Wireless LAN Solution