IHS TECHNOLOGY WHITE PAPER

How Key DAS Innovation Cuts Total Cost of Ownership

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13 May 2016

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Introduction

Large mobile operators such as AT&T Mobility and Verizon Wireless have been using distributed antenna systems (DAS) for the past two decades to improve network coverage in venues where the traditional macrocell approach does not work. In recent years, driven by a major telecom restructuring in 2008, China rose quickly to significance and became the world's second-largest DAS market after the US. As mobile networks have migrated from 2G to 3G and 4G, DAS architectures have evolved from passive to active, in which repeaters are replaced with low power remote radio heads connected to the DAS hub and capacity is added to handle the new demands of mobile smart phones.

However, the unabated smartphone-generated traffic growth experienced at major events such as the Super Bowl and the FIFA World Cup keeps mobile operators and venue owners busy with major network upgrades to stay ahead of the curve. Alternatives to offload traffic from the cellular network—such as WiFi, and more recently, small cells that densify existing macrocell networks—have been threatening the well-established DAS option, pushing major DAS players to innovate and find new ways to stay competitive. As cost is always the decisive factor, this paper proposes a framework that starts from a tactical analysis of the total cost of DAS ownership, and addresses the most significant cost points through innovative DAS designs and features.

TCO Reduction Starts with Tactical DAS Capex and Opex Analysis

By definition, the total cost of ownership (TCO) of a system is a financial estimate aimed at helping the owner determine all costs associated with the system, direct and indirect. Applied to DAS, the TCO is the sum of the capital and operational expenditures detailed in Exhibit 1. Capital expenditures are funds used by the company to either acquire or upgrade a DAS system; operational expenditures represent the cost of running the DAS system.

Exhibit 1 DAS Total Cost of Ownership Structure

Capital Expenditures	Operational Expenditures
Site acquisition cost	Operation & maintenance
Site footprint reduction	Utility fees (e.g., electricity)
Cooling/HVAC equipment	Site lease
Power equipment	Fiber lease
Cable/fiber infrastructure	IP Backhaul
Civil work/construction	
Deployment/commissioning	

Source: IHS

Optimizing DAS Equipment Installation Time and Cost and Minimizing Footprint Can Significantly Decrease Capex

Capital expenditures required to install a new DAS are the first thing the owner is exposed to, typically during an extensive review of many vendor proposals sent through a competitive bidding process. Every product or system feature that optimizes the DAS equipment footprint and speeds up the installation has been shown to dramatically decrease the bill. Exhibit 2 illustrates the key potential areas a DAS vendor can address to decrease capex.

Exhibit 2 Capital Expenditures as a Function of Potential Product/System Features

Capital Expenditures	Installation Time & Cost	Equipment Footprint	Alternate Deployment Models
Site acquisition cost	✓	✓	✓
Site footprint reduction	✓	✓	✓
Cooling/HVAC equipment			✓
Power equipment			✓
Cable/fiber infrastructure	✓	✓	✓
Civil work/construction	✓	✓	✓
Deployment/commissioning	✓		

Source: IHS

Five Features that Optimize DAS Installation Time and Cost

A DAS platform addresses critical cost and time-consuming areas if it is designed with five key embedded capabilities that streamline the time and cost to install the system by automating the process or removing the manual process entirely. These critical areas include installation of physical equipment and cabling infrastructure, system identification, configuration, and commissioning. The five features are:

- **System discovery tool:** The supervisory intelligence provides automated identity of system elements, including all modules within master unit sub racks and remote units (RUs). As a result, a typical system in a venue can be discovered within a few minutes, allowing engineers to move more swiftly through the commissioning process.

- **Automatic gain control:** With an optical loss compensation with up to 10dB of optical link budget, this feature automatically measures and calibrates for link losses without the need for additional equipment, manual measurement, and time-consuming tuning of the link within a venue.

- **One-click close-out package:** This feature rolls up and saves a complete configuration of the system, which saves a significant amount of time documenting system configuration, streamlines venue expansions, and eliminates manual configuration tracking.

- **Integrated and intelligent DAS tray and POI:** This is an integrated intelligent base station to the DAS master unit interface that uses a common sub-rack, is managed as a single system, enables remote optimization of the site parameters, and provides alarming for base station failures. Its small footprint can reduce rack mounting requirements and the amount of related manpower.

- **True remote unit (RU) power level detection:** Rather than being estimated, the actual power level is measured at the RU to assure the accuracy of RU power levels to within +/- 1.5 dB without the need for engineers to perform the test at the RU location.

The Smaller the DAS Footprint, the Lower the Cost; Specific Attributes Will Achieve that Goal

The premium on equipment that consumes more space is high and can have a direct impact on the costs to host and install the DAS system. Key attributes that can significantly reduce the footprint requirements of the equipment and provide flexibility for carriers to more easily adapt to change include:

- **Single common sub-rack for multiple head-end services:** A sub-rack that uses a common shelf for DAS tray, POI, combining, supervision, and fiber RF multiplexing minimizes the system footprint in head-end locations. This eliminates third-party trays and can save 30% to 70% of critical space requirements within venues, BTS hotels, and colocation environments.

- **Integrated POI DAS tray:** Already mentioned in the previous section, an integrated and intelligent DAS tray and POI is optimized for physical space requirements and reduces footprint by 60% to 70%.

- **Optional donor front-head:** This option to drive the optical DAS without the need for dedicated BTS/NodeB/eNodeB is integral to the master unit to eliminate the need for external repeaters and provides methods for service continuity and pre-BTS testing for public safety bands or other non- critical capacity bands.

- **Low and high power in a single optical transceiver:** Multiple power classes, for up to six bands, can be combined in a single transceiver, including 31, 36, 40, 43, and 46 dBm per frequency band. This is accomplished by leveraging common optical transceivers and master units configured for mixed high power and low power configurations, entirely managed as a single system. This eliminates the need for parallel head-ends for different power needs in a facility.

- **Multi-band, single-fiber RUs:** Up to six bands to the RUs over a single fiber can reduce the fiber requirement compared with digital. Dual RUs support 2x2 MIMO by using two fiber strands versus six strands.

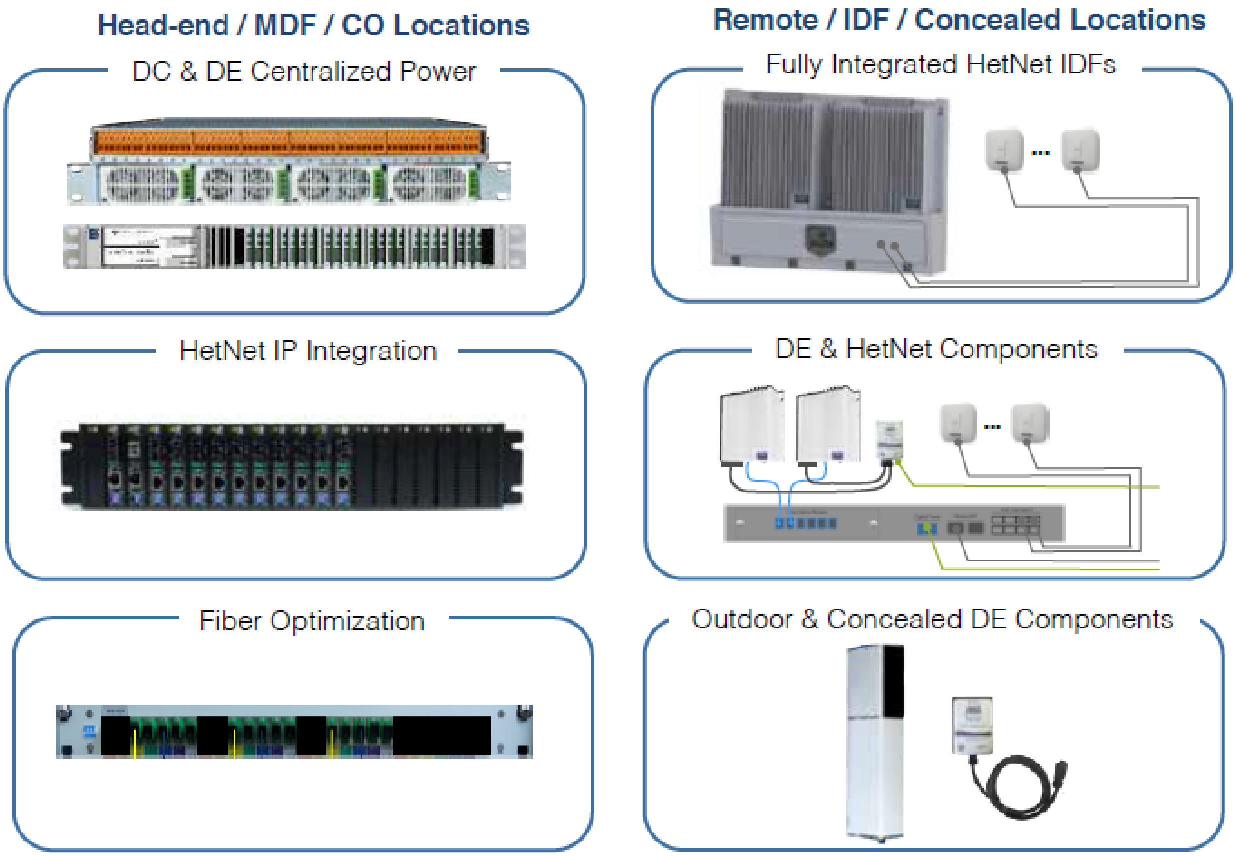
Lastly, Streamlining the Overall DAS Installation with a Modular Approach Is the Ultimate Goal

A typical installation of DAS equipment within a building's IDFs (intermediate distribution frames) or TRs (technical rooms) requires significant consideration, cost, and manpower for mounting the equipment (often to a wall or a makeshift back plate), powering the equipment (typically AC but also DC), and distributing and arranging the coaxial cables for antennas and fiber optic cables, including fiber splicing at each location.

The everyday life of DAS installation shows that integrators generally source multiple components and create their own cabling and mounting options, often different from one venue to another. The best way to streamline this installation and mounting process is to conceive a modular system that provides a range of options that cut dependencies on third-party electrical contractors and minimize the number of individual components.

For example, JMA Wireless has developed a set of modules named FUZE, which is illustrated in Exhibit 3. FUZE provides several options at the head end (e.g., MDF) and the remote end (e.g., IDF) that optimize deployments. They allow the use of AC, DC, or newer DE (digital electricity), provide for optimization (multiplexing) of fiber optics, are optimized to leverage composite fiber (fiber and copper), and provide the integration of wireless access point (WAP) transport and powering in the deployments across the same core infrastructure.

Exhibit 3 Modular System Approach Named FUZE



Source: JMA Wireless

As WiFi is ubiquitous in every in-building venue, the fully integrated HetNet IDF module plays an important role of providing a clean, simple, professional-grade mounting unit that secures all cabling and fundamentally lowers deployment costs with the following attributes:

- Flexible integration of power choices: AC, DC, or digital electricity that provides power up to 1 mile
- Integral fiber splice that eliminates external boxes
- Add-on internal modules to provide POE + service to carrier WiFi access points
- Composite fiber cable with single pull that minimizes capital
- Use of Category 5 or 6 wire infrastructure for power delivery
- All cabling contained and secured with locking cabinet

But Alternate Deployment Models Such as C-DAS Lower Capex and Opex Substantially

As depicted in Exhibit 5, the alternate DAS deployment model known as centralized DAS (C-DAS) is the option that addresses the highest number of capex points; in fact, everything but cooling and powering the equipment. Exhibit 4 shows that this alternate DAS model can also address key opex issues. In addition, as seen in the previous capex section, it does not come as a surprise that a small equipment footprint has a direct impact on the size needed for the site: the smaller the equipment the lower the cost works for capex and opex.

Exhibit 4 Operational Expenditures as a Function of Potential Product/System Features

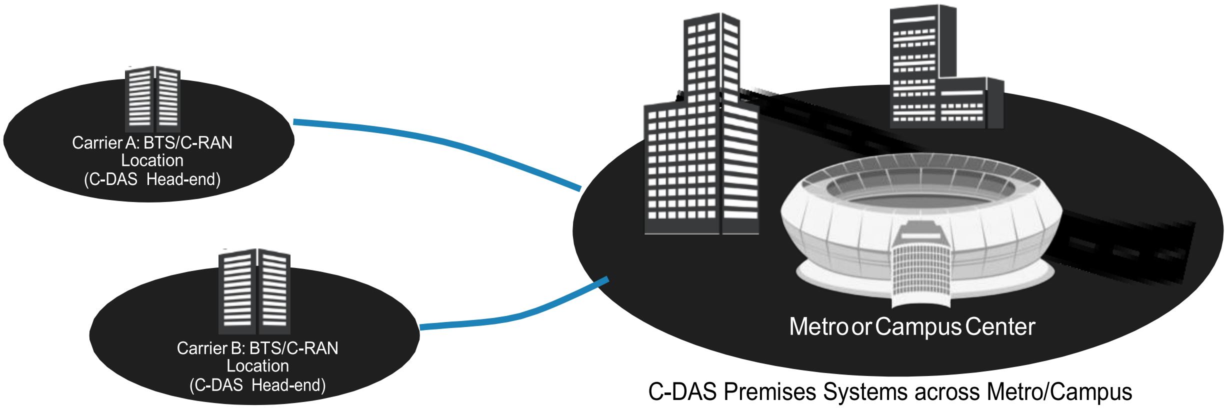
Operational Expenditures	High Signal Quality	Equipment Footprint	Operations & Maintenance Tools	Alternate Deployment Models
Operations & maintenance	✓		✓	
Utility fees (e.g., electricity)				✓
Site lease		✓		✓
Fiber lease				✓

Source: IHS

C-DAS Is the Multi-Carrier, Multi-Band In-Building C-RAN

In a centralized RAN architecture, the BTS (base transceiver station) is decomposed and baseband units (BBUs) are grouped in a hotel at a single central location from which fiber connects all the remote radio heads. C-RAN is mainly used in dense urban areas where many BTSs are needed to provide outdoor coverage and capacity. In a C-DAS architecture, cellular signals from different mobile operators are collected from nearby BTSs or BBUs, attenuated, and combined in a DAS hub installed in a single adequate location. From that single central location, the DAS will send the signals to the buildings they need to go. Exhibit 5 illustrates a C-DAS in a metro environment.

Exhibit 5 Centralized DAS



Source: JMA Wireless

C-DAS enables independent carrier RAN sites to be used, and converges each carrier's bands at the venue to enable multi-carrier, multi-band services at the site. This approach leverages the C-RAN architecture to service delivery for in-building and complex signal delivery areas while reducing the cost of front-haul fiber required to deliver service, and it cuts the footprint on-premises significantly over traditional on-site or off-site BTS hotels.

The chief cost benefits of C-DAS include:

- **Site costs:** The convergence of multiple carriers from their independent RAN serving locations at the venue premises means no additional site equipment needs to be deployed to enable a multi-carrier coverage solution. This preserves the capital costs associated with additional RRHs (remote radio heads).

- **Fiber costs:** Fiber optic lease for fronthaul can be significantly reduced. For example, a typical 30-sector 5-band site that requires RRHs can require upwards of 300 fiber strands. By using an optimized platform for site distribution of these bands, the fiber can be reduced by as much as a factor of 10.

- **System costs:** C-DAS can start with one carrier but can support several on the same platform. Multi-carrier deployments with C-DAS (where one carrier is the lead) allow the additional carriers and associated costs to be easily isolated to that carrier. This includes all head-end (BTS and C-DAS master) site acquisition and related powering and cooling. In addition, since the secondary carrier bands are converged at the customer site, all additional fiber fronthaul capex and ongoing opex can be isolated.

DAS vendor JMA Wireless has designed a specific C-DAS platform that enables flexible configurations to allow carriers to optimize delivery of wireless coverage and capacity from their independent centralized locations, minimizing costs and maximizing the ability to deliver multi-carrier, multi-band service with a minimized venue footprint. Exhibit 6 shows the key C-DAS platform attributes.

Exhibit 6 JMA Wireless C-DAS Attributes

Attributes	Description	Key Benefits
Capacity management switch card options	Selective redirection of sectors to optimize coverage	Reduces the BTS, DAS tray, and overall RF path requirements by up to 25% when applied across a facility or two venues
Multi-carrier convergence at venues	Multi-site, multi-carrier C-RANs to be converged at the venue	Enables a neutral hosting approach without additional on-premises equipment; key is delivering this architecture without spoiling the system performance (NF) and supporting all RU types
DWDM	Passive wavelength multiplexing	Converges multiple RF paths into a small number of fibers to reduce costs of metro fiber leases
Point-to-point fiber links	Slave-mode master unit connected over WDM fiber, up to 4 sectors per fiber	Allows multi-band services to be delivered across distributed venues (up to 12 miles apart) and managed as a single system while optimizing fiber needs

Source: IHS

C-DAS Delivers Sound Economics

To help understand the economic merits of using C-DAS architecture, the following two scenarios contrast costs and illustrate savings by using some basic assumptions.

First Scenario: C-DAS as an Alternative to In-Building RRHs

C-DAS enables multi-carrier venues with a lower cost per carrier, an in-venue footprint reduction, and venue readiness that either reduces or fully eliminates venue disruption during carrier add-ons, and a savings on fronthaul fiber compared with in-venue RRHs. The following analysis illustrates just the savings for fronthaul fiber:

<u>Simple assumptions</u>

- Enterprise facility: 10 sectors, 5 bands (no MIMO)
- Approximate fiber distance to C-RAN = 5 miles

<u>C-RAN-RRH costs</u>

- 5 RRHs per sector (per band), two-strand fiber per RRH—backhaul to C-RAN site
- 10 strands/sector * 10 sectors = 100 CPRI fiber runs to C-RAN
- Est $200 fiber term fee/month/strand = $20,000 per month ($240K/year)

Note: A $25/month/mile/strand rate lowers this to about $150K/year.

<u>C-RAN-C-DAS with Teko P2P costs</u>

- 1 Remote Unit per sector (supports all bands, multiple carriers)
- C-DAS head-end (slave) in-venue for RU fiber distribution (OTRX)
- 10 fronthaul fiber strands cover all 10 sectors, all bands (***no DWDM required***)
- Est $200 fiber term fee/month/strand = $2,000 ($24k/year)

Note: A $25/month/mile/strand rate lowers this to about $15K/year.

<u>C-DAS estimated savings on fronthaul fiber</u>

- $216K/year (or $135K/year at lower rate)
- 10-year savings range: $1.25M to $2.16M

Second Scenario: C-DAS versus In-Venue BTS Hotel + DAS

C-DAS deployments have proven to reduce the in-venue footprint required by 80% to 95%. This also reduces site acquisition costs, site leasing, reduces or eliminates civil buildout, battery plant, and HVAC requirements. The following analysis illustrates the estimated savings by using existing mobile switching facilities, CO, or extending a pre-existing BTS hotel and servicing the venue via C-DAS.

Site assumptions

- Sports facility: 15 sectors, all bands, single carrier
- BTS physical space = 1,000 sq. ft. total (BTS, battery, AC)
- BTS and DAS equipment capital cost assumed to be equal

BTS hotel in-venue cost assumptions

- Capital costs:
  - Site acq/prep costs: $250K
  - HVAC & battery plant capital: $550K
  - Service aggregation equipment: $250K
- Opex costs:
  - Site lease: $300K/year (based on $25/sq ft/month)
  - Backhaul circuits: $50K/year (est. for 10Gbps core backhaul) C-DAS

C-DAS in-venue costs

- Capital costs:
  - C-DAS point-to-point fiber equip $75K
  - Additional Teko gear $25K
  - C-DAS point-to point at C-RAN site $75K
  - C-RAN/BTS equip expansion: $300K (SAR, battery, etc., assumption)
- Opex costs:
  - Fronthaul fiber lease $36K/year (based on 15 strands @$200/month)

Estimated cost savings

- Capital savings: $575K
- Opex savings: $3.14M (based on 10-year period)

Then, High Signal Quality and Operation and Maintenance Tools Will Contribute to Lower Opex

Each single DAS installation has very strict requirements to ensure the highest RF signal quality to mobile devices by providing ultra-reliable fast speed connections. This requires specific focus on the quality of the RF signal with the development and implementation of some innovative features that need to be thought of and engineered in the planning stage. Put another way, the lack of RF signal features from day one can lead to significant operating cost over time; they include:

- **High peak-to-average amplifier ratio**: Peak-to-average amplifier ratio of 9dB for high power and 12dB for low power for high capacity modulation maintains excellent EVM performance and high throughput to ensure LTE and UMTS performance and sector utilization efficiency.

- **Software configurable digital attenuation:** Adjustable remote unit IIP3/NF with variable15dB UL minimizes signal to noise ratios, increases resiliency to interference and near-far scenarios, and increases data performance.

- **High isolation output combiner:** 83/93dB output combiner isolation assures negligible IMD levels and lowers interference and noise in UL bands for multi- operator scenarios; it also increases data throughput and assists in markets with UL frequency sub-bands.

- **Extremely low EVM:** EVM across remote units typically below 1% maximizes the modulation scheme across the venue to ensure the maximum throughput for mobile users’ devices.

- **True 40 Watt high power remote:** 4-band, 40W remote with 9.6 PAR delivers true power to each band, providing up to 390W per band of peak power.

- **High linearity power amplifiers:** In-house feed-forward and DPD amplifier designs are critical to maximizing DAS performance; they minimize amplifier footprint while providing best-in-class digital pre-distortion (DPD) and they allow control of minimizing IMD.

Powerful Operation and Maintenance Tools Make a Big Impact

Applying manpower to operate and maintain an in-venue wireless system can be costly for carriers. Moreover, it is seen as intrusive for end-customers who prefer not to have technical personnel on their premises. There is a strong advantage for a DAS vendor able to design its equipment with a level of autonomic response capabilities to ensure venue performance while alerting O&M engineers of a variance they can act on remotely.

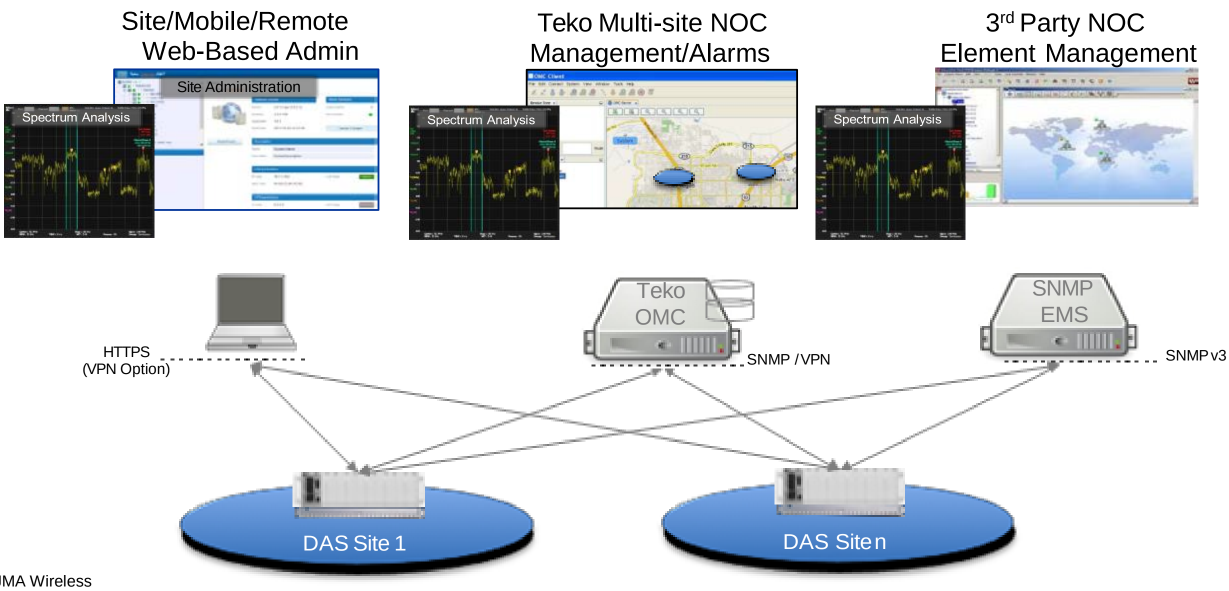
As commonly seen in real life, new in-venue system issues may not arise until the venue is actually in use. Facilities often have different use considerations, such as a stadium or arena used for sports and concerts. There is a need for the ability to adapt the system to these different uses easily, typically as part of a calendar of events.

Highlights of integral capabilities that provide powerful O&M tools include the following:

- **Active/managed BTS point of interface (POI):** This automatic power limiting feature equipped with alerts and remote administration automatically monitors operator input power, and with alarms it attenuates the power to maintain RF coverage and balance across multiple POI inputs.
- **Event specific configuration:** This feature schedules the application of different configurations to change coverage on a per-event basis and remotely adapts use of the DAS in multi-use venues that have different coverage needs based on the events or to achieve power savings when the venue is not in use.
- **Multi-band spectrum analyzer:** Remote spectrum analysis or recording for noise levels, interference, PIM analysis, etc., for up to five bands on a single port enables field teams to remotely analyze performance or initiate recording to capture system performance. This feature can be applied without adding couplers for each RF path.
- **Remote administration and monitoring:** Single-point Web-based administration with SSL security for access with PCs or tablets enables field teams to easily access venues from remote locations, saving on costs and response time.
- **Integrated monitoring ports:** Monitoring ports for master unit TAPOI, OTRX, and remote units enables easy troubleshooting, maintenance, and monitoring without affecting operational (live) system.

Illustrated in Exhibit 7, the system architecture includes several options that integrate with a carrier's administration practices and policies to streamline site administration. The system enables administration via standard SNMP v3 to allow integration with third-party EMS. The Teko Operations and Management Center (OMC) provides a secure administration center for multiple sites, while the integrated Operations and Management Terminal (OMT) is accessible via secure (SSL) web browsers to enable quick access to sites to address alerts from virtually anywhere.

Exhibit 7 Multi-level Administration System Tools and EMS Support



Source: JMA Wireless

Each site converges access to administration of the entire system via a single supervisory module. To secure information, this module is armed with security, virtual private network, and firewall protocols, protecting access to the system. The supervisory module hosts an integral secure (SSL) web administration tool for the system, along with web-based access to the system's multi-band spectrum analyzers when used.

All SNMP MIB (management information base) files are readily available for mapping into a third-party element management system.

And Finally, for Enterprise Applications, Femto/Microcells Can Certainly Bring a Compelling Low Cost Variation to DAS

As in-building systems need low power RF signals, an enterprise femtocell or even microcell can interconnect with the IP network and be used as the RF source for the DAS. This results in a much more flexible and cost effective architecture. Those types of enterprise-specific cells can support multiple bands and multiple carriers, which easily can be mixed and matched. In other words, there is no need for a separate network for each band and carrier as is required with more traditional small cell implementations proposed by RAN and small cell specialist vendors.

Enterprise femtocells and microcells can easily address coverage and capacity as needed. For example, office buildings may require more capacity due to the number of employees, and accompanying parking garages may need less of it. By using the DAS platform, coverage is enabled by providing low power RF input or POI in the master unit to feed out of the antenna ports of the enterprise femto/microcell and into the DAS system. And as they are fully integrated in the DAS system, those small cells do not require any dedicated backhaul and become part of the entire enterprise IT environment. In addition, fewer nodes have to be managed with the DAS system than in a traditional small cell architecture.

The flexible platform allows different styles of antennas to be used to address RF needs and can be used to distribute SISO or MIMO implementations. Simulations as well as real life experience suggest the cost per square foot runs around $0.40 for a smaller facility (50K) and gradually decreases as the number of square feet increases. Initial price comparisons indicate this is very competitive, and even lower in price, compared to enterprise small cell solutions such as Ericsson Radio Dot and SpiderCloud when an apples-to-apples solution is compared. When you add the benefits of the DAS flexibility and even more when you add a second mobile operator to the venue, the gap in the cost widens significantly in favor of using DAS technology for enterprises.

Conclusion

This technology paper shows that DAS innovation can substantially address major cost points in capex and opex and ultimately lead to a lower TCO.

A tactical analysis shows that by focusing first on the highest cost areas such as site acquisition, site footprint, cooling/HVAC equipment, power equipment, cable/fiber infrastructure, and civil work/construction, capital expenditures can be substantially reduced through a design that minimizes footprint. This design also includes the implementation of innovative features such as system discovery tools, automatic gain control, one click-close-out package, integrated and intelligent DAS tray and POI, and true remote unit power level detection. In addition, this paper proposes a modular approach to streamline the DAS installation, which in turn cuts another cost point.

Nonetheless, the implementation of an alternative DAS architecture, known as C-DAS, lowers capital and operational expenditures simultaneously because it minimizes site, fiber, and system costs. This paper discusses two scenarios that deliver sound economics: C-DAS as an alternative to in-building RRH and C-DAS versus in-venue BTS hotel + DAS.

Finally, ensuring high signal quality and deploying powerful operation and maintenance tools provide the final touch to lower operational expenditures. In addition, using ad hoc enterprise femto/microcells as the DAS RF generates incremental cost savings. Consequently, the total cost of ownership of the in-building DAS system is minimized.

Commissioned by JMA Wireless to educate the wireless industry about DAS economics, this paper was written autonomously by analyst Stéphane Téral based on IHS's independent mobile infrastructure, small cell, and DAS research.

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