SMALL CELLS AND DISTRIBUTED ANTENNA SYSTEMS

STRATEGIC WHITE PAPER

Distributed antenna systems (DAS) often provide wireless coverage in areas experiencing poor signal strength; for example, tunnels, large venues, and shopping malls. Similarly, small cells have also initially targeted weak coverage areas. While they both seem to target the same applications, there can be significant architecture and design differences between them depending upon the situation being addressed.

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AN INTRODUCTION TO DAS

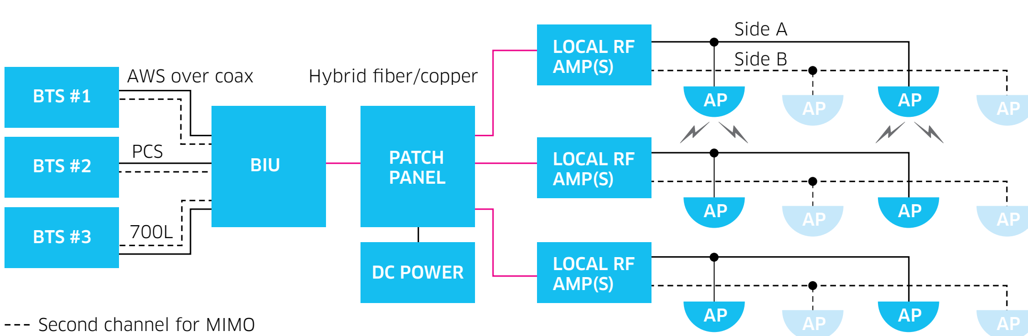
Most DAS systems act as an extension of the baseband transceiver station (BTS) and represent one or more wireless cell site sectors. Usually connected to one or more radio frequency (RF) transceiver(s), they appear as one or more remote antennas to the BTS. Through use of multiple access points (APs) they can provide a very widespread footprint, covering high rises, stadiums, or irregular-shaped buildings. Used in conjunction with radiating cable (also known as "leaky coax"), DAS can be operated to provide tunnel coverage very effectively.

The three primary elements of DAS are the baseband interface unit (BIU – a combination broadband RF amplifier and fiber optic transponder), the in-building wiring system (usually hybrid fiber/copper connecting the BIU to the access points through a patch panel to apply power), and the broadband wireless access points. Because they are designed to be "mobile provider agnostic," DAS is often utilized to satisfy the coverage needs of multiple operators; for example, enabling transmission of 800 MHz, advanced wireless service (AWS), or personal communications service (PCS) signals simultaneously in support of what is referred to as "neutral host" operation.

As with any RF system, placement of DAS usually starts with an RF analysis and design, along with a set of expected characteristics as to performance outcome. For example, the expected performance might be received signal strength of -75 dBm across 85 percent of the coverage area. Naturally, final measurements and tuning are required to validate the design and optimize performance.

While most existing DAS installations are configured to accommodate single input/single output (SISO) connectivity, it is also possible to accommodate multiple-input multiple-output (MIMO) operation for Long Term Evolution (LTE) by using a second RF feed and interleaving access points along a transmission line or collocating parallel systems. This action is illustrated in Figure 1 as "Side B."

Figure 1. Distributed antenna systems



DAS configurations

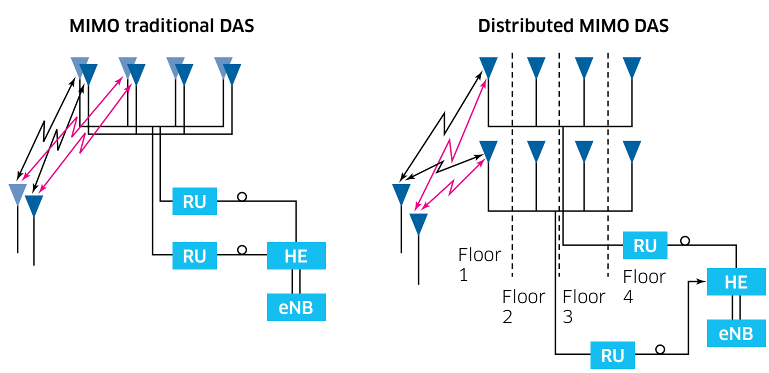
For indoor MIMO DAS it is sensible to divide the range of venues into line of sight (LOS) and non-LOS applications. A LOS venue might be a large football stadium or basketball arena while a non-LOS venue would likely be an office building or a shopping mall. In a LOS venue, there are at least two options for deploying a DAS. If a 2x2 system will provide acceptable capacity improvements, and cross polarized antennas are available at the DAS node as well as at the mobile, then a dual polarization MIMO DAS should provide a twofold improvement in capacity. If dual polarization antennas are not an option, then it is possible to sectorize the venue and achieve gains that scale with the fractional increase in the number of sectors.

To support MIMO using passive DAS, two parallel subsystems/layers need to be installed, and a minimum of 3-5 feet of separation must be deployed between the two sets of interior antenna arrays to gain maximum efficiencies for MIMO technology. This said, deployment of MIMO with active DAS will be noticeably different, as the RF amplifiers are local to the antennas. Configuration of MIMO with active DAS will vary by manufacturer.

Signal to interference plus noise ratio (SINR) is arguably the most important variable in designing a MIMO DAS network (this assumes the RF scattering environment is sufficiently rich). A high SINR supports higher modulation rates and it improves MIMO gains. In non-LOS venues, MIMO DAS can take several topological forms.

Figure 2 illustrates that a 2x2 MIMO DAS deployment can require much more infrastructure as a SISO system, but this again varies significantly by DAS design (for example, active versus passive, or how the RF/antenna distribution is designed using active DAS).

Figure 2. Typical MIMO configurations in non-LOS applications using passive DAS



It is anticipated that future DAS equipment will begin to represent an amalgam of existing DAS and small cells, bringing with it some of the small cells attributes discussed below. In particular, manufacturers all agree that significant savings could be attained by reducing the equipment required at the head end, further minimizing distribution costs through use of Ethernet, and lowering the backhaul costs as much as possible.

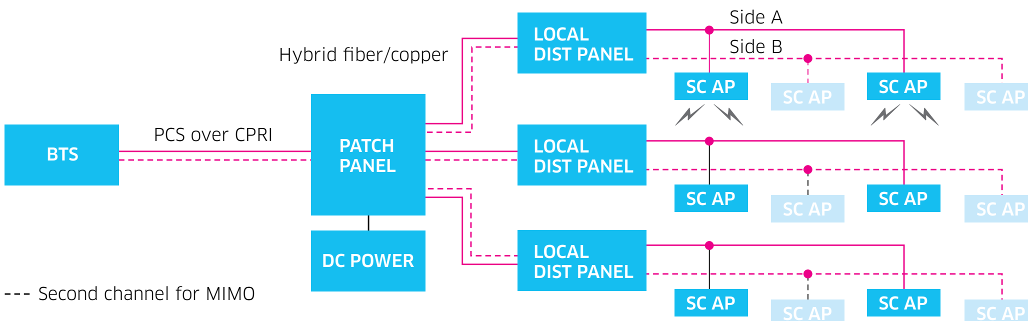
AN INTRODUCTION TO SMALL CELLS

Small cells represent wireless access points that are today usually dedicated to 1 to 2 regulated wireless bands (for example, AWS plus PCS, or 2600 MHz plus 1800 MHz), and perhaps Wi-Fi®. They can be designed to support many bands and any of the common generational technologies (2G, 3G, 4G), but they are usually focused on a particular mobile operator's specific network requirements to curb product costs. Because of this, small cells today are usually not considered in instances where neutral host operation is a requirement. But this is not to say that future small cells cannot support requirements for multi-operator core networks (MOCN) or multi-public land mobile networks (multi-PLMN), in which two or more providers share a mobile network operating on common bands, because they can.

Similar to DAS, small cells consist of a fiber optic transport network and multiple wireless access points. Unlike DAS, a fiber optic transponder (BIU) bridging the base station RF signals to fiber is not required — small cells are attached either directly to the BTS baseband unit, or to the wireless core using a common 3G gateway or evolved packet core (EPC) in the case of LTE. When they are attached to the baseband unit (BBU), they employ the common public radio interface (CPRI). When they attach to the core using a 3G gateway or EPC, they employ Ethernet.

Depending on the chosen network architecture, small cells can appear as a single cell site sector (in the case of CPRI-connected small cells), or as a very small (pico) cell site. The selection of which configuration to use depends on the application as well as engineering preferences.

Figure 3. CPRI-connected small cells using PCS as the example band

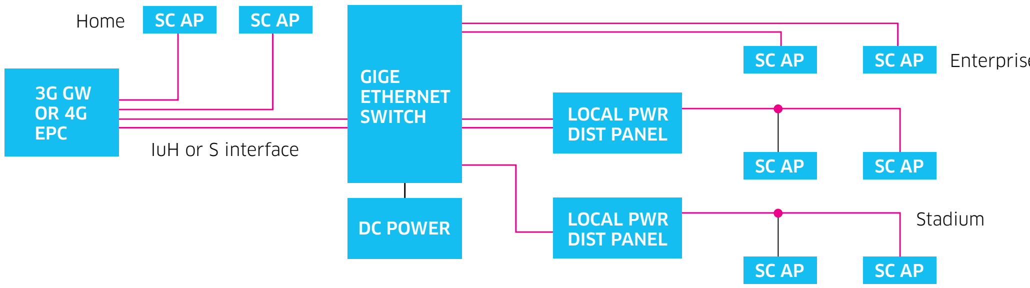


CPRI-connected small cells contain an RF transceiver and antenna. They are very similar to DAS in application, as both present themselves as one cellular sector. And, depending on network design, they can appear as one long antenna segment. However, a BIU is unnecessary in a small cells network because small cells are either directly attached to the BBU, a small cells gateway (in the case of 3G), or an EPC (in the case of LTE).

SMALL CELLS ADVANTAGES USING ETHERNET CONNECTIVITY

Ethernet-connected small cells are quite different from DAS. These types of small cells contain the antenna, RF transceiver, and baseband modulation (that is, BBU). From a network architecture perspective, Ethernet-connected small cells resemble a radio access network (RAN) of many cell sites. In the case of 3G, the addition of many access points is masked by the 3G gateway (a set of server functions containing security, timing, and radio control). In the case of LTE, the small cells terminate at the EPC. The advantage to using Ethernet-connected small cells is that they can be terminated anywhere in a network, irrespective of the remaining RAN. This eliminates the need to have the BTS and/or RF transceiver close to the small cells location, making small cells use much more practical.

Figure 4. Ethernet-connected small cells



The capacity of small cells varies based on the following:

- With CPRI-connected small cells, the capacity is generally limited to the per-sector performance of the BBU it is connected to and the airlink (whichever exhausts first).
- With Ethernet-connected small cells, the capacity is generally limited by the backhaul and its connections or the airlink (whichever exhausts first).
- In all instances — DAS included — limits could be experienced in the core.

With regard to the above, CPRI-connected small cells largely mimic the limits of DAS, while Ethernet-connected small cells are in a league of their own.

Because Ethernet-connected small cells represent a standalone base station of sorts, they can provide significant capacity. By example, a gigabit Ethernet-connected small cell has 1000 Mb/s at its disposal (assuming no further limitations in the network). Based on use of 4x4 LTE MIMO at the downlink, four 300 Mb/s unicast streams can be delivered simultaneously to a set of users, or 64 15 Mb/s can be delivered simultaneously (discounting any overhead for simplicity in discussion). By comparison, the total sector throughput of a single BTS in the same scenario would be 300 Mb/s. If they were to serve the identical footprint, a set of 10 small cells would then offer 3000 Mb/s worth of capacity as opposed to 300 Mb/s worth of capacity of a single sector. Of course, this example ignores many real-world realities in order to draw the comparison as clearly as possible.

From a mobility perspective, both CPRI-connected small cells and DAS are quite similar; the access points represent a single sector in which the user is located. The opposite is true with Ethernet-connected small cells in which users appear to roam among a set of small cell sites.

COST OF SMALL CELLS VERSUS DAS

The cost to implement small cells or DAS very much depends on application topology and expected performance characteristics.

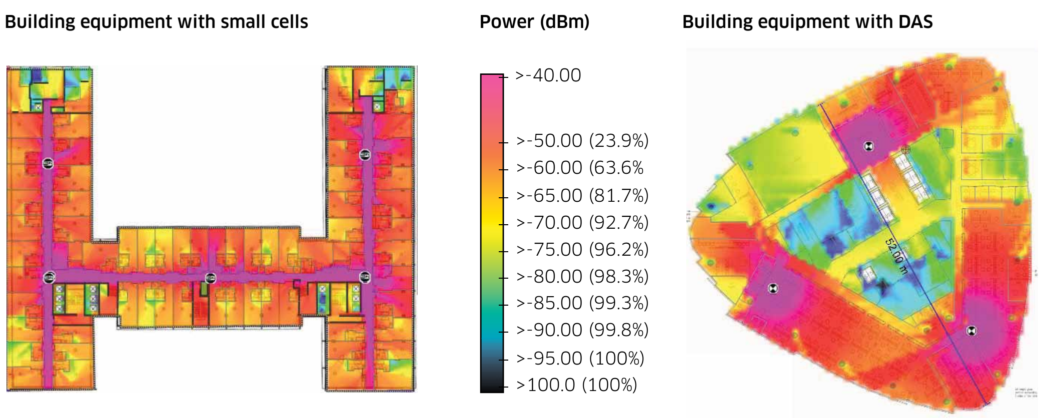
Alcatel-Lucent has modeled many types of networks using both small cells, active DAS and passive DAS, and aside from the usual variations in equipment cost, has found the following variables to impact total cost of ownership (TCO) significantly:

- Desired capacity/total throughput and bandwidth per user: The ability to satisfy many users with a single radio sector versus multiple active radios determines whether the system can be passive or active.

- Building configuration and location of risers: Depending on architecture chosen, labor to install feeders and drops can vary widely.
- Cost of installation labor: This single variable can influence whether passive DAS is at all cost effective due to the solution being “coax intensive.”
- Indoor versus outdoor coverage: Outdoor hardened access points are significantly more expensive than non-hardened, indoor units.

Two contrasting situations are provided in Figure 5 in which a rather common hotel layout is compared with a single tower building that has ready access for placement of RF equipment and coax using existing risers.

Figure 5. Comparison of irregular and ideal-shaped buildings



Note: RF design created using iBwave; resulting power calculations are for illustration only

As seen from the heat chart above, coverage of this H-shaped building layout required the placement of numerous access points throughout the floors of the building. In this case, passive DAS simply could not compete in terms of cost with either small cells or active DAS if performance objectives were to be met. However, in the three-sided single tower, a minimum number of passive DAS elements could easily be used to cover multiple floors simultaneously. Ready access to risers minimized the labor costs to distribute the passive antennas. Both of these caused its cost to be substantially lower than an active solution.

From a perspective of cost, DAS is often stated to cost US$1 per square foot of coverage, while small cells are often stated to cost between $60 to $100 for a home femto cell unit, and $2000 or more for a multi-user unit. Unfortunately, the sheer number of variables involved relegates anecdotal quantifications like this to nothing more than that. Because of labor involved to install and support these systems, as well as the cost of backhaul, a five-year TCO analysis is warranted.

Based upon the two examples above, we see that building configuration can dictate whether one technology is less expensive than another.

Table 1. Case example of DAS and small cells using opposing building configurations

	H-SHAPED HOTEL BUILDING	TRIANGLE-SHAPED HIGH-RISE OFFICE
Main characteristics	• 19-floor hotel with ground level shopping area • Guest rooms from floors 7-19 • 6300 m^2 (67,800 ft^2)	• 32 floors with 3 basic office layouts per floor • 1486 m^2 (16,000 ft^2)
Expected coverage	• >85 dBm CPIC/RSCP throughout hotel with no dropped calls in stairways or restrooms	• >80 dBm CPIC/RSCP throughout office space with no dropped calls in stairways or restrooms
5-year TCO and equipment required using DAS	• 187 DAS antenna points • 248,000 € ($335,000 at 1.35:1 constant exchange rate)	• 113 DAS antenna points • 265,000 € ($358,000 at 1.35:1 constant exchange rate)
5-year TCO and equipment required using small cells	• 33 small cells • 184,000 € ($248,000 at 1.35:1 constant exchange rate)	• 81 small cells • 424,000 € ($572,000 at 1.35:1 constant exchange rate)
Findings	• Small cells costs are 25% less than DAS	• DAS costs are 38% less than small cells

Lastly, and to satisfy the reader's curiosity, the capital expenditures (CAPEX)-only cost to equip the triangle-shaped building with DAS was calculated to be $3 per square foot, while it was 25 percent higher than that to equip the H-shaped hotel.

SUMMARY

The principle similarities between DAS and small cells can be summed up as follows:

- Both satisfy the need to extend coverage.
- Both satisfy the same capacity in the case of CPRI-connected small cells, and both genre of products satisfy MIMO.
- Both active DAS and small cells rely upon high-speed connectivity to the access points, principally fiber; coax is used in the case of passive DAS.
- Both require much of the same engineering and deployment considerations, as well as installation effort, although passive DAS can require more installation effort.

The principle differences between DAS and small cells can be summed up as follows:

- Active DAS requires an intermediate transponder between the access points and base transceiver station, whereas small cells do not (although 3G small cells employ a gateway, while LTE small cells connect directly to the EPC).
- DAS is better suited in the near-term for neutral host operation.
- A configuration of Ethernet-connected small cells provides much greater capacity than DAS when DAS is deployed in a traditional configuration (that is, not using many redundant systems, excess baseband units).

The following table provides a guide as to technology fit and use.

Table 2. Guide to DAS and small cells fit

	SMALL TO MEDIUM FLOOR BUILDING (RESTAURANT, SHOP)	LARGE SINGLE FLOOR BUILDING (FACTORY)	2-5 FLOOR BUILDING	5-10 FLOOR BUILDING	10-20 FLOOR BUILDING	OVER 20-FLOOR BUILDING	AIRPORT, SHOPPING MALLS
Indoor small cell	1	1 to 2	2 to 4 per floor depending on storey size, morphology and capacity				
Node B with DAS	Not cost effective	Not cost effective	1 Sector	1-2 Sectors	2-4 Sectors	>4 Sectors	>4 Sectors
RRH with DAS	Not cost effective	Not cost effective	1 RRU	1-2 RRU (*)	2-4 RRU (*)	>4 RRU (*)	>4 RRU (*)
RF repeater with DAS	If low traffic				Insufficient capacity		If low traffic
DAS type	Small to medium area or 1-5 floors: Passive DAS Large area and more than 5 floors: Active DAS						