Hotel Technology next generation™

Cellular Coverage Workgroup

A Hotelier's Guide to Cellular Coverage Solutions

Solution Architectures

Version 1.00

About HTNG

Hotel Technology Next Generation (HTNG) is a non-profit association with a mission to foster, through collaboration and partnership, the development of next-generation systems and solutions that will enable hoteliers and their technology vendors to do business globally in the 21st century; to be recognized as a leading voice of the global hotel community, articulating the technology requirements of hotel companies of all sizes to the vendor community; and to facilitate the development of technology models for hospitality that will foster innovation, improve the guest experience, increase the effectiveness and efficiency of hotels, and create a healthy ecosystem of technology suppliers.

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1 Introduction

The cellular coverage best practices guide is intended to educate hoteliers and hospitality technology management organizations recommending and supporting hotel properties on the fundamentals of cellular coverage solutions. This guide includes an overview of the wireless technologies supported by the cellular coverage solutions, available solutions and their strengths and weaknesses, as well as design, installation and post-installations considerations.

This guide is intended to provide the hospitality IT or telecom manager with a thorough overview and explains the process that hundreds of hotels have undertaken to select and implement a cellular coverage solution. 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 comprehensive understanding of the technologies, issues, and concerns.

The contents of this guide are provided on the HTNG website in the following sections:

- Solution Architectures
- Design Considerations
- Installation and Post-Installation Considerations
- Glossary

2 Cellular Coverage Solutions

Mobile Network Operators (MNOs) -- like AT&T, Sprint, T-Mobile and Verizon – have experienced astonishing subscriber growth and today the majority of all cellular calls are made in building. The expectations for both guests and staff have increased in parallel.

Typically, in order to keep up with customer demand, MNOs have grown their footprint by constructing more 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 within the MNOs existing network of cell sites.

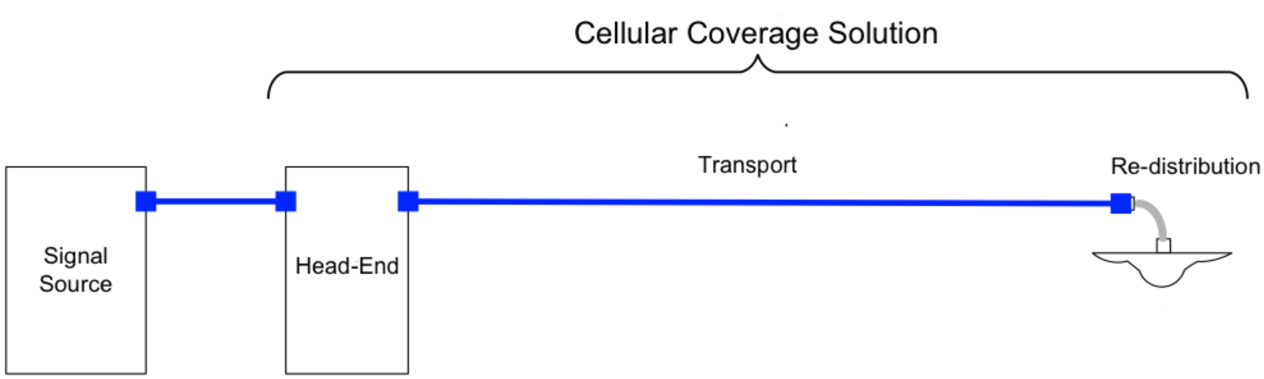
However using a MNO cell-site to provide coverage inside a building is not always practical. For a hotel property, there are many factors that determine practicality. Proximity to a cell site is one major factor, but a property's size and physical structure (e.g. steel, concrete, reflective glass, etc.) also play a role by limiting RF penetration from a cell site. Additionally, the advent of the smartphone and newer 4G technologies used by the MNOs, such as HSPA+ and LTE, require very good coverage and depending on a cell site for in-building coverage is becoming is less and less practical.

Cellular coverage solutions allow hoteliers to improve MNO coverage inside buildings by deploying an antenna system directly in a facility.

Ubiquitous cell coverage for all carriers is becoming an expected amenity, much as high-speed Internet access has become, and a cellular coverage solutions supporting multi-MNOs not only ensures that hoteliers have a new amenity, but can also differentiate when it comes to revenue opportunity, such as convention business.

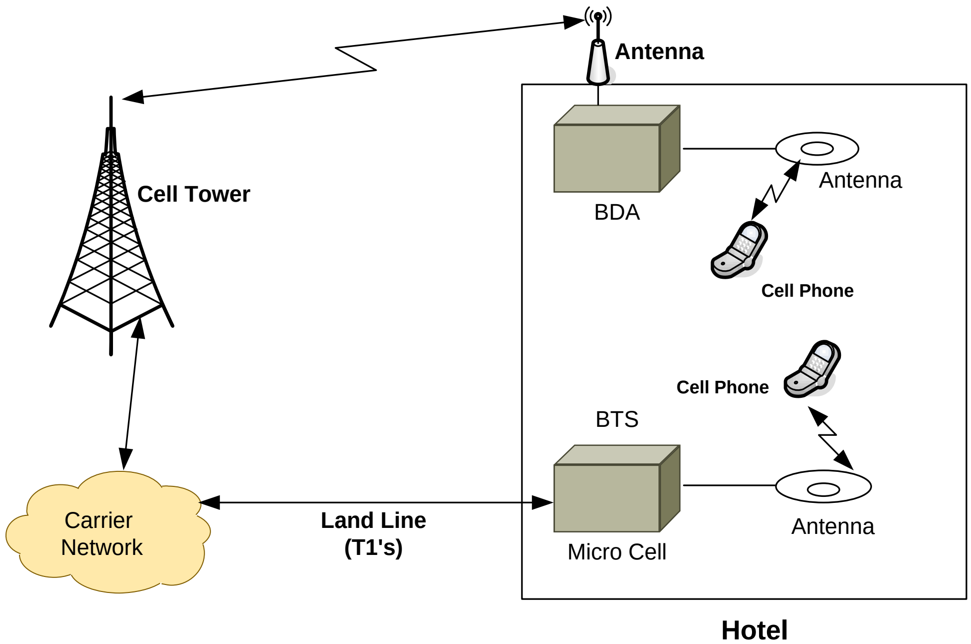
2.1 Basic Structure and Elements

For cellular services, a MNO provides a signal source that enables cellular signals to be communicated between the MNO network and a cellular coverage solution. The cellular coverage solution distributes the cellular signals in-building and consists of a head-end that interfaces to the MNO signal source, a cable transport, and antennas as shown in the diagram below.



2.2 Wireless Service Provider (MNO) Connectivity

The two most common signal sources for MNO connectivity are the bi-directional amplifier (BDA) and base station (BTS). Each can provide the link to the MNO's network and the MNO will typically recommend the correct signal source for the facility, and then supply and maintain the equipment. Additionally, ownership of the signal source typically remains with the MNO.



BTS systems come in various sizes and capacities but are typically larger and more expensive than BDA. They require a T1 or other backhaul to the MNO's call-switching center and more HVAC resources than a BDA. A BTS, in essence, acts as miniature cell site. It is connected directly to the MNO network and provides dedicated capacity to the facility through the cellular coverage solution. With the increase in smartphones and data services this dedicated capacity is becoming more critical and a BTS is being required by MNOs more often than a BDA.

Bi-directional amplifiers 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 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 cellular coverage solution. Similarly, the return signals are passed by the cellular coverage solution back to the BDA, where they are amplified for transport back to the cell site outside the building.

While BDAs are lower in cost and typically much smaller than BTSs, several guidelines must be adhered to with a BDA. First, a BDA should only be installed with prior consent and coordination with the MNO (failure to do so may result in interference to the MNO network and it is illegal to install a BDA without MNO prior consent to do so). Second, capacity should be carefully examined. Since the BDA shares capacity with an outdoor cell site, if the outside cell site is loaded with traffic outside the building, the ability to get acceptable coverage in the facility may be limited. Next, a BDA with an off-air interface is more susceptible to interference and to causing interference. Finally, depending on the type of cellular coverage solution, the cost of a BDA cost can vary.

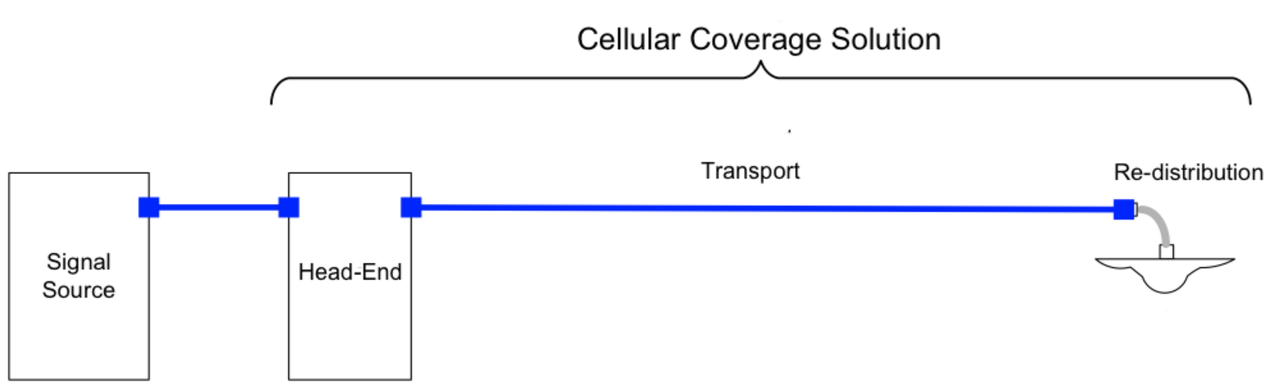
Note: A BDA is almost always used to communicate with the public safety network. These are relatively un-complex for public safety in the 700 and 800 MHz bands, but may be quite complex and expensive for public safety in the 150 or 450 MHz band.

IP base station. The advent of IP base stations in both the macro (outdoor) and indoor environments provides WSPs with another solution to address coverage gaps and to increase coverage capacity to meet the ever increasing demand of data traffic. The IP base stations are easier to locate within a facility due to their smaller form factor while providing backhaul savings due to improved bandwidth utilization. Again, this is another factor considered by the WSP in determining the location-specific solution.

Ultimately there are tradeoffs between all of these solutions. Therefore, it is recommended, and often required, that the WSP determine the correct signal source working with both the facility and cellular coverage solution integrator. Once this is done, the WSP will provide appropriate guidelines on connecting the signal source to the WSP network.

2.3 Coverage Solution Components

As mentioned previously, the cellular coverage solution itself consists of head-end, transport, and re-distribution. The head-end places the RF signals from the MNO signal source into a format suitable for distribution over the transport cabling and the re-distribution element (s) (typically a small in-building antenna about the size of a smoke alarm).



While simple in concept, cellular coverage solutions can differ in many ways and the industry has categorized them in the terms active, passive, and hybrid. These terms refer to the electronics or lack of electronics in the head-end and transport. Before covering the differences in these areas, it is useful to discuss some common elements – the transport cabling and re-distribution elements.

½" Plenum Rated Coaxial Cable

Omni-directional Ceiling Mount Antenna

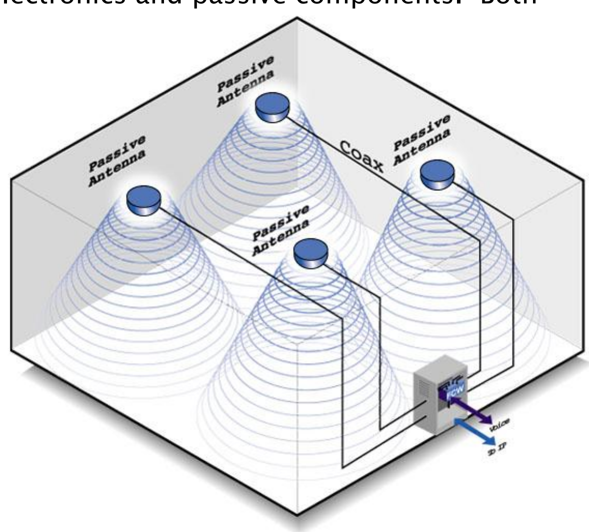
All cellular coverage solutions use cabling for transportation of RF signals from the head-end to the re-distribution. These signals are transported in one of the following ways:

Coaxial cable, usually a half-inch in diameter, it has the largest diameter of any medium. Coax is very high bandwidth and can support both high throughput and a wide variety of RF signals. Coax is expensive to install relative to other transport mediums like CATV or CAT5/6, but with lower RF signal loss, it may be used for distances up to 250 feet without any conversion (electrical) or re-amplification of the RF signals.

Fiber, either single-mode or multi-mode optical fiber, can transport many frequencies on the same fiber at distances greater than any other medium. While electrical to optical conversion is required, fiber provides the greatest level of flexibility and scalability.

Mixed transport uses a combination of CAT5/6, CATV and/or fiber. The use of these mediums can be attractive, as they may already exist in a facility. However, this transport presents high loss to the RF signal and requires the RF signals be manipulated (usually down converted). Manipulation can increase the cost of the coverage solution and may limit bandwidth, so multiple services may require multiple or parallel systems.

Redistribution is most often accomplished via antennas. These devices may be completely passive in nature or be a combination of active electronics and passive components. Both directional and omni-directional antennas may be used, with omni-directional being most common. **Omni-directional antennas** provide consistent signal levels in all directions and are generally mounted in the ceiling as shown in the diagram. **Directional antennas** focus the signal strength in one direction and work well for narrow hallways or large rooms.



Typically, antennas cover an area of about 2,000 to 20,000 square feet depending upon the power of the coverage solution, the required signal strength of the wireless services being provided, obstructions in the coverage area, and the pattern of the antenna. For example, 4G technologies may require a denser antenna deployment than previous generations of cellular technology.

2.4 Cellular Coverage Solution Architectures

As mentioned previously, the terms, active, passive, and hybrid have become an industry standard method of categorizing cellular coverage solutions. These terms refer to the use of electronics in the head-end and transport. **Passive**, as the name suggests, is non-powered, usually using half-inch diameter (or greater) coaxial cable. Signals simply pass from the head-end over the transport coaxial cables to re-distribution. **Active**, on the other hand, is powered and electronic components are used to manipulate the RF signals at the head-end, the transport, and re-distribution.

In reality, all of the coverage 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 (i.e. the system is mostly active or mostly passive). A **hybrid** system comes closest to a 50-50 mixture of active and passive methodologies.

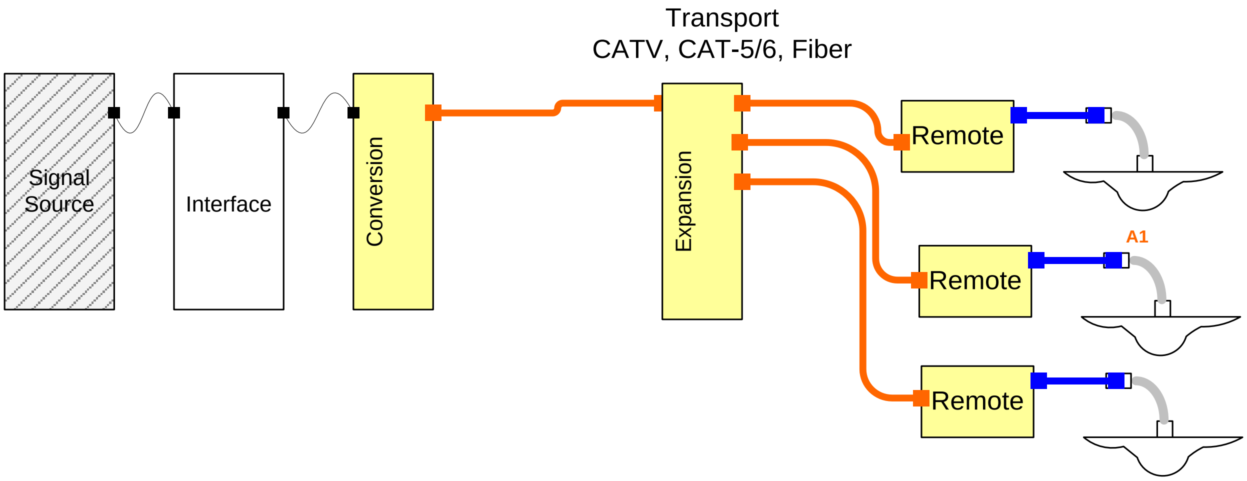
Coverage solutions offered by different vendors vary in capabilities, flexibility, and complexity. Generally, capabilities and cost are traded off by the different technologies. Some support multi-MNOs, some are optimized for specific MNOs, and some support convergence of other services, such as Public Safety and WLAN.

2.4.1 Active Systems

Active systems utilize a high level of active components in the head-end, transport, and re-distribution. With the large number of active components, these systems can use inexpensive mediums, such as CATV, CAT5/6 and fiber.

The active electronics take native RF signals from the signal source through the head-end and convert the signal to a lower frequency for transmission over CATV, CAT5/6 or convert the signal to optical for transmission over fiber. These signal are converted back to RF at the remote and transmitted over an antenna (or two if MIMO is being used) at the re-distribution point.

Active systems scale very well. To increase the number of remote amplifiers and antennas in a large building, an expansion hub may be added to the transport points as illustrated in the diagram below. These expansion hubs are typically located in an IDF closet. Several expansion hubs may be added that feed multiple remote units thereby expanding the overall system footprint.



Active systems are best at providing coverage for a single MNO, grouping of MNOs, or grouping of services, such as cellular/PCS, and can be very cost effective. However, when a large number of MNOs or numerous services on a single MNO, such as cellular/PCS/LTE, then multiple "parallel" networks may be required. For a building, the actual design will be typically based on size, cost, output power, and antenna configuration option considerations.

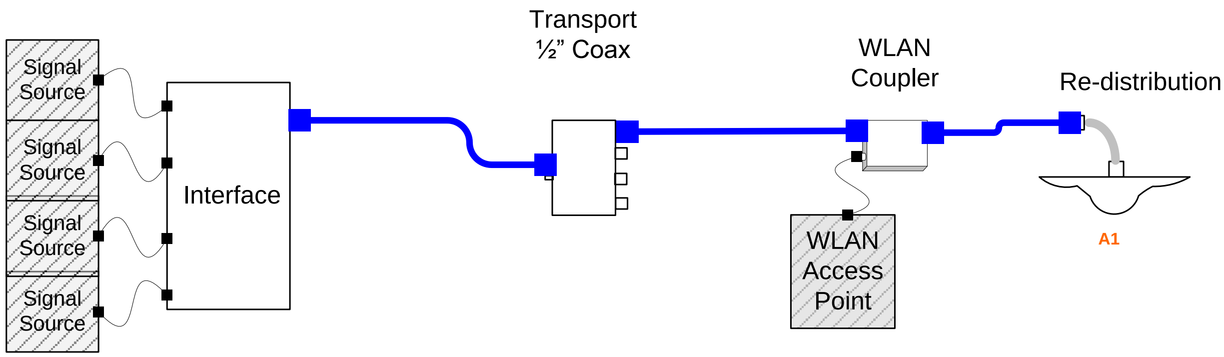
Converged services, such as Public Safety and WLAN, are not typically supported on active systems; however in one case of newer technology, CAT5e/6 is being used to support both cellular signal and Ethernet signals, such that the same cable is used to transport both cellular and Ethernet/WLAN connectivity with no interference to either technology.

There are numerous active solutions on the market. The table below shows different potential solutions, including the function of the head-end, transport equipment and cabling, as well as the type of re-distribution *(note: in the case of the nomenclature cable 1/cable 2, cable 1 is used between the head-end and the transport equipment and cable 2 is used between the transport equipment and the re-distribution).*

Solution	Head-End Equipment	Transport Cabling	Transport Equipment	Re-Distribution
Fiber/CAT5 or RG6	Conversion to Fiber	Fiber/CAT5 or RG6	Fiber to RF Conversion then Conversion to CAT 5 or RG6	Active Device with Antennas
CAT5/6	Conversion to CAT5/6	CAT5/6	Re-Amplification	Active Device with Antennas
Fiber	Conversion to Fiber	Fiber	Fiber MUX or Conversion to RF then back to Fiber	Active Device with Antennas

2.4.2 Passive Systems

Passive systems consist primarily of passive components, such as splitters or couplers , half-inch coaxial cable, and antennas to distribute the RF signal from the signal source to different areas of the building or coverage area without conversion or amplification. The head-end simply combines RF signals from several services that are then re-distributed over a broadband antenna – the simplicity is the fundamental benefit of a passive system.



Passive systems are the least expensive type of system in smaller facilities. However, they require professional engineering design, due to installation complexities. Additionally, the power of the signal source needs to be stronger than in an active or hybrid coverage solution and this generally increases the cost of the signal source the MNO has to provide.

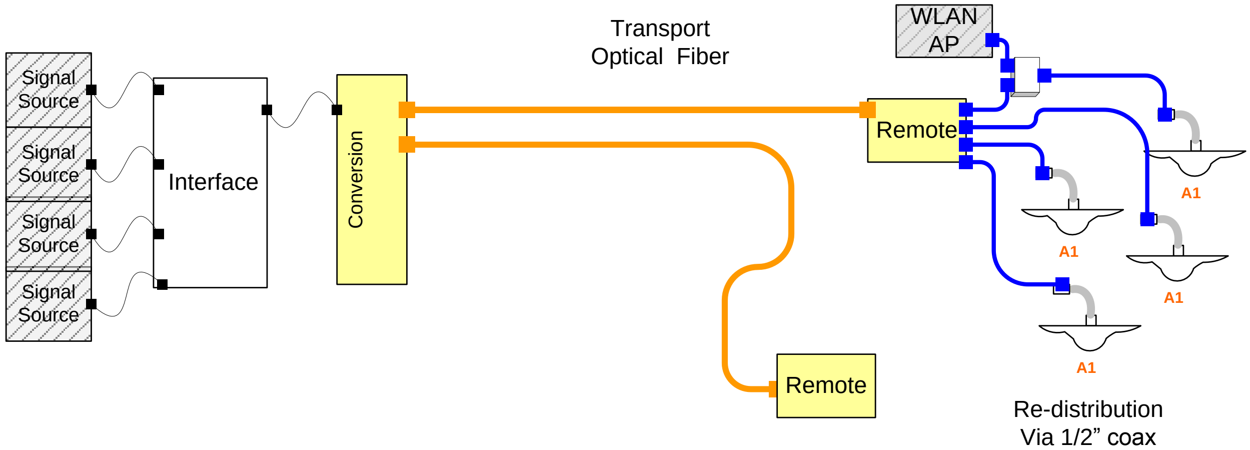
Converged services, such as Public Safety and WLAN are supported on passive systems. Integration of WLAN is achieved by passively coupling the output of a WLAN access point onto the distribution coax, such that WLAN services share the antenna with the cellular services.

The passive solutions available on the market are described below:

Solution	Head-End Equipment	Transport Cabling	Transport Equipment	Re-Distribution
Coax	Frequency Combiner	Coax	Splitters	Passive Antennas
Coax with Wi-Fi	Frequency Combiner	Coax	Splitters, Passive Combiners to Wi-Fi AP Connections	Passive Antennas

2.4.3 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 before connecting to multiple antennas for re-distribution. However, at this point, the active and hybrid system differ. 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, coax is deployed to support multiple passive antennas. 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 MNOs. This is a highly desirable feature, since it lowers the financial barrier for the MNOs. 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.

Hybrid systems can support WLAN with the access points injected at the remote or on the distribution coax (in the same way as a passive system).

There hybrid solutions available are described below (*note: in the case of the nomenclature cable 1/cable 2, cable 1 is used between the head-end and the transport equipment and cable 2 is used between the transport equipment and the re-distribution).*

Solution	Head-End Equipment	Transport Cabling	Transport Equipment	Re-Distribution
Fiber/Coax	Conversion to Fiber	Fiber/Coax	Amplifier	Passive Antennas

2.4.4 Comparison of Cellular Coverage Solution Architectures

As described above, there are many different types of architectures and solutions for cellular coverage solutions. The following table outlines the pros and cons:

	Active	Passive	Hybrid
MNO Connectivity	Accepted by MNOs	Accepted by MNOs; however, requires high-power signal source	Accepted by MNOs
Modularity	Not modular, limited number of MNOs or MNO services. Low cost for single MNO/service	Not modular, supports all MNO and MNO services	Modular, easily expanded from single MNO/MNO service to multiple MNO/MNO services
Scalability	Scalable from small to large deployments, adjustable signal power level per each antenna	Best suited for smaller deployments, but can scale with professional design and deployment	Scalable from small to large deployments
Reliability and Monitoring	Multiple failure points, pro-active monitoring for all elements of the system	Limited failure points, monitoring not available, troubleshooting requires professional support	Medium failure points, pro-active monitoring of active components, troubleshooting of passive components requires professional support
Environmental	Active equipment in MDF, IDF, and ceilings with Power/HVAC requirement.	Passive equipment in MDF, IDF, and ceilings with no power/HVAC requirement.	Active equipment in MDF, IDF with power/HVAC requirement. Passive equipment in ceilings with no power/HVAC requirement.
4G	Supports MIMO with single cable run	MIMO requires completely parallel system deployment	MIMO requires parallel cable infrastructure (some active electronics can be shared)
Converged Services	Typically, MNO Only	Supports Public Safety and WLAN	Supports Public Safety and WLAN

2.5 The Impact of 4G on Cellular Coverage Solutions

Beginning in 2011, MNOs have started to deploy 4G technologies, most notably 4G LTE.

4G LTE has several major requirements that must be taken into consideration for an existing as well as new cellular coverage solutions. These include:

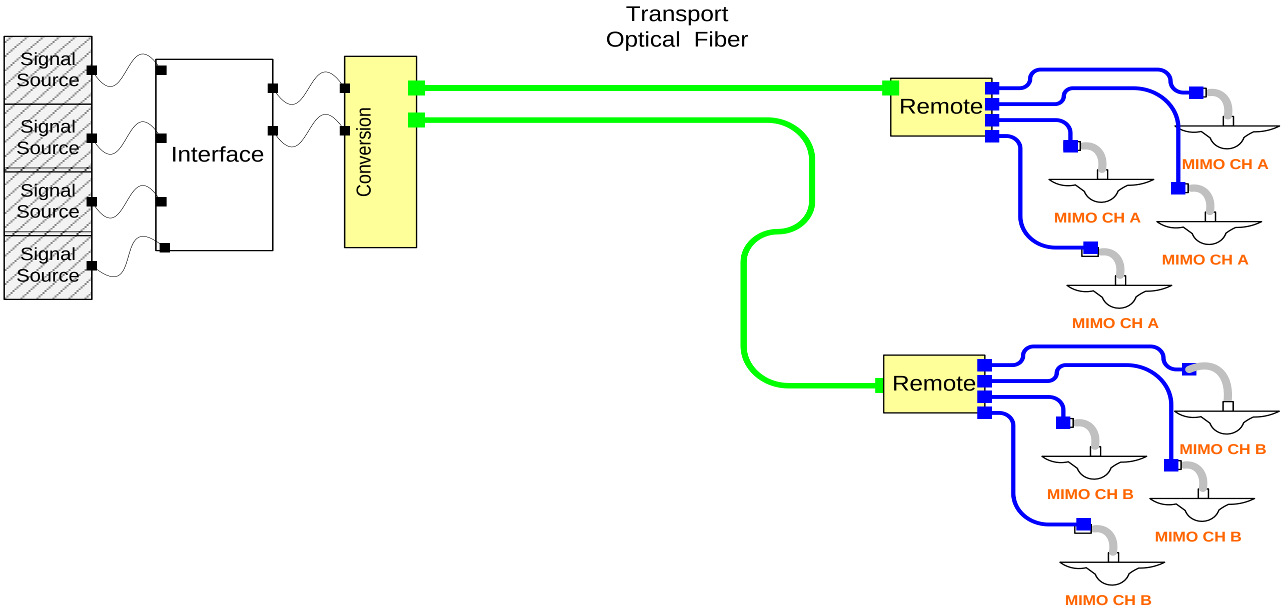
- High modulation techniques that require better coverage and higher signal strength
- MIMO (multiple input, multiple output) antenna configurations
- New frequency bands (700 MHz & 1.7/2.1 GHz spectrum, but may be expanded to other spectrums, including 850 MHz and 1900 MHz)
- Channel bandwidth: 1.25-20 MHz

The impact to cellular coverage solutions include:

Coverage and signal strength – Traditionally, cellular coverage solutions have been deployed for voice and antennas could be placed far apart and still achieve adequate coverage and signal strength. With high-speed data services enabled by 4G, a denser antenna deployment is required, which affects both number of antennas and associated transport cabling.

MIMO – MIMO (multiple input multiple output) technology is a key element of 4G LTE. MIMO requires that RF be distributed over two independent channels. Depending on the coverage solution, this may simply mean that two antennas be deployed at each antenna location (vs. one for other cellular technologies, such as voice), but depending on the architecture, it may also require duplication of hubs and remotes. In some cases, MNOs will require MIMO for 4G and in other cases they do not. Upgrading to MIMO post installation can be expensive and MIMO requirements should be understood from the beginning. The following diagram displays a hybrid cellular coverage solution supporting

4G MIMO technology:



New frequency bands – New spectrum was acquired by MNOs to implement high-speed data services, specifically 700 MHz, 1.6 GHz, 1.7/2.1 GHz. When these are added to a cellular coverage solution, the number of frequencies that are required to be supported can rise to 6 or 7 and the system must be carefully planned and designed to be able to add new bands and avoid possible interference. In older systems, some components, such as combiners and splitters, may be incompatible with these new bands and have to be replaced.

Channel bandwidth – currently LTE is implemented over single wideband channel however future technology, LTE advanced, will require an increase spectrum usage through contiguous and non-contiguous channel bonding. This may impact current cellular coverage solutions.