AVARI WIRELESS

ENABLING EMERGENCY COMMUNICATIONS INDOORS

Avari® VL™ Series

INTRO TO PUBLIC SAFETY IN-BUILDING COMMUNICATION

Being able to communicate with public safety two-way radio systems in buildings is crucial for first responders to execute time-sensitive and mission-critical tasks to protect the public. Emergency Responder Communications Enhancement Systems (ERCES) are often installed to provide these necessary means of communication.

Avari Wireless's public safety digital Distributed Antenna System (DAS), known as the Avari™ VL™ Series, provides a reliable, high-performance, and high availability system designed to support both current and future public safety communication requirements.

CANADA HQ
8618 COMMERCE COURT
BURNABY BC, V5A 4N6
CANADA

UNITED STATES HQ
1400 112TH AVE SE, STE 100
BELLEVUE, WA 98004
USA

UNITED KINGDOM HQ
40 CAVERSHAM ROAD
READING, BERKSHIRE RG1 7EB
UK

CONTACT
+1 (833) 502-2144
INFO@AVARIWIRELESS.COM
WWW.AVARIWIRELESS.COM

Introduction

Reliable public safety in-building radio communications are vital in today's emergency services operation, from dispatch to mission-critical situations, and from voice-only capabilities to voice and data.

Public safety communications have evolved from fire call boxes and trunked radio systems including analog and digital mobile radios. This evolution was mainly driven by technological advancements and the need for higher reliability.

Traditionally, public safety uses lower frequency bands such as 150 MHz and 450 MHz. As the public safety network operations move to higher spectrum bands such as 700MHz or 800 MHz, the propagation characteristics of the spectrum limit the in-building signal penetration.

In addition, with new building materials like coated energy-efficient windows used in modern green buildings meeting LEED standards, radio signals can be even further reduced or blocked which can impair effective communications between first responders indoors.

Improving public safety coverage indoors is a long-standing challenge. An evolution in the in-building public safety infrastructure (Figure 1) is required to allow two-way radios or trunked radio systems to work seamlessly and reliably inside buildings and in underground tunnels, metros or mines and remote or isolated areas.

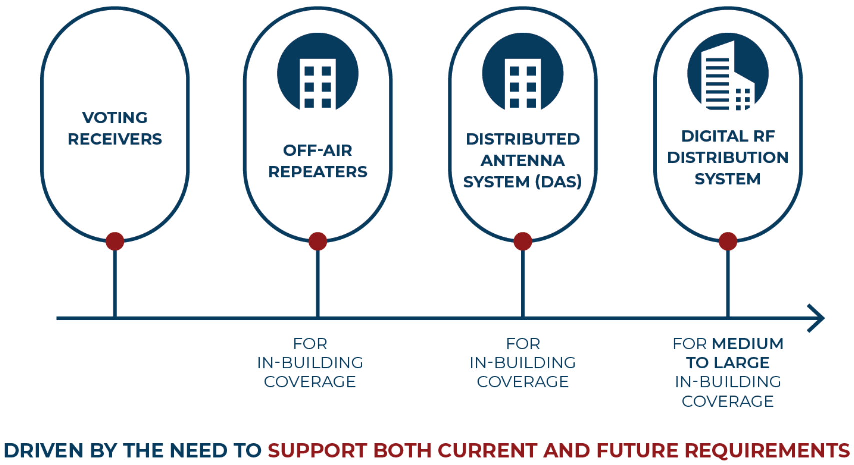

Figure 1. The Evolution of Public Safety Coverage Solutions

Current Requirements for Public Safety In-Building Coverage Systems

The purpose of an in-building public safety system is to provide enhanced coverage when the existing macro network is not able to adequately provide the required radio signals. In-building public safety coverage is required by first responders to properly use their communication systems in order to do their job and execute mission-critical tasks in the midst of an emergency.

Radio coverage is required at all times and also in areas such as stairwells and backrooms, which are not commonly the prime coverage areas in commercial wireless systems. Public safety in-building systems must comply with local Fire Codes and Ordinance, largely based on NFPA and IFC codes, and also with NEMA 4/4X or IP66 enclosure requirements to stand up to harsh environments.

According to NFPA, critical areas, such as the fire command centers, fire pump rooms, exit stairs, exit passageways, elevator lobbies, standpipe cabinets, sprinkler sectional, valve locations, and other areas deemed critical by the authority having jurisdiction, shall be provided with 99 percent floor area radio coverage and with a minimum inbound signal strength of -95dBm. These requirements are based on current analog and P25 narrowband radio systems.

Besides the quality of service, the availability of service is also one of the main requirements of the mission-critical communication system for emergency responders. The system cannot suffer the loss of service due to single-point failures. Therefore, the in-building public safety distribution system should be designed and constructed with the required level of availability in mind.

Redundancy or fault tolerance is required to minimize the impact of component failure upon the operation of the whole system. Battery backup is also required under NFPA to ensure that first responders' communication won't be interrupted in the event of power failure.

Future Requirements for Public Safety In-Building Coverage Systems

Public safety requirements are evolving with improved methods in which emergency personnel communicate. Being able to transmit high-resolution imagery or real-time video footage can bring improvements in efficiencies and response time to further enhance methods to protect the public, and just as importantly, provide additional safety for first responders. For instance, those in dispatch centers who receive the real-time multimedia footage from front-line personnel can now have more insight into what necessary steps should be taken to provide more timely and appropriate response and support.

Public safety agencies around the world are looking at the opportunity to leverage Long Term Evolution (LTE) technology for use in public safety radio communications. The evolution to broadband LTE-based public safety from the current narrowband systems such as P25 Phase I and II, and TETRA will happen gradually.

In the United States, the First Responder Network Authority, FirstNet, was signed into law on February 22, 2012, to build, operate and maintain the first high-speed nationwide wireless broadband network dedicated to public safety. The goal is to provide a single interoperable platform for emergency and daily public safety communications. Buildouts are rapidly progressing across the country, by AT&T, the selected service provider.
Apart from financial and contractual commitments, one of the biggest challenges slowing the adoption of wideband LTE systems is well warranted – having to replace reliable first responder systems that have been proven to work so well for so long, that are familiar to users with instinctive familiarity and comfort level.

Despite the revolutionary capabilities broadband technology provides for mission-critical communications and situational awareness, the transition to LTE will likely be more of a gradual evolutionary process, where narrowband land mobile radio (LMR) systems, like P25 and TETRA, will work in parallel with broadband systems, coexisting for many years.
This requires an in-building ERCES DAS system capable of carrying both narrowband and broadband, current and future technologies, connecting

different responder radio systems and providing more efficient communications and operational response for mission-critical emergency service providers.

Internationally, as regional standards institutes like ETSI work on enhancing the narrowband TETRA standard, and global bodies like 3GPP continue their important broadband development work, coordination of interface standards and interoperability across borders becomes even more essential.

Options for Public Safety In-Building Coverage Systems

Public safety in-building coverage systems are used in situations where the signal outside the building may be optimal, but the signal inside the building is weak due to the attenuation of the building. In this section, we will review the options for enhancing public safety in-building coverage. The solution chosen to be deployed will vary between applications and will depend on:

- System reliability and redundancy requirements
- Number of required public safety frequency bands, responder agencies and channels
- Required technologies: P25 Phase I & II, Tetrapol, TETRA, LTE, DMR
- Current and future requirements
- Venue size and layout
- Existing cable infrastructure

Generally, to meet most current public safety requirements, a standard channelized off-air system is sufficient. However, to satisfy both current and future requirements discussed in earlier sections, a future-proof and software-configurable in-building coverage solution is required. This will be further discussed in the section – "Digital Distributed Antenna System (DAS) – The Next Generation Approach".

Off-Air Bi-Directional Amplifiers (BDA)

Off-air Bi-Directional Amplifiers (BDA), also known as Signal Boosters, receive radio signals from a pickup antenna that is pointed towards a radio tower donor site. The off-air BDA amplifies and retransmits the RF signal through a series of in-building antennas which radiate the amplified signal inside the building. The BDA also transmits the in-building radio signals back to the donor site (uplink path). The RF distribution network consists of coaxial cables, combiners and splitters. With passive components, the RF signal degrades with every device in the transmission chain. Therefore, sometimes additional BDAs are required on each floor to further amplify the signals (Figure 2).

BDA units were originally band-selective only, whose performance can be easily affected by interfering signals that are either close to or within the passband bandwidth of the duplexer in the BDAs. More recently, due to both technical and legal considerations, channelized BDAs are deployed. With channelization, only the desired signals will be retransmitted. The unwanted signal interference, even in-band, can be eliminated with digital filtering, which can also protect the donor sites from the unwanted uplink signal transmission.

Even though channelized BDAs offer superior RF performance and noise mitigation, both kinds of products may work well in isolated single building deployments, but have problems in large dense urban areas where too many units are often located in close proximity.

This can generate interference or transmit uplink noise to the donor site, and lately, it has been widely recognized that “too many BDAs” in a city environment can have a negative impact on first responder radio systems, including shrinking the BTS macro coverage area. A properly engineered direct-fed integrated fiber DAS system including channelized operation in both uplink and downlink paths offers a remedy for overcoming problems associated with aggregating off-air BDAs in close proximity, in applications like downtown and campus deployments.

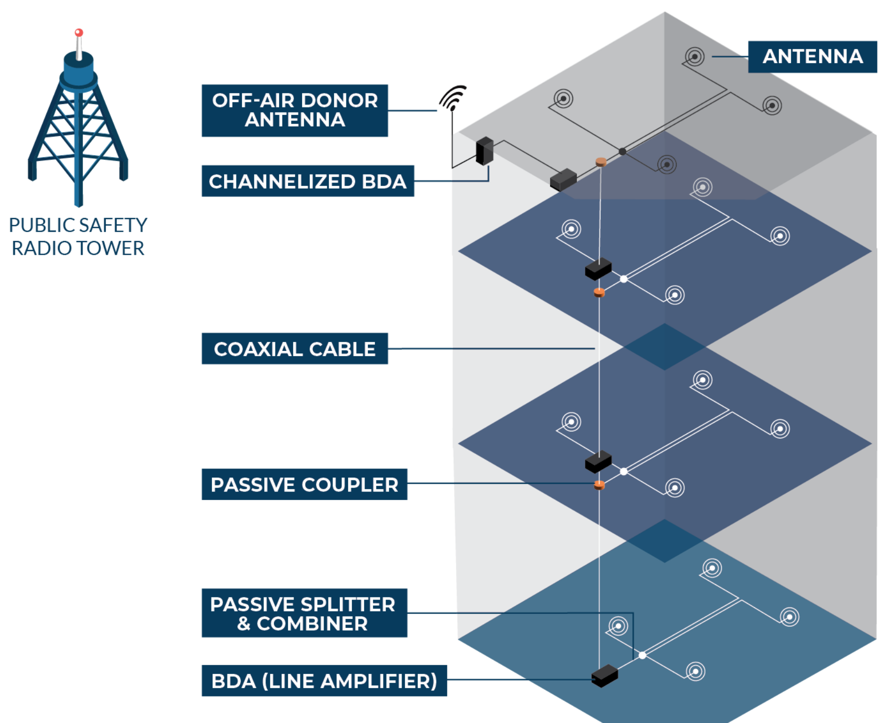

Figure 2. Off-Air Bi-Directional Amplifier

Distributed Antenna Systems (DAS)

A Distributed Antenna System (DAS) receives RF signals from the base station or off-air BDA and distributes the RF signals to antennas over either coaxial cable (Passive DAS) or fiber (Active DAS). With passive DAS, coaxial cable and other passive components, splitters and couplers are used. Usually, a central headend BDA drives the passive DAS elements or leaky feeder cable. With passive components, the RF signal degrades with every device in the transmission chain. The antennas might have varying output power depending on the distance from the BDA. Cable losses also decrease the signal levels. Therefore, additional BDAs, referred to as Line Amplifiers, are used downstream sometimes to offset signal losses and extend the range of the passive DAS. However, adding amplifiers also adds to overall system noise.

Passive DAS can cost-effectively enhance public safety radio communication in small-sized buildings with weak signal penetration from outdoor macro systems. The losses in coaxial cables, fiber, splitters and combiners are usually too large for this system to be effective in large venues.

This gives rise to the use of analog RF over fibre-optic transport, commonly referred to as Active DAS or Analog Fiber DAS. This is usually the preferred in-building wireless solution over passive DAS in larger facilities such as airports, hospitals, stadiums, high-rises, subway systems and multi-building campuses. Active DAS provides improved installation and maintenance benefits over Passive DAS, but still poses some design challenges including limited range, system noise, limited connectivity options (star topology) and fiber plant consumption in multi-node deployments.

Regardless of passive or active DAS, Public safety RF signal sources can come from BDAs or base stations. When receiving multiple RF signal sources, RF combining is required at the headend. With passive and active DAS, passive intermodulation (PIM) is introduced at each RF combining step and PIM degrades the quality of the signal within the distribution network.

Typically, with a DAS, adjustments such as power level and optical delay compensation are difficult to make. The power levels at the antenna are based on the cable or fiber losses (distances between the head-end and remotes), and the splitting ratio of the installed splitters and couplers. Therefore, changing the power at one antenna will impact the other antennas. For example, in analog RF over fiber DAS, optical delay compensation is done by either using the same length of fiber to all remotes or manually calculating the delay and adding delay elements to synchronize transmission from the headend. Digital DAS allows the delay to be added to each remote unit to synchronize the simulcast and minimize any time delay interference.

Avari's State-Of-The-Art Approach to Digital DAS

To satisfy current public safety requirements, while being able to seamlessly migrate to future network requirements, Avari Wireless has developed a state-of-the-art solution for providing in-building public safety coverage.

Avari's public safety digital DAS supports a two-tier architecture consisting of the host (headend) and remotes. For large and complex building structures, Avari's digital DAS also supports a three-tier architecture with a distribution layer between the headend and remotes. RF signals from off-air macro towers or base stations or a combination thereof can be received. For instance, the host has the option to combine the off-air macro signals, and a direct-feed base station signal digitally over fiber to provide transmission and distribution of radio signals.

The signal is digitally filtered on a per-channel basis using software configurable narrowband or wideband filters, and then the signal is converted to a digital CPRI data stream. The digital CPRI packet data stream is transported via single-mode fiber or multimode fiber to the remotes. The remotes then convert the digital CPRI packet data stream back to RF and amplify the signal for delivery to the antennas. On the reverse path (uplink), the remotes and host perform the inverse functions and deliver the signals back to the corresponding off-air donor sites as RF (Figure 3).

Avari uses a single, bidirectional optical transceiver for transport of both uplink and downlink signals, which means that a single fiber can be used to transmit and receive signals using WDM, wave division multiplexing. In this way, the number of fibers required for any given deployment is reduced and this, in turn, reduces the cost of deployment and operation. Also, in the Avari network, a separate 1-Gbps Ethernet tunnel with Power Over Ethernet (POE) option on each fiber connection can be used to carry IP traffic from devices such as surveillance cameras, digital announcement systems, electronic messaging boards, webcams or other IP-based equipment. The IP packet data is simply embedded into the CPRI framed data stream. Having an all-digital platform enables many advanced capabilities which will be further described in the sections following.

STANDARD TOPOLOGY

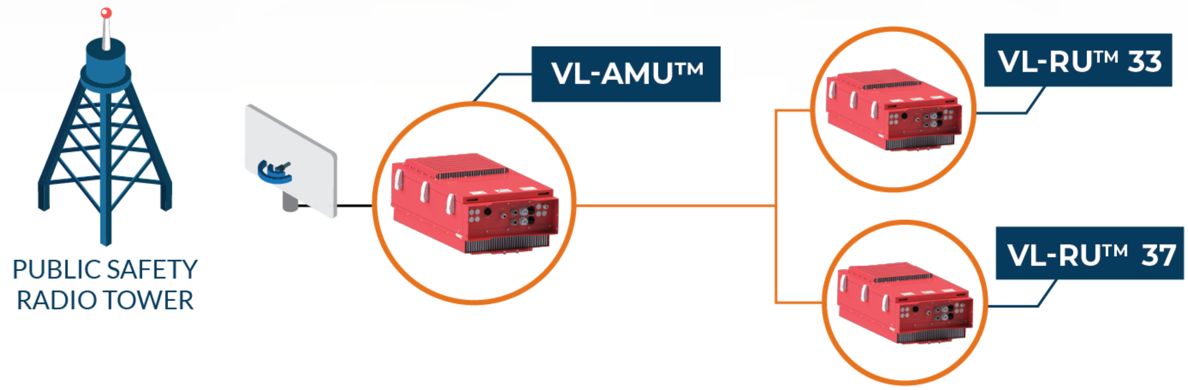

Figure 3. Standard Topology

Channelization

With off-air signals, Avari uses digital filtering to eliminate or reduce the impact of interfering signals, which reduces extraneous noise pick-up. On the uplink side, the harmful effects of a high-power handset located near an antenna are suppressed while the weak signal from the handset far away from the antenna is boosted. This is done by a combination of dual-stage advanced Automatic Digital Gain Control (ADGC) algorithm, high-performance digital filtering as well as squelch function to provide the best possible dynamic range, and minimal in-band interference supporting multiple time slot operations.

Long Distance

The ability to carry optical signals over a long distance, as far as 40 km/25 mi (up to 27dBo optical link budget) without any signal quality degradation is the result of the Avari digital transport capabilities. It enables new deployment architecture such as centralized headend in wide-area networks making it ideal for covering railway stations, long tunnels, underground mines and large campuses.

Flexible Topology

The flexibility provided by Avari's digital DAS is a key aspect to achieving the lowest total cost of ownership. The all-digital architecture enables multiple network topologies including star, daisy-chain and hybrid to cater to different deployment scenarios (Figure 4). These network topologies provide reduced fiber plant usage and installation cost, and effective redundancy configurations. Avari provides optical bypass switches for use in daisy-chain configurations to ensure that a single remote failure does not take out the entire chain. In addition, with the ability to cascade host units, digital DAS can support centralized headend architecture. It can easily enable new RF sources from different locations to be incrementally added to the existing distribution network without introducing passive intermodulation (PIM).

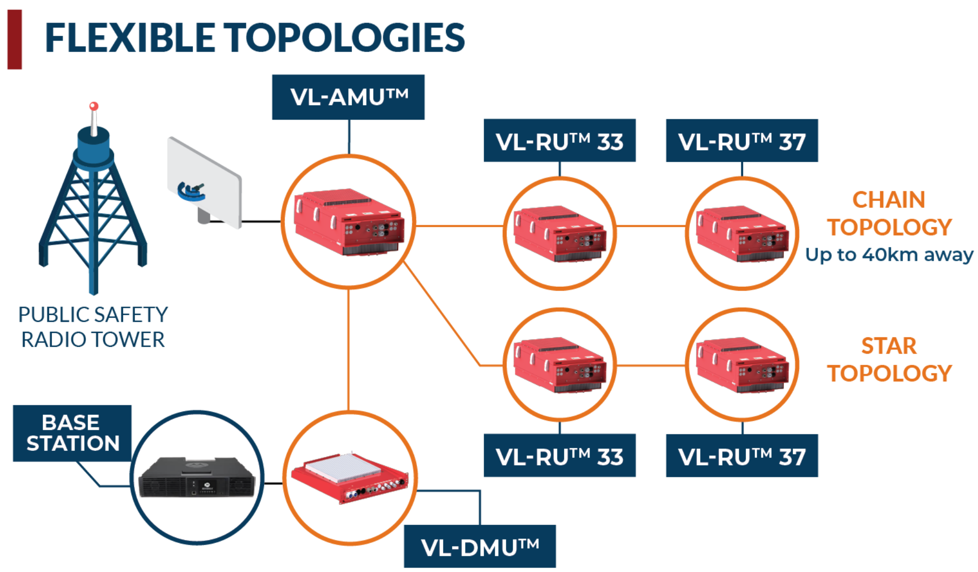

Figure 4. Flexible Topologies

IP Backhaul

A separate 1Gbps Ethernet tunnel from each remote over fiber back to the headend makes it convenient for a number of applications. For example, alarms from each Battery Backup Unit can be transported over the Ethernet tunnel to where the centralized Fire Alarm Panel is located. Other IP devices such as WiFi Access Points or security cameras can easily be added at required remote locations for internet access and surveillance. POE enables a single Ethernet cable connection

IP BACKHAUL

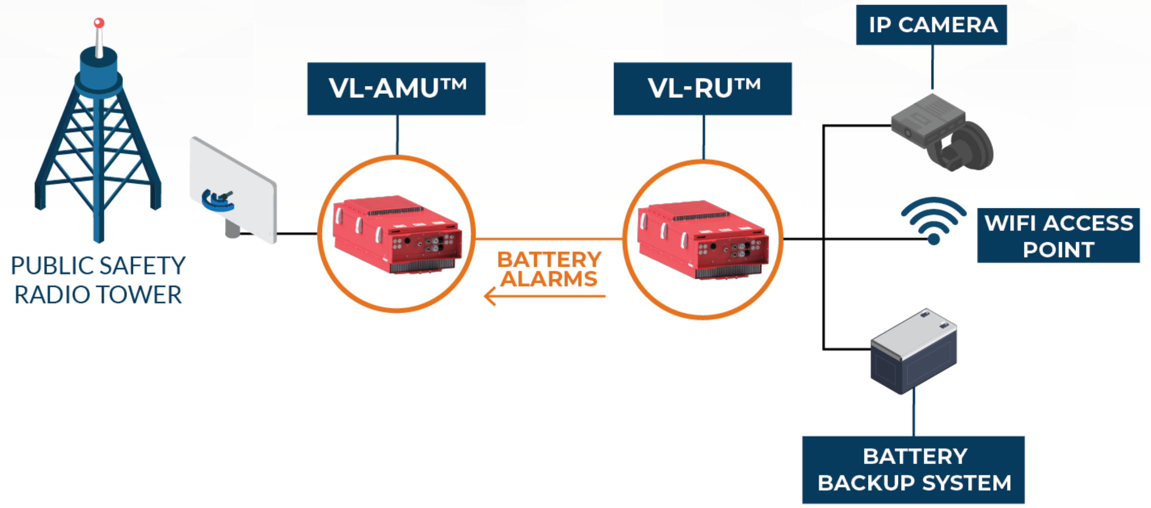

Figure 5. IP Backhaul

Automatic Optical Delay Compensation

Traditionally, optical delay compensation is done by using the same length of fiber to all remotes, or manually calculating the delay and adding delay elements to synchronize transmission from the headend to the remotes. With an all-digital and software-configurable platform, the optical delay is measured and the compensation is calculated. Then the delay is normalized automatically across all fibers with just a click of a button to synchronize transmission from multiple simulcast antennas (Figure 6). This saves site engineers time as no additional hardware is required to fine-tune delay once the in-building public safety system is installed, and it minimizes any time delay interference.

AUTOMATIC OPTICAL DELAY COMPENSATION

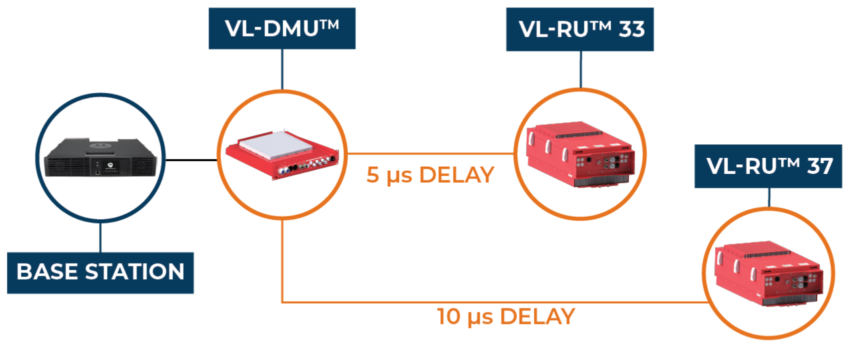

Figure 6. Automatic Optical Delay Compensation

Supports LTE and FirstNet Today

Avari's all-digital and software-configurable platform supports FirstNet and LTE technologies today, hence integrators and public safety operators can easily transition from P25 Phase I and II or TETRA/Tetrapol to LTE. This platform is also future-ready since new waveforms/standards can be easily implemented. This is possible since the digital signal processing is conducted using Field Programmable Gate Array (FPGA) devices that enable changes or upgrades by simply uploading a new image into the FPGA. Therefore, with an all-digital and software-configurable solution, integrators and public safety operators only need to make the hardware investment initially, and can easily expand and upgrade their network without a major overhaul.

System Redundancy and Self-Healing

Seamless mission-critical public safety communication is required at all times. The system cannot suffer the loss of service due to a single point of failure; therefore, redundancy is very important to ensure that communication between the first responders does not get interrupted. With its all-digital nature, the Avari digital DAS can provide a range of redundancy features including hot-standby host, hot-standby RF modules inside the host, hot-standby remote, secondary fiber optic link, and automatic equipment failure detection and switchover. 1:1 redundancy is achieved by deploying a secondary host in hot-standby mode and the same can be accomplished at the remote site by deploying a secondary remote with an optical and RF bypass kit. Fiber diversity can be attained by deploying a secondary fiber that runs on a different path from the host to the remote (Figure 7.)

Another feature that is unique to digital DAS is the automatic equipment failure detection and switchover. In the case of primary host failure, and/or primary fiber failure, the intelligent remotes will detect a loss of signal and automatically switch to the secondary optical link and standby host. In addition, digital DAS will automatically measure and compensate for changes in delays in the fiber connected to the remotes caused by the introduction of the secondary optical link. This is important for narrowband waveforms but will become particularly important with broadband waveforms like LTE which has a stringent delay balance requirement.

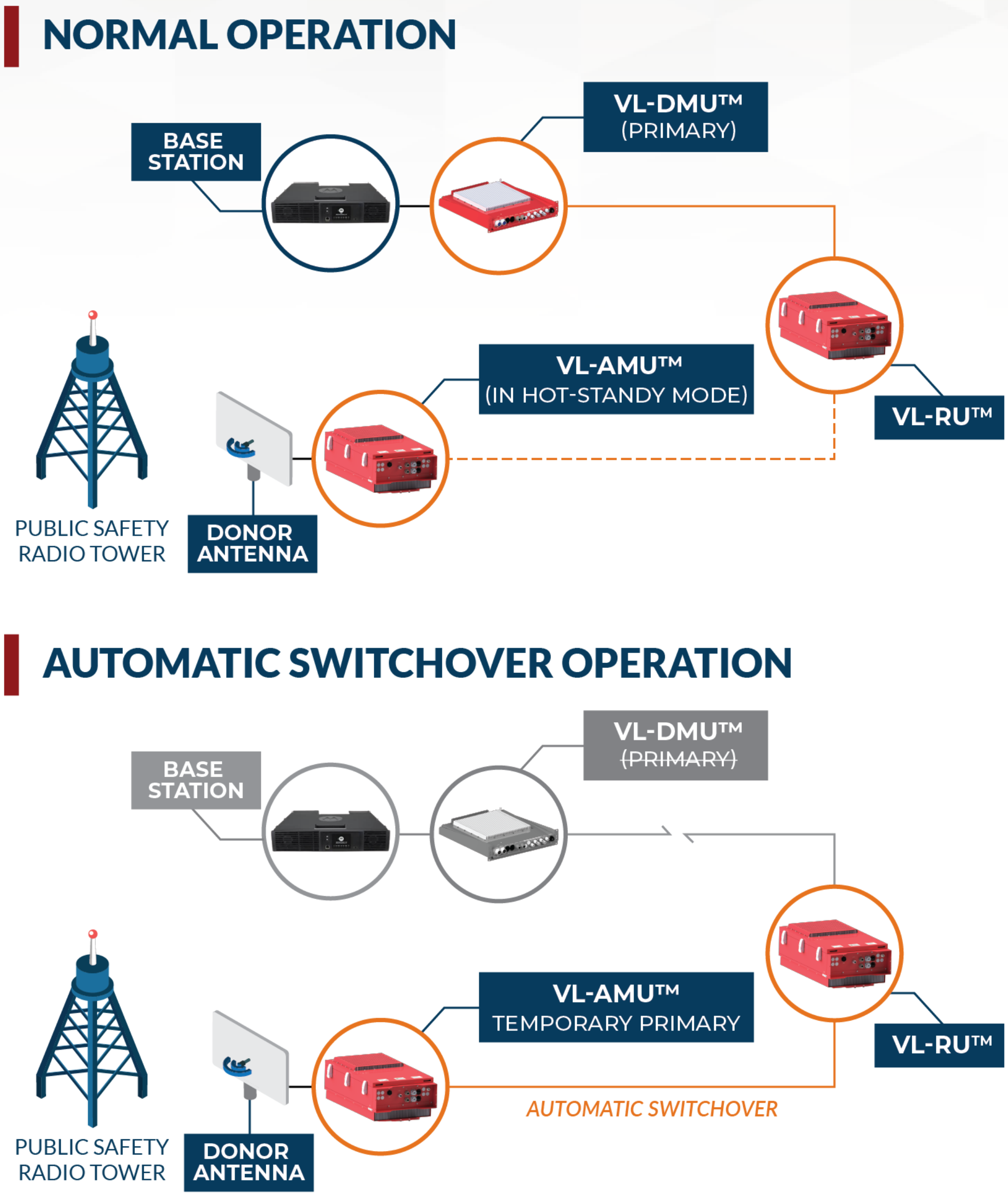

Figure 7. Redundancy

Data Scrambling & Encryption

Secure radio communications between first responders and public safety organizations are required. Systems should apply features counteracting eavesdropping, content tampering and content forging. Besides the encryption done by trunked radio systems, digital DAS adds additional scrambling of the data being transmitted over the fiber link, further increasing the protection of the content if intercepted during transport.

Avari® Digital DAS Key Differentiators

- Long reach with no loss of signal quality
- Channelized operation with advanced software-configurable digital filters (64 channels)
- Automatic digital gain control with squelch to ensure the best audio quality
- Purpose-built for high availability mission-critical applications
- 1 Gbps Ethernet backhaul over fiber
- System redundancy with self-healing capability
- Flexible deployment topology with star and daisy-chain configurations
- Multi-band support with high power output per band
- No off-air BDA required
- Intelligent system control with fault analyzer

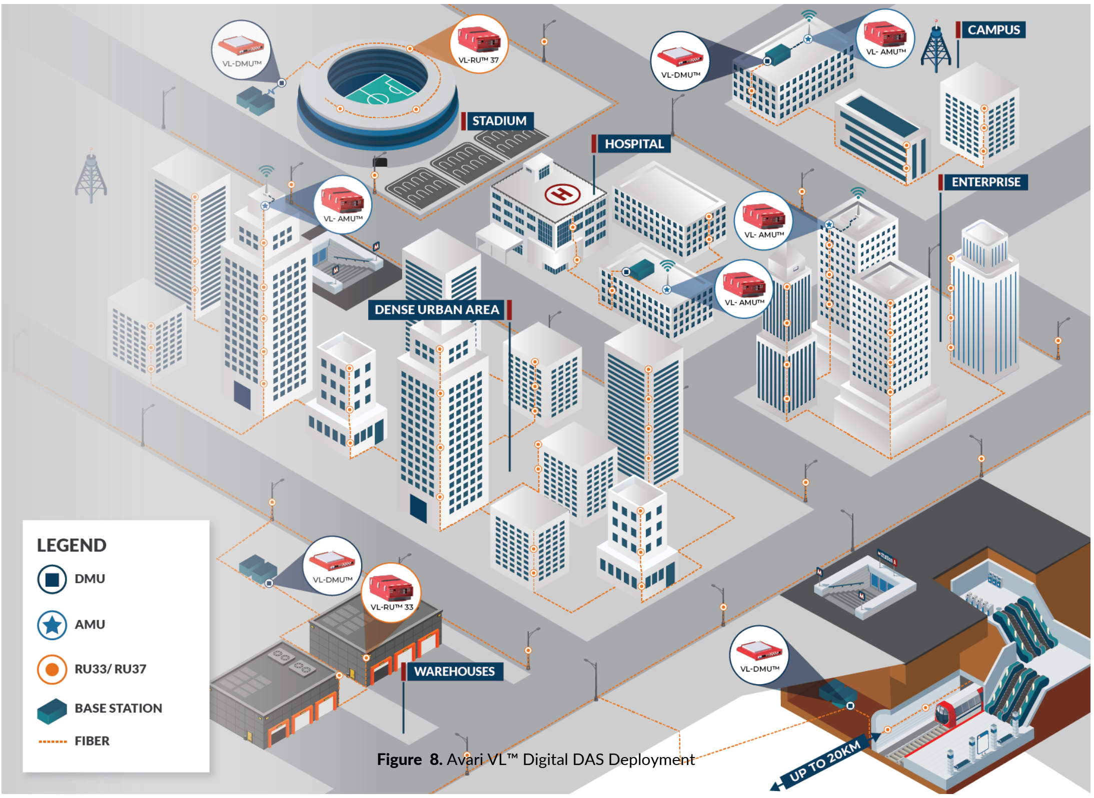

Figure 8. Avari VL™ Digital DAS Deployment

Conclusion

Public safety agencies around the world are recognizing the opportunity to leverage LTE for public safety radio communications, which will include data, video and location-based applications. FirstNet is bringing a nationwide broadband interoperable public safety network for the first responders and other emergency personnel in the United States. In the United Kingdom, ESN will provide the next generation integrated critical voice and broadband data services. According to the cited references below; given the limited ability of today's public safety networks to offer modern data connectivity and the growing need among first responders for precise connectivity to effectively do their jobs, governments of more than 80% of countries around the world are looking to upgrade their current narrow-band, voice-oriented systems to broadband alternatives.

The evolution to broadband LTE-based public safety from the current narrowband systems such as P25 Phase I and II, and TETRA will continue to happen gradually. Therefore, a flexible, future-proof and reliable solution is required to satisfy both the current requirements and future, next-generation public safety in-building radio communication requirements.

Avari VL™ Series public safety digital DAS is a next-generation solution that transcends the traditional RF-over-fiber analog DAS or Bi-Directional Amplifiers (BDAs). With its patented digital signal processing and software reconfigurability, the VL™ Series enables a unified broadband/narrowband communications infrastructure supporting the interoperability of current P25/TETRA systems and broadband systems like LTE.

With such a flexible system, Avari enables public safety operators and system integrators to meet today's voice and data requirements while providing them with a seamless migration path to address evolving public safety broadband requirements including LTE and FirstNet.

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About Avari

In the event of a crisis, public safety personnel and first responders require reliable emergency responder radio coverage.

Being able to communicate with public safety two-way radio systems in buildings is crucial for first responders to execute time-sensitive and mission-critical tasks to protect the public. Emergency Responder Communications Enhancement Systems (ERCES) are often installed to provide these necessary means of communication.

Avari® Wireless's public safety digital Distributed Antenna System (DAS), known as the Avari® VL™ Series, provides a reliable, high-performance, and high-availability system designed to support both current and future public safety communication requirements.

Avari's systems are enabling emergency communications indoors, which helps keep public safety personnel, first responders and the public alike safe.