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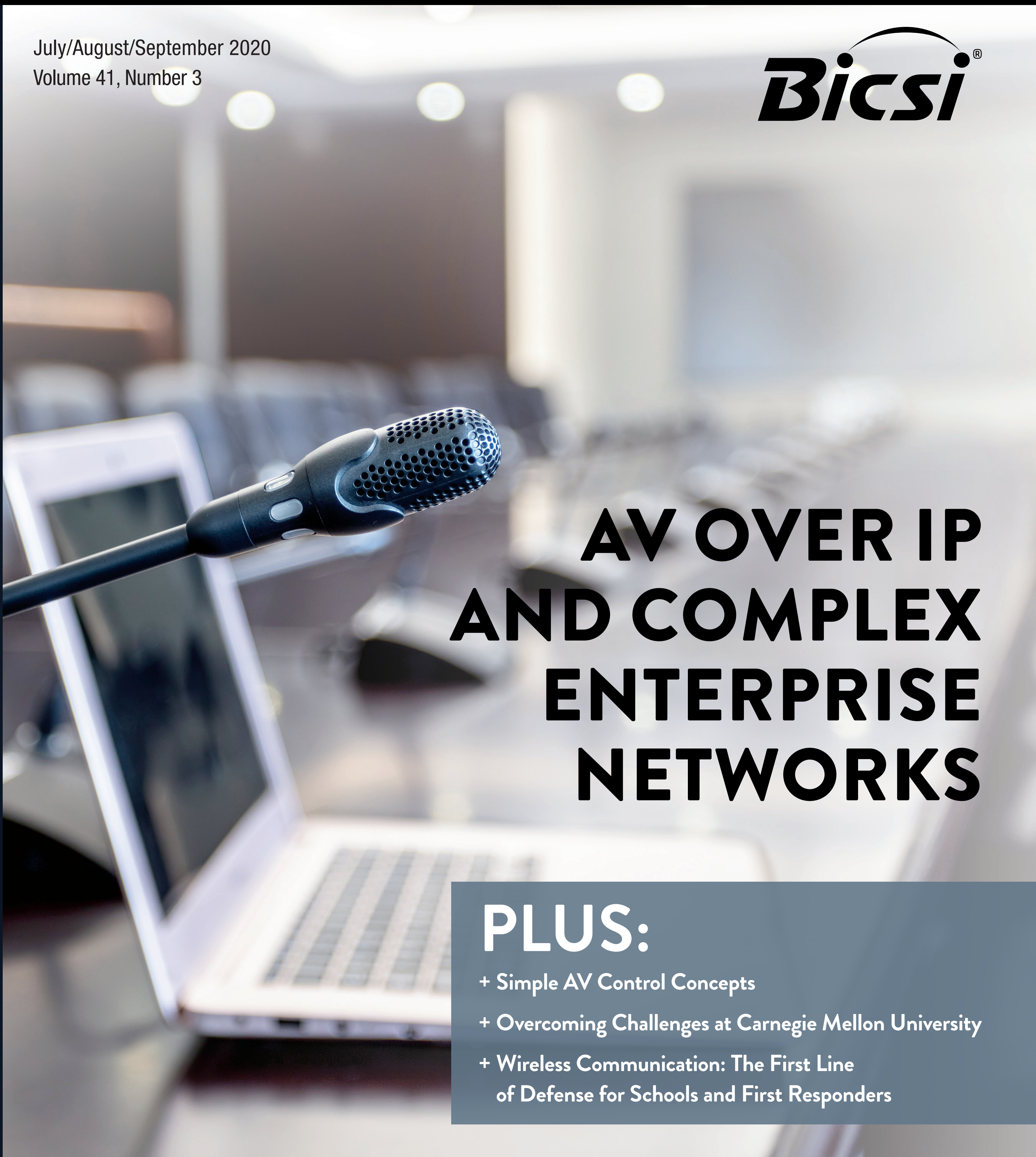

AV OVER IP AND COMPLEX ENTERPRISE NETWORKS

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Wireless Communication: The First Line of Defense for Schools and First Responders

By Jim Lilienfeld

Over the years, the public has had to cope with fatal active shooter events at schools throughout the nation. There have been at least 180 K-12 school shootings in the U.S. since 2009[1] with 356 victims serving as a somber reminder that action must be taken to prevent further tragedies.

Following a stark increase in school shootings, states have implemented laws and requirements to protect students and staff, encouraging them to monitor for warning signs from their peers. School districts are leveraging not only behavioral analysis to prevent future school shootings, but also significant changes in school safety measures that include implementing the design and communication of new technologies. The main goal is to keep students, staff, police, EMS, and other responders safe, whether using facial recognition capable devices, security surveillance systems, automated door locks or other wireless communication services. Orian Research projects by 2025 that the public safety wireless communication market will reach over $2.2 billion.[2]

This article explores advanced public safety technologies and relevant codes and standards in schools with a special focus on the critical role of wireless technologies. It is especially relevant today for ICT designers, installers, and integrators as many districts are using school closures in response to the COVID-19 pandemic to expedite public safety system installations for when students return.

SAFETY IN SCHOOLS

While schools are becoming much safer due to changes in school design and extra security, there is still much concern about the quality and level of safety.

The earliest schools in the U.S. were predominantly single-building designs. Now, they have become expansive multi-building campuses that can often accommodate thousands of students. Thus, recently built schools are essentially concrete fortresses that often double as town or city evacuation centers during natural disasters, such as hurricanes and wild fires.

Given the current climate of violence, most schools are beginning to focus on buildings that can better protect students. Design considerations include access control, site perimeter protection and better site and hallway visibility for surveillance that promote better facility supervision. For detailed information on the design and installation of wireless and other access control systems, site perimeter measures, wireless and other surveillance guidelines, and alarm systems, refer to BICSI's *Telecommunications Distribution Methods Manual*, 14th edition.

Improving school design is only one aspect of student safety and does not account for optimizing school security and communication services. Implementing new security measures is not always a decision that a school administrator makes; it is most often at the behest of budget committees. According to the *2019 State of School Report*, both parents and educator survey respondents prioritized additional funding to improve school safety, largely due to student and parent concerns over active shooter threats.[3] While K-12 schools are increasing spending on new technologies, there are still many actions that must be taken to ensure the safety of students.

Schools have invested in technologies, such as digital surveillance systems, which can detect abnormal behavior in students. However, knowing that there is a threat is only a part of improving public safety. The most recent edition of the Partner Alliance for Safer Schools' (PASS) *Safety and Security Guidelines for K-12 Schools*[4] identifies key technologies that enable security teams to communicate with school communities, as well as calls for in-building emergency communication systems that enable access to radio frequencies used by emergency services. An interesting finding reported by PASS is that one of the major security and safety pitfalls of schools is the "reliance on technology for emergency communications that is not designed for such use." PASS also makes it clear that a strong IT network, emergency communications system, and a reliable physical ICT cabling infrastructure to support them is crucial.

CONNECTING THE NATION'S FIRST RESPONDERS: FIRSTNET

Currently, schools and many other enterprises rely on traditional public safety communication frequency bands, such as the most commonly used 800 MHz band for first responder communication. The very high frequency (VHF) and ultra high frequency (UHF) bands range from 136 to 174 MHz and 380 to 512 MHz, respectively. Because VHF offers longer wavelengths, it can travel far distances with minimal disruption to first responders' push-to-talk radios, while UHF has shorter waves and is susceptible to interruption.

In 2012, the use of VHF and UHF changed with the creation of the First Responder Network Authority (FirstNet)[5] whose mission is to develop, build and operate the nationwide, broadband network that equips first responders to save lives and protect U.S. communities. FirstNet uses Band-14, also known as the 700 MHz public safety band, to provide the first high-speed nationwide wireless broadband network dedicated to public safety.

It was created to address a lack of standardization within public safety networks across state lines. When it is fully rolled out (currently, it is about 80 percent deployed), FirstNet may revolutionize public safety communication functions; first responders will be able to use dedicated commercial smartphones to communicate with one another regardless of region or district.

However, the FirstNet transition has its growing pains as more jurisdictions opt into the service and the infrastructure is implemented nationally. ANSI/BICSI 006-2020, *Distributed Antenna System (DAS) Design and Implementation Best Practices* standard, states that "Within jurisdictions utilizing FirstNet, DASs supporting FirstNet shall meet the requirements for both the contracted [wireless service provider] (WSP) and as an emergency services communication system. Where requirements are in conflict, the stricter of the two shall be met unless otherwise stated by the [authority having jurisdiction] (AHJ)."

ALERTING FIRST RESPONDERS

Beyond first responder intercommunication, 80 percent of 911 calls today are generated from a cell phone and 60 percent from a cell phone within a building, according to the Congressional Research Service (CRS).[6] This places the public safety sector in the prime position to create synergies between public safety and commercial connectivity.

In-building wireless networking solutions, such as DAS and repeaters, provide public safety frequencies for first responders, but students, faculty, and staff also rely on the commercial frequency bands to contact 911 during emergencies. In this instance, they can be considered first responders as well, since they are likely the ones to witness incidents first. When a crisis occurs and hundreds of students call the police or loved ones, it can cause a bandwidth surge and negatively impact the network via congestion. By implementing a robust network that has greater capacity, the school can bolster the safety of school attendees and first responders with the proper communication methods and reliable signal.

Separate from public enablement for emergency responses, Enhanced 911 (E911) is a continually updated mandate from the Federal Communications Commission (FCC) that seeks to improve the effectiveness and reliability of wireless 911 services.

The U.S. government is beginning to migrate the nation's emergency call centers from analog to digital with Next Generation 911 (NG911) as the 5G rollout begins to support additional data requirements.[7] It calls for the standardization of a nationwide, all-IP emergency communications infrastructure that enables voice and multimedia communications between a caller, the 911 center, and responders in the field. This transition will provide a new method for the public to communicate with 911 services through text, video, photos and voice.

As a result, first responders can better assess a situation and be ready prior to arriving on a scene. However, like many other services that rely on video and photo sharing on a large scale, they can create significant mobile network congestion that will be exacerbated by the volume of simultaneous calls to 911 during an emergency. To power this demanding service, proper network infrastructure using DAS, repeaters or small cells must be in place to maintain optimal function of the service.

Separate from public enablement for emergency responses, Enhanced 911 (E911) is a continually updated mandate from the Federal Communications Commission (FCC) that seeks to improve the effectiveness and reliability of wireless 911 services.[8] This service provides phone numbers and caller locations to local public safety answering points (PSAPs), as well as precise geolocation of the caller anywhere in the building. It uses the Z-axis location metric for vertical localization.[9]

As part of E911, governments can turn toward investments in in-building geolocation services. Schools can also opt into the citizens broadband radio service (CBRS) for a private LTE network that grants access to a wide variety of internet of things (IoT) services, including geolocation.[10] Once law enforcement, EMTs and other first responders show up on site, they can use an IoT service platform that shows a visual representation of students and where an active shooter may be located.

These new 911 technologies may be similar in many ways, but the main focus is to respond to the increasing numbers of tragedies in a fast tracked motion by eliminating many pain points that today's 911 service experiences.

IN-BUILDING COMMUNICATION REQUIREMENTS

The 911 calls from the public and in-building first responder communication need proper wireless technologies to function, but local governments have largely been reactive in implementing new public safety and design measures. To ensure the safety and communication of students and first responders, states and building code committees are constantly implementing and updating laws and requirements for public safety in-building communication devices, thereby urging schools to become more proactive in protecting students and staff.

The public safety market's rules and regulations are widely motivated by the International Code Council's International Fire Codes (IFC)[11] and the National Fire Protection Association (NFPA)[12] (Figure 1). The codes are revised every two to three years to offer new in-building safety compliance requirements for building owners. For example, codes such as NFPA 1221-26-2019 set the standard for the installation, performance, operation, and maintenance of public emergency services, communication systems and facilities. Authorities having jurisdiction interpret and enforce these codes in their regions, and with every code change, building owners must comply and update their wireless communication technologies, such as DAS, repeaters, and passive components.

Updated safety codes are generally enforced only on newly constructed buildings and those that are older are grandfathered to previous requirements. With safety incidents gaining media attention, policymakers are beginning to no longer allow older buildings to grandfather codes. This action is leading the public safety industry toward upholding the latest standards for all structures.

Recently, Underwriters Laboratories (UL) created the UL-2524 standard for in-building two-way emergency communication enhancement systems.[13] It addresses in-building public safety compliance with specific communication device performance requirements for life safety systems in construction and testing in accordance with the IFC-2018 and NFPA 1221-2019 codes. Currently,

Public Safety Code Reference

	NFPA 72 - 2013	NFPA 1221 - 2016	NFPA 1221 - 2019	IFC - 2015	IFC - 2018	IFC - 2021
In-Building Solution Required	NFPA 1 Section 11.10	NFPA 1 Section 11.10	NFPA 1 Section 11.10	*Sec. 510.1*	*Sec. 510.1*	*Sec. 510.1*
Pathway Survivability for Coaxial Cable Required	2 Hour for Riser Coaxial Cable – Sec. 24.3.6.8	2-Hour for Riser Coaxial Cable - Sec. 9.6.2.1.3	Backbone Cable Routed Through Enclosure Matching Bldgs. Fire Rating Sec. 9.6.2.3	*Not Specifically Addressed in Section 510. Referenced in 2013 NFPA 72 Sec. 24.3.6.8*	*Yes, Section 510.4.2. Reference to NFPA 1221. ** Also See NFPA 1221 TIA 16-2*	*Yes, Section 510.4.2. Reference to NFPA 1221.*
Plenum Rated Coaxial Cable Required	Yes, Riser & Feeder Coaxial Cable Sec. 24.3.6.8	Yes, Riser & Feeder Coaxial Cable – Sec. 9.6.2.1.1.1	Yes, Backbone & Antenna Distribution Cables Sec. 9.6.2.1	*Not Specifically Addressed in Section 510. Referenced in 2013 NFPA 72 Sec. 24.3.6.8*	*Yes, Sec. 510.4.2. Reference to NFPA 1221*	*Yes, Section 510.4.2 Reference to NFPA 1221*
Lighting Protection Required	Not addressed in Section 24.5.2	Yes, In accordance with NFPA 780 – Sec. 9.6.3	Yes, Section 9.6.3 Installed per NFPA 780	*Not Specifically Addressed in Section 510*	*Yes, Sec. 510.4.2 Per NFPA 780 as Referenced in NFPA 1221*	*Yes, Sec. 510.4.2 Per NFPA 1221 Sec. 9.6.3 Installed per NFPA 780*
Isolation of Donor Antenna Required	Yes, 15 db – Sec. 24.5.2.3.3	Yes, 20 db – Sec. 9.6.9	Yes, 20 dB Above System Gain Sec. 9.6.9	*Not Specifically Addressed in Section 510*	*Yes, 20 db – Sec. 510.4.2.4 (4)*	*Yes, 20 db – Sec. 510.4.2.4 (4)*
Battery Backup Required	12 Hours – Sec. 24.5.2.5.5.2	12 Hours – Sec. 9.6.12.2	12 Hours Battery or Generator Section 9.6.12.2	*24 Hours – Sec. 510.4.2.3*	*12 Hours – Sec. 510.4.2.3 or 2-Hours Battery w/ Emergency Generator*	*12 Hours – Sec. 510.4.2.3 or 2-Hours Battery w/ Emergency Generator*
Signal Strength & Area Coverage Required	-95 dBm – Sec. 24.5.2.3 90% General – Sec. 24.5.2.2.2 99% Critical – Sec. 24.5.2.2.1	DAQ 3.0 - Sec. 9.6.8 90% General - Sec. 9.6.7.5 99% Critical - Sec. 9.6.7.4	DAQ 3.0 - Sec. 9.6.8 90% General - Sec. 9.6.7.4 99% Critical - Sec. 9.6.7.3	*-95 dBm – Sec. 510.4.1 95% General – Sec. 510.4.1 99% Critical – Not Specifically Addressed in Sec. 510*	*DAQ 3.0 - Sec. 510.4.1.1 95% General - Sec. 510.4.1 99% Critical - Sec. 510.4.2 Reference to NFPA 1221*	*DAQ 3.0 - Sec. 510.4.1.1 95% General - Sec. 510.4.1 99% Critical - Sec. 510.4.1*
Monitoring By Fire Alarm Required	Yes – Sec. 24.5.2.6	Yes – Sec. 9.6.13	Yes – Sec. 9.6.13 & Chapter 10 of NFPA 72	*Not Specifically Addressed in Sec. 510 – See 2013 NFPA 72*	*Yes – Sec. 510.4.2.5*	*Yes – Sec. 510.4.2.5*
Cabinets for Equipment & Battery Backup Required	Yes, NEMA 4/NEMA 4X – Sec. 24.5.2.5.2	Yes, NEMA 4/NEMA 4X – Sec. 9.6.11.2	Yes, NEMA 4/4X & NEMA 3R for Batteries Sec. 9.6.11.2	*Yes, NEMA 4 – Sec. 510.4.2.4 (1) & (2)*	*Yes, NEMA 4/NEMA 3R – Sec. 510.4.2.4 (1) & (2)*	*Yes, NEMA 4/NEMA 3R – Sec. 510.4.2.4 (1) & (2)*
Monitor Antenna Malfunction Required	Yes, Donor Antenna – Sec. 24.5.2.6(2)(a)	Yes, Donor Antenna – Sec. 9.6.13.1(2)(a)	Yes, Donor Antenna – Sec. 9.6.13.2.1(5)	*Not Specifically Addressed in Section 510*	*Yes, Donor Antenna – Sec. 510.4.2.4(4)*	*Yes, Donor Antenna – Sec. 510.4.2.4(4)*
System Acceptance /Testing	Section 24.5.2.1.2 &14.4.10	Section 9.6.4, 11.3.9 & 11.3.9.1	Section 9.6.4, 11.3.9 & 11.3.9.1	*Section 510.5.3*	*Section 510.5.3*	*Section 9.6.4, 11.3.9 & 11.3.9.1*
Lisiting of Equipment	Not Specifically Addressed	Not Specifically Addressed	Specific Listing Requirement TBD by the AHJ	*Not Required by Section 510*	*Not Required by Section 510*	*Yes, Section 510.4*
Mounting of Donor Antenna	n/a	n/a	Not Specifically Addressed	*Not Specifically Addressed*	*Not Specifically Addressed*	*Section 510.5.1*

SAFER BUILDINGS COALITION

FIGURE 1: Reference guide for public safety codes.

compliance is optional in many regions, such as counties within Florida, California, and Nevada, but AHJs' nationwide demand for UL-2524-compliant wireless networking equipment continues to grow as the importance of better public safety communications takes center stage.

To advocate and proactively propose new fire codes and standards, the Safer Buildings Coalition (SBC) was created in 2012 to foster constructive collaboration among wireless industry stakeholders, such as AHJs, wireless carriers, manufactures and others, to further the mission of making buildings safer.[14] Many original equipment manufacturers (OEMs) are members of this organization.

IMPLEMENTING IN-BUILDING TECHNOLOGIES

Many schools have become near-impenetrable to natural disasters and perhaps intruders, including those that are built and used as evacuation centers. However, improvements in building construction have affected the reinforcement layers that have altered how two-way radio systems can be implemented within a school. Many school administrators assume they have a poor signal based on the approximate distance from a cell tower. However, the school's surrounding obstacles and structures can attenuate the signal. This challenge, combined with the increase in public response technologies such as E911, creates a need for adequate wireless infrastructure now more than ever.

> *Denser materials and low-emission energy saving windows can disrupt a signal anywhere between -24 to -40 dB.*

A typical cellular phone signal operates with a frequency ranging from >-70 dBm (full bars) to -120 dBm (no signal), and building materials and outdoor obstructions are known to cause a subtraction in decibel (dB) readings. Schools are fortifying their walls with metal roofs, heavier glass and more rebar meant to strengthen concrete under tension. Most notorious for causing disruptions are metal (-32 to -50 dB), wood (-5 to -12 dB), plaster (-8 to -16 dB) and concrete (-32 to -50 dB). As schools also focus on becoming more energy efficient, denser materials and low-emission energy saving windows can disrupt a signal anywhere between -24 to -40 dB.

Adding trees and architectural structures meant to break up open spaces can also negatively impact the 90-99% signal strength required by the NFPA and IFC codes for communication systems.[15] Tall trees and other vegetation can form natural barriers to cellular signal waves, attenuating the signal anywhere from -7 dB to -20 dB.

Findings from a report by the Marjory Stoneman Douglas High School Public Safety Commission[16] revealed that there was sporadic functioning of the Broward Sheriff Office's radios, and to an unknown extent the school structure itself also hindered the radio functionality.

To prevent a similar tragedy, school districts should implement an in-building public safety communication system to ensure that radio signals can penetrate all areas of buildings, including especially difficult areas for radio frequency (RF), such as stairwells, elevators, basements, and thick-walled or shielded areas. Schools are encouraged to engage with the AHJ early in the process to understand the set of requirements for in-building public safety systems since each AHJ interprets each code differently. This helps to prevent delays during installation.

Before contacting a systems integrator (SI) or original equipment manufacturer (OEM), school district officials should make a list of important goals and objectives to address. If cost savings is a concern, a modular DAS can be upgraded easily to stay compliant with code updates. Some OEMs and integrators also provide 24/7 technical support in case an issue arises.

Selecting a qualified SI, such as an experienced Registered Communications Distribution Designer (RCDD), should come after understanding the specific school needs and local AHJ requirements. The right SI is trained in selecting the best RF, design, and system based on a building's architectural design. The SI is responsible for site survey/baseline testing, preliminary design, statement of work, RF surveying, design revisions and finalizations for ordering equipment, installation, commissioning, and system acceptance. They may also perform annual maintenance and health checks after the system is deployed.

The system design is based on three considerations: equipment, capacity and coverage. Public safety communication is rarely restricted by capacity when compared to the data-heavy communication of commercial systems. In public safety systems, the propagation characteristics of the low frequencies dictate the use of an active or passive DAS based on the size of the building and its required coverage needs.

For buildings of less than 120 thousand square feet (approximately 11,150 m^2), a passive public safety DAS consisting of a signal source (typically a repeater) is used to feed a network of passive components through server antennas to provide coverage throughout a building. This is the most common solution for public safety deployments due to the use of lower frequency bands that allow for better propagation and coverage of large areas with the same RF output power.

An active public safety DAS, also known as an optical fiber DAS, is used in venues or schools that are more than 120 thousand square feet (Figure 2). It consists of a signal source repeater that feeds into a fiber DAS headend that converts the RF to optical signal and distributes it over fiber to multiple remote amplifier locations. It is then converted back to RF and distributed to passive networks of components and antennas.

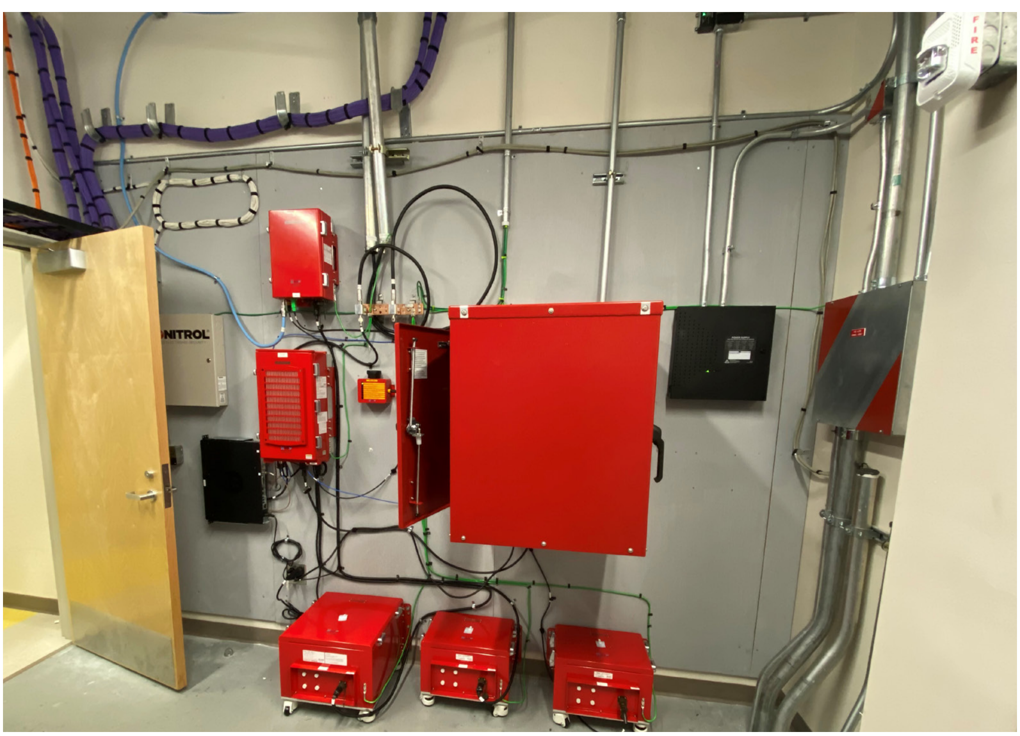

FIGURE 2: Active public safety DAS fed by a repeater attached to the battery backups.

For detailed information about the design and installation of passive and active DAS, including hybrid solutions, consult the ANSI/BICSI 006-2020 *Distributed Antenna System (DAS) Design and Implementation Best Practices* standard. ANSI/BICSI 006-2020 thoroughly addresses public safety and contains a special section about the particular needs of schools in section 10.7.

Common deployment delays, such as DAS alarming, battery backup alarming, and insufficient RF coverage at critical areas (e.g., elevators, stairwells, battery backup) can occur, but with proper planning upfront and engaging the right partners, school districts can save time and money.

Many districts throughout Florida are issuing requests for proposals (RFPs) to develop two-way radio communication systems for entire campuses. These public safety projects are designed to cover elementary, middle, high schools and administration buildings. In coordination with AHJs, OEMs are currently working with the counties to deploy a state-of-the-art public safety system in all the schools that fail the mandated grid testing required throughout the state.

5G PUBLIC SAFETY DEPLOYMENTS

While 5G is promising for many commercial use cases and massive IoT applications supporting public safety needs, portions of the LTE spectrum still remain sufficient for in-building wireless communication systems meant for first responders now and in the near future. It is what all mobile carriers continue to use for their public safety networks, including FirstNet. This is largely because of the new deployment challenges that arise as a result of the frequency bands used for 5G. The 4G/LTE frequency bands are characterized as traversing long distances and can more easily penetrate building materials without severe attenuation of RF signals. Conversely, 5G frequency bands that deliver faster speeds and ultra-reliable low-latency communication (URLLC), such as mmWave, travel much shorter distances and are more easily disrupted by walls and environmental interference. These issues for both outdoor and indoor connectivity makes 5G akin to a “hotspot” for better connectivity supporting specific applications over the blanket coverage people typically associate with LTE.

In public safety systems, the propagation characteristics of the low frequencies dictate the use of an active or passive DAS based on the size of the building and its required coverage needs.

Due to these limitations, in-building deployments may require additional wireless infrastructure to provide ubiquitous coverage to the same area, such as additional repeaters, DAS or the inclusion of cloud radio access networks (C-RAN) small cells. Using small cells as a stand-alone solution is not cost-effective because of the many devices it would take to fill a school with complete coverage. When and if LTE is completely phased out, carrier aggregation will likely occur, delivering 5G with a lower frequency band, which provides equivalent speeds but also reduces the infrastructure needed. In preparation for 5G, schools should consider developing a commercial network parallel to the public safety network by running structured cabling and implementing a DAS that supports the 5G frequency bands. Currently, Verizon uses 28 GHz and 39 GHz, AT&T uses 39 GHz, and T-Mobile/Sprint uses 600 MHz, 28 GHz, 39 GHz, and 2.5 GHz.

According to ANSI/BICSI 006-2020, “To provide adequate bandwidth and coverage, a DAS may need to be supplemented by either small cell antenna or cloud radio access networks (C-RAN) solutions to distribute 5G signals in buildings with large number of users that wish to use 5G mobile phones within the building.”

As described earlier, the mobile phones used by people in schools and other first responders are part of the overall public safety system, so the in-building wireless infrastructure should be able to support 5G as users migrate to 5G devices (e.g., smartphones and tablets). To prepare for this transition and an evolving DAS infrastructure solution, such as a C-RAN based small cell system, at minimum the telecommunications cabling infrastructure and cabinet/rack space should be planned for such a deployment.

CONCLUSION

As school districts strive to improve the safety of students, faculty and staff during emergencies, they will increasingly rely on wireless technologies for mission-critical use cases. Reliable wireless connectivity can make a difference in protecting the lives of the public and those responding to emergencies.

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