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THE OFFICIAL TRADE JOURNAL OF BICSI

July/August 2018
Volume 39, Number 4

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From the President, Jeff Beavers, RCDD, OSP, CFHP

OSP IS EVERYWHERE AND OFTEN OVERLOOKED

Will That Insatiable Broadband Appetite Ever be Satisfied? Never!

Upon the release of the *Outside Plant Design Reference Manual (OSPDRM),* 4th edition in 2007, BICSI lead the change in the outside plant (OSP) marketplace where "customer-owned" and its application had changed. The *Customer-Owned Outside Plant Design Manual (CO-OSPDM)*, 3rd edition was changed to the OSPDRM; customer-owned OSP was not specific to a campus environment. Codes, standards and best practices no longer pointed to who owned the infrastructure. The information became relevant and applicable to campuses, military bases, utility-owned networks, publicly-owned networks and even traditional service providers.

The BICSI Technical Information and Methods Committee OSP subject matter expert team leader, John Adams, wrote "…this name change reflects a broader applicability of the information contained in the manual. In today's OSP marketplace, the lines between customer-owned and other information transport systems infrastructure have blurred. Following this same trend, the need for a design reference manual specifically focused on customer-owned facilities has become less important. The information contained within this new fourth edition is useful for anyone who is involved in the design or construction of OSP projects."

Communities are investing in their own broadband infrastructure to provide access to essential services, stimulate economic growth and development and improve quality of life for residents and guests. In the U.S., more than 130 communities have a publicly-owned network offering at least 1 gigabit services. Globally, several cities lead the way in connected communities.

Utilities around the world are deploying optical fiber networks to support automation applications such as supervisory control and data acquisition, advanced metering infrastructure, and distribution automation, with the optical fiber network as the backbone of a smart grid. The utility-owned optical fiber networks also transport corporate networks.

Traditional service providers, who once were the source for the design, construction, operations and maintenance of an OSP network, also rely on the services from design firms and construction companies for the design and construction, and oftentimes the operations and maintenance, of their OSP network. They are now "the customer."

It is estimated that 1,390,816 miles of optical fiber cable would be required to provide full 5G service to just the top 25 metropolitan land areas in the United States.[1] 5G, small cell, autonomous cars, artificial intelligence, internet of things, connected communities, campuses, smart cities, smart utilities and our insatiable broadband appetite demand an incredible amount of optical fiber—a lot of it, everywhere.

The recently released *OSPDRM*, 6th edition contains new and updated material such as OSP-specific information on passive optical networks, updated relevant project management information as it concerns OSP design and information on geographic information systems.

Although there are new methods for construction such as micro-trenching and new design tools such as light imaging detection and ranging, ground penetrating radar, and automated OSP design software, OSP has remained largely unchanged for decades. OSP may not be considered glamorous, but it is a very important part of the ICT world.

The *OSPDRM* defines an underground plant as having the "longest projected lifespan, typically in excess of 50 years." A well designed, installed and maintained pathway system might be considered the best form of future-proofing.

I was told of a recent OSP project that almost saw brand new optical fiber cable deployed through existing (creosote-soaked) wooden conduits. The wooden conduits could have been utilized as they presented an option to the customer as a means for fast deployment—as well as reduced design time, construction costs and permitting requirements. From as long ago as the 1890s, creosote-soaked wooden conduit systems may still exist in urban areas and be found usable.

It is fascinating to think that emerging technologies and smart city infrastructure could have been deployed in a pathway system more than 100 years old!

OSP is everywhere yet is often overlooked.

Simply put, we cannot have advanced networks without OSP and optical fiber everywhere. That insatiable broadband appetite makes the future for the OSP professional look good.

One last note: OSP is inherently dangerous, so be careful out there.

Be safe; someone is counting on you.

REFERENCE: [1] "The Road to 5G is Paved with Fiber", Fiber Broadband Association

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July/August 2018 Volume 39, Issue 4

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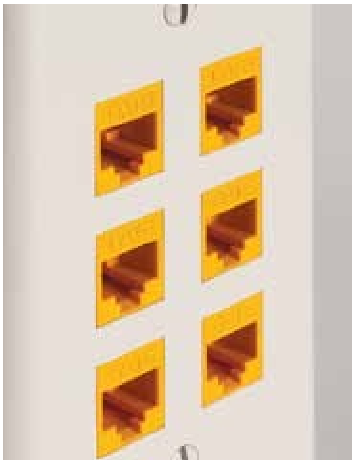

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Can We Take the Art of Aerial Construction to New Heights?

Not long ago, aerial infrastructure for spanning distances great and small was considered easily deployable and readily accessible for maintenance, becoming the basis for rapidly connecting people first by phone and then internet. Over time, concerns about pathway survivability, security and aesthetics literally forced aerial infrastructure underground.

By John Romanski, OSP, WD, ESS, DCDC, RTPM

But has aerial plant truly been grounded? Zion Market Research recently released findings that the global aerial equipment market was valued at around $8.3 billion in 2016 and is expected to reach over $14.3 billion by the end of 2022, growing at a compound annual growth rate of 9.5 percent between 2017 and 2022. This rapid growth is driven in part by a rising demand from telecommunications and electrical line maintenance. Where there is demand for maintenance, it stands to reason that a large installed aerial plant base continues to be used, with enough new aerial plant construction to partially offset aerial plant being abandoned and removed.

Where there is demand to keep aerial plant aloft, it stands to reason that the requisite knowledge, skills and workforce also exist. Or do they? A Department of Energy study in 2015 on the utility workforce found that "as of 2012, the largest percentage of utility employees were in the 48 to 52 and 53 to 57 age groups; 38 percent of electric and natural gas employees will be eligible to retire in the next decade." Those with a lifetime of knowledge and experience are readying to leave the field.

Unlike times past, recording and archiving this knowledge has become easier to perform and pass down.

As part of that effort, the BICSI® Standards Outside Plant (OSP) Construction and Installation Subcommittee has been capturing information from those who have put on the spikes, dug a hole or two (thousand) or placed cables in a variety of locations. While the following is not a comprehensive look at constructing aerial plant, it provides insight into the major stages of the construction process.

Pre-construction

Once the bid is awarded for a design, the construction phase may begin. But before the first hole can be dug, several tasks need to occur to ensure success. The bid package, scope of work, schematic design and work prints all contain information relevant to the project and need to be collected or completed during the pre-construction phase. For example, a design should include information from at least one site or pathway survey, including general conditions, notable geographical, vegetation or other environmental issues, and potential right-of-way, regulatory or other permission issues.
If a bid package does not have these findings, either integrated or as a separate report, pre-construction work becomes even more critical.

The bid package must include a number to call for location marking along with a list of permits that will be required. While separate activities, these actions need to be coordinated. In many areas, location marking is the easier of the two tasks; the United States and other countries have

Makeready Design

Within aerial plant, the use of existing poles within a proposed route is a common practice.

Makeready design typically uses the following process:

- **Complete a field survey and identify the pole owners and proposed locations for attachments.**
- **Identify the owners of all attached plant.**
- **Schedule a pre-construction survey with the owners and other attached utilities.**
- **Conduct the pre-construction survey and identify the costs, requirements, scheduling and right-of-way needs.**
- **Review all applicable codes, standards and regulations and note specific requirements for incorporation into the documentation.**
- **Create construction drawings with all proposals.**
- **Fill out all joint use requests and billing forms, and note any special arrangements required.**
- **Send out copies to all associated parties for final review.**
- **Obtain authorizations and approvals to commence work.**
- **Issue the drawings to construction.**

While makeready design can provide construction savings for the specific aerial pathway, there may be costs associated with the work required to create the joint use pole, including moving existing utilities to create required clearances (e.g., clearances around medium and high voltage wire) for the new pathway. And as each pole owner and location is unique, any joint use agreement entered into by all parties (e.g., pole owner, other existing joint use pathway owners) will be similar.

made efforts to centralize location marking of all utilities through a centralized source, typically referred to as a One Call Center. While most aerial plant is above ground, more than one project has been set back by the unintentional drilling through underground utility infrastructure for electrical, water, gas/petroleum or even telecommunications equipment.

Location marking can happen in short order—a matter of days. However, some location marking may require approval of adjacent property owners if crossing over the property is required to access the route. As one or more permits are required for aspects of construction to occur, calling for location marking before permits can be issued may result in altered or removed markings, necessitating a reperformance.

As is the nature of construction, other tasks need to be completed, such as arranging for the delivery and storage of materials, verifying safety plans, training and equipment, and the numerous other details specific to the actual project. This culminates with one of the last tasks just prior to the commencement of work, a pre-construction field verification where the site and pathway conditions are physically surveyed to ensure all is ready.

Creating Holes and Placing the Poles

Unless makeready design can eliminate the need for new poles, aerial plant projects that involve anything beyond creating a drop or service wire will require the addition of one or more new poles to serve as an attachment point for cabling. While poles come in material options of wood, concrete, steel and composite, all use embedment (e.g., place in holes) as the preferred method for installation.

Creating the hole for a pole is more involved than just digging a hole. If the crew responsible for indicating the location of a pole has performed their work, there will be a stake indicating location, size and class of the pole, and the size and number of guys, as well as location stakes for the anchor. The pole stake will be the initial spot of the hole and the depth and width of the hole will vary depending on the size of the pole.

For sizing of the hole, 100 mm (4 in) of horizontal clearance is needed around the pole to allow backfill. For the depth of the hole, this varies by length of the pole and the ground type. For common firm soil types, the minimum hole depth needs to be at least 1.1 m (3.5 ft) and steadily increases as the overall pole length increases (Table 1). When setting in solid rock, a minimum hole depth of only 0.9 m (3.0 ft) is needed until poles exceed 7.6 m (25 ft) in length.

The depth of holes can also be affected by the presence of underground rock. Potentially undetectable during initial site surveys, creating holes in rock requires different methods and, depending on the depth, can affect the pole's footing. As shown in Table 2, the further rock is found from the surface, the larger the minimum hole depth needs to be until it reaches the minimum depth of common soil.

The creation of the holes is routine because machine power augers or borers have replaced the use of shovels for a majority of the work. For unstable soil types or where subsurface water is encountered, the use of a high-pressure water stream can serve as the digging method. It is common to perform this method while setting the pole, as the water stream will provide a temporary void into which the pole can drop.

The raising and setting of poles used to be labor intensive, potentially back-breaking work (Figure 1). Today, setting poles by a line truck is usually the simplest and safest method. Some line trucks are

LENGTH OF POLE	DEPTH OF SETTING IN AVERAGE FIRM SOIL	DEPTH OF SETTING IN SOLID ROCK
4.9 m (16 ft)	1.1 m (3.5 ft)	0.9 m (3.0 ft)
5.5 m (18 ft)	1.1 m (3.5 ft)	0.9 m (3.0 ft)
6.1 m (20 ft)	1.2 m (4.0 ft)	0.9 m (3.0 ft)
6.7 m (22 ft)	1.2 m (4.0 ft)	0.9 m (3.0 ft)
7.6 m (25 ft)	1.5 m (5.0 ft)	0.9 m (3.0 ft)
9.1 m (30 ft)	1.7 m (5.5 ft)	1.1 m (3.5 ft)
10.7 m (35 ft)	1.8 m (6.0 ft)	1.2 m (4.0 ft)

TABLE 1: Typical depth of hole in firm ground or solid rock.

Distance of Solid Rock Below Surface Level	POLE LENGTH			
	6.1 m (20 ft)	7.6 m (25 ft)	9.1 m (30 ft)	10.7 m (35 ft)
0.0 m (0.0 ft)	0.9 m (3.0 ft)	0.9 m (3.0 ft)	1.1 m (3.5 ft)	1.2 m (4.0 ft)
0.2 m (0.5 ft)	1.1 m (3.5 ft)	1.1 m (3.5 ft)	1.2 m (4.0 ft)	1.4 m (4.5 ft)
0.3 m (1.0 ft)	1.2 m (4.0 ft)	1.2 m (4.0 ft)	1.4 m (4.5 ft)	1.5 m (5.0 ft)
0.5 m (1.5 ft)	1.2 m (4.0 ft)	1.4 m (4.5 ft)	1.5 m (5.0 ft)	1.7 m (5.5 ft)
0.6 m (2.0 ft)	1.2 m (4.0 ft)	1.5 m (5.0 ft)	1.7 m (5.5 ft)	1.8 m (6.0 ft)

TABLE 2: Minimum hole depths for poles when solid rock is below ground level.

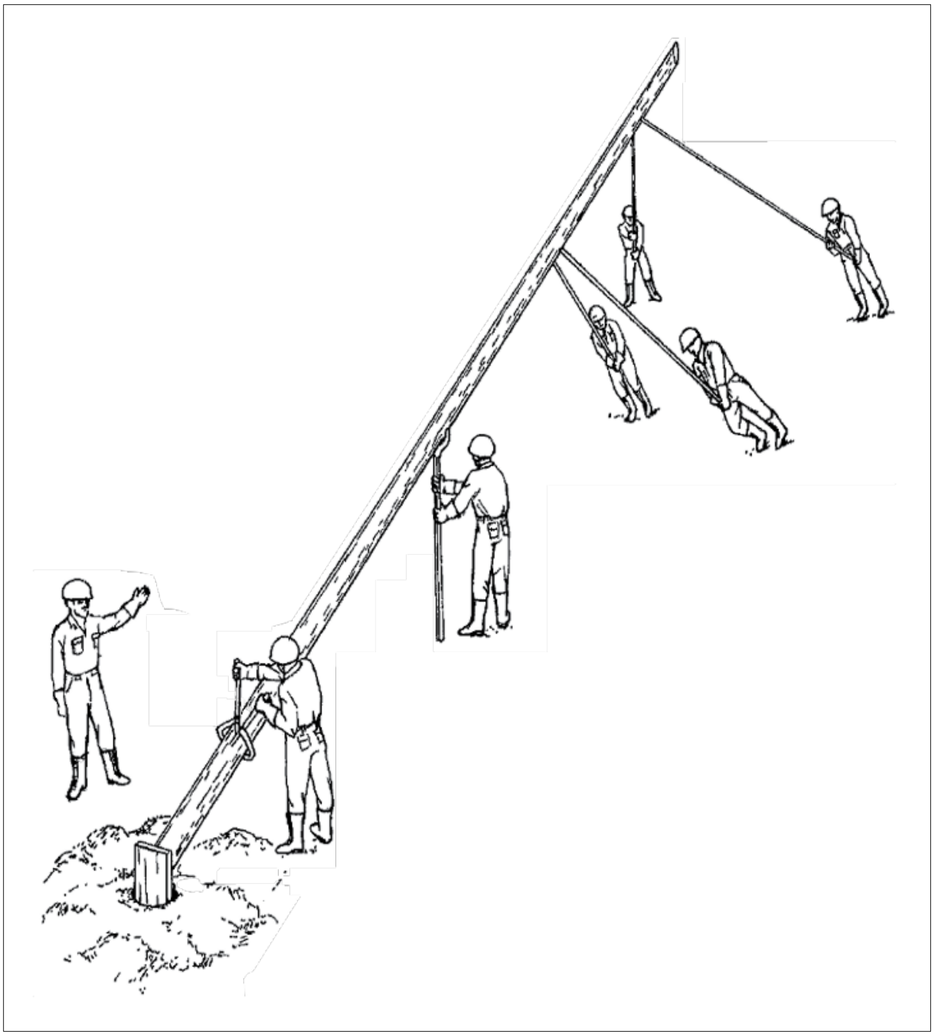

FIGURE 1: Manually raising a pole.

equipped wit an A frame derrick and a winch line, others are equipped with a rigid extendable arm or derrick to raise and lower poles, both of which are suitable for any pole up to 13.7 m (45 ft) in length. However, there will be instances where hand-setting of poles will be required (e.g., inability to use line trucks or other power equipment due to access issues to the site or terrain).

Once poles are set, the space around them needs to be backfilled. As the hole is filled, tamping and compacting needs to occur each time 150 mm (6 in) of earth is added. Large stones and rocks can also be added during the backfill to act as wedges. Once the hole is filled, a final tamping needs to occur to ensure that the fill has reached ground level, though 150 mm (6 in) above is preferable.

While earth is commonly used, it is not the only fill material. Where poles are set in solid rock, new rock or the rock debris from the hole creation can be wedged around the inserted pole. Depending on soil condition or the design plan, cement, concrete or polymer fills may be specified as an additional measure against ground line rot or corrosion of the pole.

Attachments

Once the pole is set, it needs to be prepared to support the cable(s) and any other elements specified on the plan. While there are numerous types of devices to do this, all are generally termed attachments, and each pole will have at least one.

While installers need a pole to affix an attachment, there is no one preferred sequence when setting poles and connecting the attachments. In some scenarios, it may be easier to add the attachments while the pole is on the ground; other times placement of the attachment requires knowledge of the final position of other poles, anchors, or clearances with other attachments. For new poles, considerations for adding the attachment prior to the pole setting activities include:

- Type of pole.
- Connecting method of the attachment (e.g., through bolt, strap).
- Presence of attachment points or pre-drilling.
- Physical size of attachment (e.g., cable clamp versus extension arm).
- Pole lifting method.
- Placement of other elements completed (e.g., anchors, adjacent poles in the span).

The size of the project, the number and type of work crews and the schedule of work may also affect the sequence. Some projects may have a pole/digging team that sets poles and anchors before the next crew adds the attachments and guys and prepares for cable placement by a third crew.

Guys and Anchors

Guys are wire cable used to balance tension on a pole line. While not every pole in an aerial pathway will have a guy, there will be a minimum of two in any permanent aerial pathway, one at each end. Guys are typically connected at the pole with a guy hook or eyebolt and to the ground by an anchor.

As shown in Figure 2, an anchor is composed of two parts: an anchor and an anchor rod. Anchors are named for their composition (e.g., log) or primary means of holding (e.g., expanding, screw). Like selecting a digging method based on the ground type (e.g., soil, rock, wet ground) for the hole, anchors are also selected based on ground type, though the selection of the anchor is more nuanced given the composition in any category can vary. Table 3 provides information on anchor types for commonly found soil types.

While the selection of the anchor is often performed by the design team, occasionally field conditions change (e.g., presence of subsurface moisture) or the specific location for the anchor is different than expected (e.g., unseen raising/lowering of an underground rock layer).

In addition to the soil condition, the expected force load is also a factor in anchor selection. While increasing the size of an anchor and anchor rod can increase loading capacity, specific anchoring methods can have a maximum loading. To aid both designers and installers in anchor selection, anchors with similar loading capacities are sorted into groups. Table 4 contains examples of Group III, IV and V anchors and their related sizes.

The installation of anchors will require some amount of digging. Whether digging a shallow starting hole for screw anchors or a wide

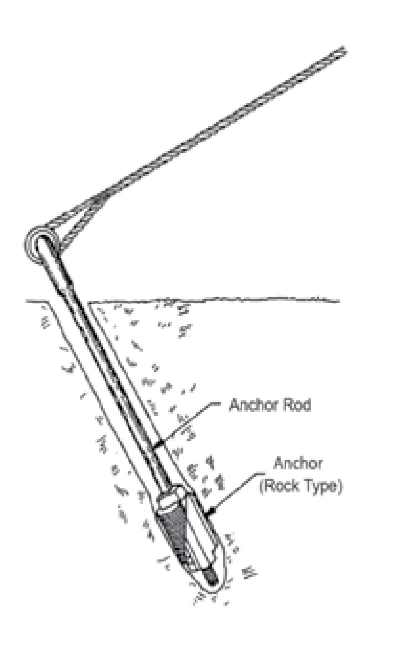

FIGURE 2: Illustration of a rock anchor, anchor rod and guy.

SOIL TYPE	RECOMMENDED ANCHOR TYPES
SOLID ROCK	Expanding Rock
LAYERED ROCK	Cross plate, Cone, Log
HARDPAN	Cross plate, Plate, Cone, Log
CRUMBLY, DAMP	Cross plate, Plate, Expanding earth, Cone, Log, Screw
FIRM, MOIST	Cross plate, Plate, Expanding earth, Log, Screw
PLASTIC, WET	Cross plate, Plate, Expanding earth, Log, Screw
LOOSE, DRY or WET	Screw, Expanding earth, Cross plate, Log
SWAMP	Cross plate (enlarged by 60%), Swamp screw, Log

TABLE 3: Anchor types for different types of soil.

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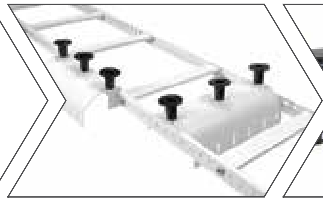

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GROUP	TYPE	PHYSICAL SIZE OF ANCHOR	
III	Screw	250 mm (1.7 m rod)	10 in (5.5 ft rod)
	Cone	250 mm	10 in
	Expanding	150 mm	6 in 4-way
	Log	900 mm x 125 mm	36 in x 5 in
IV	Screw	250 mm (2.4 m rod)	10 in (8 ft rod)
	Cone	300 mm	12 in
	Expanding	200 mm 2-way	8 in 2-way
	Expanding	200 mm 4-way	8 in 4-way
	Plate	150 mm x 430 mm	6 in x 17 in
	Log	1.2 m x 150 mm	48 in x 6 in
V	Expanding	200 mm 4-way	8 in 4-way
	Plate	150 mm x 560 mm	6 in x 22 in
	Cross Plate	400 mm	16 in
	Log	1.2 m x 175 mm	48 in x 7 in

TABLE 4: Example of anchor size groups.

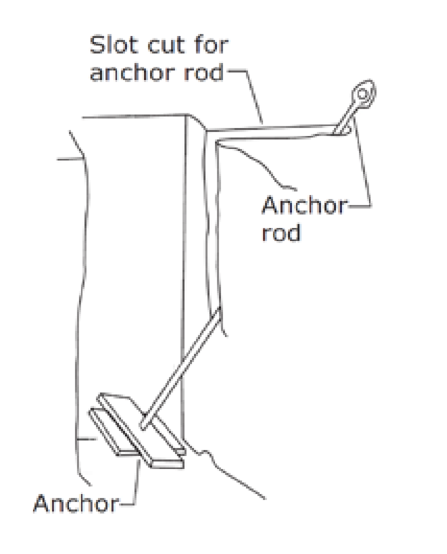


FIGURE 3: Example of a hole for a cross plate anchor.

vertical hole for cross plate (Figure 3) and precast concrete anchors, digging is unavoidable.

Once the anchors and attachment hardware for the guy have been set, the guy wire can be attached, starting at the pole. Common practice is to place the guy wire through the eyebolt or guy hook and then clamp the end back onto the guy. Guy clamps are used to create a secured loop. Once complete, a similar procedure is done at the anchor, though the clamp near the anchor is only applied after tension has been applied to remove slack in the guy while keeping the pole upright. After the guy is clamped by leaving a sufficient tail, the guy can be re-tensioned when additional load from the cable is applied.

Adding the Messenger

Once the guys have been placed and tensioned, the poles within the span are ready to have the cable installed. As most communications cables cannot span long distances without failing from the tensional loads required, messenger strand is used to support cables. Messenger strand is commonly denoted by its approximate breaking strength in thousands of pounds-force, followed by the capital "M" denoting an aluminum clad construction. For example, a 6M messenger has an approximate breaking strength

Figure-Eight and ADSS Cable

Figure-eight and all-dielectric self-supporting (ADSS) cables are common names for aerial cables that have an integrated supported strand, which avoids the need to place messenger strand first. Given the specialized construction, the use of specific tools such as a web cutter and a jacket splitter ease the effort required to separate and expose the support strand for pole attachment. These cables utilize many of the common methods and strategies for typical aerial cable, but with hardware designed for the different physical shape of the cable.

of 6,000 lbf (pounds-force) or 26.7 kN (kilonewtons). For most aerial communication installation, 6M and 10M messenger are typically used.

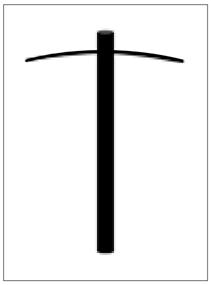
Messenger strand can either be pulled into position from a stationary reel or deployed by moving the reel on a vehicle alongside the pole line. When possible, the moving reel method is preferred. While messenger strand is relatively light—6M strand is about 120 lbs/1,000 ft or 180 kg/km—pulling messenger from a stationary reel along the ground, let alone while at an elevated position, is less than ideal.

For moving reel operations, messenger is installed starting at one end of the pole span and may be either temporarily secured at the base of the first pole or permanently attached to the first pole. Once the messenger is secured, the reel is moved down the pole line, allowing the messenger to unroll. Once the reel has moved some distance down the span (e.g., 150 m [500 ft]), workers can begin raising the messenger, tensioning to specification and securing in place.

While raising messenger is essentially lifting it into place, tensioning messenger and securing it into place on poles involves placing the messenger under forces of 8.9 kN (2,000 lbf) or more, depending on the messenger, air temperature and span length. While securing is typically performed by a messenger clamp that holds messenger under tension, some poles and designs will require specific hardware and methods (e.g., strand vise, strand grips) because of specific loading(s) at the pole.

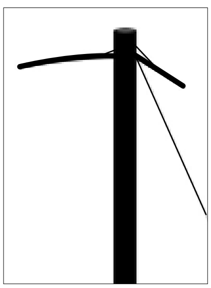
KNOW YOUR POLES

While a pole is a pole, not every pole serves the same function. Poles are generally categorized into one of four functions:



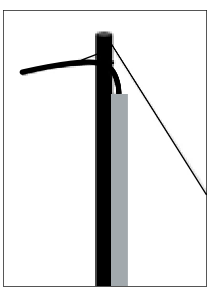
Line Pole

Supports cable in straight sections. Does not typically have guys.



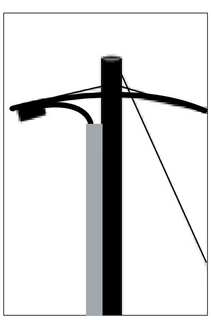
Corner Pole

Used to redirect (turn) cable more than 5 degrees. May have one or more guys.



Dead-End (shown with a cable guard)

Last pole in a span. Used to transition cable to the ground.



False Dead-End (shown with guy, splice case and cable guard)

A line pole that serves as a corner and/or dead-end pole for some cables. Typically has additional connections to maintain messenger tension. May use a guy for additional pole support.

Given that some of the forces that are being loaded onto the span during this activity are held by temporary means, this work is often scheduled in sections, where a section of span can be tensioned and permanently installed within the course of one work day.

Lashing the Cable

Once the messenger has been hung on the poles with care, the main event can begin: placing the cable. As with placing the messenger, placing the cable requires planning. Attaching the cable to the messenger is termed lashing and, in simplistic terms, consists of spiral wrapping a 14–18 American wire gauge stainless steel wire around the cable and messenger. Given the span lengths involved, most installers prefer to use a cable lashing machine which will traverse the messenger line rather than apply the spiral wrap by hand.

Since a cable lasher can be pulled by a ground line, cable lashers are often used with the moving reel approach to deploy cable (Figure 4). The vehicle with the cable leads out front, while the cable lasher and a cable guide used to keep the cable properly oriented are both pulled at the same time.

When coming to poles or other obstructions (e.g., span clamps), both the cable guide and lasher can be removed and placed on the other side, keeping both the cable and messenger intact.

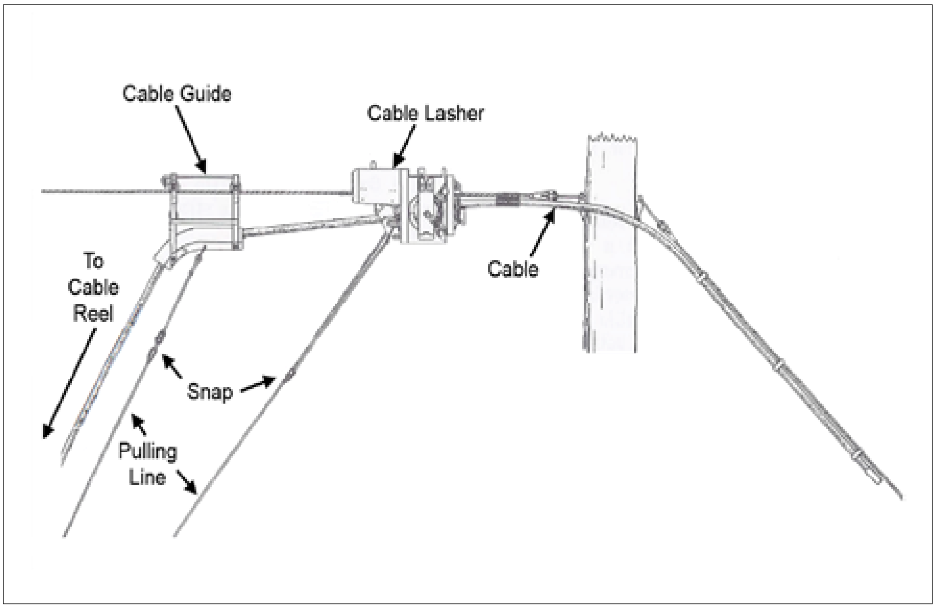


FIGURE 4: Cable lasher and cable guide.

Splicing

At some point, splicing will occur for messenger strand and cable. Splicing the cable can be performed by using a premade device, commonly known as a strand connector or "pickle." Splicing may also be performed by interweaving the wire strand, similar to performing a rope splice, but is seen as labor intensive and very difficult to modify if future events warrant.

Splicing methods are like those of indoor cable; however, pair and optical fiber counts are typically much larger, with the jacket construction providing more layers to fold back and work around. Placing slack within a splice case and stored on the cable run or nearby transition are recommended to minimize the likelihood that the installer will need to reopen and perform splicing operations while off the ground.

Testing

Once all poles, guys, messengers and cable have been installed and all tension values and clearances for guys and messengers have been verified, the aerial pathway is considered complete. Testing of the cable typically occurs once the ends have been terminated and are being readied for installation onto the appropriate structure (e.g., primary protector).

At a minimum, continuity testing is performed for both copper and optical fiber media, with most optical fiber projects requiring Tier 1 fiber testing. Given the distances and number of splices that can be within the cable, Tier 2 testing with an optical time domain reflectometer in both directions is highly recommended when not already required by the contract.

Conclusion

As with much of the visible infrastructure left by the builders of old, aerial OSP is more than meets the eye. The knowledge and skills that professionals within OSP aerial construction utilize to create monuments of our technological age have been honed over the years through trial and error. Looking ahead, efforts are under way to capture this knowledge so that it does not fade into history.

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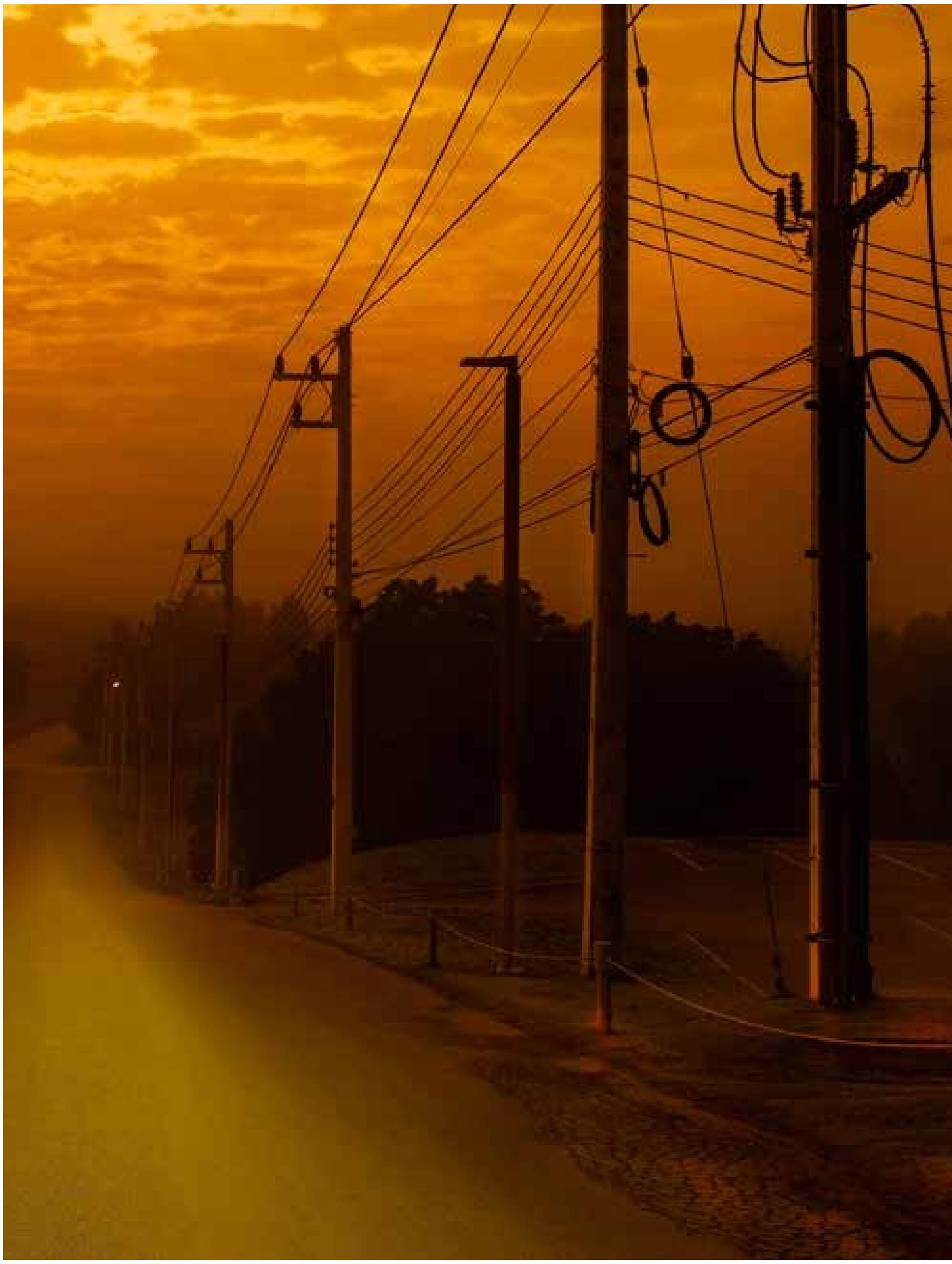

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By Sheard T. Goodwin III, RCDD, OSP

Wi-Fi in Green Spaces, Where OSP Shines

Fast, stable and easily accessible Wi-Fi service across campus is important at almost all institutions of higher education. More common in smaller colleges, many institutions of all sizes aspire to have reliable, far-reaching Wi-Fi for students and faculty. This goal can be hindered by the presence of green spaces and outdoor facilities, like those at the University of Florida (UF), which complicate deployment of the technology necessary for the true college experience. Studying out on the plaza, watching classes in hammocks and signing up for student events is not possible without Wi-Fi.

Deploying Wi-Fi electronics in green spaces comes with a special set of challenges. Distance limitations on cabling restrict how far away from a source device equipment can be placed. Weather conditions in Florida seem to exist only to destroy anything placed outside. Electrical service delivered to outside spaces can be expensive and no one wants to dig up those green spaces or interrupt the daily schedule of activities that take place in them. Universities never truly close and woe to the IT staff member that would interrupt an ultimate Frisbee® tournament.

In the fall of 2016, UF embarked on a project to renovate one of its premier green spaces, the Plaza of the Americas. The plaza is in the center of the historic UF main campus and surrounded by buildings that are in the national registry of historic places. Plaza renovation designers envisioned the project as an opportunity to provide students more study space, formalize the club gathering space and provide designated quiet meditation space, all in one location. UF would lay new sidewalks and install new seating areas and new lighting to ensure after-hours student safety. The renovation would fit new electrical utilities across the plaza to facilitate the needs of future events.

Beyond the initial amusement of the designers, there was no interest

Deploying Wi-Fi electronics in green spaces comes with a special set of challenges.

in adding an IT component to this project; however, the University of Florida Information Technology (UFIT) department had been attempting to deploy more Wi-Fi to the plaza for years but found few opportunities. UF frowns on drilling holes and mounting antennas where architectural history is concerned and UFIT was reluctant to make changes to historic buildings to extend the reach of wireless networking.

Previous attempts to install facilities in the plaza itself had not succeeded due to budgetary considerations and calendaring issues. This seemed the very definition of scope creep. Realizing the opportunity for IT expansion, UFIT used money from their own budget to fund their way into the project and a Wi-Fi plan was born.

Not Building the Wi-Fi Design

Producing a radio frequency (RF) design for wireless network access requires the attention to detail of an artist. Cross referencing architectural design, material composition, expected use conditions, and the limitations of an exterior design requires a Van Gogh. UFIT joined the project near the end of the design phase when landscape designers had specified most of the architectural details. This limited UFIT to operating within those parameters because the landscape design would not shift at the request of UFIT. With no ability to shift the design or anticipate the effect upon the RF landscape, UFIT was uncertain they could produce a Wi-Fi design that would also have the confidence of UF's network engineers.

With no assurance as to the best locations for electronics, or RF design to work from, UFIT turned to the outside plant (OSP) design to offer up the most flexibility for deploying a solution after the plaza renovations were complete.

Since 2014 UFIT has been working to document the OSP spaces and pathways of the main campus. Using that documentation and extensive consultations with UF's principal OSP contractors, UFIT mapped out the existing conduit infrastructure (Figure 1).

FIGURE 1: Original conduit structure.

FIGURE 2: Plaza locations.

The plaza had ample handholes placed around the perimeter: a single ≈101.6-millimeter (mm [4-inch (in)]) conduit connected each handhole with its neighbor and a single ≈101.6-mm (4-in) conduit exited the plaza from each corner handhole. These conduits provided pathways to the nearest adjacent buildings. As an integrated part of the project meetings, UFIT ensured that none of these spaces would need to be moved.

To provide for the best Wi-Fi, UFIT planned to overfill the area with wireless access point (WAP) locations. Without the ability to choose the perfect locations ahead of time, UFIT proposed to seed the area with multiple locations for wireless electronics and feed them all from the adjacent buildings.

With a multitude of locations to choose from, network designers could then place access points (APs) where needed once the bulk of the landscaping work had been done. Contractors would install ≈25.4 mm (1 in) conduits from the existing handhole and OSP spaces to each proposed location. Using the current handhole and OSP spaces, UFIT plotted out thirteen new host locations (marked 5-17) surrounding the perimeter of the plaza. Four new locations (marked 1-4) were placed in the middle of the plaza. UFIT desired the placement of more locations in the plaza itself but the renovation project had planned out all the spaces that were deemed most useful (Figure 2).

In addition, UFIT chose not to specify the type of visible OSP housing or aboveground installation type at each location until after the bulk of the project-managed landscaping work had been completed. UFIT had no desire to pollute the renovation project with poor aesthetic choices that did not blend well with foliage, sidewalk or other features installed by the renovation. UFIT designers decided that those choices would be better made after truly experiencing the space as UF landscapers originally envisioned. Installers placed conduits, capped them and marked each of the host locations with the intention of later completion.

As UFIT finished the installation of the new OSP pathways during the summer of 2017, their visible impact appeared minimal. Landscapers continued laying new sidewalks, placing benches and replanting foliage to support the green space renovation project. All the information technology work was underground.

Making It Work

With the beginning of the fall 2017 semester, the renovation passed the halfway mark and the landscaping was completed for the east side of the plaza. UFIT returned to install the Wi-Fi in the newly landscaped areas.

Contractors had installed category 6 cabling and conduits for up to nine different locations along the eastern and southern sides (locations 5-13) of the plaza. UFIT Wi-Fi designers had to balance installing additional electronics for coverage while minimizing electronics so that they would not interfere with each other. UFIT decided to use four of these nine locations (marked 5, 7, 10 and 13) for WAP installation.

Along the perimeter, all conduits terminated near a ≈356 mm (14 in) high guardrail that landscapers had installed to define the space. To match the aesthetic, at WAP locations, UFIT terminated all cabling and installed electronics in National Electrical Manufacturers Association (NEMA)-rated enclosures mounted ≈406 mm (16 in) above the ground and alongside the railing. Enclosures were painted to match. At locations with no WAPs, installers terminated conduits and mounted single gang weatherproof boxes. Category 6 cabling was terminated at every location. At locations where WAPs were not mounted (locations 6, 8, 9, 11 and 12), UF faculty/staff/students would use the cabling to support special campus events or other seasonal/security needs as determined by UFIT.

UFIT terminated and housed the cabling in the interior of the plaza (locations 1-4) using a different methodology. Electrical utilities had been installed at various points in the plaza using a hinged top outlet pedestal with an integrated base (Figures 3 and 4).

To carry on the aesthetic choice, UFIT mimicked this deployment and terminated all cabling interior to the plaza in the same pedestal type, matching manufacturer and

FIGURES 3 & 4 : Electrical pedestal and networking pedestal.

While proper planning and design are critical for a successful project, under circumstances where the unknowns outnumber the knowns, the key to success is flexibility.

model of pedestal. UFIT attached NEMA-rated enclosures for the WAP housing to the rear of the pedestal where necessary.

UFIT installed WAPs at two of the four pedestal locations (marked 1 and 3) and determined that placing wireless electronics at the other two central locations would be counterproductive. With each of the remaining two central pedestal locations (marked 2 and 4), UFIT was more ambitious. Rather than install category 6 cabling at those locations, UFIT installed 12 strands of singlemode optical fiber cable. This optical fiber will be used to support television network broadcast events, temporary wired network deployment needs in the plaza and UF's own analog video transmission needs. In the past, UFIT has provided these connections using long exposed temporary cable installations to neighboring buildings. These connections are now available on the premises.

All cabling for the plaza originates from the neighboring buildings using the original OSP entrances into those buildings. In the telecommunications room, contractors terminated all cabling feeding exterior spaces onto dedicated patch panels that are located on a wall away from the internal cabling. UFIT network technicians then connected those exterior cables to dedicated switch infrastructure that is also wall mounted. Those switches connect to the building network using optical fiber connections to maintain electrical isolation. Lightning is a danger in Florida and isolating the exterior feeding network from the building network was part of UFIT's strategy in addressing that issue.

The dedicated network switches act as power source devices and power all remote wireless electronics using power over Ethernet (PoE). During initial design, UFIT acknowledged that longer than average cable length could interfere with plans for using network and power connections from the neighboring buildings. On other projects, UFIT successfully used Ethernet extenders to expand the reach of 100-megabit (Mb) connections and PoE beyond the standards-based 100-meter channel. UFIT purchased extenders in advance in case they were needed. Fortunately, for wireless electronics deployed along the eastern and southern perimeter of the plaza (marked 5-13) and one central location (marked 1), those issues failed to materialize. Cabling distances proved shorter than

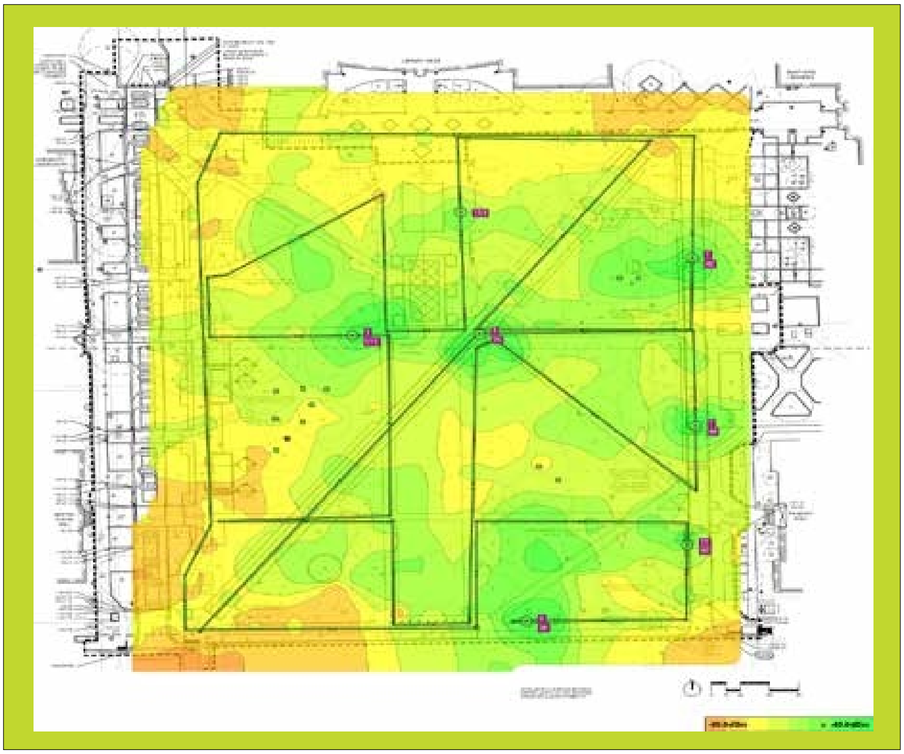

FIGURE 5: Plaza signal strength.

expected and building network switches now provide all Wi-Fi devices at those locations with the necessary PoE and 1-gigabit (Gb) connections.

Upon initial installation, UFIT provided a new Wi-Fi network to the Plaza of the Americas using seven WAPs fed from the surrounding buildings (Figure 5). In only one instance (location 3), was UFIT required to use an Ethernet extender and reduce the possible network connection from 1 Gb to 100 Mb. In all, the OSP design enabled UFIT to deploy a robust Wi-Fi network that has been in use since November 2017.

Making It Great

The plaza renovation project has been completed and students have been using the new space for months. With the student population dropping in the summer, UFIT returned to address the dearth of wireless electronics along the western side of the plaza. UFIT's completion of the Wi-Fi portion of the project will also boost the capacity to support larger crowds in the plaza expected during the fall 2018 semester (this is football country).

During the fall 2017 phase of Wi-Fi deployment, UFIT determined that longer cable lengths prevented the use of native PoE from powering the wireless electronics deployed on the west side of the plaza. A single WAP in the center of the plaza (location 1), fed from a neighboring building to the west, required an Ethernet extender to maintain connectivity, lowering the bandwidth to 100 Mb. UFIT considers this an unacceptable solution for the completion of the project.

Designers discussed the possibility of locating network power source devices in the plaza, but decided the establishment of new environmentally-controlled subterranean OSP spaces was too expensive and brought a new host of support issues no one was eager to address. Staff quickly shelved the idea of deploying network switches to the plaza.

Since extensive pathways were placed as part of the initial OSP installation, UFIT plans to use those new pathways to install optical fiber cable along with category 6 unshielded twisted-pair (UTP) to the four new AP locations (marked 14-17). The wireless electronics on the western side of the plaza will utilize category 6 and Ethernet extenders for power purposes only. New AP locations will use the optical fiber cable for network connectivity. The new wireless electronics will receive 1 Gb network connectivity along the optical fiber cable and power along the UTP. All

Fast, stable and easily accessible Wi-Fi service across campus is important at almost all institutions of higher education.

OSP spaces and pathways will either cost a project unnecessary time and money or will be the asset that gives repeatedly over time.

connectivity will be controlled from the neighboring buildings.

This design requires the installation of a new dedicated optical fiber network switch in the neighboring western building. UFIT has included this in the new design. In addition, to simplify support and improve reliability, UFIT has planned to replace all the original WAPs in the plaza with the newer model used for the western side. The newer model will still utilize the existing UTP and powered switch infrastructure of the eastern side, but is more weather resistant. The dedicated network electronics in the supporting buildings and newer APs on the plaza will furnish Wi-Fi to students for years to come. With the proper OSP pathways in place, UFIT expects any future upgrades to consist primarily of electronics replacement, not costly physical renovations.

Final Lessons

While proper planning and design are critical for a successful project, under circumstances where the unknowns outnumber the knowns, the key to success is flexibility. Being open to new solutions and new approaches as problems emerge is more crucial than having an excellent initial design.

IT has a role in every project. While a project manager may loathe to expand the scope of a project, managers can no longer pretend that IT involvement is just about desktop support. New technologies are pushing IT needs into locations and projects never considered before and IT professionals should be consulted on all projects before budget creation. The rewards are tangible.

The plaza renovation project was primarily a landscaping project. That objective has been accomplished. More and more students are using the space and spending time there between classes. They are also spending time there with their laptops open, planning group meetings in the space.

OSP spaces and pathways will either cost a project unnecessary time and money or will be the asset that gives repeatedly over time. The original OSP work in placing spaces and pathways around the plaza in this project proved invaluable. Overfilling the area with conduits made the Wi-Fi installation possible and provided the flexibility to offer low cost solutions to later issues: cable length concerns, additional optical fiber installation opportunities and additional wired connections for event support. Future facilities services projects, security projects and even entertainment projects will benefit from the installation of the OSP facilities placed in this project.

No design is perfect, so it is critical to plan for the possibility of failure. During initial stages of planning, designers acknowledged that cable length might be an issue. UFIT purchased Ethernet extenders to account for this possibility. The extenders were not needed immediately, and the University might have interpreted their purchase as a waste of resources, but that planning proved integral to understanding the use of the technology. Those extenders will support the installation of devices along the western side of the plaza.

Planning for possible setbacks is not the same as a failure to plan. Always carry out extensive testing before and after a Wi-Fi installation. UFIT was unable to thoroughly survey the area before the project began. They pushed off Wi-Fi design in favor of waiting for the landscaping work to be completed. Only overbuilding the OSP pathway design enabled UFIT to pull off the design. By preparing for several possible designs, UFIT was ready to deploy the best design.

Waiting resulted in a wireless design that provides Wi-Fi coverage to almost every corner of the plaza without any of the western APs being yet online. Surveying the Wi-Fi situation following initial installation helped inform the follow-up project and has informed UFIT that the primary issue to address is not coverage, but capacity.

Pathway and space design is often overlooked, but pathways and spaces have the longest impact on any build project. Electronics and use cases will come and go but pathways and spaces will remain. Successful OSP design will pay dividends long after the completion of any project but no one will remember or applaud the designer for spending the extra money at the time. In this case, UFIT's success would not have been possible without the forethought and planning of those that placed handholes and ≈101.6-mm (4-in) conduits around the plaza. In the years to come, the conduits placed as part of this project will support unimagined endeavors. Plan OSP accordingly and always size for expansion.

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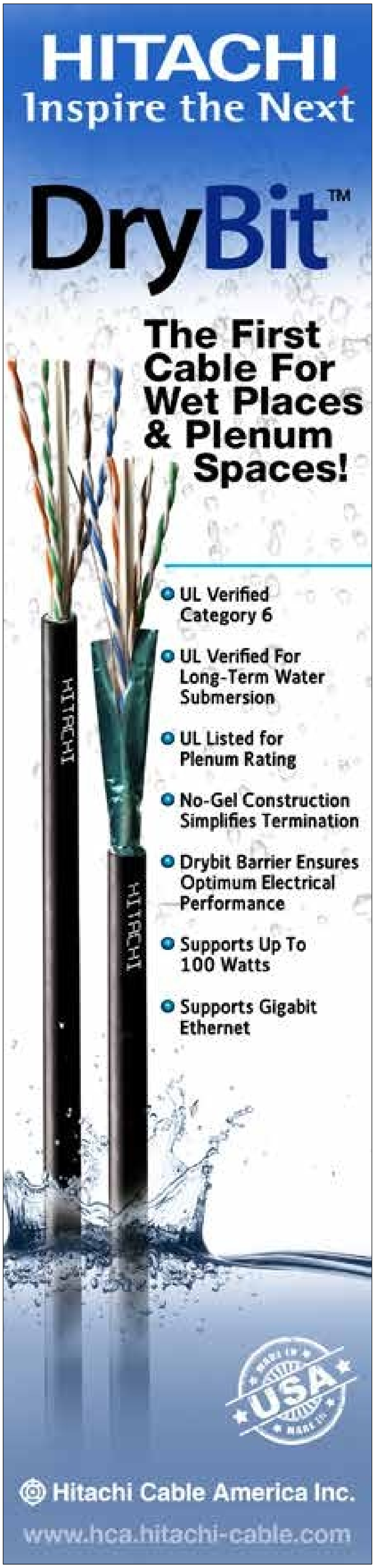

By Scott Smith, RCDD

Waterway Crossings for OSP Pathways

Outside plant (OSP) pathways which cross waterways (e.g., lakes, rivers, creeks, bays) may require special design and construction techniques. Additionally, the OSP designer should evaluate the cost of crossing a waterway for an OSP pathway route compared to alternate methods.

Considerations and Types of Waterway Crossings

The choice of a specific waterway crossing option and its associated costs are influenced by the following factors:

- Length of the crossing
- Presence of currents, wave action, and/or tidal influences and historical flood levels
- Presence of fresh or salt water in waterway
- Characteristics of the waterway bottom (e.g., rock, gravel, sand, silt, absence of or degree of severity of pollution/contamination)
- Characteristics and degree of development of the waterway shoreline
- Type of marine vessels which may transit the waterway
- Number and type of OSP cables to be placed for current and future requirements
- Presence of other utility and/or facility construction within the waterway at the crossing location
- Periodic restricted access to the shoreline and adjacent land areas because of wildlife nesting (e.g., turtles, alligators, crabs, birds) which can be dependent on time of the year and varying length of duration for the access restrictions
- Restrictions from areas where marine life occupy the area below the waterline, such as shellfish beds (e.g., clams, mussels), coral reefs and marine life mating areas (e.g., horseshoe crabs)
- Codes, standards, rules and regulations enforced by the authority having jurisdiction (AHJ) (e.g., in the United States, this can include agencies such as the US Army Corps of Engineers, the US Coast Guard, and state Departments of Environmental Protection/Management)

In addition, routes often deviate from normal shared utility pathways. Right-of-way acquisition, along with associated permits and licenses, may be required before any OSP cables or pathways will be allowed to cross the waterway and any associated shore-side properties, regardless of whether they are private or public.

When faced with a proposed waterway crossing, the OSP designer has several options:

Use an aerial crossing, utilizing catenary construction techniques

Catenary construction may be necessary where span lengths, cable weights, and similar factors prevent setting of poles at normal intervals to provide support for the line. Waterway crossings using aerial catenary construction are usually the cheapest construction method available, but have the following disadvantages:

- They have a negative visual impact
- The vertical clearance above the waterline required by the AHJ for safe vessel passage may not be obtainable with catenary construction techniques
- Like other aerial OSP, it is subject to hazards such as wind, ice and lightning strikes

Catenary construction requires the use of well supported and anchored structures at each end of the span. These can range in complexity from large poles (class and height) to the H-fixtures with additional bracing, anchoring and guying, and in some cases, specially engineered and constructed metal structures.

Special attention must be paid to the terrain and soil conditions at the locations used for the end structures. The number and arrangement of catenary supports will be dictated by the length of the catenary span, the number and weights of the cables to be supported and the required mid-span clearance over the waterway.

Use an existing bridge crossing

Before considering use of an existing bridge crossing, the following items must be considered:

- Overall condition of the bridge and remaining useful life
- Upcoming rehabilitation/replacement activities by the bridge owner
- Historic or other restrictions regarding additions or modifications to the bridge structure
- Availability of intermediate cable pull points on the structure (for long bridge crossings)

Whenever conduit will cross an existing or planned bridge, always consult with the AHJ and a structural or civil engineer regarding:

- Structural strength problems if the ducts will be incorporated in the bridge structure.
- Obstruction of waterways if the ducts will be attached under the bridge.
- Compensation for axial movement at each required expansion joint.
- Expansion or slip sleeve requirements on the bridge to compensate for bridge movement due to expansion and contraction

Each bridge crossing must be individually designed to conform to local conditions and restraints imposed by the bridge site, design, and construction, along with AHJ requirements.

Trench the bottom of the waterway and install underground duct facilities in the trench

Depending on the width, depth and bottom characteristics, trenching on a waterway bottom for installation of conduit is typically accomplished by using a barge-mounted backhoe, a crane equipped with a clamshell bucket, or a dredging rig. Upon completion of the trenching activity, the conduit assemblies may be pulled into the trench from either shore, usually by using roller assemblies, to guide the conduit in place within the trench. If the excavated material is suitable for use as

Special attention must be paid to the terrain and soil conditions at the locations used for the end structures. The number and arrangement of catenary supports will be dictated by the length of the catenary span, the number and weights of the cables to be supported, and the required mid-span clearance over the waterway.

backfill and permitted by the AHJ, it will be used to cover the trench once the conduit is installed.

Utilize directional boring methodologies to provide a pathway under the bottom of the waterway

This system uses a liquid mixture that can be composed of natural muds (e.g., bentonite), chemical compounds, or combinations of both. These stabilizers, called bore gel, when forced through the end of the bore head (drill or reamer), loosen and aid in drilling and back reaming operations by lubricating and temporarily stabilizing the soil around the drilled hole. Various types of drills and reamers allow for boring in most types of soils, clays, and soft rock; however, loose types of soils (e.g., mixtures containing high percentages of sand and gravel) are very difficult to stabilize and are not good candidates for directional boring operations.

Additional equipment is required for handling conduit reels (e.g., if HDPE smooth-bore duct is used) if the drilling rig pulls the duct through on the last back reaming operation. Rigid conduit or steel pipe requires additional ground operations (e.g., glue, weld) to assemble before it can be pulled through.

After the drill head completes the bore, a back reamer may be placed on the end of the rod and pulled back through the drilled hole. The purpose of the back reamer is to clear the drilled hole as the cable or conduit is pulled through or to open the drilled hole to a larger size. A large dimension bore, requiring multiple passes, can be made by increasing the size of the drill and back reamers. When the drilled hole is the proper size, the casing, conduit, or cable can be attached behind the back reamer and pulled back through the drilled hole.

Where cable is placed directly on top of the waterway bottom, appropriate warning signage is required at both shorelines notifying vessel operators and dredging crews of the cable location.

The main items to be considered for directional boring in a waterway crossing include location of and access to the bore entry and exit pit locations, available space for the associated machinery, the composition of the waterway bottom and the length of the crossing.

> Whenever conduit will cross an existing or planned bridge, always consult with the AHJ and a structural or civil engineer.

Place OSP cables which are specially manufactured for submarine (underwater) use

An OSP submarine cable crossing can provide a cost-effective solution for a waterway crossing situation. These cables are manufactured with additional protective elements which can include wire or tape armoring and additional sheathing and jacketing layers. These allow the cable to be placed directly on the waterway bottom and provide physical and mechanical protection from conditions present at the waterway bottom, including currents, tidal action, corrosive conditions, marine life, and the possibility of vessel anchors and fishing gear getting fouled on the cable.

Where cable is placed directly on top of the waterway bottom, appropriate warning signage is required at both shorelines notifying vessel operators and dredging crews of the cable location, and that there shall be no anchorage in the area. In areas with significant current or tidal action, the cables are anchored at the shore landing ends to secure the cable in place.

OSP submarine cables typically transition from normal OSP cables within maintenance holes or terminal poles located near the crossing. Installation can be as simple as pulling the cable above the waterway and then allowing it to settle to the bottom, or as sophisticated as a specially equipped cable laying vessel. Typically, OSP submarine cables are installed in a continuous length between the transition points, if the width of the crossing allows the use of a standard reel length of cable.

> Installation can be as simple as pulling the cable above the waterway and then allowing it to settle to the bottom, or as sophisticated as a specially equipped cable laying vessel.

If splicing is necessary, the OSP designer must consider the environment with regards to the splicing method to be used. The cables will typically require the inner jacket and the inside media (e.g., copper conductors, optical fiber strands) to be spliced first and then sealed from water intrusion. Then the outer strength members will have to be joined together to provide an overall outer protection and longitudinal strength when the cable is pulled lengthwise, so that it does not part. Splicing submarine cable requires a dual expertise: ICT, where the copper or optical fiber media has to be spliced together and mechanical, where the outer steel strands are either woven together creating a center lock that unites the strength members of the two cables together or by the use of auxiliary splicing hardware to maintain the mechanical strength and continuity of the strength members at the splice.

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Disaster Recovery Planning in the OSP World

By Phil Janeway, RCDD

Pre-Disaster Planning Is Key

Planning for outside plant (OSP) disaster recovery is far more complicated than simply installing a cabling facility on a pole or in the ground and assuming the systems are protected. The same holds true for customer-owned OSP premise campus environments. When a budget is prepared for OSP construction, part of this budget must include needed funds for planning. Planning should not only be on how to construct the plant, but also the durability and survivability of the network once installed. Simply put, consider if network infrastructure can survive catastrophic conditions.

The best defense for recovering quickly from a disaster relies on good plant records, sufficient available funds and people to rebuild it.

Bonding and grounding, lightning protection, aerial height, attachments, placement of access points, buried depth and unpredictable circumstances such as extreme weather and seismic events are a few key items to plan for when constructing all OSP facilities. Paying close attention to these details will go a long way towards planning for disasters.

Along with consulting the local authority having jurisdiction (AHJ), recommended reference material for ensuring OSP disaster recovery should include:

- BICSI®'s *Outside Plant Design Reference Manual, (OSPDRM),* 6th edition
- National Fire Protection Association *National Electrical Code® (NEC®* NFPA70)
- IEEE® *National Electrical Safety Code® (NESC®* IEEE C2).

Work is now under way for BICSI's *Telecommunications Distribution Methods Manual (TDMM),* 14th edition, which will include a new chapter on disaster recovery methods.

Design and install with these manuals and references and be sure to follow the code requirements when building disaster recovery into an OSP facility.

Get Out and Take a Look

When planning construction, an OSP engineer is also putting together the requirements for vendor bidding specifications and quotes. The engineer typically will not feel comfortable about designing the construction after only seeing a plot, route or online photos, and the engineer cannot rely on construction vendors to do this work during the bid process. Get out of the office and do the pre-planning. Site/field surveys are worth the time it takes to ensure accuracy.

OSP engineers have all left the office with support documents, cameras, hard hats, safety glasses and a measuring wheel, not knowing what to expect. Rarely, if ever, do the current drawings totally reflect actuality. In addition to visual inspections, an engineer must recognize the environmental conditions.

For customer-owned campus environments, meeting with the customer can help clarify environmental conditions and plan for the unpredictable. The campus network OSP maintenance person can provide invaluable planning information.

Aerial OSP Disaster Planning

The following information will provide some things to consider in planning disaster recovery for aerial OSP infrastructure.

Go to The Pole(s)

Aerial OSP construction is a common method used to get cabling from one place to another and into a building. It can also be the least expensive construction method. Of primary concern is the age of the poles (e.g., new or existing).

A correctly set pole has required classification information (often called a birthmark) burned into it or on a plastic or metal tag attached to it (Figure 1). Pole identification shows who owns the pole, what length it is and when it was manufactured. This information, based on the *NESC*, will confirm whether the support strand and cable(s) can attach to it legally.

This helps when considering how to properly space attachments, maintain span height (clearances) while considering storm loading and if the pole will support the weight of the attachments.

Is the pole in acceptable condition? It will be easy to

FIGURE 1: Birthmark (right) and other identifiers on a joint use pole.

determine if the pole is degraded due to age, has evidence of rot or insect damage or has been struck by vehicles. If a ground wire is present from earth to the attachment points, is it still intact? If required, is the pole solidly anchored? Is it correctly guyed and braced?

The owner of the pole must be contacted when using an existing pole. The owner will have a form to complete for every piece of required information for a pole, including every pole along the route. Typically, the form will require what is being attached to the pole (e.g., cable, strand, terminals), its weight, loading factors and attachment methods.

When the owner has the completed form, they determine if it meets applicable codes, if the pole is in good condition, if the pole will support additional attachments and what the charge will be to attach to or replace the pole. In some cases, they may require certain methods for attaching to a pole.

Aerial to direct-buried plant transitions require protection from garden implements such as weed whackers and vehicle hits. The cable must be enclosed within a metal or heavy plastic U-guard (Figure 2). To avoid vehicle hits, design the guard on the back side of the pole away from traffic. Try to keep a 180 degree separation from other vertical runs on the pole. Typically, the guard is installed ≈6 feet (ft) [1.83 meters (m)]) to ≈8 ft (2.4 m) above the ground. Bury the bottom of the guard ≈18 to 24 inches (457 to 610 millimeters) under the earth. Secure it with metal clamps and lag bolts onto the pole. In some cases, a metal conduit may be required instead of a U-guard.

Look for Unusual Circumstances

An OSP engineer must be prepared to determine street, river, creek or other water crossings, railroad and utility crossings. Attention must be given to height and span height requirements. The two attaching poles for crossings must also meet *NESC* (or AHJ) pole classification requirements. The following are some of the more significant considerations:

- **Tree damage** from weather-related events can significantly damage aerial OSP, so an engineer must look at the degree of tree growth along the route. Where practical, avoid a route with heavy

FIGURE 2: Correctly installed pedestal, U-guard and anchors.

FIGURE 3: Optical fiber cable splice vault with warning marker.

tree growth. Removal and heavy trimming can be costly and not possible in some instances. Where unavoidable, consider installing OSP that will minimize the amount of damages in these areas (e.g., strand-supported optical fiber cable instead of an all dielectric type).

- **Railroad crossings** can present a challenge. The railroad owner must be contacted immediately when a crossing is found. Railroad height requirements must be met or exceeded. The railroad permits department will dictate the railroad's strict adherence requirements for cable crossing height. Be prepared to comply with these requirements. Be aware that obtaining the railroad's approval to cross over tracks can be a lengthy process.
- **Aerial building attachments** must be well understood to ensure there is a solid means for attaching to a building. Establish the distance from incoming power and other telecommunications entrance attachments. Calculate the height of the span from the building to the last pole.

When an OSP engineer knows everything about the aerial plant build and follows accepted practices, methods, standards and codes, disaster recovery will be built as well.

Buried OSP Disaster Planning

The following information will provide some things to consider in planning disaster recovery for buried OSP infrastructure.

Walk the Pathway

An OSP engineer should visit the pathway of the buried plant project and take measurements between planned pedestals, splice pedestals and how far away the last pedestal will be from the premise entrance facility. For example, these measurements can assist with copper wire cable gauge selection and help determine when load coil or repeater points are required when planning analog applications. Measurements also help to determine the lengths of cables required on a reel.

BICSI's *OSPDRM* provides the methods for ensuring buried plant will be designed and installed properly.

Look for Unusual Circumstances

When planning the location of buried copper and optical fiber cables, always place them as deep as possible. This also applies to duct and maintenance hole (MH) systems. When visiting the pathway, look at other items such as telephone, cable TV, power, water, sewer and other public utilities. They may have signs warning what is buried below (Figure 3).

To aid planning, many areas are covered by a one-call service that notifies buried utility owners of actual and potential digging operations. Responding utility owners will mark their underground facility with flags, color-coded paint or both. In customer-owned campus environments, a facility may not be a participant in the one-call location service. Locating existing underground facilities is important when multiple utility lines are near the pathway and the plant must follow or cross them.

OSP engineers are always required to place special burial requirements on construction drawings. Oil and gas pipelines, rivers, creeks, marshes, swamps or other waterways, streets, railroad crossings and other utilities should have specific construction information on engineering and contractor drawings. Owners of oil and gas pipelines and railroads must be contacted for their buried plant specifications. They may have specific depth requirements and may want the installation of a concrete encasement or pipe surrounding the plant as a protection barrier.

If an OSP engineer is designing a duct bank and MH system, knowing what is within the system pathway is especially important due to the depth and width of the plant. Contact the one-call service to find out what is within the pathway. The engineer must contact the AHJ regarding the right-of-way if streets or alleys will be cut and dug up for the OSP infrastructure. The AHJ will provide where to get their requirements and gather information for permits and fees that may be involved.

Labeling the MH lid cover will inform future earthwork contractors on how to find the owner of the duct MH system.

It is valuable for disaster recovery efforts to produce an as-built drawing for all OSP projects for future references. This information should be shared with the local utility underground protection agency, utilities, city and town engineers, oil and gas pipeline companies and railroads. Each will dictate how much information they require.

The OSP engineer should consider previous events that have disrupted or damaged OSP infrastructures in the area. This includes weather events such as floods, hurricanes, tornados and ice storms. A washed-out bridge, river or creek may not be a good place for a typical buried plant crossing. Consider a submarine-type cable or a directional boring type of underground plant method.

Plan Pedestal Locations

Plan where aboveground pedestals will be installed. Common disasters for pedestals include being mowed down, run over by vehicles and tractors, being flooded or washed out underneath and infested with insects, rodents and other unpleasantries.

County highway crews mow roadside ditches. If a pedestal is installed too far away from a fence line within a right-of-way, or within a weedy or brush area, they may not be able to see it. It could be heavily damaged or mowed off at the ground if it is made of fiberglass. Buried cable warning signs, installed along cable routes, are inexpensive when compared to repairing or replacing a pedestal.

A pedestal located too close to an intersection is subject to being struck by vehicles or farmers who have large, long implements attached to a tractor. Install a pedestal as far away as possible from an intersection. Accident histories can identify vehicle crash hot spots during planning to avoid damage by a vehicle or tractor. If a better location is not possible, round metal posts with or without cement inside (bollards), installed near the front of the pedestal, can offer some protection.

If a pedestal is placed too close to a creek, gulley or river bank, a dry area can fill up quickly with changing water levels. Pedestals placed too close to these areas or on a steep bank can wash out. This leaves the bottom of the pedestal open to rodents who are seeking shelter. Pick a location away from these potential hazards and ensure that they are installed with the base well underground. A pedestal must be filled with expandable foam and pea gravel above where it is buried.

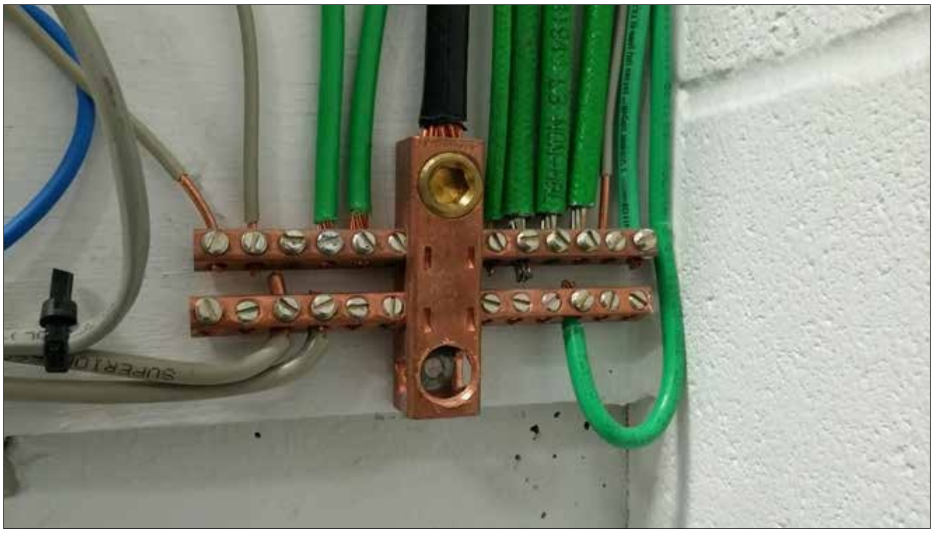

FIGURE 4: Premise principal point ground bus.

Bonding, Grounding (Earthing) and Lightning Protection

Aerial and underground plants that have metallic characteristics are vulnerable to lightning strikes and foreign electrical influences. This includes the metallic sheath within the outer sheath and copper cable conductors. The metallic sheaths must be bonded and grounded together in several places along a pathway and within a building. Copper conductors must be protected from lightning and power contact exposures at both ends of the cable run if they are considered “exposed to electrical interference” by the governing code.

Engineers who follow the *OSPDRM* and *Telecommunications Distribution Methods Manual (TDMM)* methods and practices will learn how to protect metallic types of cables. The IEEE, *NESC* and *NEC* provide specific code requirements for designing and installing the required protection and associated bonding and grounding. To avoid a disaster, OSP engineers must be familiar with these publications.

Bonding and Grounding Cable Sheaths

Aerial and underground plant cables with a metallic sheath must be bonded and grounded. This offers some protection from lightning and foreign electricity sources traveling down the metallic components. When cables are opened in the field for a splice point, cross connect box and possible load coil or repeater point, bonding and grounding must be performed.

For aerial plants, bonding must occur between the strand and the existing grounding conductor at various points along the route (e.g., splice points). Older poles have a ground rod sunk into the earth and connected to the ground conductor. Newer poles have a ground plate installed onto the bottom of the pole connected to the ground conductor.

Splice enclosures generally require a 6 American wire gauge (AWG [4.1 millimeter (mm [0.16 inch (in)])]) stranded wire that is attached to the strand or ground conductor clamp and to a ground connecting point within the splice enclosure. Splice enclosures include ground and bonding clamps with teeth that are sunk into the metallic sheath of a cable. When the clamp is installed onto each cable end, the enclosure vises the connection when tightened. This addition, as well as a crossing support bar within the enclosure, provide bonding and grounding from one cable metallic sheath to another.

For a pedestal, a metal stake anchoring it to the earth provides the ground source. When the pedestal is bolted to the stake, a ground connecting point is

Premises that contain large amounts of ICT network equipment (e.g., data centers, phone switching offices) have unique and detailed bonding and grounding requirements.

connected inside the pedestal to the post. A bonding strap has a connection with teeth on one end to dig into the cable metallic sheath. After opening the metallic sheath and installing the connector to it, a tool crimps the teeth to the sheath. This connection is surrounded with electrical tape. The bond and ground are complete when the ends of the connecting wire are attached to the ground point.

An OSP engineer must be careful when installing another ground rod in the underground system at a pedestal. If a cable path is directly below high voltage power lines, additional ground rods at pedestals may be required to help bleed off power influences. When installing load coil and repeater locations or an outdoor cross connect box, they will require a separate ground rod installed that is bonded to the metal posts. These additional ground techniques add additional protection and will also ensure a bond and ground of the metallic cable sheaths.

An MH must include bonding and grounding provisions. Older MHs were equipped with ground rods, solid copper conductors and a ground wire connection bus for grounding. Newer MHs may include an integrated bonding and grounding system, using the MH itself as a concrete enclosed electrode. Some may have holes in the flooring for installing rods. Within these MH systems, cable sheaths and enclosures must be bonded and grounded.

Splices within an MH use similar technologies for bonding and grounding cable sheaths. The splice enclosure is water sealed, so enclosure manufacturers provide an exterior connecting point for a wire from the ground bus to the splice enclosure. When connected, the cable sheaths and enclosures are bonded and grounded.

Grounding OSP Infrastructure in ICT Equipment Locations

Premises that contain large amounts of ICT network equipment (e.g., data centers, phone switching offices) have unique and detailed bonding and grounding requirements. Typically, the building housing the equipment creates the grounding electrode from very large ground rods, the incoming alternating current (ac) power ground and known metallic water pipes within the immediate area. These are all attached to a principal point ground bus, which is a multipoint, very large and thick copper plate (Figure 4). Auxiliary copper ground busses, wherever needed within the building, attach directly to the principal point ground bus. All items will be clearly labeled.

Many ground electrode systems such as these are made using a trench around the building perimeter for an engineered ground ring. Over ≈4.6 m (15 ft) long and ≈66 mm (0.63 in) thick copper-clad steel rods are driven into the earth within this trench. Some may use a stainless-steel rod when corrosion is an issue. Typically, these rods are spaced several meters (feet) apart. A 6 AWG [4.1 mm (0.16 in)], solid copper-clad wire, without an outer sheath, is welded to each ground rod. A wire lead from the two closest rods is brought into and anchored to the principal point ground bus. Every ground source incoming or outgoing on the bus is labeled to show what it is.

Lightning protection for copper pairs; all metallic cable sheaths; racks; bays; cabinets; heating, ventilation, and air-conditioning systems; power panel connections; security systems; generators; transfer switches and uninterruptible power supply systems are bonded and grounded to the principle or auxiliary grounding point within the building. Anything that can and should be bonded and grounded eventually ties into the principal point ground bus.

At the lightning protector, OSP cable pairs are usually spliced to a fusible link cable. This cable is a smaller gauged wire that will

Planning should not only be on how to construct the plant, but also the durability and survivability of the network once installed.

melt if a direct lightning hit enters the building via OSP copper-paired cables or sheaths. An engineer will decide what type of fuse or protector module to install into the lightning protector module port depending upon the governing code requirements. There are several types with different voltage applications. These protectors are usually frame/bay mounted.

Grounding Premise Locations

When an OSP engineer installs a metal-sheathed or copper-paired cable into a premise, a principal point ground bus is established and labeled. This is required for both access/service provider connections and customer-owned OSP connections. The bus size is based on the amount of known current and possible future ground connection possibilities.

This bus usually has a connection to the ground electrode (typically a single ground rod) and the incoming ac power ground. OSP copper-paired lightning protection and metallic cable sheaths are bonded and grounded to the bus.

For most premise applications, lightning protection is installed on plywood within the premise main telecommunications room or can be mounted outdoors in a weatherproof housing.

What is Within the Warehouse

Planning for disaster recovery should include what stock in-hand will speed up the rebuilding process. This should include different types and sizes of pedestals, types of splicing enclosures, splicing materials, spare protection modules, protectors, various pole sizes and cable counts, wire gauges and lengths of optical fiber and copper cable. Service providers can have these items stored in various locations nearby.

If storage is an issue, talk to telecommunications material suppliers. Provide a list of common items. They sometimes can (for a fee) store these items in a convenient location. They can also provide lead times for items that are difficult to have on-hand locally. Material suppliers have their own disaster recovery plans and can share them.

Conclusion

An OSP system cannot be completely immune to natural disasters or unusual circumstances. The best defense for recovering quickly from a disaster relies on good plant records, sufficient available funds and people to rebuild it.

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BY ALEXANDRA MANNING

THE INTERNET OF THINGS AND THE DIGITAL TRANSFORMATION OF AGING U.S. AIRPORTS

The United States was once the global leader of the skies, having launched the first commercial flight and built the world's first modern airports with exceptional passenger service. Today, not one U.S. airport appears in the top 25 in the well-respected 2018 Skytrax list of the World's Top 100 Airport Awards, based on nearly 14 million airport survey questionnaires completed by airline passengers of over 100 different nationalities. Dominating the list are more modern, smart and internet of things (IoT)-ready airports primarily in Asia, Europe, and the Middle East, including:

- Singapore Changi Airport #1 (for the sixth year in a row)
- Hong Kong International Airport #4
- Munich Airport #6
- London Heathrow Airport #8
- Dubai International Airport #23

Besides not keeping pace with global competition, the U.S. airport industry faces massive budgetary and infrastructure capacity challenges in the midst of upcoming significant passenger growth.

The only airport in North America to make the Top 25 is Vancouver International Airport at #14. The highest-ranking U.S. airports, according to Skytrax, are Denver International Airport (#29) and Cincinnati/Northern Kentucky International Airport (#34). Furthermore, U.S. airports received a "D" on the 2017 Infrastructure Report Card by the American Society of Civil Engineers.

Besides not keeping pace with global competition, the U.S. airport industry faces massive budgetary and infrastructure capacity challenges in the midst of upcoming significant passenger growth, as explained in the Airport Infrastructure Needs 2017-2021 report by ACI-NA (Airport Council International-North America). The ACI-NA, therefore, is voicing with urgent fury its crucial airport modernization requirements, including Airport Digital Transformation advocated by ACI.

According to ACI-NA President and CEO Kevin M. Burke, "The longer we delay, America's airports will fall behind and our infrastructure needs become more expensive to fix. Time is of the essence."[1]

By understanding the challenges, unique and complex infrastructure requirements of aging airports and the modernization and digital transformation goals of the ACI-NA—in context with ANSI/BICSI 007-2017, *Information Communication Technology Design and Implementation Practices for Intelligent Buildings and Premises*—designers and installers can better serve the airport industry in its quest to improve the passenger experience via IoT, and empower local communities to compete more profitably in the 21st century global economy.

AIRPORT IoT FOCUSES ON THE TERMINAL AND HEIGHTENING THE PASSENGER EXPERIENCE

From the world's largest waterfall at Changi Airport to a luxury spa and squash court at Qatar's Hamad International Airport, airports around the globe have built and continue to expand their multi-million square foot terminals to improve the passenger experience. After all, the terminal is the airport's core business and profit center. With the advent of IoT in 2012 and the seemingly endless possibilities to deploy it in the terminal ecosystem, global airports have embraced with unbridled enthusiasm the promises of IoT, network convergence, and digital transformation to improve not only the passenger experience, but to also take the airport to new heights of efficiencies and lower costs. With IoT, virtually anything that can be touched can become an IP-enabled device including seats—and many airports worldwide seem not to be leaving a cushion unturned.

Hong Kong International Airport has installed about 10,000 IoT sensors deployed at the terminal to monitor and analyze passenger flow, luggage handling, retail traffic, and even toilet usage.[2] Gatwick Airport has installed about 2,000 beacons across its two terminals for a mobile device wayfinding tool that provides a more reliable navigation system than GPS for passengers.[3] Recently, the world's first biometric bag drop system has been installed at Auckland Airport in New Zealand.

Changi Airport has introduced biometric facial recognition at Terminal 4 to reduce staff and streamline passenger validation. Many airports have deployed IoT for asset tracking using GPS and Wi-Fi to follow important airport equipment that lessens flight delays. The most unusual application to date is Josie Pepper, "the new robotic humanoid staff member at Munich

The most unusual application to date is Josie Pepper, "the new robotic humanoid staff member at Munich Airport's Terminal 2 whose brain contains an advanced processor with a WLAN [wireless LAN] internet access, creating a connection to a cloud service where speech is processed, interpreted and linked to airport data."

Airport's Terminal 2 whose brain contains an advanced processor with a WLAN [wireless LAN] internet access, creating a connection to a cloud service where speech is processed, interpreted and linked to airport data."[4] All, no doubt, are deploying IoT and convergence for their terminals' environmental conditions (e.g., temperature, air quality, humidity, LED lighting, daylight harvesting) that simultaneously enhance the passenger experience while reducing energy costs.

Many global airports have these competitive advantages over the U.S. airport industry:

- Adequate funding in support of their respective airport industries
- More committed investment and funding in deploying and testing IoT applications and related technologies
- More modern and better maintained smart, IP-enabled and IoT-ready, network infrastructures

This uneven playing field begs the question as to what will it take to get U.S. aging airport infrastructures digitally transformed and IoT-ready to accommodate the upcoming significant growth in passenger traffic?

By better comprehending the U.S. airport industry, along with its funding and budgetary challenges, ICT design engineers, installers and technicians can be better positioned to provide the most appropriate and innovative technology solutions to advance the airport industry in the evolution of IoT and the intelligent building. To begin to achieve that better understanding, the following topics are addressed:

- The current state and infrastructure needs of U.S. airports
- Assessing the cabling infrastructure of the aging airport back to the basics
- Passive optical network (PON) considerations

- Increasing passenger traffic, limited capacity and the wireless network

THE STATUS OF THE U.S. AIRPORT INFRASTRUCTURE, NEEDS AND RELATED CHALLENGES

The average U.S. airport is about 40 years old and not aging gracefully. The last new airport to be built was Denver International Airport approximately 23 years ago. Many airports do not have sufficient land to expand their terminals, airside, and landside areas, which is why LaGuardia's $4 billion redevelopment plan includes a new terminal constructed on top of the existing airport building.[5]

According to the U.S. Travel Association, it has been 17 years since Congress authorized an increase in the passenger facility charge, which is an important funding source to assist modernizing airports.

Figure 1 shows that terminal building projects account for nearly 47 percent of the total infrastructure development needs of all U.S. airports for the next four years. These projects, totaling approximately $100 billion, are needed to "accommodate more passengers and larger aircraft, implement new security requirements, facilitate increased competition among airlines, and enhance the passenger experience."[6] The next major priority at 16 percent is surface access projects to relieve landside congestion of terminal curbside, access roads and pedestrian walkways.

As shown in Table 1, terminal projects constitute 54.1 percent of the total infrastructure development costs, followed by landside projects at 24.7 percent and airside projects at 21.1 percent of total costs.

Table 2 conveys the infrastructure needs for each year through 2021, ranging from $21.9 billion in 2018 to $17.3 billion in 2021. Average annual needs amount to $20 billion. Large hub airports that handle almost 73 percent of all U.S. enplanements account for the

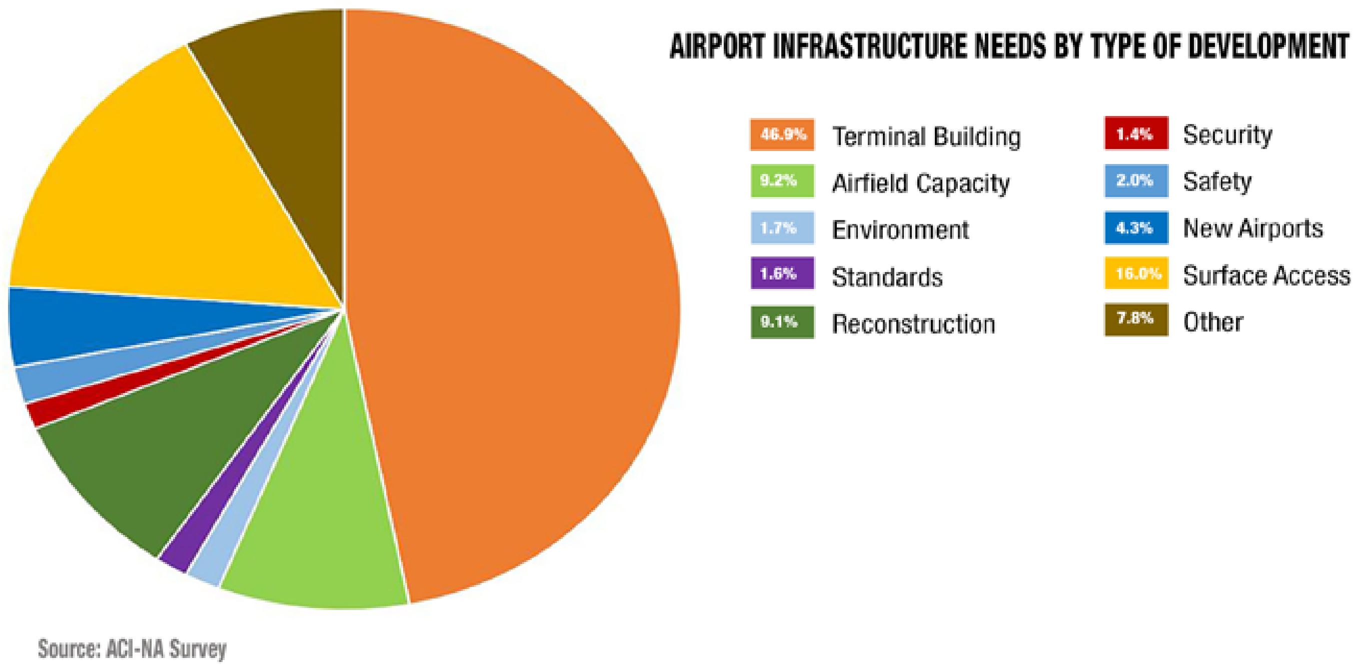

FIGURE 1: U.S. airport infrastructure needs in the next 4 years for airports that enplane 99.8 percent of U.S. passenger traffic.

PROJECT LOCATION	PERCENTAGE FOR ALL RESPONDENTS	PERCENTAGE FOR LARGE HUB RESPONDENTS	PERCENTAGE FOR MEDIUM HUB RESPONDENTS	PERCENTAGE FOR SMALL HUB RESPONDENTS
AIRSIDE	21.13%	15.95%	36.48%	50.34%
TERMINAL	54.13%	59.58%	31.98%	35.38%
LANDSIDE	24.74%	24.47%	31.54%	14.28%
TOTAL*	100.0%	79.6%	13.17%	6.4%

TABLE 1: Development cost by project location.

* **Note:** Summary excludes projects without a specified location code or projects located in multiple locations without breakdown.

Source: ACI-NA Survey

AIRPORT CATEGORY	2017	2018	2019	2020	2021	2017-2021	PERCENT
LARGE HUB	12,627	13,502	13,778	10,929	9,539	60,375	60.5%
MEDIUM HUB	2,376	2,766	2,545	1,953	2,078	11,718	11.7%
SMALL HUB	1,748	1,871	1,713	1,485	1,665	8,483	8.5%
NON-HUB	1,068	1,084	1,100	1,117	1,134	5,504	5.5%
OTHER *	2,677	2,717	2,757	2,799	2,841	13,790	13.8%
TOTAL	20,496	21,940	21,895	18,283	17,256	99,869	100.00%

TABLE 2: Airport infrastructure cost estimates by year and airport category (Millions of current year dollars).

* **Note:** "Other" includes non-commercial service airports and 8 proposed airports based on Federal Aviation Administration National Plan of Integrated Airport Systems (FAA NPIAS) report (2017-2021).

Source: ACI-NA Survey and FAA NPIAS

majority of these costs with 60.5 percent of the total, followed by non-commercial service/new airports and medium hub airports.

The ACI-NA reports that U.S. airports generate only $10 billion per year in net income, leaving a shortfall of $10 billion annually for needed terminal and other infrastructure investments.

Part of those investments need to be allocated to fulfill the Digital Transformation goals of the ACI- NA and ACI. In its white paper entitled *Airport Digital Transformation*, ACI illustrates one possible path to becoming a digital-ready airport and the myriad technologies involved to get there (Figure 2).

According to ACI, digital transformation is about business transformation in a digital world, and "about evolving processes and services to deliver a better experience to all passengers and customers through the adoption, integration and implementation of new technologies with existing ones."[7] There are pockets of terminal modernization, IoT integration, and digital transformation among more profitable airports and those that can arrange public-private funding arrangements. Orlando International Airport, for example, has begun construction on its $2.1 billion new 1,000,000 square foot South Terminal Complex, featuring a smart

Many forward thinking and well-funded airports are also implementing more advanced wireless technologies to enhance the passenger experience and to prepare for 5G.

city heavy rail terminal connecting the airport with downtown Miami. Integrating IoT, as it has already done in the North terminal, the airport authority is investing in beacon technology to create an intuitive airport mapping system and highly detailed wayfinding app.[8] Other recent terminal modernization projects include Denver, Tampa, Seattle-Tacoma and a $2.7 billion initiative to modernize all airports throughout the Hawaiian archipelago, beginning with a terminal upgrade at Ellison Onizuka Kona International Airport. Faced with pressing budgetary, capacity and aging airport conditions, Burke asks the question in the introduction of the Airport Infrastructure Needs 2017-2021 report, "But where do we begin?"

From an ICT cabling infrastructure perspective, the following scenario and lessons learned at John Glenn Columbus Airport provide insight into some of the realities of integrating IoT into U.S. aging airport infrastructures.

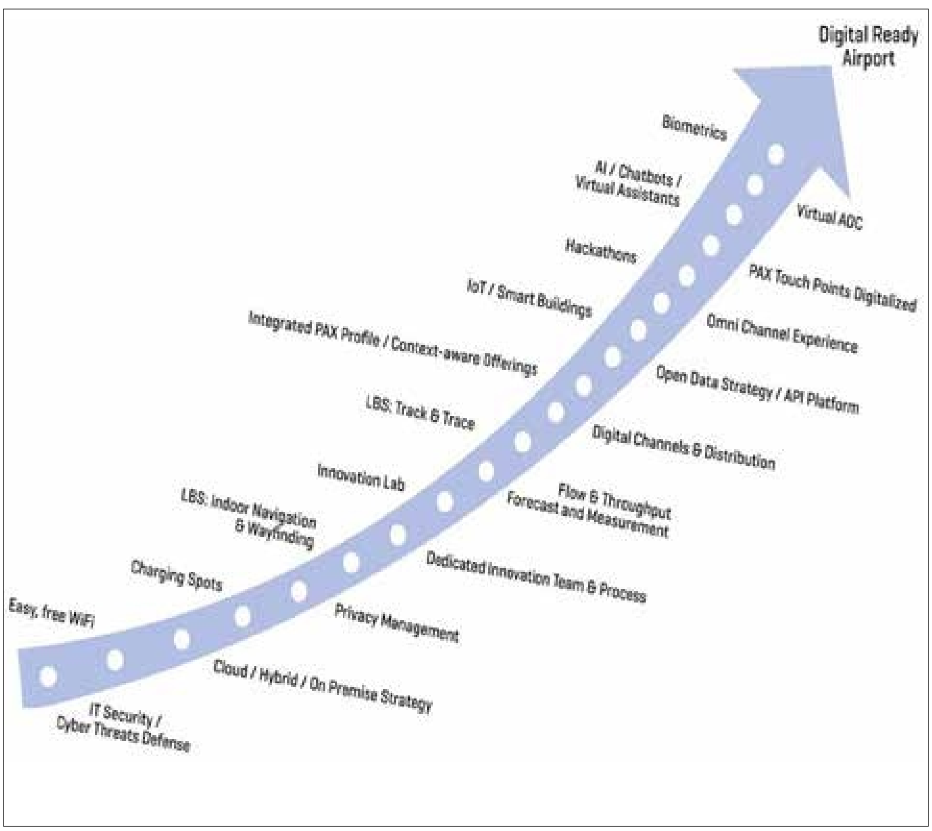

FIGURE 2: Illustrates one possible path and the enabling technologies to become a digital-ready airport according to the Airports Council International (ACI).

AGING AIRPORTS TAKE ICT BACK TO THE BASICS

It is easy to get caught up in the excitement of IoT and its seemingly endless possibilities. This is the case with Jim Lizotte, Director of Technology Services for the Columbus Regional Airport Authority. He realized that the backbone cabling infrastructure at John Glenn Columbus International Airport could not support the $1.5 million Wi-Fi upgrade (increasing wireless access points [WAPs] from 40 to about 350) that would enable his initial ideas for IoT deployment. Following major backbone work and tripling bandwidth, the airport instituted a fully mobile 4,000 employee workforce, implemented a tracking system for managing assets, as well as a passenger wayfinding app. “First, you have to make the investment. Then, you can innovate,” Lizotte advises. “We needed both the wired and wireless infrastructure in place to do that.”[9]

With the advent of IoT in 2012 and the seemingly endless possibilities to deploy it in the terminal ecosystem, global airports have embraced with unbridled enthusiasm the promises of IoT, network convergence and digital transformation to improve not only the passenger experience, but to also take the airport to new heights of efficiencies and lower costs.

When considering 40- to 50-year-old airport infrastructures, one can imagine miles of filled conduit cable pathways, abandoned legacy cables, and congested data center rack space. Within this backdrop, it is important to carefully assess whether an airport’s existing redundant backbone can support its planned intelligent building and IoT applications. Equally important is to determine whether the backbone is adequately futureproofed to introduce yet undefined high-bandwidth emerging technologies, such as new Transportation Security Administration (TSA) 3D scanners and 5G wireless. Many larger airports are installing high count singlemode optical fiber and have clear 40/25/100 gigiabit migration plans; smaller airports may be further behind in the modernization planning process.

Utilizing as much existing infrastructure in these aging airports is also a consideration before thinking of rip-and-replace due to budgetary constraints. The ANSI/BICSI-007 standard strongly asserts that the topology for horizontal and backbone cabling shall be a hierarchical star as per applicable standards (e.g., ISO/IEC 11801-6, ANSI/TIA-862-B). Backbone Cabling 5.4.1 under Communications Infrastructure provides information, as well, for the standards, requirements, and best practices for the intelligent building backbone.

PON ARCHITECTURE CONSIDERATIONS FOR THE AIRPORT

At LaGuardia Airport’s new Central Terminal B, IoT and PON technologies are being integrated into the airport’s terminal design. IoT-based applications are already sending real-time information to airport operators and airlines about the impact the construction is having on the passenger experience.[10] Dubai Airport is perhaps the most notable, having been one of the first airports to install a PON architecture. Since PON technology has evolved for the enterprise as passive optical LAN (POL), many design and installation firms are currently touting its benefits for airports. It is potentially a viable solution for aging airports with insufficient land for terminal and other area expansions (Figure 3).

There are many advantages associated with POL, including:

- Singlemode fiber
- Point-to-multipoint architecture
- Convergence of all services over a single fiber-based infrastructure
- Significant cost savings in active equipment and power

- Distance advantage of ≈20.1 kilometers (km [12.5 miles (mi)]) versus copper's ≈100 meter (m [328 feet (ft)]) limit

There are important considerations when installing a PON. Once it is implemented, it may be more difficult to upgrade. A PON is usually built with minimal spaces and pathways, so the lack of either can affect future media access controls, expansions and the ability to support new systems; therefore, it must be planned and designed carefully.

PONs are covered at length in ANSI/BICSI-007, 5.11.2, which provides valuable recommendations to be observed when considering a PON deployment.

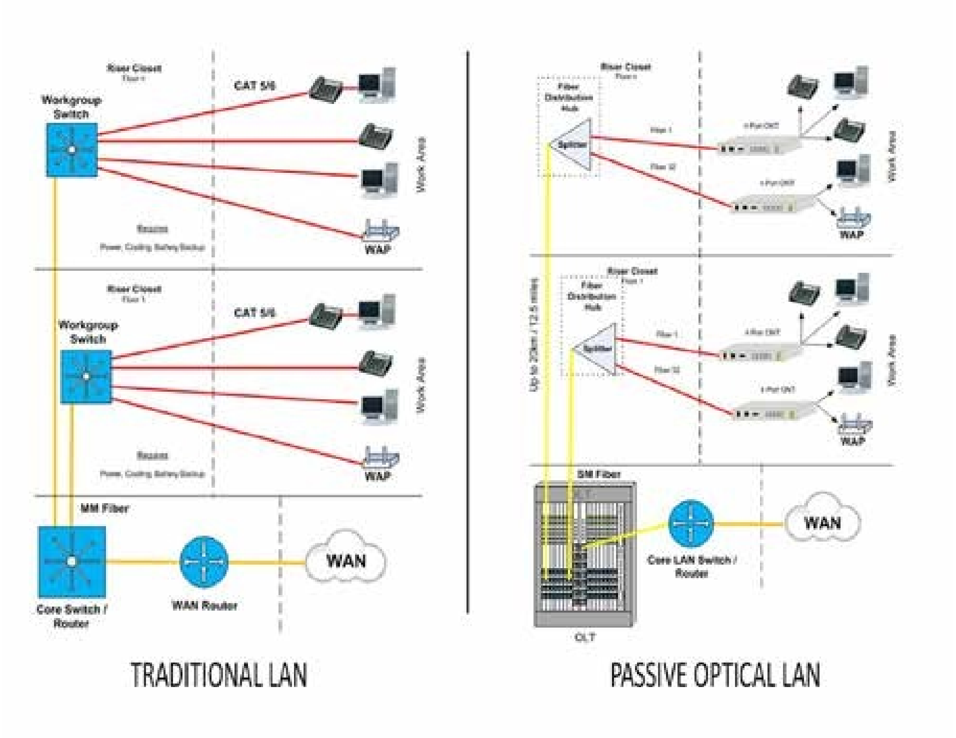

FIGURE 3: Traditional LAN versus gigabit passive optical network passive optical LAN. [11]

INCREASING PASSENGER TRAFFIC, LIMITED CAPACITY AND THE WIRELESS NETWORK

In 2016, North American passenger traffic increased nearly 4 percent. That increase meant that 65 million more people traveled through North American airports than in 2015. That passenger traffic is expected to grow substantially. ACI World forecasts that 2 billion passengers are expected to travel through North American airports in 2018 and 3 billion by 2035.

In its Airport Infrastructure Needs 2017-2021 report, ACI-NA shares some equally startling predictions for U.S. passenger growth from the FAA, which predicts U.S. airlines will reach the 1 billion passengers-per-year mark by 2027 as depicted in Figure 4.

It has been described that running the wireless network at an airport is like running the wireless network at the Super Bowl, every day.[12] With continuously increasing passenger traffic, that comparison will only compound. Why?

As ACI-NA's Burke explains when addressing North American airports, "Our current airport system was designed for half the traffic volume we have today."[13]

The additional volume of passenger traffic impacts not only the already congested and long wait times of check-in and TSA security lines but can overwhelm the wireless system to the extent that passengers and airport staff may lose mission-critical communications.

Thus far, the ACI-NA has focused on the need for the physical expansion and reconstruction of the terminal building as the solution for accommodating passenger growth. However, for the many airports with funding constraints and no land for further expansions, IoT and the development of robust wireless networks within existing terminals may offer a solution to managing the growing volume of passengers. Some airports are testing and implementing beacon technology in conjunction with video

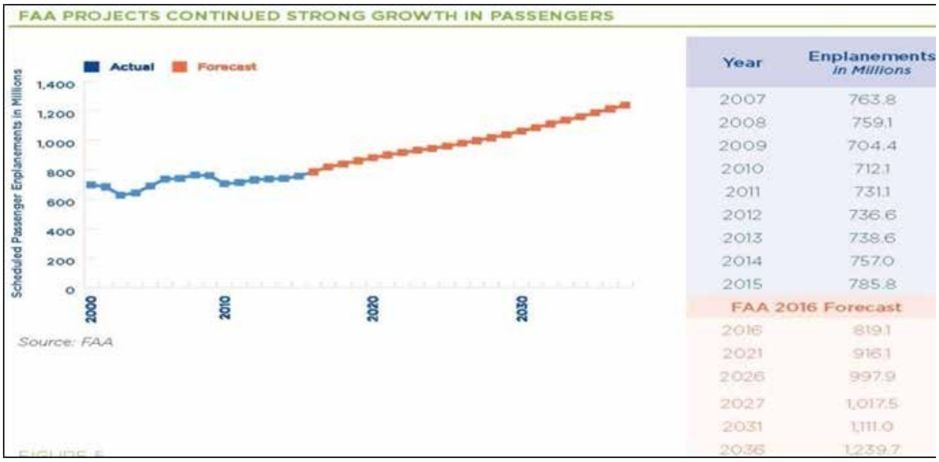

FIGURE 4: U.S. passenger growth steadily increases to 1 billion in 2027.

surveillance for real-time measurements of dwell times and queue lengths. The data that is collected is used with mobile wayfinding apps to inform passengers of waiting times, then leads them toward nearby concessions to generate revenue and offset technology investment costs. ANSI/BICSI-007, 9.1, offers valuable digital signage and wayfinding recommendations.

A robust wireless network to support the myriad of IoT applications is secondary, however, to the safety and security of passengers and airport personnel. Loss of communications caused by additional mobile device users stressing the network can deprive emergency and first responders of their life-saving communications. This importance of security and safety also pertains to any IoT-enabled device that can be hacked, making cybersecurity a growing concern.

To gain a clearer picture of the impact passenger traffic growth will

have on the wireless network, look at Cisco's June 2017 Visual Networking Index Complete Traffic Forecast (2016–2021) report. It describes North America's trends in IP and internet traffic growth that airports and their wireless service providers need to consider for their individual airport requirements and share of the 2 billion annual passengers to hit North American airports this year. According to Cisco, "North America [with a current population of 579,000,000] will generate 30 percent of global IP traffic by 2021, using approximately 85 exabytes per month" or approximately 1,020 exabytes per year. Putting this into perspective, 100 exabytes is the equivalent of a video recording of all the meetings that took place last year across the world. Other relevant trends and findings include:

- 1,020 exabytes equal 2.55 times the total amount of data that crossed the entire internet in the year 2012.
- By 2021, there will be 181 gigabytes of internet traffic per month, per user, in North America, a 166 percent increase from 2016!
- 2 billion passengers with 3.5 network devices equals 7 billion mobile devices annually passing through North American airports.

When considering the 1 billion passengers passing through U.S. airport terminals (3.1 times the current population of the United States), that amounts to 3.5 billion mobile devices annually. These statistics do not account for the mobile devices used by airport personnel. According to ACI-NA, approximately 1.2 million people work at 485 commercial airports in the United States. Imagine the number of WAPs needing to be installed in large U.S. terminals to accommodate for this passenger growth and increase in mobile device usage, while avoiding any potential Wi-Fi mobile traffic congestion and possible network downtime.

Many large hub airports boast multi-million square foot terminals, such as Hartsfield-Jackson Atlanta International Airport's 6.8 million square foot terminal complex and O'Hare International Airport's 4.3 million square foot 55-year-old Terminal 2. As a result, distance can be a design and installation issue depending on the application.

If considering power over Ethernet (PoE) for WAPs, it may be necessary to employ hybrid copper/fiber cables and optical-to-electrical media converters to overcome copper's ≈100 meter (m [328 feet (ft)]) limit. With zone cabling, for instance, airport terminals may benefit from higher outlet density at the horizontal connection point. ANSI/BICSI-007, 6.3.1 and 6.1, thoroughly cover the requirements

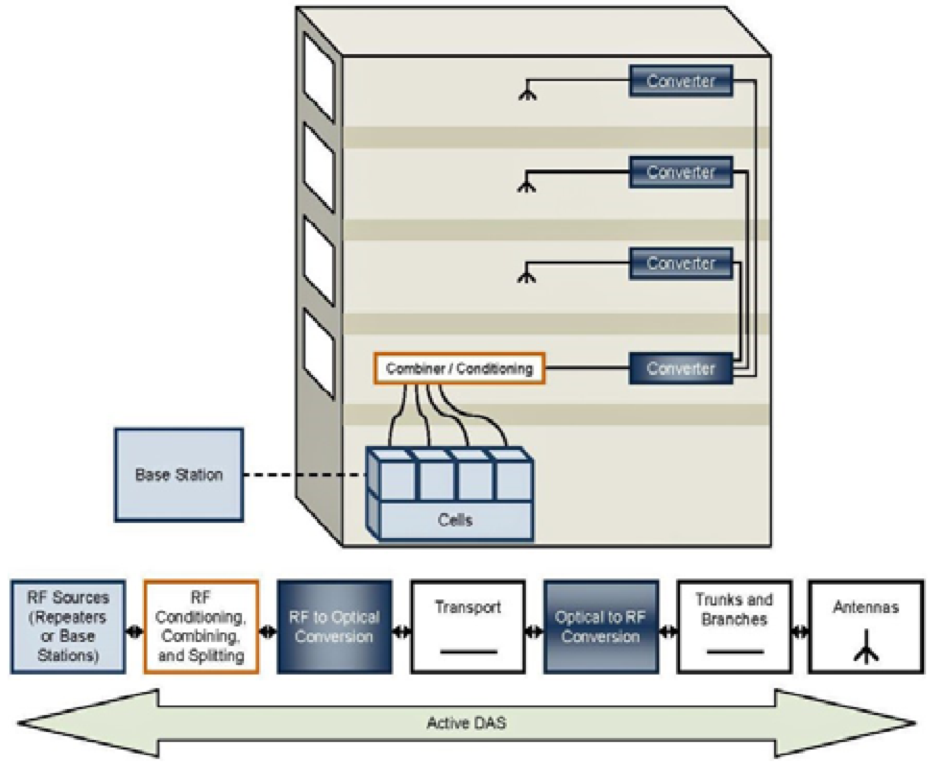

FIGURE 5: Active distributed antenna system (DAS) uses optical fiber cabling as the most common medium for the distribution of signals to the service zones. Active DAS is most often deployed for large areas such as stadiums and large hub airport terminals.

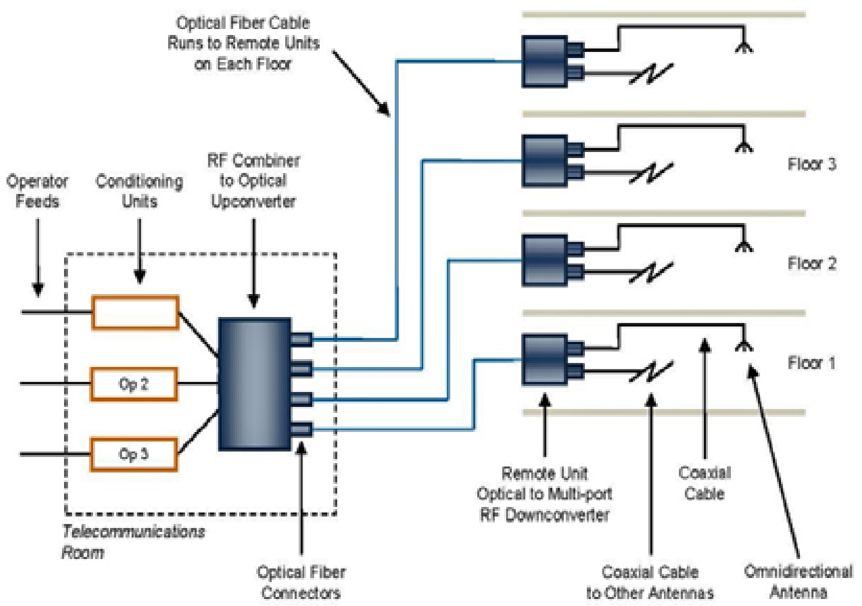

FIGURE 6: A hybrid distributed antenna system (DAS) combines the use of both active and passive components and system architectures using both fiber and coaxial cable. Hybrid systems may be a good solution for medium-sized spaces or for unusual signal problems in small hub airports with old cabling infrastructure.

and recommended practices of PoE and zone cabling for wireless installations.

Despite the staggering traffic growth statistics, many airports continue to have poor cellular coverage; Los Angeles International Airport, the second busiest airport in the U.S., is the most notorious. Much of the poor cellular coverage is due to the many impenetrable signal barriers, such as concrete, metal, and new environmentally-friendly building construction materials (e.g., E-Glass), as well as the natural terrain surrounding the terminal (e.g., mountains, utility towers, highway overpasses).

Denver International Airport's cellular coverage, for example, was negatively affected by the Rocky Mountains until it recently had every major mobile carrier substantially increase the number of antennas in the airport's indoor distributed antenna system (DAS). The upgrade provided 80 percent more LTE capacity at the airport while allowing easy adjustment to access additional capacity when it's needed most (e.g., summer vacation season, holiday travel).

Having mobile carriers fund and upgrade the DAS for more airports (Figures 5 and 6) can lead to more consistent cellular coverage from airport to airport, providing subscribers with excellent service wherever they go.

Oakland International Airport upgraded its DAS in anticipation of heavy traffic for the 2016 Super Bowl. U.S. Bank Stadium upgraded its DAS to handle the estimated 1 million additional mobile users for the 2018 Super Bowl.

In-depth information for DAS standards and installation best practices is found in ANSI/BICSI 006, *Distributed Antenna System (DAS) Design and Implementation Best Practices.*

Many forward thinking and well-funded airports are also implementing more advanced wireless technologies to enhance the passenger experience and to prepare for 5G, such as:

- Replacing free unsecured public Wi-Fi with Passpoint, which has the infrastructure in place using Hotspot 2.0 technical specifications created by the Wi-Fi Alliance to deploy secure transfer between cellular and Wi-Fi, while eliminating cumbersome Wi-Fi log-ins.
- Implementing hybrid Wi-Fi to cater to individual passenger needs.
- Considering network functions virtualization, which is a key attribute of 5G for network slicing. With network slicing airports can ultimately prioritize, provision, and manage various services and functions based on reliability, latency and throughput requirements. For example, security and safety, above all other services, can be assigned high priority to take advantage of 5G's proposed low latency of 1 millisecond or less.

- Optimizing and securing the data center for the influx of potentially massive 5G and other high-bandwidth IoT-related data traffic.

CONCLUSION

This article scratches the surface of the challenges confronting the U.S. airport industry as it endeavors to integrate 21st century IoT and related emerging technologies into 20th century airport infrastructures and facilities—and to once again become globally competitive with worldwide airports fervently embracing and implementing advanced technologies. Despite the challenges and lack of funding for infrastructure projects, the ACI-NA, representing member airports comprising more than 95 percent of the domestic and virtually all the international airline passenger and cargo traffic in North America, is enthusiastic about the future. Infrastructure improvements and changes in federal funding for U.S. airports have become important issues and garnered support from the current administration. In the meantime, there are exciting terminal modernization projects underway and likely more to come. Through understanding the concerns, challenges and goals of the U.S. airport industry, ICT design engineers, installers and technicians may have value-added insight to provide the innovative IoT and intelligent building technology solutions to meet the unique needs of today's aging U.S. airports.

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By Mark Mullins

Cloud Certification to Manage Complex Jobs

Most industries and companies have used cloud services long enough to understand the value they bring—allowing multiple users to access a single database of business-critical information. However, installers and contractors have just begun to adopt and use cloud services for certifying cabling infrastructure, with the early adopters primarily being firms that manage large-scale projects and therefore benefit the most from the organization and reduction of errors that come with a cloud-based approach.

Some data centers may choose to use direct-attach cable (DAC) solutions like SFP28 for higher speed 25 gigabits per second (Gb/s [25GBASE-CR]) direct switch-to-server connections. But unlike the ≈30 meter (m [98 feet (ft)]) distances supported by category 8, these solutions are limited to about ≈5 m (16.5 ft) , which can significantly limit flexibility of switch and server placement in the data center.

As cloud-based solutions continue to add capabilities, more installers will turn to these solutions to improve efficiency and productivity of cabling projects, which translates to more competitive bids and higher profit margins. Customers are connecting their testing and certification devices to cloud-based certification services, reducing the errors that can rapidly escalate costs in large projects. With large numbers of complex cable IDs, many companies are seeing the benefit of a single project database that combines project data with data from test equipment and labelers.

Advanced PoE on the Horizon

With the much-anticipated release of IEEE 802.3bt Type 3 and Type 4 power over Ethernet (PoE), companies will start to see more devices forgo their ac power connection for PoE—everything from LED lights, digital displays and video security systems, to building automation devices and possibly desktop computers. At the same time, changes in the 2017 *National Electrical Code®* that will be adopted by multiple municipalities will continue to raise questions on the best way to support these higher levels of PoE from an installation and testing standpoint.

As a result, in 2018 there may be more requests for field testing of dc resistance unbalance within and between pairs to ensure support for higher power four-pair PoE, as well as a focus on proper cable bundling practices to resist heat rise and subsequent insertion loss in cables delivering PoE to a multitude of devices.

Since many of these devices can be directly connected to the network using plug-terminated links rather than traditional outlets and patch cords, and the upcoming TIA 568.2-D standard includes support for this configuration (including the new modular plug terminated link testing procedure), 2018 will also likely mean more field-terminated plug options and support for plug-terminated links by both cabling and device manufacturers.

Early Adopters Will Install Category 8 Components

We will likely see initial shipments of category 8 components and installations by early adopters by the end of 2018. With backbone data center switch-to-switch optical fiber links capable of transmitting at 100 gigabits per second (Gb/s), and IEEE® already looking at 200 and 400 Gb/s, 10 Gb/s will no longer offer enough bandwidth for today's virtualized servers in cloud, hyperscale and some advanced enterprise data center environments. While optical fiber will support Ethernet rates up to 400 Gb/s, copper cabling systems remain less expensive due to lower installation and electronic costs. With its ability to support 25/40GBASE-T, category 8 is the next logical step for switch-to-server links in these environments.

Data center upgrades from category 6 or 6A to category 8 will be straightforward in most cases. These structured cabling configurations are typically row based with edge switches and their

As cloud-based solutions continue to add capabilities, more installers will turn to these solutions to improve efficiency and productivity of cabling projects, which translates to more competitive bids and higher profit margins.

corresponding patch panels residing in an end-of-row or middle-of-row networking cabinet (or rack) and servers and their corresponding patch panels located in the other cabinets within the row. With the ≈30 meters (m [98 feet (ft)]) distance offered by category 8 (like the ≈35 m (115 feet ft) distance for 10GBASE-T over category 6A in low-power short-reach mode), networking cabinets may also be in their own distribution area and connected to separate clusters of server cabinets.

Some data center owners may choose to use direct-attach cable (DAC) solutions like SFP28 for higher speed 25 Gb/s (25GBASE-CR) direct switch-to-server connections. But unlike the ≈30 m (98 feet ft) distances supported by category 8, these solutions are limited to about ≈5 m (16.5 ft), which can significantly limit flexibility of switch and server placement in the data center. Therefore, SFP28 cables are typically only deployed in top-of-rack configurations where edge switches reside in the same cabinet and connect directly to servers in that cabinet.

Unlike 25GBASE-CR, 25GBASE-T/40GBASE-T supports autonegotiation, which provides the ability to support both 25 and

Which configurations [FOCIS 5 or FOCIS 18] will become the most widely adopted is yet to be seen, but both will likely find homes, especially in hyperscale data centers.

40 Gb/s server uplinks to a single switch for efficiency, cost savings and scalability. While 25 and 40GBASE-T products are not expected to ship this year, category 8 is backwards compatible so it will support 10, 25 and 40GBASE-T. It will be deployed by those early adopters who are looking to avoid expensive future upgrades.

Push is on for MPO Technologies to Support Big Data

Multifiber push-on (MPO) technologies will continue to grow to support high-speed networking. Existing FOCIS 5 (Base 12) connectors provide single or double rows of 12 optical fibers and support 40 Gigabit Ethernet (40GBASE-SR4) and 100 Gigabit Ethernet (100GBASE-SR4) with 4 optical fibers transmitting and 4 optical fibers receiving at 10 or 25 Gb/s, as well as 100GBASE-SR10 with 10 optical fibers transmitting and 10 optical fibers receiving at 10 Gb/s.

On the horizon are new configurations (FOCIS 18) that promise faster speeds with one or two rows of 16 optical fibers in an MPO connector. These will be able to handle up to 400 Gb/s interconnections (400GBASE-SR16) with 16 optical fibers transmitting and 16 optical fibers receiving at 25 Gb/s. While the two varieties of connectors are similar in size, they will not be interoperable due to different geometry. While FOCIS 18 connectors will be welcome from a performance point of view, adding another connection type brings more complexity to the existing issues of polarity and pinning, providing additional challenges for installers and maintainers of MPO-based infrastructures. Many current solutions for testing and inspecting FOCIS 5 solutions will also not work for FOCIS 18 connectors.

Which configurations will become the most widely adopted is yet to be seen, but both will likely find homes, especially in hyperscale data centers. At the same time, enterprise data centers will continue to ramp up 40 and 100 Gb/s installations that require FOCIS 5 MPO connector technologies. Consequently, 2018 will see greater focus on topics like polarity and testing considerations for MPO deployments.

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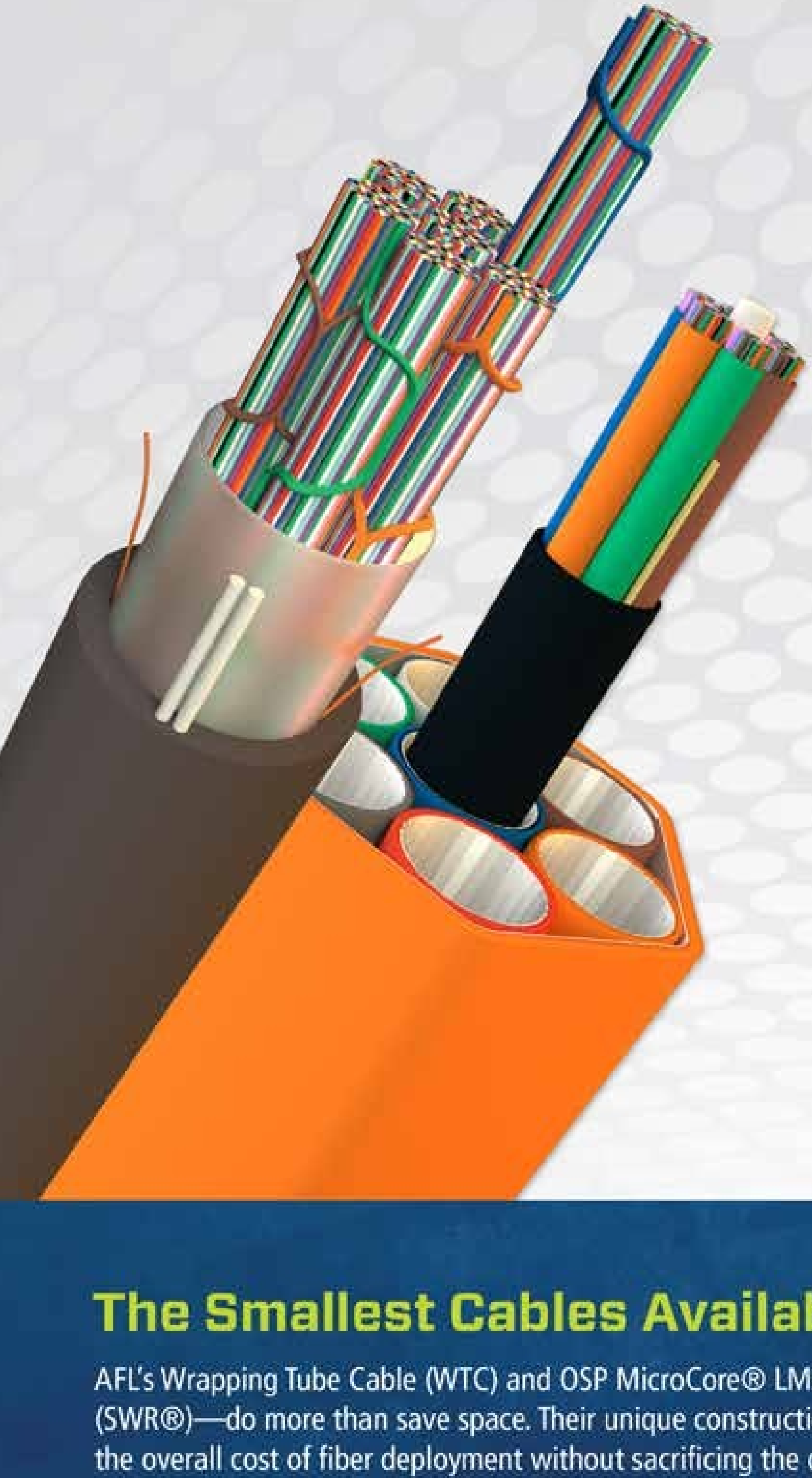

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