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Small Cell Infrastructure: Design, Construction and Maintenance Best Practices

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Introduction

The telecommunications industry is continually seeking to enhance coverage and capacity to meet the ever-increasing communications needs of the United States. To support effective broadband coverage for all requires that wireless facilities licensed by the Federal Communications Commission (FCC) be sited on wireless-specific infrastructure or on structures that have a different intended use. In some cases, this means deploying a small cell network. This white paper will identify design roadblocks and provide best practices for designing, locating, permitting, planning, constructing and maintaining small cells.

Design

As with any telecommunication project, the need for radio frequency coverage and system capacity triggers a design with an expected outcome. A small cell is typically defined as a wireless service facility where the equipment is no more than three cubic feet in volume and is designed to service a compressed geographic area or add bandwidth capacity in that area. In the simplest terms, small cells are telecommunications sites that are designed to target specific service areas and can be installed every few blocks (as close as every 500 – 700 feet), to meet coverage and capacity requirements of the network.

Since they cover a very small area and are a pin-point application, small cells are very location-sensitive. Often, they are deployed near a recreational park, school or a sports venue. Because they are very location specific, the node or series of nodes must be built in a precise area. This may involve installing a new pole or utilizing existing vertical infrastructure. Installing on existing vertical infrastructure may be the fastest approach and can often minimize the visual impact of the small cell installation. Some of the most common small cell applications that are installed in the public right of way use existing utility poles, streetlights, traffic signal poles, standalone small cell poles, signs and billboards, or other vertical infrastructure that can support a small cell node.

Collocating on a utility pole requires knowledge of applicable codes and construction standards such as the National Electric Safety Code (NESC), NFPA70e National Electric Code (NEC), State of California Rules for Overhead Electric Line Construction, General Order Number 95 (G.O.95), Rules for Construction of Underground Electric Supply and Communication Systems, and General Order Number 128 (G.O.128). Overall, these standards require the small cell node to maintain a specific distance between all communication and power facilities. Correct distance from energize facilities, other telecommunication cable and equipment on utility poles is required to maintain worker safety Occupations Safety and Health Administration (OSHA) standards and reliable operating systems. The pole owner may have additional utility-specific requirements that exceed applicable codes and may require increased clearances from facilities and equipment. Appropriate measures must be taken to maintain the worker safety zone on a pole and clear climbing space (climbing facilities) after small cell node installation. All of this requires the engagement of qualified persons who understand the telecommunications equipment and can

apply the proper codes and standards for the telecommunications equipment and the intended use of the utility pole.

Collocating on a streetlight can be less complicated than collocating on a utility pole when it comes to clearances and utility standards. Collocating on a standalone streetlight requires knowledge of the National Electric Code NFPA70 Standards (NEC). Most issues with streetlights concern the structural integrity of the proposed streetlight pole, its foundation, if it can meet the structural and design criteria, and the local Authority Having Jurisdiction's (AHJ) aesthetic requirements. Many times, to meet all these needs, the streetlight must be exchanged with a new decorative pole. These custom designed decorative poles can be costly and have long manufacturing lead times that can impact project schedules.

Small cells may be installed on traffic light poles. A traffic control system usually needs more care which is explained in TIF's Planning Advisory Notice (PAN) [Designing, Implementing, and Maintaining Traffic Control Plans](#). To install a small cell node on a traffic light pole requires adherence to the American Association of State Highway and Transportation Officials (AASHTO) standards. In most cases the existing traffic signal will not meet the AASHTO structural standard and must be replaced. Again, replacing traffic light poles with a custom solution may impact the project cost and schedule. Often, these traffic light poles are located at intersections and the network designer needs to ensure that the new equipment does not interfere with traffic or create a hazard for pedestrians utilizing sidewalks and crosswalks. Caution must be taken to follow all specific structure regulations. Noncompliance with the applicable standards unnecessarily affects the project budget and timeline. It is critical to choose a qualified design and implementation team.

New standalone poles are often the last resort if the options above cannot be used. For new standalone poles, it is important to have a thorough knowledge of underground utilities. The small cell network requires specific designs to accommodate existing underground facilities avoiding conflicts and costly relocation expenses. There is much more to consider and plan for than just an 811 design mark out.

Fiber and power supply and their placement can be challenging with tight constraints. Every small cell node will need power and it is important to identify the power source for each node. It may be difficult to stage equipment especially on narrow, congested city streets. Small cell projects require strong coordination between utility and facility owners. Build some flexibility into the project timeline and budget to accommodate unseen issues. Sometimes in congested urban area it is not possible to understand all the challenges until work begins. At times only potholing and digging will identify issues. Give special consideration to electric power service whether the small cell network is using the AHJ's streetlight power from the local electric company or from another source. It can be challenging to coordinate with fiber and power companies resulting in longer lead times negatively affecting project schedules and budgets.

The AHJ plays a crucial role in the success of any small cell project. Some AHJ's have strict aesthetic requirements for certain sections of their community and sometimes these requirements change from block to block. For instance, all poles will need to be the same height, color and require a decorative shroud. Some AHJ's prohibit installing above the power lines. It is advantageous to work with a local, knowledgeable A&E firm early in the project that understands the AHJ and utility requirements avoiding a continual plan submission rejection loop, minimize back and forth and improve deployment timelines. Please note that the AHJ has great latitude but it, too, must comply with the applicable codes and regulations that apply to the node pole structure. Again, this is where engaging a qualified team is imperative because they can coordinate the AHJ's requirements with applicable codes, standards, regulations and ordinances.

If possible, it is advisable for the Engineer of Record (EOR) at the A&E firm to physically walk the small cell network in addition to using online tools such as Google Earth to ensure the network can be built as designed. Walking the network allows the EOR to identify possible red flags and provide design recommendations. Network designers must consider the physical dimensions of the new equipment. Particularly in the case of first time installs, network designers need to ensure that there is sufficient space for the proposed equipment on the pole, inside the equipment shroud, if required, and to plan for equipment cooling and heating. In the case of an equipment upgrade, the network designer must ensure that new equipment is a like-for-like swap or smaller in dimension and can physically fit inside the existing shroud taking equipment heating and cooling into consideration.

Small cell network design engineers should be aware of whether and when to apply the International Building Code (IBC), NESC, NES, AASHTO, ASCE or Telecommunication Industry Association (TIA) guidelines. Additional applicability of codes and standards and intended use guidance is provided in a separate TIF white paper on [Intended Use of Structures With Emphasis on Small Cell: 2020 Update, Ed. 2.1 April 2023](#). Depending upon the intended use of the main structure, the A&E vendor shall design and analyze the small cell based on the applicable codes and reasonable ordinances of the AHJ. Additionally, the A&E vendor may need to conduct a field visit to provide multiple solutions for successful installation. It is worth noting that in special wind regions, hurricane zones and areas with existing utility poles with hardened lines, the structure is already overstressed if analyzed per current applicable codes and standards. More cities are moving toward line hardening. Typically, small cells are mounted on utility poles made of southern pine, northern cedar, aluminum, steel or concrete. Corrosion can exist on steel poles whereas dents and other physical damage may exist on aluminum poles. Look for cracks and plumb when using concrete poles to install a small cell node. Concrete poles may require banding and drilling which may compromise the pole's structural integrity and will need additional approvals. Structural foundations require design and analysis. It is critical to ensure that the foundation is not cracked and is installed in stable soils. Direct embedded poles will have a cap that is structural or aesthetic. Regardless, proper design, installation and maintenance is required.



Figure 1: Picture of cracked small cell pole foundation

A typical project goes through multiple rounds of coordination with entities such as the utility pole owner, Department of Transportation (DOT), carrier stakeholders and AHJ. Coordination of all applicable parties could take six to nine months or longer. Project planners will need to account for this when setting deployment timelines. Supply chain challenges, equipment unavailability, personnel changes, technological advancements and permit approval lead times can also cause delays. Lastly, for a successful, timely project become familiar with local standards. Unfortunately, each build, each utility, each AHJ could have its own reasonable processes and standards affecting attachment type, pole height and pole styles.

Coordination is the key to successful and smooth project implementation. Most AHJs have a 30 to 90 day permitting process. There is the FCC “Shot Clock” approval schedule, but that may not be applicable for all projects. Obtaining permits is typically accomplished during the design/permitting phase and once a permit is issued, it is handed off to the general contractor. The general contractor is expected to coordinate with city inspectors, and/or third-party inspectors when required. Poor coordination could lead to installing poles with no power and fiber. It is important to process permits through a vendor who understands the area and has a positive working relationship with the AHJ and the utility. The permitting vendor should assist in identifying and recommending changes during the design process to facilitate permitting.

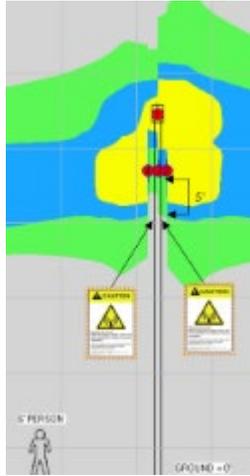
A small cell application requires several permits and approvals prior to installation. These include but are not limited to:

- Permit for highway occupancy for small cell node (zoning approval)
- Electrical permit as nodes require power
- Fiber may require conduit installation permit
- Excavation and traffic plan approval

In addition to the engineering design, be sure to install signage that complies with FCC rules for a small cell node. Below are some best practices to meet node signage requirements. These account for locations, size and coloring.

FCC Report and Order – FCC 19-126A

- “Our new rules include the requirement that signs be legible and readily viewable and readable at a minimum distance of five feet (1.52 m) from the boundary (and as necessary on approach to this boundary) at which the applicable limits are exceeded, and that controls or indicators be placed at compliance boundaries.”



Figures 2 and 3: FCC-required signage and its placement

- “To avoid over signage and confusing signage, accurate placement of appropriate signage is critical and should make clear both where limits are exceeded and where limits are not exceeded.”
- “...if the location where sign placement is feasible is not adjacent to the boundary where the general population exposure limit is exceeded, the “NOTICE” sign would provide awareness while avoiding over signage.”

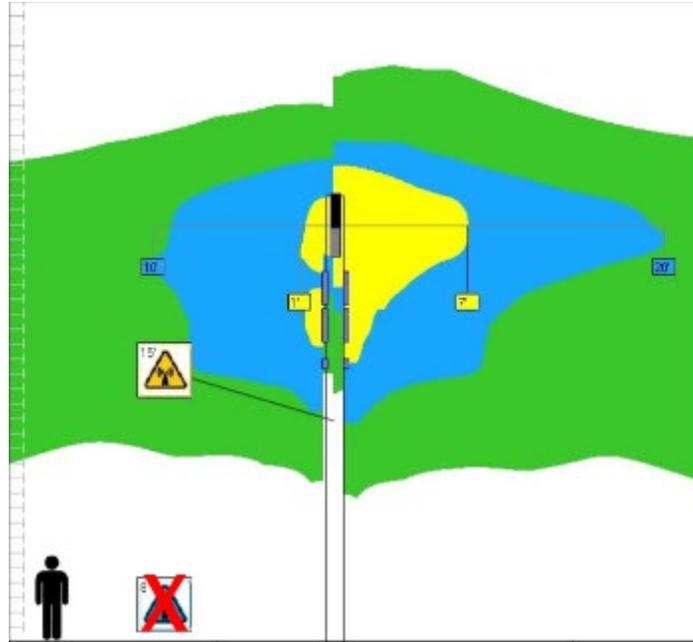


Figure 4: Illustration of where an FCC-required sign must be located on a small cell node pole

IEEE Std C95.2-2018

- To alert and inform the viewer in sufficient time to take appropriate evasive actions to avoid the potential harm from the hazard.



Figure 5: Illustration of maintaining minimum approach distance and utilizing qualified electrical workers when necessary

OSHA 1910.145(f)(4)(ii)

- “The signal word shall be readable at a minimum distance of five feet (1.52 m) or such greater distance as warranted by the hazard”

Per FCC 19-126A, all signage must contain the following:

- RF energy advisory symbol
- A signal word (e.g. “NOTICE,” “CAUTION,” or “WARNING”)
- Messaging words which provide:
 - A description of the RF source
 - Behavior necessary to avoid over-exposure
 - Up to date contact information

	GP Limit Exceeded	Occ Limit Exceeded	10x Occ Limit Exceeded	Type of Sign	Sign Placement	Is keepback distance required on sign?
Category 1				INFORMATION	Optional	NO
Category 2	✓			NOTICE	Exposure boundary	NO
					On antenna	YES
Category 3	✓	✓		CAUTION	Exposure boundary	NO
					On antenna	YES
Category 4	✓	✓	✓	WARNING	Exposure boundary	NO
					On antenna	YES

Figure 6: Exposure categories and signage requirements

Construction

Typically, small cell nodes are installed on three types of infrastructure in public rights of way: existing utility poles, streetlights or on a new standalone dedicated small cell pole. A typical project can include multiple rounds of coordination within several agencies such as the utility pole owner, electric and fiber utility providers, DOT, AHJ, and the carrier RF design team.

Each type of small cell application has its own construction considerations as well as commonalities. Every small cell application needs electric power, broadband backhaul and vertical space. These three necessities can create project scope creep and costs overruns. In some circumstances, it may be a difficult task to obtain 120vac service to a utility pole owned by the local electric power provider.

Many electric utilities require that the service be metered and some AHJ require the electric service to be underground. Getting electric power to the site can be challenging and may require special variances from the local electric provider for unmetered service or special consideration on the installed meter height. Additionally, the utility pole owner may require a pole-mounted service disconnect switch be installed so that the small cell can be powered down by a utility worker for routine work or during an emergency.

All the electric equipment and the carrier equipment must be mounted on the pole, be acceptable to the pole owner and meet any aesthetic requirements imposed by the AHJ. Additionally, the equipment on a utility pole must meet the National Electric Safety Code (NESC) and the NFPA70e National Electric Code (NEC) requirements, maintain a clear utility worker climbing path, and not create a hazard to pedestrians and the public.

Most electric utilities require a standard 200 amp meter pan socket which may require an electrical permit and inspection prior to the electric utility setting the electrical meter. The electric meter must be installed on the pole per the utility’s standard specifications and not be an obstruction for pedestrian or vehicular traffic. Again, each electric utility’s service requirements are different and the designer and the general contractor need to fully understand the utility requirements and the National Electric Code (NEC) for service and closely follow that process. It is much easier to follow the existing electric utility process and standards, than try to get the electric utility to change to meet your requirements.

Using overhead electric service and the existing fiber cable path are usually the quickest and most cost-effective solution for small cell service when available from the provider. Underground solutions can result in extensive trenching and costly excavation methods, especially in congested urban areas. In these neighborhoods the restoration costs can sometimes be as expensive as the actual service installation. The local AHJ will often dictate the installation method to mitigate traffic or conform to the aesthetics of the area.

Small cell installation on utility poles can be in the telecommunication space or in the electric power space. The telecommunication space is the area designated on utility poles for communications and is located below the electric power. Typically, this space is in the range of 17 feet to 27 feet on the utility pole. The height available on the pole can sometimes limit the network's RF design and may require the carrier to locate pole top above the power space.

Small cell installations within the telecommunications space can be performed by properly trained telecommunication workers for the RF equipment, antennas and fiber and trained electricians for the low voltage 120Vac electrical service work. These workers need to be trained in telecommunications safe practices such as OSHA 29 CFR 1910.268, NEC and the NESC. A qualified electric utility worker or qualified high voltage electrical contractor must install antenna equipment that must be located in or above the power space per OSHA 29 CFR 1910.269. This is usually a more expensive option requiring longer lead times to coordinate all the electric utility work.

Every small cell node requires broadband backhaul for data. Typically, this requires a fiber optic cable solution from a telecommunications provider. The fiber backhaul may require extensive construction efforts to get to the small cell and sometimes the underground fiber and underground electric do not come from the same area. This may result in multiple excavation areas. Many of the service providers use contractors to directionally drill inner duct for the new fiber and install small, new handhole splice boxes.

To reiterate, underground infrastructure will require permitting from the AHJ, and DOT, if applicable. Installing the new underground fiber will require coordination with the other underground utilities and following the state's 811 excavation laws. Often these installations take place in congested urban areas and rely solely on the small cell node owner to mark out the underground facilities. Following the 811 Call Before Dig laws is not enough. Ground penetrating radar (GPR) and third party locate companies can assist in determining the best path to avoid other existing utilities. By taking a proactive approach, the general contractor may be able to avoid unnecessary utility damage and interruption to the customer and the public. Coordination can lead to better relationships with the AHJ and the local utility companies.

Pole replacements can negatively impact project budgets. Streetlights are a common small cell solution, but sometimes the existing streetlight pole must be replaced with a new streetlight pole. These can be specialized decorative poles required by the AHJ. Many times, not only does the pole need to be upgraded, but the foundation and even the electric supply need to be replaced

to accommodate the small cell equipment and antennas. These decorative poles can have long order lead times and be fully custom built. The general contractor must take care not to damage them during transport or installation as the AHJ or carrier may not accept them during the final walkdown of the site. Repairing decorative painted poles can be expensive and may even require total replacement.

Concrete and special laminate wood poles can be used as small cell node poles and require special consideration during installation. Always consult the engineer of record before attaching to or modifying these pole types.

The equipment cabinet or shroud is where the carrier radios, other electronics and fiber demarcation equipment is housed. Often, these poles are decorative and project-specific. Take special care during transport and installation so as not to damage the shroud or the doors. Follow the manufacturer instructions or the construction drawings while closely paying attention to the door swing to maintain the utility worker's climbing path on the pole, if required by the pole owner.

Always consult the manufacturer for the proper shroud to pole attachment method and location. Many of these shrouds are equipment and carrier-specific. Thus, if the carrier equipment changes, the shroud may not accommodate the new equipment without modifications. Again, the general contractor should consult the EOR or the shroud manufacturer for installations solutions.

The antenna mounting and mounting location is critical. The antenna mount must be attached correctly and at the required height as designed to ensure the network operates designed. Along with the antenna, the construction drawings should outline where the RF signage should be placed on the pole. It is critical to follow all FCC and OSHA signage requirements.

Maintenance

Small cell maintenance is often overlooked and there are many instances requiring maintenance: the node pole is hit by a car and the small cell equipment is damaged; storms damage small cell equipment; carrier requirements, standards and technology change. There are three types of maintenance: immediate emergency maintenance, routine maintenance and modification maintenance.

Immediate Emergency Maintenance, as the name suggests, includes coverage restoration due to an emergency event like a storm, pole damage or an equipment failure. Restoring coverage is of utmost importance for the wireless carriers to ensure the safety and wellbeing of their end users. Be sure to consider maintenance worker safety during evening or after hours repairs. This may include additional traffic control measures, worksite lighting, coordinating with other utilities and government agencies. Working during emergency conditions requires heightened safety awareness and focus on the possible hazards. Usually, this type of work involves making the small cell site safe to the public with limited equipment replacement. Temporary solutions may be

necessary to regain service to the carrier equipment. Additional work may be required after the initial restoration to fully restore small cell site service.

Routine Maintenance includes periodic inspection of the site. Older small cell equipment may have ventilation issues and require cooling fans. The remote radio heads (RRHs) can cause excessive heating in the shroud; hence fans may be needed to cool the equipment. However, these fans may require routine maintenance and sound absorbers to prevent excessive noise and disturbance to the surrounding neighborhood. Ventilated sites pose other maintenance concerns like bird droppings, bees, rodents, dust and other debris that can accumulate inside the shroud. The routine maintenance program should include vacuuming or debris removal within the shroud to optimize RRH and other equipment cooling. Additionally, the structure should be inspected periodically for condition assessment. For instance, aluminum should be checked for dents/bends, steel should be examined for corrosion, concrete should be reviewed for cracks and wood poles should be assessed for signs of ground rot or other structural defects. All structures and foundations should be confirmed they are plumb. These inspections should be documented as part of a regular small cell node maintenance process.

Modification Maintenance includes activities triggered due to equipment upgrades or changes. The new equipment may not be the same size as the originally installed equipment. The maintenance technician will need to address possible size concerns with the existing shroud, infrastructure and real estate. Decorative shrouds and specific design poles pose several maintenance issues. For example, shrouds may need to be replaced or modified if it does not accommodate the new equipment. Replacing the original equipment may not be possible due to the manufacturer discontinuing the original equipment. The AHJ may specify replacing all shrouds in the area so that they are aesthetically the same.

Maintenance activities for a streetlight pole may require a traffic control plan. Please see the TIF PAN on Designing, Implementing, and Maintaining Traffic Control Plans for more information.

Conclusion

A successfully installed and operational small cell network requires proper design, location, permitting, planning, construction and maintenance. It is critical to have effective communication and coordination between all stakeholders to ensure successful small cell network implementation. All these factors ensure that the network provides the intended effective coverage in the communities it serves and maintains public safety.

AUTHORSHIP CONTRIBUTIONS:

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