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Powering A Utility Scale Broadband Network Through Private LTE

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SUMMARY

U.S. electric utilities are in a near-constant cycle of spending time and budget overlaying and "patching" new technologies onto an electric grid created more than a century ago. Government mandates and evolving technologies make this a more urgent requirement. They are the primary reasons utilities are trying to move away from proprietary, legacy networks to create underlying communications networks that provide greater visibility, control, and automation. For utilities, doing nothing to create a smarter grid with an underlying next-generation critical communications network is no longer optional.

Mandates include those for decarbonization, two-way flow of electricity to support distributed energy resources (DERs), Zero-Trust Architecture, which requires visibility into all aspects of the network, and others. Utilities also face rapid changes from the growth in the electric vehicle market and the need to support them, increasing storm frequency and severity, rising customer preference for clean energy, and – importantly – the expansion of the attack surface these create for potential cyber-attacks.

Why Change Grid Communications?

The vast proliferation of devices on a utility network also creates cyber vulnerabilities. At the same time, they generate massive amounts of data that must be collected, analyzed, and acted upon for better operations, customer support, and more. It is infeasible for utilities to continue to attempt to retrofit their current technology, and they cannot rely on legacy private networks or commercial cellular services to provide the capacity, low latency, and security they need.

Meeting these challenges requires smarter transmission and distribution infrastructure – modernized grids that provide the greater visibility, control, and automation they need. The communications network is often overlooked in grid modernization discussions, which is an essential element of the data-centric modern utility because it is necessary for carrying the data among devices and applications and securing data while in transit.

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However, this is changing as many utilities have begun adopting private wireless broadband networks using LTE technology to move away from legacy communications networks that are usually proprietary, single-function, low-capacity, and nearing end-of-life. Private LTE (PLTE) networks enable them to “digitize” and modernize their grids to support current demands, offer the ability to support future technology, and allow them to scale as demands grow. PLTE networks carry critical systems information to, from, and between devices and applications throughout the grid. This connectivity allows utilities to collect, analyze, and act upon real-time data for increased operational visibility, control, and automation.

The Importance of Spectrum to Grid Modernization

The most critical task in planning a PLTE network is identifying the spectrum upon which the network will operate. Spectrum is a collection of radio frequencies that can carry wireless signals and is foundational to the deployment effort, but there are few appropriate options available to utilities. In addition, spectrum bands differ in physical attributes (low-band spectrum can enable coverage with fewer, larger cells, thus reducing deployment and operations costs) and regulatory treatment (unlicensed, shared licensed, dedicated licensed), so the choice is important. And because it is so scarce, utilities typically must plan the network around the available spectrum rather than selecting the best suited from a wide range of bands. That scarcity also can affect the ecosystem of goods and services available in the marketplace—limited availability in a band makes for too small a market to inspire and support the vibrant, innovative, option-rich ecosystem the utility industry requires. When possible, in light of this mixture of factors, a utility would do well to consider adopting a multi-band strategy.

KEYWORDS

Broadband Communications, Decarbonization, Decentralization, Digitization, Distributed Energy Resources, Grid Modernization, Spectrum, Private LTE, Zero-Trust Architecture, Cybersecurity, Cyber Security

What is the Cost of Doing Nothing?

Electric utilities across the country operate private wireless data networks to support grid operations.[1] These networks are proprietary, narrowband (low capacity), frequently use unlicensed spectrum, and typically carry data for a single application. They also are frequently at end-of-life and subject to reduced support or even vendor obsolescence. Are these existing networks sufficient to help meet the substantial changes facing the industry? Do utilities really need to do anything to their communications systems?

Decarbonization mandates require vastly increased integration of intermittent, distributed energy resources (DERs) into the grid. To safely and efficiently manage this integration, operators need greatly improved grid visibility, control, and automation capabilities. The sensors, smart devices, and applications that will provide operators these enhanced capabilities depend upon connectivity via a data network. Such sensors and devices—built for a variety of proprietary, legacy communications systems—are already proliferating well beyond those deployed even a few years ago: Navigant Research estimated in 2018 that a one million-meter IOU will see an eight-fold increase in connected endpoints by 2028.[2] Greater sophistication and number of applications and endpoints means vastly more data traversing the network, and increased automation requires that the data be communicated in real-time with extremely low latency.

Legacy And Commercial Networks Cannot Meet Utility Requirements.

Utilities' legacy narrowband networks cannot provide such low latency and capacity; they are not designed for it. Rather, they are generally intended to support only the application for which they were initially deployed. Single-purpose legacy networks cannot accommodate additional, data-intensive applications, nor can they scale or help future-proof the utility.[3]

Wireless broadband service available from commercial carriers is also a poor fit for modern utility mission-critical communications, but for reasons unrelated to the technology. Commercial networks may provide service with adequate low latency and capacity, but they cannot provide the level of control utilities require to ensure network availability and security. Commercial networks are designed to meet the needs of the consumer mass market, not the more rigorous requirements of the nation's most critical infrastructure industry.[4] For example, commercial networks typically do not provide coverage in areas with lower population numbers,[5] despite the presence of utility infrastructure that requires connectivity. Similarly, commercial carriers deploy only those security measures that do not overly inconvenience their mass market subscribers; utilities require the ability to implement more rigorous—and frequently more burdensome—protections.[6] And finally, commercial carrier services sunset: 2G gave way to 3G, and 3G is the latest to be discontinued.[7] When these network evolutions occur, they are on the carrier's schedule, forcing customers to replace the old devices at substantial cost.

Maintaining Legacy Networks Is Unsustainable.

Even without a grid modernization imperative, the cost of maintaining multiple legacy networks will force utilities to address their communications systems. In its 2018 paper, Navigant/Guidehouse stated, "At the end of the day, the economics of maintaining dozens of limited purpose networks – and the staff to support them – will become impossible to justify. Reliance upon a vast array of incompatible networks within and among the more than 3,000 power utilities operating across the U.S. is inefficient and will ultimately become unmanageable.[8]

PRIVATE LTE OFFERS A SOLUTION

LTE is an open standard with a broad ecosystem of sensors and devices, facilitating the integration of those devices into the network and the integration of the data they produce into the utility's overall grid monitoring and control approach. Private LTE (PLTE) would provide network control, improved cybersecurity, a vibrant standards-based ecosystem of goods and services, and the ability to realize substantial economies of scale and scope.

Cybersecurity for critical infrastructure is a high-priority issue at all government levels; migrating from legacy communications networks to a state-of-the-art private LTE network hardened to utility requirements could improve a utility's security posture. LTE offers state-of-the-art security capabilities—some of which are optional within the LTE standard and not necessarily deployed by commercial carriers. However, because the utility owns, operates, and controls its own private broadband network, it can choose to adopt cyber protections as stringent as it desires to meet its critical infrastructure function.

A PLTE network will enable the utility to deploy new applications its legacy networks could not support. San Diego Gas & Electric, for example, has announced its intent to deploy a new application even before completing the construction of its PLTE network. The utility will deploy Falling Conductor Protection, which requires low-latency broadband connectivity to de-energize a falling line before it hits the ground and can cause a wildfire.[9] This technology is capable because of its new PLTE network and could save property and lives in the future.

More generally, a private LTE network will allow a utility to capture, aggregate, analyze and act upon data created by sensors installed throughout the grid using the open communications standard that is LTE. Leveraging data analytics, artificial intelligence, and machine learning to model and exercise the transmission and distribution systems, it will be able to forecast failures, prevent outages, and minimize truck rolls. It will have true visibility into and control over the grid—all because the private, high-performance LTE network carries that data to its applications in a secure, reliable, and virtually real-time fashion.

Coordinated, broad adoption of PLTE networks also will unleash a new category of benefits made possible by enabling utility communications networks to interoperate. One utility network will be able to connect to another that uses the same technology and band, opening an array of possibilities ranging from the current and known to the futuristic and visionary. In the short term, repair crews from a neighboring utility providing mutual aid after a significant storm could use their own mobile devices to access the host utility's critical operational systems, thus reducing recovery time.

Utilities could gain efficiencies by adopting a network architecture that includes shared use of specific network elements located in the cloud. In the longer term, a utility may be able to securely communicate with out-of-territory electric vehicles as they traverse its service area, helping predict and manage charging loads and vehicle-to-grid power supply. Also, by sharing some of the infrastructure deployed in building a new PLTE network (such as fiber backhaul and radio towers), utilities can help internet service providers reduce the cost of providing consumer broadband internet access to rural areas that otherwise would be too expensive to serve. This approach to helping bridge the digital divide can contribute to utilities' efforts to promote diversity and equity in their operations.[10]

A utility will find value in adopting a band that is also available and adopted by utilities in neighboring and even distant geographies. Because PLTE devices and radio access network (RAN) equipment are designed and built for use with specific spectrum bands, a utility wishing to enjoy wide choice and vibrant innovation in the marketplace should be careful to select spectrum that other utilities are also choosing—thus creating a more prolific market to entice vendors and innovators. The resulting ecosystem creates a virtuous cycle: more utilities adopting private LTE bring more vendors to the marketplace, and the choice and innovation provided by a more robust marketplace bring more utilities to private LTE.

Several utilities already have announced their intent to proceed with private LTE network investments. Ameren, San Diego Gas & Electric, and Evergy have taken steps toward deployment. Avangrid, Dominion Energy, Exelon, New York Power Authority, [11] and Xcel[12] also are evaluating private LTE for modern grid applications.

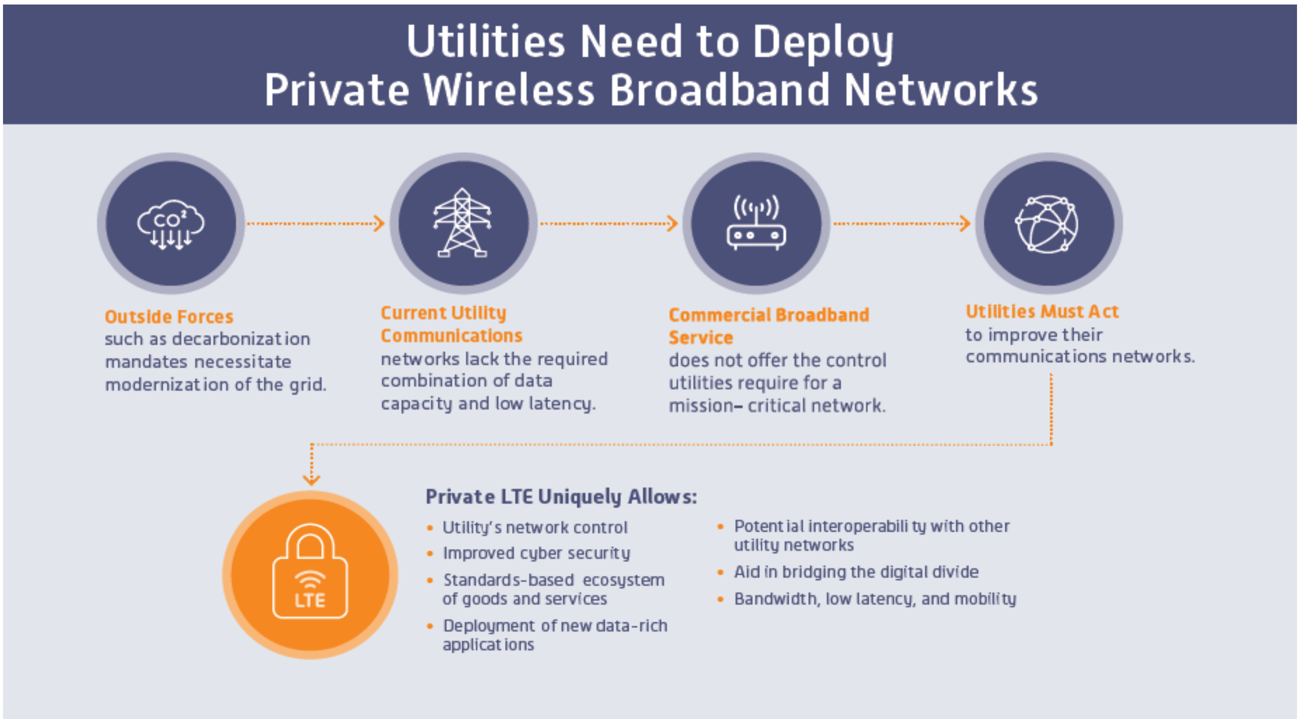

Figure 1. Drivers of Utility Private Broadband

SPECTRUM

Spectrum is a collection of radio frequencies that are the indispensable foundation upon which many other decisions about the network will depend. A PLTE network cannot work without spectrum, and the specific spectrum the utility selects will impact the design and performance of the network, as well as the business model for sustaining it.

When a utility seeks spectrum for its PLTE network, it is trying to identify a contiguous block of enough radio frequencies to support a private LTE deployment of sufficient bandwidth to meet the utility's data communications needs. Spectrum is identified by the frequency of its radio waves as measured in hertz (Hz); the amount of spectrum in a block is measured by subtracting the frequency at the bottom of the block from the frequency at the top of the block, also measured in hertz. Thus, a 500-MHz block of spectrum might extend from the 2.3 gigahertz (GHz) frequency to the 2.8 GHz frequency. For broadband, the LTE standard currently requires at least 1.4 megahertz (MHz) of spectrum in two separate blocks (one for transmitting and one for receiving); in the 900 MHz band, for example, 6 MHz of spectrum are available in two blocks of 3 MHz each at 897.5-900.5 MHz and 936.5-939.5 MHz.

The critical point to understand here is that spectrum bands differ—as a matter of both physics and regulation. A utility must choose spectrum carefully because it will serve as the foundation supporting the new PLTE network.

How Spectrum Bands Differ.

Spectrum in various bands differs in both physical characteristics and regulatory treatment. Because of the nature of radio waves, signals in low-band spectrum (below 1 GHz) can travel farther than signals in higher-band spectrum and can better penetrate obstacles (such as buildings and foliage). As a result of these "propagation characteristics," networks that use low-band spectrum require fewer cell sites (towers with antennae) than do networks using higher-band spectrum, thus significantly reducing the system's total cost of ownership.

Another physical feature of spectrum is the amount of data transmission it can support. As a rule, a network using a larger block of spectrum has a greater communications capacity than a network using a smaller block of spectrum. Thus, a utility's spectrum choice should consider the amount of spectrum it needs to meet its use cases.

These physical differences lead some utilities to adopt a multi-band network plan. For example, as noted, San Diego Gas & Electric has announced its intent to build a private LTE network using 900 MHz low-band spectrum (two blocks of 3 MHz each) as the foundation covering its entire service territory while also using 3.5 GHz ("CBRS") mid-band spectrum (a 10 MHz block) in specific areas where it has particular requirements for high capacity.

Regulatory differences among bands also will play into the utility's spectrum decision. Most utilities will insist on licensed spectrum, which generally provides an exclusive right to use the spectrum with legal recourse through the Federal Communications Commission (FCC) if an unauthorized system encroaches on the utility's use. Unlicensed spectrum is open to the public, and systems that use unlicensed spectrum (such as that consumer Wi-Fi, Bluetooth, and cordless telephone systems) are widely available in the consumer market. To facilitate and coordinate spectrum usage in a way that controls radio interference among systems, the FCC also sets technical limits on the systems that use specific bands, including restrictions on the power of signals transmitted over the band. These rules can affect both the cost and performance of the utility network.

With An Eye on The Future, Consider the Right Mix of Spectrum Bands.

Finally, there's the question of additional spectrum. A utility should plan for its PLTE network to increase coverage and capability as grid applications and network use cases proliferate over time. As noted above, different bands are better suited to varying purposes; a utility should consider future plans in selecting the spectrum to use for its initial network deployment. One approach could be to choose an initial spectrum band to provide broad coverage and serve as a foundation, then deploy a different band better suited to provide capacity in specific areas of heavy traffic and greater device density. The SDG&E network mentioned above offers an example, though in reverse: it won CBRS spectrum (capacity) at auction and subsequently obtained use of 900 MHz spectrum (foundational coverage). As planned, the two bands complement each other.

What Are Key Elements And Major Considerations In Designing A Private LTE Network?

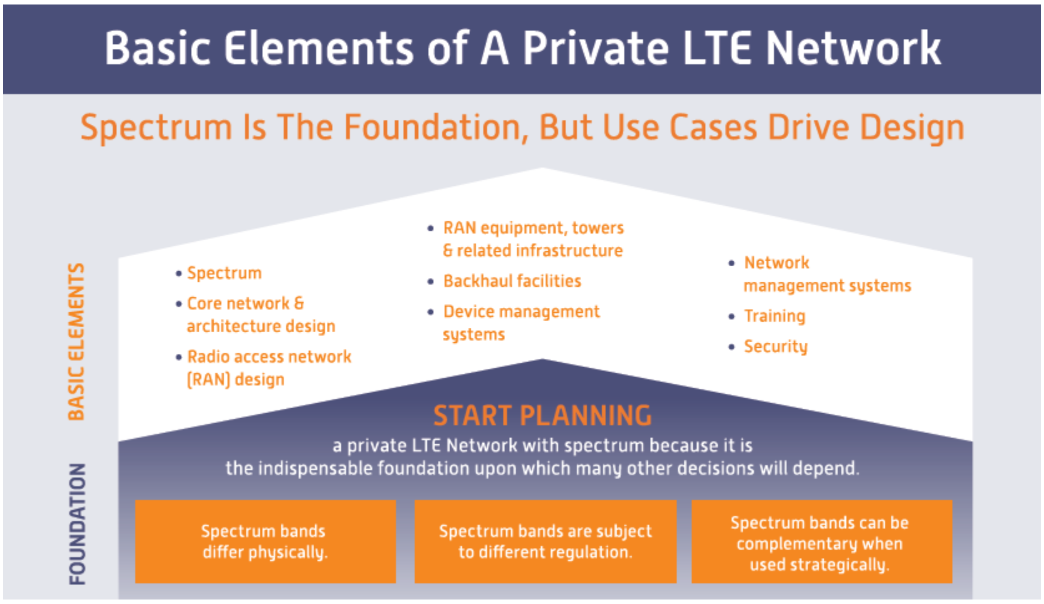

Figure 2. Basic Elements of a Private LTE Network

Though each utility will have varying goals, use cases, and constraints that will determine the specifics of the private LTE network it deploys, there are certain basic elements virtually all of these networks will have in common and which must be included in planning. At a very high level, those elements include spectrum, core network and architecture design, RAN design, RAN equipment, towers, and related infrastructure, backhaul facilities, device management systems, network management systems, training, and security.

Designing a private LTE network means specifying the infrastructure (equipment and devices), the specific location in which the infrastructure will be deployed, and the technical configuration of the deployed infrastructure. The network design considers not just the placement of cell towers but also the locations and configurations of fiber connections, microwave links, sensors and smart devices, and core network elements.

The most important considerations in your private LTE network design will be your use cases—the specific tasks you want your network to accomplish and the applications you want the network to support. What network capabilities do those use cases require? Low latency? Wide coverage? Capacity? Prioritization of traffic? Your use cases will determine your network design. Here are a few of the most common capabilities that drive design decisions.

ENSURE COVERAGE WHERE YOU'LL NEED IT.

Many utilities will have specific areas where many devices will need to access the network. Such high-density locations might include cities and generation facilities, for example, where there might be a greater need for large numbers of connected sensors. Much of the utility's service territory, however, may be sparsely populated—with grid facilities that are more distributed and a lower density of connected devices. Wherever a device is located, if it will need connectivity, the network must be designed to provide coverage for it—whether it exists today or is planned to exist in the future.

Coverage is not a binary feature, however. As anybody with a cell phone knows, coverage at a certain location may be excellent, nonexistent, or any degree in between. Some applications may not function properly if an associated device has less than optimal connectivity; others may be more forgiving. Because coverage comes with a cost—the investment in building or leasing a cell tower, for example, and the expense of maintenance—network designers working within a budget will need to make trade-offs, strategically placing infrastructure where it can best meet the coverage needs of the utility's primary use cases.

Rather than just a single use case, a utility will likely build its PLTE network to enable many use cases with requirements ranging from "basic" to "complex." Suppose certain use cases will apply only in certain parts of the service territory. In that case, a network of geographically varying capabilities might be possible. Still, as a general rule, the use case with the most complex requirements will drive the network design throughout. A straightforward example: a network sufficient to support a residential meter application might provide fair coverage in a residential area, and none out on the interstate highway, but a network built to support a mission-critical mobile application will require strong coverage on both the highway and in the residential area. In short, a utility will typically design the network for its most challenging use case, which will be more than sufficient for the less demanding use cases.

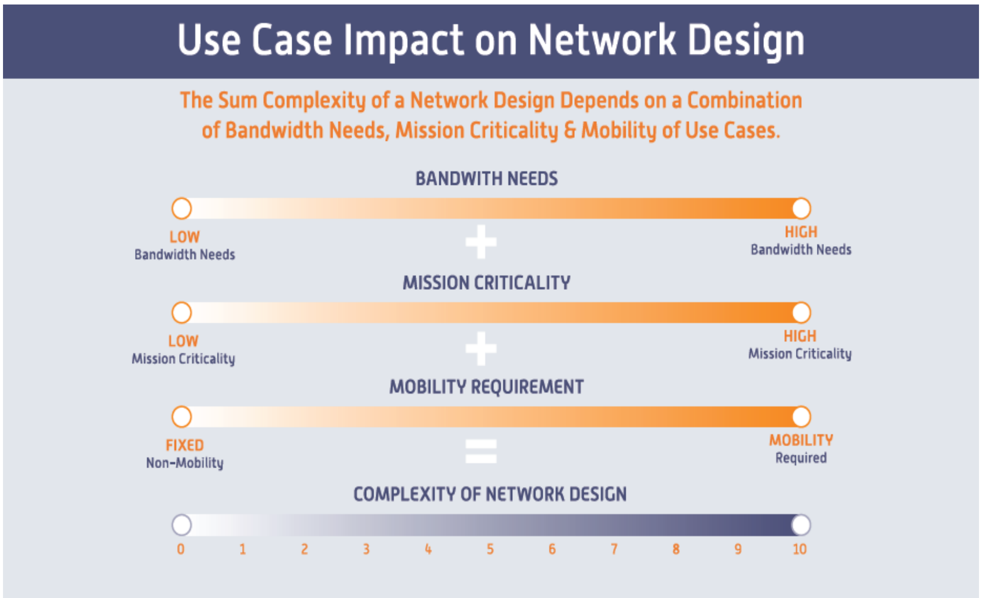

Figure 3. Use Case Impact on Network Design

MANAGING DEVICES

What devices should we use, where do we find them, and how do we manage them?

Ultimately, the purpose of your PLTE network is to enable wireless communications to and from devices in the field, whether they be sensors monitoring voltage, circuit status, or weather conditions that only provide data, or active devices (like circuit reclosers) that take a physical action on the grid based upon received data. The devices must include a module designed to transmit and receive LTE communications over your selected spectrum to connect over the network. That module will include a microchip containing information about the device's identity so that the network can determine how to treat its requests to connect and its payload traffic—for example, the priority level to assign to data from this device.

You may be connecting thousands or tens of thousands of devices to your new private LTE network, so keeping track of them and managing them will be necessary. The device management platform is software and firmware that handles tasks like fulfilling, provisioning, activating, and patching devices, all over the air via the PLTE network. Many such platforms are available in the marketplace and are typically acquired separately from the LTE RAN and core.

Using Devices—Even Before Your Network Is Complete.

Building out the full extent of planned coverage for a private LTE network will take time. Nonetheless, a utility may have a pressing need to deploy and activate a new application in a particular area. This requirement cannot wait until private LTE coverage is activated there. In the meantime, operating an application over a commercial cellular network may be an acceptable short-term solution.

Devices identify themselves and assert permission to connect to a network through a code (called an international mobile subscriber identity or IMSI number) contained on a subscriber identity module (SIM) card. A device “homed” on your private LTE network will have a SIM card with the IMSI number corresponding to your network. With the carrier’s permission, your devices can connect to the carrier’s network if either (a) the devices’ SIMs also include the carrier network’s IMSI or (b) the carrier allows devices with your network IMSI to “roam” onto the carrier network.

Dispatching a crew to a remote location for the initial deployment of a device (using a carrier network) can be costly. To avoid the need for a second truck roll to switch that device to the utility’s network when private LTE coverage to the area is activated, a utility may wish to employ one of the above options. Because utilities frequently do not possess in-house experience or expertise in the carrier negotiations required to set up these arrangements, they may wish to procure third-party solutions that address this issue that arises as they transition to new private LTE networks.

Integration Is Key to Successfully Supporting Devices.

Embedding LTE modules into devices the network will support requires effort and investment from application vendors and the cost of obtaining federal regulatory approval to sell the device for use in a particular spectrum band. In some cases, the module may be external but connected to the device, but most often—and most efficiently and securely—the module will be embedded within the device. Because the device will be specific to the application, this integration will be accomplished by the device/application vendor.

For example, Falling Conductor Protection, a wildfire mitigation application from Schweitzer Engineering Laboratories, senses a falling line and de-energizes it before it reaches the ground. The application requires a remote protective relay to collect phasor data for each line segment and send it to the centrally located controller running the falling conductor detection algorithm, which then returns a signal to a remote switch to de-energize the line. Those signals are wireless communications enabled by integrated 900 MHz LTE modules embedded within the protective relay, the controller, and the switch. Since the entire process must be completed before the line hits the ground, the communication must be extremely low- latency, so efficient integration is critical.

How do we make sure our network is cyber-secure—and physically secure?

Cyber-attacks are evolving and becoming increasingly sophisticated. For legacy networks, this is a significant problem—as vendors reduce and discontinue support for older communications systems, keeping them patched and secure from new exploits becomes a losing battle.

An initial, major step a utility can take to secure its wireless communications network is simply to migrate its applications from legacy networks to LTE. LTE is the first cellular standard developed for cybersecurity at the outset, not added on at the end of the process. In addition, the 3GPP international partnership of standards bodies constantly reviews and revises LTE to address new and emerging cyber threats.

By adopting private LTE—ensuring unfettered control over the network—a utility can go several steps further. Importantly, LTE includes a range of cybersecurity features, but only some of them are required for compliance with the standard. Other features can provide stronger cyber protection, but implementation is left to the discretion of the network operator. Because these optional features can be burdensome on users and/or operators, deciding whether to implement them requires some balancing of the burden against the security benefit. Thus, while a commercial carrier serving the mass market may not be willing to impose such a burden on its consumer subscribers, an electric utility will have a different calculus. Private LTE allows a utility to impose even the strongest and most burdensome protections without considering the preferences of any other entity.

Another benefit of private LTE in the area of cybersecurity is that, as in other areas, a vibrant LTE ecosystem for equipment and applications is driving innovation and cybersecurity options for utilities that adopt LTE.

A utility adopting a private network can also implement one particularly valuable protection that has nothing to do with LTE. As a quick review of the headlines will reveal, many attacks on critical infrastructure systems are launched remotely over the internet. A longstanding best practice in the utility industry is to isolate from the internet networks used for mission-critical grid communications. Known as "air-gapping," this measure can be implemented only in a private-network scenario.

In addition to cybersecurity, a utility must also consider the physical security of its network. Even with an air-gapped network, cell sites require fencing, surveillance, and other measures to protect against physical attacks. Utilities have long been the nation's model for the physical security of critical assets; because the PLTE network will be such a critical asset, a utility will need to apply its well-developed physical security standards and practices to elements of the network.

SERVING OTHER UTILITIES

Electric utilities have long been interested in the idea of using their private communications networks to support other non-electric utilities within their service areas. In the past, the technology focus was on mesh networks; today, with private LTE, there is finally a standards-based, scalable way to make this vision a reality. So, for example, consider a water utility serving an area overlapping with the electric utility's service territory. The electric utility might allow the water utility to use the private LTE network to support its own operations, whether mission-critical or perhaps less-critical functions like meter reading. The electric utility could even use its private LTE network to provide billing services for the water utility, not just connectivity. Such external uses—which could create new revenue streams—could affect network requirements like capacity and coverage, so they should be considered in network design.

BRIDGING THE DIGITAL DIVIDE

As referenced above, utilities have a potentially attractive opportunity to leverage communications infrastructure to help address the digital divide, an area of considerable interest among utilities and policymakers alike. Construction of a PLTE network typically will include deploying fiber optic cable, tower structures, and other infrastructure. The utility could augment such "middle mile" infrastructure and then allow a third party to lease access to it, thus reducing the up-front cost of deploying consumer broadband internet service to rural areas that commercial carriers do not adequately serve. In designing its network and planning the build, the utility should account for any augmentation or configuration of network elements (for example, deployment of extra fiber or placement of antennae on a tower—even siting of the tower itself).

While this is a potentially attractive approach to addressing a major national challenge, implementing it will first require the development of a business case specific to the leveraging of utility "middle mile" infrastructure, identification of partners (including those entities that will lease the assets, such as internet service providers), and perhaps statutory or regulatory policy changes to allow the utility to lease its infrastructure for this purpose—and even to specify the accounting treatment of the utility's investment in such infrastructure.[13] Utilities should consult their peers that have pursued this approach to benefit from their experiences and expedite their efforts, maximize the value of their investment in broadband, and best address the needs of their customers. Though there would likely be a deployment cost consideration in enabling "middle mile" leasing—the infrastructure must be constructed before it can be leased out—the lease fees may be used to help support ongoing network operations. Any of these considerations may affect network design.

PARTICIPATION IN A NETWORK OF PRIVATE LTE NETWORKS

Finally, a utility might enjoy additional capabilities and efficiencies if neighboring utilities also deploy private LTE networks. Not only will such utilities be able to form a coalition for sharing information and technical expertise, but they also could form a coordinated procurement mechanism that takes advantage of their combined purchasing power, scale, and scope, leading to measurable savings. Further, collaboration among utilities to deploy a common technology in a single spectrum band would enable roaming among neighboring utility private LTE networks: the ability of one utility's users to connect, with appropriate authorization, to another utility's network (Interestingly, the service territories of Ameren and Evergy--both of which have moved to deploy 900 MHz private LTE networks—border each other, perhaps creating an opportunity for an early 'network of networks' implementation.) Whether it be the macro issues of resiliency, cybersecurity, and decarbonization or the sharing of infrastructure, talent, knowledge, and technology, a "network" of individual networks can drive enhanced innovation and value to each participating utility.

A range of initiatives would help foster growth of such a network of networks, including:

- A **4G/5G cloud core** to extend the capabilities of utilities' own private broadband networks by bringing solutions such as private roaming to enable mutual aid, private to public roaming for increased resiliency and failover, and spectrum coordination.
- An **enhanced multiband communications module** to enable the vendor community to provide lower-cost and higher functionality products.
- Integrated **cybersecurity offerings** to further enhance the existing private broadband security capabilities.
- A **connected lab environment**, supported by utilities and vendors, to provide collective utility-grade device testing and accelerate the integration of utility solutions.
- A **turnkey solution** for connectivity management, delivering utilities the device control and network resiliency required for grid modernization.

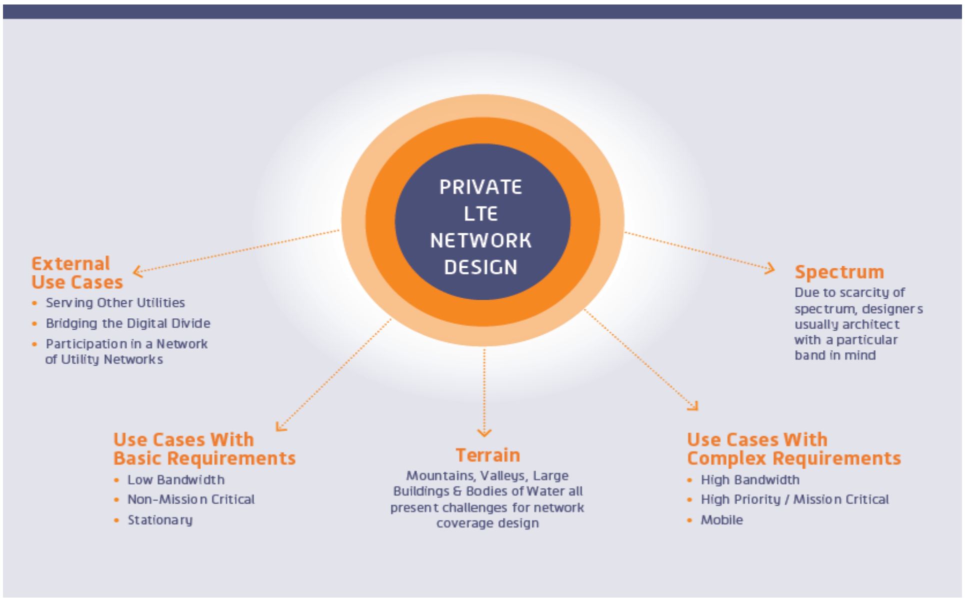

Figure 4. Drivers of Network Design

CONCLUSION

Utilities must address their grid-management communications capabilities—reaching that conclusion is relatively simple. But deciding on the solution and implementing it requires many more complex, nuanced decisions. For utilities with decades of experience operating private land mobile radio systems, wireless broadband technologies like LTE come with a learning curve.

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