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Network of Networks: The Power of Collectively Adopting Private LTE to Modernize the U.S. Electric Grid

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SUMMARY

Electric utilities have a rare and valuable opportunity to address pressing industry-wide challenges with a single solution that will allow them to meet their own specific needs even as the shared approach creates additional value for the benefit of the industry, the own enterprises, and their customers.

U.S. electric utilities—every one of them—currently faces a confluence of trends largely arising out of global climate change. Decarbonization mandates are causing a rise in decentralized power generation (including from resources not directly controlled by the utility), which in turn is driving a need to increase power grid monitoring and control capabilities through increased digitization and reliance upon information and computer technologies (ICT). Combined with more frequent and severe natural disasters and escalating cyber risks, those "three Ds" create a pressing need among utilities to upgrade the communications networks they rely upon to manage the grid and ensure the continued safe, efficient, reliable, and resilient delivery of electricity to their customers. The grid communications network challenge is industrywide.

The key technical requirements for communications networks are common across utilities. The modern grid will require standardized broadband networks that provide the capabilities necessary for the ever-increasing number of common utility use cases. Mobility, wide-area coverage, and low latency are the key capabilities utilities require from their communications networks.

In light of those requirements, private wireless networks in licensed low-band spectrum using LTE technology rise to the top among available options. LTE is the flagship among standardized, mature cellular technologies, and the spectrum is available nationwide. Further, the Department of Energy's National Renewable Energy Laboratory, in a "high impact" project, has validated its performance for critical utility use cases. No utility needs to go it alone in this critical decision.

Electric utilities have built a culture of industry-wide collaboration. They are already working together to share information and expertise about private LTE. Their collective buying power and influence are driving the market to reduce cost, increase innovation, and expand choice in a growing, vibrant ecosystem of products and services.

Beyond those effective and important cooperative efforts, communications networks for grid modernization offer an opportunity for the industry to take its collaboration to a higher level, to look to the future and set out on a visionary path that will create additional value by adopting 900 MHz

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private LTE throughout the industry. With that platform broadly deployed across the industry, a utility could allow users of other utility networks with appropriate authorization to connect to (roam onto) its own private network, enabling additional value created by operation of the "network effect."

With each new participant in a network, the network effect creates additional value for each existing participant. Thus, if utilities create a network of their private LTE networks by allowing inter-utility roaming, they will be able to generate value above what they realize from their own private use of their own individual networks. Examples of use cases enabled by the network of networks include, in the short-, medium-, and long-term, respectively: transformation of mutual aid to hasten power restoration after a storm; management of electric vehicles as mobile prosumer distributed energy resources; and the still-developing advances made possible by 5G.

The opportunity to pursue this vision is limited; utilities are already considering and deciding upon the private wireless broadband solutions they will deploy. Though many are leaning toward 900 MHz private LTE, and some have already announced that decision, each utility that opts for a different solution stands to reduce the overall value of the cooperative effort. Taking advantage of the wide range of active utility organizations, industry leaders should exploit this rare opportunity to help the utilities take a major step forward, together, and enable a stronger, more capable, standardized and coordinated power grid.

KEYWORDS

Broadband Communications, Decarbonization, Decentralization, Digitization, Distributed Energy Resources, Electric Vehicles, Mutual Aid, Network Effect, Private LTE

I. Introduction

Major global and national trends affect every electric utility in the U.S., and each one could address these trends alone, without external input and without consideration of the choices of others in the industry facing the same challenges. But U.S. utilities have opted for a better model; their inclination to collaborate, facilitated by industry organizations, is well-known and undeniably successful. From mutual aid networks supporting storm restoration to the Spare Transformer Equipment Program (STEP),[1] they do best when they work together to solve common problems.

The value of collaborating to identify solutions to industry-wide challenges is obvious—two (or fifty) heads are invariably better than one. When each individual utility must address essentially the same problem, sharing information and expertise is typically more efficient and effective than each utility hiring its own experts and performing its own research and testing. At the conclusion of the investigation, it makes sense that, where the need is universal and the core requirements widely shared, the solution that rises to the top will be the first choice for each individual utility.

But the value of collaboration does not end with the identification of the best solution. For many solutions, utilities can act collectively to maximize their buying power in the marketplace for that solution and leading vendors to invest in further improving the solution. And beyond procurement, utilities can create industry-wide interest groups to share expert resources and ongoing experience, benefiting each individual utility's stand-alone implementation of the solution.

The deepest collaboration occurs when utilities coordinate and integrate their implementations and operations, creating greater value. Not every challenge or solution lends itself to such collective action, but where the opportunity arises, the benefits can be remarkable.

Private wireless broadband networks represent an opportunity for such deep collaboration and value creation. The essential ingredients are all there: powerful trends largely driven by climate change are causing virtually every U.S. utility to modernize its grid by deploying "smart" applications, using information and computer technologies (ICT) to gain situational awareness and control grid operations. Those new applications as a rule require secure, reliable broadband communications networks. Because they also require a vast proliferation of connected end points, including remote ones, wired (fiber optic cable) connectivity will not make economic sense for every use case (particularly mobile use cases), so most utilities must deploy wireless technologies to meet the rest of their connectivity requirements.

Once they have identified the best wireless broadband network solution to meet the grid modernization challenge, utilities can collectively procure the elements of that solution, from spectrum (radio frequencies) and wireless base stations to core network technologies and end-user devices. They can take advantage of technologies that allow them to share elements of the core network, perhaps from cloud services providers. With aggregated buying power, they can further grow and direct the ecosystem of vendors and manufacturers, designers and consultants to improve the number, quality, and innovation of their offerings.

By coordinating their network implementations, utilities can create greater value. Each can control its own network in service of its own needs. If each utility builds its network to the same standard, implementing the same spectrum and the same wireless broadband technology, users of one utility's network could—with appropriate authorization and security—connect to another utility's network. The universe of utility private wireless broadband networks across the country could become a "network of networks," creating additional value for each participating utility.

II. Shared Challenges, Industry-wide

Electric utilities face a host of evolving challenges that require them to increase the capabilities of their distribution and transmission grids by incorporating ICT and the broadband communications networks upon which it depends. From climate change to cyberattacks, the same powerful trends are causing virtually every U.S. utility to look to new technologies to make their grids smarter.

A. The "Three Ds"

Global climate change imposes on utilities a trio of successive imperatives, driving the need for secure, reliable broadband communications networks. Known as the "three Ds," they are: decarbonization, decentralization, and digitization.

Decarbonization. Under Biden Administration policy, the U.S. power sector will be carbon-pollution free by 2035.[2] State legislatures and utility regulators are considering or have adopted decarbonization targets.[3] Utilities have begun to announce their own carbon-reduction goals.[4] To meet these goals, utilities must substantially alter their electricity generation mix, increasing reliance on cleaner technologies like solar photovoltaic and wind.

Decentralization. Since the advent of the grid, utilities have generated electricity in centralized plants and moved that power in one direction: from the plant to the end-user customer. The decarbonization-driven proliferation of renewable energy sources is changing that paradigm. They are frequently widely distributed and smaller than the typical central generation facility. They also are often outside the direct control of the utility. In many cases, these distributed energy resources (DERs) intermittently switch between providing and consuming power, reversing the flow of electricity in the line(s) connecting the DER to the rest of the grid. A home with a rooftop solar installation is an example of this kind of "prosumer" (producer-consumer).

Managing the two-way flow of energy to and from prosumer DERs requires capabilities the century-old U.S. power grid does not generally possess. To integrate DERs into the grid, utility operators must have far greater real-time awareness and control of the grid than current systems provide.

Digitization. Through the creation and analysis of data, ICT can provide the requisite awareness; by acting upon the data, it can provide the needed control. Sensors deployed throughout the grid can measure voltage, current, line sag, power factor, status of field equipment, line fault location—any number of variables that, when received and analyzed by an appropriately programmed computer, can tell operators if there is a power surge, or a transformer is overheating, or a line is dangerously loose. In response, operators can take action: throw a circuit breaker, disconnect a piece of equipment, or dispatch a crew. In many cases, a computer can make that decision and effectuate that action automatically. The grid no longer relies on operators responding to historical data collected manually each month; it is increasingly a dynamic, self-correcting machine, constantly evaluating and acting upon thousands of real-time data inputs.

It all comes down to creating, analyzing, and acting on data. Moving the data is critical—communicating it from a sensor to the analysis-performing software and carrying a resulting command (more data) from that software to a smart device that performs a physical action out on the grid. Following in the footsteps of sectors ranging from finance to transportation, U.S. electric utilities are poised to take advantage of the power of digitization.

B. A Fourth "D"—Natural Disasters

Even as utilities strive to meet the requirements imposed by the "three Ds," they are buffeted by increasingly severe and frequent natural disasters. New technologies cannot stop the storm or the naturally occurring wildfire, but they can help mitigate the damage. They can route power around a damaged line or automatically re-start power. In a disaster, neighboring utilities (and sometimes distant ones) send repair crews to help in the recovery. With new technologies and communications capabilities, providers of this "mutual aid" can cut the time to power restoration, saving the affected communities unnecessary expense and suffering.

C. Cyber Threats

Though ICT offers utilities powerful tools to address the three (or four) "Ds" above, increasing reliance upon data can also make utilities more susceptible to damage from cyberattack. Cyberattacks on utilities and other critical infrastructure are increasing in both frequency and sophistication.[5] Just this year, hackers have attempted to poison a Florida town's water supply[6] and caused the shutdown of the largest fuel pipeline in the United States.[7] For large investor-owned utilities and small rural power cooperatives alike, there no longer exists any doubt that they will be attacked; it remains only to discover when—and the extent of the damage.

Protecting against cyberattack requires vigilance and systems designed and maintained to keep up with the attackers' rapidly advancing capabilities. Utilities maintain systems and applications for years, even decades; those systems frequently pre-date modern cyber-protections, and some are no longer supported by their manufacturers. Advanced authentication and encryption techniques built into modern networks and applications can help protect against the inevitable attack.

III. A Proven, Standardized Solution, Available to Every Utility

Often overlooked in grid modernization discussions, the communications network is an essential element of the data-centric modern utility. Such networks will carry the data among devices and applications and will secure the data while in transit.

A. Legacy and Commercial Options Fall Short

To provide connectivity where wired, fiber optic cable is not a good fit (either because of cost or wireless-specific requirements such as mobility), virtually every electric utility in the country operates one or more (sometimes many more) private wireless data networks to support grid operations. These networks are proprietary, narrowband (low capacity), frequently use unlicensed spectrum, and typically carry data for only a single application. They also are frequently at end-of-life and subject to reduced support from vendors and even vendor obsolescence.

To safely and efficiently manage the integration of DERs to the grid, 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. Greater sophistication and number of applications and endpoints means vastly more data traversing the network, requiring broadband capacity. Increased automation requires that the data be communicated in real time with extremely low latency (the time a data packet takes to get from its source to its destination). Proprietary, legacy narrowband networks cannot meet these requirements, and as they age and vendors cease to support them, the cost, complexity, and risk of maintaining them will increase.

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. Though commercial networks may provide service with adequate capacity and low latency, 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. For example, commercial networks typically do not provide coverage in areas where few people go, despite the presence of utility infrastructure that requires connectivity. When there is a network outage, carriers will bring coverage back on-line at a pace and in an order that reflects carrier priorities, not necessarily utility needs. Similarly, commercial carriers deploy only those security measures that do not overly burden their mass market subscribers; utilities require the ability to implement more rigorous—and frequently more burdensome—protections. And finally, commercial carrier services sunset: 2G gave way to 3G, and 3G is the latest to be discontinued. When these network evolutions occur, they are on the carrier's schedule, forcing customers to replace the old devices at substantial cost.

B. Private LTE: The Leading Wireless Broadband Solution, Available to Every U.S. Utility

Utilities can have the same modern cellular technology widely adopted by commercial carriers without giving up the required network control. That technology—Long Term Evolution ("LTE")—is the world's leading mature, proven cellular technology; it is the "fourth generation" (4G) cellular standard from the 3GPP group of standards organization supported by a vast global ecosystem of goods and services, an evolutionary step leading to 5G.

Private network means utility control. By adopting LTE in a *private* implementation, a utility can deploy the technology in the way that best meets its own needs. LTE offers state-of-the-art security capabilities—some of which are optional within the LTE standard and not necessarily deployed by commercial carriers. But a utility that owns, operates, and controls its own private broadband network can choose to adopt cyber protections as stringent as it desires to meet its critical infrastructure function. For example, with a private network, a utility can set a policy allowing and defining a secure connection to the public internet, or it can require complete isolation from other networks, including the public internet.

Further, a utility can deploy a private LTE network to provide coverage where and how it is needed for utility operations, regardless of whether that coverage would reach enough potential subscribers to make business sense to a commercial carrier. And a utility that controls its own private network can choose when to schedule maintenance and how to use the network, including whether to share it with other critical infrastructure entities such as water utilities with overlapping service territories.

Private network requires licensed spectrum. A key aspect of a private network is controlling not only the equipment, configuration, and use of the network, but also controlling access to the spectrum on which the network runs. Only a utility that possesses a legally protected right to exclusive use of the frequencies employed by its network can have a truly private network; otherwise, where spectrum is unlicensed or otherwise open to usage by other networks, the utility may find the spectrum unavailable to carry its mission-critical communications because of interference from other network's transmissions, thus impacting the reliability of the utility's mission-critical system that must work every time, without fail. That is why U.S. utilities typically insist upon spectrum that is licensed by the Federal Communications Commission (FCC).

Until relatively recently, spectrum has been the sticking point in utility efforts to deploy private wireless broadband networks. It was very difficult to find spectrum in large enough blocks to support broadband, or those blocks would not be unavailable all parts of a given utility's service territory. Today, there are two major spectrum options for utility private broadband networks: six megahertz of spectrum 900 MHz band are available for dedicated use in virtually every county in the country, and 10 utilities have recently won licenses to exclusively use up to 40 MHz of spectrum in the 3.5 GHz ("CBRS") band in their service territories. Between the two bands, any utility that wishes to deploy private LTE to support its grid modernization initiatives can now do so.

Common utility use cases indicate private LTE in low-band spectrum. Though the specific use cases for which utilities require private wireless broadband network may vary, those use cases drive certain common network requirements that are in high demand across the industry. It is that set of key requirements—mobility, wide coverage, and low latency—that establish LTE in low-band spectrum as the optimal solution.

Secure access to utility operations and maintenance applications for mobile repair crews is an important use case for most utilities because it promises to drastically reduce the time it takes to restore power in an outage. Among wireless broadband technologies, only cellular and satellite offer a mobile capability. For cellular, LTE is the leading mature technology and will evolve over time to 5G. Mobility also requires with broad coverage, essentially providing network access throughout the utility's service territory, wherever a repair vehicle might go. And cellular deployments that use low-band spectrum (sub-1 GHz) can provide that coverage at substantially lower cost than higher-band spectrum because lower frequencies are better able to carry signal over long distances and through obstructions like foliage. As a result, low-band networks can provide coverage with fewer (larger) cell sites, thus reducing the cost of both deployment and operations. Other broad-coverage use cases that are very common among utilities include SCADA and telemetry (coverage for grid elements even in remote locations) and smart and advanced metering systems (coverage for a large number of end points).

In addition to mobility and broad coverage, the other key capability utilities broadly require in a wireless broadband network is low latency. With DERs driving ever-growing grid complexity and the proliferation of sensors creating a flood of data, human operators cannot be expected to analyze the inputs, decide on a course of action, and implement it in the split-second that can make the difference between an incident averted and a rolling blackout. Using ICT including machine learning and artificial intelligence, utilities are beginning to automate those functions. But though lightning-fast computer chips can help perform the data analysis and issue a command in the blink of an eye, if the data does not get from the sensor (such as line voltage) to the application or the command from the application is not delivered to the smart device in the field (such as a circuit breaker) fast enough, the speed advantage of automation can be lost. The time it takes for a message to travel across a network from the sender to the recipient is called latency, and because of automation of mission-critical functions, utility networks must possess low latency.

A good illustration of an automation application driving utilities' low latency requirement is Falling Line Conductor (FCP). In this application, a protective relay installed on a segment of line acts as a phasor measurement unit (PMU) to collect phasor data for a line segment, sampling conductor voltage 30 times per second. The system sends the data to the concentrator/controller (typically at the substation) running the falling conductor detection algorithm which uses the data to determine if the conductor is falling, and if so on which phase. If a conductor is falling, the controller sends a trip message to the protective relay, which de-energizes the line before it hits the ground, which takes about 1.25 seconds after the break occurs. Because the switch gear on the line takes about 300 milliseconds to operate, the rest of the system must collect and analyze the data, make the decision and send the trip command in 950 milliseconds. Delay in the transmission if the data over the communications network (latency) could result in a live wire hitting the ground and sparking a wildfire.

Of the wireless technologies that can meet the mobility and coverage requirements described above—low-band LTE and satellite—only LTE can meet the low-latency requirements.

C. Technology Validated in NREL Testing

Since 2018, the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) has investigated the performance of LTE technology in real-world utility use cases. The purpose of the NREL project, entitled "Enabling Realistic Communications Evaluations for ADMS," is "to evaluate how private LTE wireless network performance impacted grid-related control and protection use cases by leveraging NREL's advanced distribution management system (ADMS) test bed."[8] The Department of Energy has designated it a "high impact" project.[9]

Using low-band 900 MHz spectrum for its LTE implementation, the NREL team conducted two phases of testing of LTE communications with DERs in the field, first evaluating performance in support of direct transfer trip (DTT), a fast DER disconnection use case. In its published report on the first phase of testing, NREL stated:

> DTT relaying requires low latency communications and utilities often use fiber or dedicated lease lines to implement DTT. With the increased deployment of DERs, the cost of providing fiber-based communications to all DERs is prohibitive and leased lines are being phased out by the industry necessitating alternative but effective communications methods. A wireless network solution appears ideal to inexpensively connect many DERs which are spread out over a relatively large area if DTT latency can be decreased to an acceptable level.[10]

The direct transfer trip relaying scenario focused on the latency impact of various scenarios of signal strength and traffic priority (prioritization is an LTE feature).

> This work demonstrates the impact from private LTE communications on latency, and thus the potential impact on a low-latency grid application such as a direct transfer trip scenario of a recloser system. Measurements show the expected trend of increasing latency for weaker communication links and more traffic congestion.[11]

A CIGRE 2019 Grid of the Future paper providing early results of phase one testing stated, "Results show that under both strong and weaker LTE signal strength and quality, the DTT application nonetheless operated with consistency and relatively low delay."[12] One of the authors of that paper, Barry Mather, group manager in NREL's Power Systems Engineering Center, said that the project, using a 900 MHz private LTE network, had "shown that it's possible to prioritize the most critical network traffic, enabling reliable communications for increasingly complex and distributed energy systems."[13]

The second phase of testing focused on a dynamic voltage regulation (DVR) use case (bringing voltage back into the target range), assessing the impact on grid performance of two-way communications over the 900 MHz private LTE network. Soon to be published, the results of this phase of the project will show the performance of the application over wired and wireless connections in a range of scenarios involving normal and attenuated wireless signal and inclusion/exclusion of a DER management system (DERMS). The DVR experiments validate the use of 900 MHz private wireless LTE communications in a peak load management grid application using two-way communications.

The testing for the "Enabling Realistic Communications Evaluations for ADMS" project was conducted in the ADMS testbed, including its integrated implementation, at NREL's Energy Systems Integration Facility in Golden, Colorado.

IV. The Power of Collaborative Adoption

Long known for its collaborative culture, the electric utility industry today has a rare and valuable opportunity to embrace that cooperative instinct in a way that will profoundly benefit each individual utility as well as the industry as a whole—and its customers across the country—for decades. Consider the commonalities present in the current situation:

a. Every utility is subject to national and global trends like decarbonization, decentralization and digitization, as well as natural disasters and cyber threats.
b. To accommodate these trends, common utility use cases implicate the same requirements for utility broadband communications networks, like mobility, coverage, and low latency.
c. A broadband network solution exists that meets those requirements, and it is available to virtually every utility in the nation.
d. That broadband network solution—900 MHz private LTE—has been technically validated by a federal laboratory for utility grid use cases.

The stage is set for the industry to benefit from collaborative efforts on wireless broadband communications.

A. Sharing Information and Expertise

Across the industry, utilities already are collaborating to evaluate and deploy private LTE. Led by early adopters Ameren,[14] San Diego Gas & Electric (SDG&E),[15] Southern Linc,[16] and others,[17] industry organizations like Utility Broadband Alliance,[18] On-Go Alliance,[19] and Utilities Technology Council[20] facilitate the exchange of information and experiences. Larger utility-focused associations including Edison Electric Institute and National Association of Regulatory Utility Commissioners also support this function, regularly convening interested utilities and publishing information to support the community. Utilities share expertise, helping each other climb the substantial learning curve as staff familiar with narrowband land mobile radio systems become familiar with the complex, state-of-the-art technology that is LTE. Through these collaborations, utilities are improving their individual and collective knowledge about deciding whether to adopt private LTE; designing, procuring, and deploying a private LTE network; and even applying best practices for private LTE network operation.

B. Driving a Responsive, Innovative Market

With enough participants pursuing a single solution, utilities can create the opportunity to collaborate in a way that affects the market, perhaps improving the selection and quality of goods and services and reducing prices. They can aggregate their buying power to realize economies of both scale and scope.

The 900 MHz private LTE market is already feeling the impact of utilities' collective interest. Through the Anterix Active Ecosystem program, over 50 leading technology companies are working together to support utilities adopting 900 MHz private LTE networks, helping participants develop and bring to market products and services specifically designed for that platform.[21] From devices certified by the FCC for use in the 900 MHz band to cybersecurity products tailored to utility use cases relying on private LTE networks, the breadth and depth of the effort is a testament to the influence a group of utilities can wield when it focuses on a particular market—in this case, the 900 MHz private LTE market in the U.S.

C. The Network Effect

The above collaborations can be effective, and utilities can benefit from participation. But private LTE in 900 MHz low-band spectrum represents for U.S. utilities a rare opportunity to collaborate not only to realize the benefits flowing from each utility's *own* optimized implementation of a technical solution, but also from broad adoption of that same solution by *other* utilities. That opportunity exists today because the solution at issue here is a *communications* technology, the widespread adoption of which can create a "network effect."

Person-to-person payment platforms provide a simple example of network effect benefits. If only a dozen people used Zelle, for example, the platform would not be of great value to them (not many people to send money to or receive money from). But with millions of people participating, the value of Zelle *to that same dozen people* is much greater. That is the network effect at work: it can create value for users of a network not because those users did anything differently, but because other people (or utilities) also became users of the network.

In the above analogy, each Zelle user represents a utility with a 900 MHz private LTE network. The Zelle application and the internet together enable each Zelle user to transact with and participate in the broader Zelle community. The corollary for utilities is that 900 MHz LTE devices, with appropriate authorization, enable a utility (via its personnel and systems) to communicate with and participate in the nationwide community of electric utilities. Just as a Zelle user can allow another community member to place funds in the user's bank account, a utility with a 900 MHz private LTE network can allow a visiting line crew providing mutual aid from another utility to access the host utility's grid-recovery systems, viewing and relying upon grid-status information in supporting the restoration of power. The network effect applies in both cases: the more participants there are (Zelle users or utilities with 900 MHz private LTE networks), the greater the value to the individual participant.

D. Creating an Industry-wide "Network of Networks" by Enabling Inter-Utility Roaming

By collectively adopting 900 MHz private LTE to meet their broadband communications needs, utilities would be able as a technical matter to create an industry-wide network of their individual private networks (a "network of networks" or "NofN"). Such an arrangement would be akin to what commercial cellular carriers created decades ago: the ability for subscribers of one carrier's network to connect (with appropriate authorization) to the network of another carrier. It used to be that a Verizon subscriber outside range of a Verizon cell tower lost all connectivity, even if an AT&T was nearby. Then, with technical compatibility and commercial agreements, the carriers began to allow subscribers of other carriers to "roam" onto their networks—usually for a fee to the subscriber. Eventually, separate roaming fees faded away, leaving commercial cellular users with the seamless experience they enjoy today—fully transparent roaming enabling connectivity regardless of the carrier providing the coverage.

The idea is not novel: a number of utility executives and other industry thought leaders have proposed broad adoption of a single wireless broadband technology to facilitate inter-utility collaboration. "As part of the overall U.S. electric industry, we are prepared to share the knowledge gained from the development of our own mission-critical LTE network with other utilities," stated Southern Linc President Tami Barron. "Utilities have a long history of working together, and collectively, a network of utility broadband networks will provide a powerful benefit to the industry as a whole." Similarly, in announcing a pilot of LTE technology in the 900 MHz band, Gil Quiniones, President and CEO of New York Power Authority said, "We believe that collective action by the utility sector embracing private LTE will lead to a broader range of benefits both for utilities and our customers." In a "C-Suite Take Note" briefing paper, Navigant (now Guidehouse) advised:

> By standardizing not only on LTE technology, but also on the spectrum band in which it is deployed, utilities for the first time have an opportunity to optimize their wireless networks so that they are both interoperable and futureproof … benefit[ting] from roaming capability across the territories of other utilities.[22]

The NofN concept is taking hold among policymakers, as well. In a September 2020 resolution, the Southern States Energy Board, an interstate compact comprised of 18 southern states and territories, encouraged

> the region's utilities that deploy private wireless broadband networks for grid-management communications to coordinate their planning, and Public Utility Commissions to facilitate such planning, to adopt a common spectrum band and technology for such networks to enable wireless network interoperability, increased functionality, and cost savings across the region.[23]

E. Short-term Benefits from the "Network of Networks"

The benefits of creating a network of utility private wireless broadband networks range from the very clear and short-term to those stemming from applications yet to be imagined. As suggested above, one of the quickest and clearest benefits of the NofN could be the transformation of utilities' critical mutual aid operations, increasing resilience by improving the speed, safety, and efficiency of disaster recovery.

<u>The NofN can transform mutual aid for improved reliability and resilience</u>. Each storm season, convoys of repair crews descending on storm-ravaged neighborhoods, racing against the clock to restore power as freezers thaw, home health equipment stops working, customers swelter, regulators launch inquiries, and businesses grind to a halt. Focusing on major industries at particular risk of losses from power outages, Bloom Energy in 2019 sited surveys showing that each hour power restoration is delayed can cost a large retailer over $200,000, a data center over $500,000, and a large manufacturer $5 million.[24] For the utilities themselves, major recovery efforts can be extremely expensive; where recovery insurance is in place, it frequently does not cover the entire bill.

Today—as for the past decade or more—a crew arriving to provide mutual aid often receives its assignments by voice phone call, in-person presentation, or paper instruction. The host utility might provide visiting crews paper printouts of feeder circuits to investigate or simply specify a location from which to start driving the circuit, searching for the problem. When it identifies and assesses the problem, the crew might require materials to accomplish the repair (a phone call or paper delivery request process). After completing the repair, the crew may discover a "nested" outage requiring location, assessment, and repair of another problem before power can be restored. The host utility's disaster response workflow, supporting systems, and communications capabilities all conspire to slow—and increase the cost of—the recovery effort.

Some utilities provide information to repair crews via the internet, which the crews access over the commercial wireless broadband services they commonly use. Even when those commercial cellular service survives the storm, coverage gaps can leave crews without communications, particularly in rural areas. And utilities are understandably hesitant to allow full access to critical systems over the public internet.

As utilities deploy private wireless broadband networks, their own repair crews will become far more efficient, because they have both the connectivity (activated device) and authorization (credentials/permissions) required for direct, secure mobile access to the utility's internal applications, such as a supply chain management system and a digital overhead map of the lines, fuses, substations, transformers, and poles that make up the distribution system. With access to these resources, the host utility's own crews will be better able to find and diagnose the problems and proceed more quickly with the repair, saving tremendous time. Even today, visiting crews frequently pair up with local crews to benefit not only from their familiarity of the system but also from their communications capabilities.

With private wireless broadband coverage in place, a utility could vastly increase its deployment of sensors and smart devices to obtain detailed, real-time situational awareness of grid events. The data the network collects from these sensors would further enhance repair crews' ability to find problems and safely restore power—and the operations team's ability to coordinate and execute an efficient recovery.

If the utility providing mutual aid had deployed the same private wireless broadband network solution as the requesting utility, the visiting crews would carry with them devices capable of connecting to the host network. With their own familiar, on-board devices, they could operate with comparable efficiency as the local crews if they possessed permission to (1) connect their devices to the host network and (2) access the host's applications. With this ability to roam—paired with appropriately stringent authorization and security measures—mutual aid providers could benefit from a utility-grade "mobile desktop" experience and the bevy of efficiencies that come along with it.

<u>The NofN can help electric utilities provide connectivity to water and gas utilities</u>. With a private wireless broadband network, an electric utility controls who can use the network, and how they use it. The utility may wish to take advantage of its investment by providing network services to other critical infrastructure enterprises that operate within its service territory. In this way, the electric utility can help gas and water utilities to improve their cyber security postures and operational capabilities even as the electric utility creates a new revenue stream to offset its recurring costs and reduces overall cost to consumers by helping water and gas utilities avoid building their own networks.

The service areas of water and gas utilities, however, frequently spill outside of the service area of a single electric utility. To gain full utility-grade coverage for its own service territory without building its own wireless broadband network, a water utility, for example, may have to subscribe to private networks deployed by multiple electric utilities and procure devices that can connect to each of those networks. If every electric utility that overlaps the water utility's territory participates in a network of networks, however, those electric utilities could together provide connectivity throughout the water utility's service area, allowing the same water utility devices to connect regardless of the network providing the coverage. This shared use of a common communications platform could improve coordination and cooperation among critical infrastructure industries throughout the region.

F. Electric Vehicles: Potential Middle-term Benefits from the "Network of Networks"

The above short-term benefits of the NofN can be realized after completion of each utility's own private wireless broadband network with little more than policy agreements among network operators and procurement of devices. Other benefits will take more time to develop, but they, too, could provide substantial value.

<u>The NofN could enable the next level of electric vehicle (EV) management</u>. Many U.S. utilities are testing and demonstrating managed charging technologies to help EV owners take advantage of lower electricity rates at off-peak times—and help utilities reduce the need to purchase from expensive peak-power generating facilities.[25] Such programs typically provide the EV owner a financial incentive to allow the utility to control the time and amount of charging provided to the EV. This function can be effectuated through a smart-phone app and control of the owner's residential charging station.

In addition to the importance of managing EV charging because of the growing demand for electricity it represents, utilities also must consider the EV's related role as a source of stored power. Providing power back into the grid (vehicle-to-grid, or V2G) allows EVs to serve a leveling function, helping flatten the peaks and valleys of generation as demand fluctuates and potentially reducing the need to maintain peak-load generation facilities. Fleet vehicles like school buses are particularly attractive for this purpose: "We know when buses will drop off kids and [t]hen they sit. Most of the time they are sitting. These are like mobile microgrids to help balance the grid," said Mathew Sachs, senior vice president of strategy and business development for CPower.[26] The Federal Energy Regulatory Commission included EVs among the DERs to benefit from wholesale markets under the aggregation provisions of its Order 2222.[27] FERC Chairman Chatterjee explained:

> Estimates from EEI show there will be almost 19 million electric vehicles on the road in the United States by the end of this decade alone … When those vehicles are charging, say, in our garages, they amount to a significant energy resource that could – over time, *using the power of advanced technologies* – be managed through aggregations to provide a range of services in our organized energy markets. They could provide energy and spinning reserves, or even frequency regulation. By unleashing the power of EVs in this way, we have the ability to further drive down costs in our markets and bolster grid resilience.[28] [*emphasis added*]

Like homes with rooftop solar installations, EVs can be both providers and consumers of electricity, requiring the modern grid upgrades necessary to manage other intermittent, distributed DERs—including private wireless broadband connectivity. Currently, the focus is on the charging station as the point at which utilities will gain the visibility and control of EV DERs needed to manage both G2V and V2G use cases; a communications network will extend to the charging station, and the EV will gain connectivity when plugged into the charging station. But where the management application requires connectivity to the EVs when they are not connected to a charging station, the NofN could be of tremendous value. In a report on the ChargeForward project with Pacific Gas & Electric (PG&E), BMW calls out the value of mobile connectivity even in this early pilot implementation, focusing on the telematics data cars routinely communicate today:

> Telematics data is mobile. Unlike wall outlets or charging stations, which are stationary, … telematics data follows the vehicle wherever it goes. … [I]n order to effectively manage and evaluate a smart charging program, vehicle charging data needs to be directly accessible, across all times and locations.[29]

In addition to PG&E, as of 2019, at least three other utilities—Consumers Energy, DTE Energy, and Southern California Edison—had also included "direct load control via automaker telematics" in their managed charging programs.[30]

The advent of transparent subscriber roaming among commercial cellular carriers (creating a carrier NofN) helped pave the way to an explosion in smartphone application innovation, development, and usage—and value for network operators. Strong indicators are already suggesting similar impact from an electric utility NofN: ChargeForward is highlighting the importance of mobile data connectivity for EV management; FERC has recognized the critical role EVs could play for utilities in grid service reliability and efficiency; and—bringing together the NofN benefits for mutual aid and EVs—Con Edison this year announced that by 2022, it will roll out grid repair vehicles that are EVs.[31] Even if utilities require secure, mission-critical communications only for large fleet vehicles with high-capacity batteries capable of impacting the regional balance of load and demand, a network of utility private wireless broadband networks will make it possible.

G. 5G Future: Imagining the Long-Term Benefits of a Network of Networks

As 4G LTE evolves into 5G and 5G matures, utility private LTE networks also will evolve to 5G. And with that evolution, history suggests that a new wave of utility applications will be designed to take advantage of 5G's advanced capabilities. 5G technologies are expected to disrupt both the technology world as well as traditional sectors like manufacturing, agriculture, and transportation.[32]

In its future-looking paper exploring the network of networks concept, Guidehouse referred to the long-term benefits of 5G as "A Gleam in a Garage Entrepreneur's Eye."[33] But to take part in the 5G revolution, a utility will need to build a 5G network. 5G is 3GPP's next evolutionary step, built on an LTE foundation. Before LTE networks fully move to 5G, many network owners will become "5G ready" by upgrading the core network to 5G compliance, maintaining the 4G LTE radio access network. Because LTE devices will continue to operate with new 5G networks—and new 5G devices will be able to connect to LTE networks—the network of utility private networks could be built on a combination of LTE and 5G deployments.

V. Conclusion: Making It Happen

As noted above, electric utilities already are sharing wireless broadband information and expertise and influencing the ecosystem of 900 MHz private LTE products and services. Industry thought leaders are talking about broad adoption of a single solution and the potential for a nationwide utility network of networks. The industry may be on the cusp of something truly transformative.

But as with any cooperative endeavor, each potential participant that goes a different way not only becomes an island in a sea of shared communications innovation, but it also deprives the rest of the group of its participation, thus reducing the overall value of the community effort.

As a result, the challenge for the industry and its leaders is to openly and actively embrace the broad adoption of 900 MHz private LTE by each individual utility as an enabler for a stronger, more innovative and capable industry overall. The electric utility community has adequate venues for undertaking such a coordinated, collaborative initiative. No utility should go its own way because it lacks information or awareness of 900 MHz private LTE or network of networks initiative.

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