Before the
Department of Energy
Washington, D.C. 20585

In the Matter of	)
	)
Implementing the National Broadband	)
Plan by Studying the Communications	)
Requirements of Electric Utilities To	)
Inform Federal Smart Grid Policy	)

NBP RFI: Communications Requirements

COMMENTS OF UTILITIES TELECOM COUNCIL

Michael Oldak, Vice President & General Counsel
Brett Kilbourne, Director of Regulatory Service & Associate Counsel
Utilities Telecom Council
1901 Pennsylvania Avenue, NW
Fifth Floor
Washington, DC 20006
202-872-0030

July 12, 2010

SUMMARY

Utilities and other critical infrastructure industries (CII) rely on private internal communications networks to ensure the safe, reliable, efficient and secure delivery of electric, water, gas and other essential services to the public at large. Smart grid and other CII communications needs will require that utilities and other CII upgrade their communications systems. Utilities and other CII will use various different technology solutions, such as fiber, microwave, and land mobile radio, at different tiers of their communications network, such as the Tier 1 core backbone, the Tier 2 distribution backhaul and the Tier 3 access layers of the network. While utilities will use various technology solutions, wireless solutions will play an essential role for quick, cost-effective and reliable wide area coverage and long range backhaul. However, utilities lack access to spectrum that is suitable to support their wireless system upgrades.

Based on data provided to UTC by its investor-owned, cooperative, and municipal utility members, UTC estimates that utilities and other CII will need access to 30 MHz of licensed spectrum in frequency ranges below 2 GHz to support their current and future wireless communications needs. This amount of spectrum (30 MHz) is needed to support wireless communications at the Tier 2 distribution backhaul layer of the network. This frequency range (below 2 GHz) is needed in order to provide favorable propagation characteristics to cover wide areas and support high-capacity backhaul point-to-point links. Lower frequency ranges (i.e. below 1 GHz) are especially needed at the edge of the network in order to penetrate walls and other obstructions and to overcome moisture and foliage, which can block or otherwise degrade

communications at higher frequencies.

Utilities have and will continue to use commercial carriers to support some of their applications; but the majority of utilities will primarily rely on private internal communications for their mission-critical applications. Many mission-critical applications have functional requirements for survivability, availability, coverage, latency, security and life cycle that carrier services might not currently be configured to meet. To this end, UTC is conducting a study for publication in September to identify opportunities for collaboration between technology providers and utilities with the goal of articulating the business, technical and functional requirements of both core and edge communication functions within utilities. This effort should help both utilities and telecom providers better understand the unique nature of utility communications so that carriers can better determine whether they can, as a business proposition, meet the specific functional requirements for utility communications.

Urgent action is needed to address utilities communications needs. Utilities and other CII are deploying smart grid and making investments in communications upgrades now. Promoting access to spectrum will accelerate the deployment of smart grid and other CII communications, which will in turn promote larger public policy goals for energy independence, infrastructure security, environmental quality and public safety. Therefore, UTC looks forward to working with the DOE, as well as the FCC and NTIA to support the communications needs of utilities and other CII.

TABLE OF CONTENTS

SUMMARY ii
TABLE OF CONTENTS iv
I. Introduction 2
II. Basic Requirements 10
III. Additional Considerations 13
IV. Use Cases 15
V. Technology Options 29
VI. Recommendations to Meet Current and Future Communications Needs. 33
VII. Commercial Networks 39
  A. Can commercial networks meet utilities' needs? 39
  B. Suggestions for improvements of commercial networks. 43
VIII. Evolution and Expansion of Communications Needs with Growth in Smart Grid. 44

Before the
Department of Energy
Washington, D.C. 20585

In the Matter of	)
	)
Implementing the National Broadband	)
Plan by Studying the Communications	)
Requirements of Electric Utilities To	)
Inform Federal Smart Grid Policy	)

NBP RFI: Communications Requirements

COMMENTS OF UTILITIES TELECOM COUNCIL

The Utilities Telecom Council (UTC) hereby comments in response to the Department of Energy (DOE) request for information on the communications needs of electric utilities and other such critical infrastructure industries (CII).[1] In summary, UTC submits that utility and CII communications needs are increasing and that wireless will be an important technology option in meeting those needs. However, utilities and CII lack access to suitable spectrum to support their wireless communications needs. Utilities and CII need access to 30 MHz of licensed spectrum below 2 GHz to provide sufficient capacity and coverage to meet their current and future needs cost effectively. While commercial systems and other technology alternatives will help to offset some of the need for licensed spectrum, they are not appropriate for mission critical communications because they lack sufficient reliability, geographic coverage and response speed (low latency). Mission critical communications refer to utility

[1] Critical infrastructure industries (CII) include electric, gas and water utilities, pipeline companies and other companies that provide essential services to the public at large. *See also* Department of Energy, *Implementing the National Broadband Plan by Studying the Communications Needs of Electric Utilities to Inform Federal Smart Grid Policy,* 75 Fed. Reg. 26206 (May 11, 2010) ("DOE RFI").

communication needs that require the highest level of reliability in order to keep the supply and demand in balance. Often these communications require less than 3 milliseconds of delay and redundant communication paths. These conclusions are based on industry-wide data collected by UTC that quantifies the communications needs of utilities to support smart grid and other utility and CII communications, as requested by the FCC in its National Broadband Plan.[2] Now that the industry has provided this data, it is urgent that DOE, the FCC and NTIA move quickly to meet the communications needs of utilities in order to realize the vision of smart grid and ensure the safe, efficient and reliable delivery of essential services to the public at large. UTC looks forward to working with the DOE to develop its report.

I. Introduction

UTC is the international trade association for the telecommunications and information technology interests of electric, gas and water utilities, pipeline companies and other critical infrastructure industries. Its members include large investor-owned utilities that serve millions of customers across multi-state service territories to relatively smaller municipal and cooperative utilities that may serve thousands of customers in isolated towns, cities and rural areas of the country.   In addition, UTC is allied with all of the major electric, gas and water utility associations, as well as other organizations representing various other critical infrastructure industries – as part of its Critical Infrastructure Communications Coalition.[3]

---

[2] *See* National Broadband Plan at Recommendation 12.6 ("The U.S. Department of Energy (DOE), in collaboration with the FCC, should study the communications requirements of electric utilities to inform Federal Smart Grid policy.") at http://www.broadband.gov/plan/12-energy-and-the-environment/#r12-6.

[3] For more information about the Critical Infrastructure Communications Coalition go to http://www.utc.org/utc/critical-infrastructure-communications-coalition.

All of UTC's members own, manage or control extensive communications systems to support the safe, reliable and efficient delivery of essential services to the public at large. Due to the critical nature of these communications systems, they are designed, built and operated to demanding standards that exceed those of commercial communications systems for coverage, availability and survivability. Utilities need ubiquitous coverage all across their service territories, including remote areas that tend to be underserved or unserved by commercial carriers. They also need communications systems that do not become unavailable due to traffic congestion, particularly during emergency scenarios when utilities need reliable communications the most. Finally, their networks need to be able to survive natural and manmade disasters; so they have extended power back-up and they are built to withstand high winds and heavy ice. As such, utility networks are designed for reliability; which sets them apart from commercial systems that are designed for capacity.

Utilities rely on private internal communications systems and have done so for decades. These private internal systems include various different technologies, including fiber, power line, land mobile wireless, microwave, satellite and various unlicensed technologies. Utilities are technology agnostic and will use technologies that are reliable and cost effective. However, wireless is a key component of their private networks. In fact, utilities were using wireless before commercial wireless networks even existed. As such, utilities have extensive communications expertise in general and with wireless specifically, and will use the appropriate technologies that are proven, reliable and cost effective.

Wireless communications serve a variety of purposes for utilities. They are used for routine voice dispatch and for emergency restoration. They are also used for data communications to support remote monitoring and control of critical infrastructure systems. SCADA[4] is a classic example. These wireless communications include both mobile and fixed communications. Most wireless systems are narrowband, although utilities are increasingly using broadband wireless for fixed and mobile data applications, including video.[5]

Spectrum is the lifeblood of wireless systems. Utilities need to use licensed spectrum to support mission critical applications, because licensed spectrum generally offers greater protection against interference and congestion. However, the licensed spectrum that is currently available to utilities is predominately narrowband, particularly in the frequencies below 2 GHz, where there are more favorable propagation characteristics. Moreover, there is a shortage of available spectrum below 2 GHz, and the data channels for primary use in the bands below 512 MHz where many utilities operate are shared with a wide variety of other eligible entities, whose operations are often incompatible with those of utilities. There is effectively no protection from interference in this shared spectrum below 512 MHz, because the channels in these bands are primarily allocated for voice dispatch service, not critical SCADA services. While utilities that employ voice trunking can protect their service contours in theory, it is increasingly difficult to add data operations as a practical matter.

As utilities deploy smart grid, they need to upgrade their communications networks. For most utilities, this will require upgraded communications to support two

[4] Supervisory Control and Data Acquisition

[5] Existing utility systems consist of FCC Part 101 point-to-point microwave systems, which can support long-haul broadband applications, and FCC Part 90 point to multipoint land mobile radio systems, which can support wide area narrowband applications.

way communications all the way to the customer premises. Utilities will need to upgrade communications to support synchrophasors on the transmission infrastructure, as these devices require end to end communications latency of less than 20 milliseconds. Utilities report that only 13% of their distribution substations have access to *any* form of broadband, and most utilities will need broadband connectivity to these substations in order to support a variety of applications, including video monitoring for both operational needs and security.[6] Utilities will be pushing two-way communications beyond the distribution substation to support applications on the distribution grid, such as outage detection and power quality monitoring.[7] Of those utilities that have intelligent grid devices, and many don't due to the historical lack of communications options, they estimate that 72% of their intelligent grid devices will need upgraded communications.[8] Finally at the customer premises, utilities will need to support millions of smart meters and smart appliances and will need broadband to backhaul that data. Utilities estimate that they will need upgraded communications for 91% of their customers to support applications at the customer premises, such as AMI, demand response and direct load control.[9]

Wireless will play an important part in cost effectively upgrading utility communications to support smart grid. First, wireless is uniquely capable of providing

---

[6] *See* Comments of the Utilities Telecom Council in FCC Docket No. 09-51, Appendix A "Survey of Utility Communications Conducted by the Utilities Telecom Council in Preparation for the FCC's Public Notice Seeking Comment on the Implementation of Smart Grid Technology" filed Oct. 2, 2009 ("UTC NBP Smart Grid PN Comments").

[7] These kinds of applications are the prime focus of smart grid. Smart metering is only the first step in the evolution of most utilities' smart grid activities.

[8] UTC NBP Smart Grid PN Comments at Appendix A.

[9] *Id.*

wide area coverage. While utilities may use other technologies, such as fiber, on their backbone infrastructure, wireless can provide wide area connectivity to millions of devices on the grid, as well as point-to-point connectivity to distribution substations. Second, this can be done cost effectively with relatively low capital and operational investment compared with wireline technologies. Not every smart grid application will need fiber to each device, and to do so would be cost-prohibitive. Third, wireless can be deployed quickly and easily, and time is of the essence as many utilities must meet near term deadlines for their smart grid deployment plans. For example, using wireless in substations may represent a safe, time-saving and cost-effective alternative to using copper wireline technologies, which require the installation of high voltage protection systems to prevent ground fault current from leaving the substation.

Utilities can and will turn to commercial wireless carriers to support some of their smart grid applications. Duke Energy is working with Verizon to support its smart grid deployment, and AT&T is working with Texas-New Mexico Power on their deployments.[10] Commercial systems can provide connectivity on either a temporary or permanent basis, and that connectivity can meet other functional requirements necessary for certain smart grid applications. Where these commercial systems are available, they can meet some of utilities' immediate needs to support a smart grid roll out for certain applications, particularly smart meters.

---

[10] *See* Kelly McGuire, "Texas Utility to Push for More Smart Meters, Uses AT&T and SmartSynch Solution" May 27, 2010 (reporting Texas-New Mexico Power's expansion of its 10,000 meter deployment with AT&T and SmartSynch to cover all of its customers in the next five years.) *and see* "Duke Energy taps Ambient for Smart Grid Communications" GreenBeat at 1 (stating "Ambient's nodes, which tap into wireless networks mostly operated by Verizon, will be added to the transformers fed by these [Echelon] meters.") at http://green.venturebeat.com/2009/09/10/duke-energy-taps-ambient-for-smart-grid-communications/.

However, the vast majority of utilities will continue to rely on private internal communications systems for most if not all of their smart grid applications.   As noted later in the filing, any technology provider to the utility industry, including carriers, must meet unique coverage, safety and reliability requirements. In most circumstances where telecom networks do not offer, for example, 100% geographic coverage for wireless services, utilities will continue to rely on their own private internal systems rather than opt for carrier service that is not ubiquitous. Similarly, utilities have extensive emergency situation requirements which necessitate power back-up capabilities that might not be found in many carrier options. Finally, utilities must meet detailed requirements for critical infrastructure protection and in cases where carriers cannot meet these requirements, utilities must rely on their own infrastructure.   Thus, utilities and other CII need access to spectrum in order to upgrade their communications networks to support smart grid and other applications.

The question is how much and what kind of spectrum is required to meet utility and other CII communications needs? As described more fully below, utilities and other CII will need access to 30 MHz of spectrum that is either dedicated for utility and other CII purposes or shared with other compatible users to meet their current and future communications needs.[11] This is based on the estimated throughput requirements for each smart grid application, extrapolated by the number of devices/nodes and the average number of collectors per branch of the network. The spectrum should be in frequency ranges under 2 GHz in order to provide optimal propagation characteristics, which in turn plays into the overall cost effectiveness of the network. While spectrum

[11] As an alternative to using dedicated spectrum, utilities and other CII could share spectrum with other compatible users, such as Federal or state and local government and public safety entities.

above 2 GHz could be used for certain short range applications, such as those for metering and Home Area Network (HAN) devices, it is not suited for long-haul communications or in areas with line of sight (LOS) issues. As such, utilities need spectrum in lower frequency ranges (i.e. below 1 GHz), particularly in rural areas and at the edge of the network, where signals must penetrate into buildings and must contend with attenuation due to moisture (e.g., fog).

There are overriding public policy considerations that factor into the need for additional communications. So much is riding on smart grid -- whether it is energy security, environmental quality, economic recovery, or public safety -- that it would be foolish to gamble with its future. In recognition of its importance, Congress appropriated $4.5 billion in matching funds for smart grid demonstration projects and smart grid investment grants.[12] In addition, state public service and public utility commissions around the country have also approved billions of dollars of smart grid investment, as well. NIST and hundreds of stakeholders have spent the past two years developing a roadmap for smart grid interoperability, including a priority action plan for wireless communications.[13] Meanwhile, FERC and NERC are implementing Critical Infrastructure Protection (CIP) security requirements, and smart grid with its enabling communications infrastructure will be an important component to meet those

[12] *See* "Bill Summary: American Recovery and Reinvestment Bill of 2009 (ARRA) Energy & Commerce Provisions on Health Care, Broadband, and Energy" at http://energycommerce.house.gov/Press_111/20090212/economiceecoverysummary.pdf. See also "Obama Administration Announces Availability of $3.9 Billion to Invest in Smart Grid Technologies and Electric Transmission Infrastructure," Press Release, Department of Energy, June 25, 2009 at http://www.energy.gov/news2009/7503.htm.

[13] *See* NIST Smart Grid Interoperability Standards Project at http://www.nist.gov/smartgrid/.

requirements.[14] Finally, DHS has an interest in the development and deployment of smart grid in order to protect utility infrastructure against physical and cyber threats.[15] Thus, there is a convergence of public policy initiatives and federal and state agencies that is focused on smart grid, which underscores the need for reliable, secure and interoperable communications to support smart grid and other CII communications.

Thus, UTC applauds DOE for initiating its study of the communications needs of utilities and other CII. This comes at a critical juncture, as utilities are deploying smart grid and are undergoing a spectrum crisis to support smart grid and other communications applications.[16] As will be demonstrated in more detail, this spectrum crisis is real and it needs to be addressed urgently. Utilities are technology agnostic, and providing access to spectrum will provide them with options that they don't have to meet current and future communications requirements. In addition, this will promote interoperability by providing a spectrum home from which utilities and technology providers can develop standardized, non-proprietary equipment as they upgrade their communications systems for smart grid and other utility and CII applications. Moreover, access to spectrum is essential for the quick and cost effective deployment of smart grid by many utilities. As such, UTC looks forward to working with DOE to support the development of smart grid through policies that promote access to spectrum by utilities.

---

[14] *See* NERC CIP Requirements at http://www.nerc.com/page.php?cid=2%7C20. For example, video cameras and perimeter protection systems will be an increasingly important smart grid application, as more assets are deemed "critical assets" for purposes of NERC CIP requirements. This could have significant implications for the bandwidth requirements to support smart grid.

[15] *See* DHS National Cybersecurity Division at http://www.dhs.gov/xabout/structure/editorial_0839.shtm.

[16] *See* "The Utility Spectrum Crisis: A Critical Need to Enable Smart Grid" at http://www.utc.org/utc/utility-spectrum-crisis-critical-need-enable-smart-grids.

II. Basic Requirements

In its RFI, DOE asks, "What are the basic requirements, such as security, bandwidth, reliability, coverage, latency, and backup, for smart grid communications and electric utility communications systems in general— today and tomorrow? How do these requirements impact the utilities' communication needs?"[17] In response, UTC provides the following explanation of these basic requirements.

Security is the ability of communications networks to withstand physical and cyber security attacks, as well as to protect personal information. Due to the critical nature of utility communications, security is a high priority for most applications. There is wide-spread agreement that end-to-end security is needed, and that any vulnerability in the communications network can be exploited. In addition, it is important to incorporate upfront and design from end-to-end security, rather than to retrofit security solutions to communications systems, which can be an expensive and time consuming process.

Bandwidth and throughput are closely related terms that refer to the upload and download speeds needed to support specific applications. Some applications may transmit hundreds of bytes per day and others may require megabits per second. These requirements will also change over time as the business needs and capabilities of the underlying technology evolve. A communications solution that is suitable today may be outgrown tomorrow.

Reliability is the degree to which a communications system must remain operational. Some applications that gather operational data for historical records and

[17] DOE RFI, 75 Fed. Reg. at 26208.

long term trending can often tolerate intermittent outages whereas some mission-critical applications that affect the safe, reliable operation of the grid cannot. Utilities measure reliability either in general terms (low, medium, high) or in terms of specific percentages of operation during the course of a year (i.e. 99.999%).

Coverage refers to the extent to which a communications network serves a given area. Again, the importance of coverage will depend on the criticality of the underlying application to the operation of the grid. Utilities generally require 100% coverage of their service territories for most of their applications, particularly for mission-critical voice and data applications. However, there are communications gaps that currently exist, which will need to be filled in order to support certain smart grid applications, such as distribution automation and smart metering.

Latency is the time that a message is received after an instruction message is sent. The response message could contain critical data or confirmation that some action has taken place at the distant point. For certain applications, such as teleprotection systems, latency is a crucial consideration. Faults that occur on the grid must be isolated in milliseconds to prevent the fault from cascading. For other applications, such as metering, latency is not as important, because meter data does not affect the reliability of the grid and pricing information does not tend to vary significantly over short periods of time. As such, utility requirements for latency will vary depending on the application.

Back-up power is necessary to ensure that mission-critical communications remain functional even during power outages. Utilities will use batteries or generators to provide back-up power. Back-up power requirements are measured in minimum hours and will vary depending on the criticality of the communications, but in general, utilities require extended back-up power for their communications networks. Some remote utility sites have propane tanks with enough fuel to power the site for weeks.

In addition to the requirements identified by DOE, there are other considerations that factor into technology selection. Interoperability is a challenge for utility communications, and utilities must deploy smart grid technologies that meet upcoming NIST guidelines for interoperability. Currently, utilities lack interoperable communications between utilities during mutual aid scenarios in the aftermath of major storms or other disasters that cause widespread outages. They also lack interoperability with public safety entities, during emergency response scenarios. Both of these problems are related to the lack of a spectrum home for utilities, but they are also related to the use of proprietary technologies that do not interoperate with each other. Congress sought to avert this problem with smart grid by directing NIST to develop guidelines for interoperability between smart grid devices.

Finally, equipment must be durable and have a long-useful life. Utilities communicate in harsh and demanding environments that are distinctly different from those typical of commercial services. Equipment must be grounded to industrial standards and/or otherwise designed for safety and reliability in environments where there is high voltage electricity or where lightning is a problem. In addition, equipment must be ruggedized so that they remain operational despite severe weather, extreme temperatures, humidity, and dusty environments or other conditions. Finally, utility radio and network equipment is typically depreciated over 25 year cycles, and thus communications equipment must not be subject to technology obsolescence in a short period of time. Basic utility operations will not change as fast as new commercial carrier offerings to the public will. Therefore a utility build out of a network with a reasonable spectrum allocation today will provide a strong communications base for many years to come.

III. Additional Considerations

In its RFI, DOE asks the question: "What are other additional considerations (e.g. terrain, foliage, customer density and size of service territory)?"[18] In response, UTC provides the following issues that utilities must factor when selecting technology solutions.

At the outset, each utility is unique based on the topology of their grid, the size and customer density of their service territory, and local and regional considerations, including hurricanes/ice storms, terrain, and foliage. So, for example, fiber or some other wireline solution may be more appropriate for a utility seeking to support applications for underground grid infrastructure. In addition, utilities and other CII may form strategic partnerships with third parties that may determine technology choices. So for example, a utility may partner with a commercial service provider, technology provider or a public safety entity using a wireless solution that may be different from wireless solutions used by other utilities. As such, there may not be any one particular technology solution that will work for all utilities for a given application. Each will choose the appropriate technology for their utility, depending on these factors.

Topology of the grid will be a key factor influencing the technology options of utilities. Utilities have overhead and underground infrastructure, and there will be smart grid applications and communications solutions that are uniquely designed for these

[18] DOE RFI, 75 Fed. Reg. at 26208.

infrastructures. In addition, certain grids are radial by design and others are networked, and these designs can have implications for both the applications and the communications solutions that enable them.

The size and customer density of the service territory will also have a significant impact on the technology solution that a utility chooses to enable smart grid and other applications. Rural cooperative utilities that serve large, sparsely populated areas may choose a terrestrial wireless solution, while an investor-owned utility or municipal utility serving an urban, highly populated area may choose a fiber or other wireline solution. Finally, a small utility may choose to use a commercial service provider, rather than operate their own private internal network.

Local and regional considerations, such as terrain, foliage and weather will also have a significant impact on the technology solution that a utility or other CII chooses to enable smart grid and other applications. Terrain plays a big part in frequency selection for wireless applications, favoring lower frequency ranges for better propagation in hilly areas. Foliage, particularly evergreens, can absorb RF at certain frequencies (e.g., 800 – 900 MHz) and limit the distance that a wireless communications signal can propagate. Finally, weather issues, such as hurricanes and ice storms can influence the technology choices, making wireline solutions less attractive in those areas.

Finally, the technology choice may be determined by strategic partnerships that utilities form with service providers, technology providers and/or public safety providers. As noted above, some utilities have partnered with commercial carriers to deploy wireless and/or wireline solutions to support smart grid and other CII communications. Other utilities have partnered with third parties that provide leased access to spectrum in order to upgrade their wireless communications systems. Finally, some utilities have partnered or are proposing to partner with public safety entities to deploy public safety/public service shared systems that promote interoperable and reliable communications for emergency response as well as routine data and voice communications.[19]

IV. Use Cases

In the RFI, the DOE asks "What are the use cases for various smart grid applications and other communications needs?"[20] In response, UTC offers the following use cases for smart grid and other communications needs.

There are numerous use cases for smart grid applications and other communications needs. Indeed, smart grid is a term that is still evolving and expanding in its definition and scope. Below, UTC has listed some of the different applications that currently exist or are anticipated, and it has provided a brief description of each application, as well as the functional requirements for the communications systems for these applications. These use cases are consistent with the work that is currently ongoing within OpenSG and NIST, which are developing a more granular analysis of the various smart grid use cases and their functional requirements.[21]

---

[19] *See e.g.* Request for Waiver -- Expedited Action Requested of Nevada Department of Transportation, et al, PS Docket No. 06-229, filed May 9, 2010 (requesting a FCC waiver to permit a consortium, including NV Energy, to build a regional 700 MHz Public Safety broadband communications network.).

[20] DOE RFI, 75 Fed. Reg. at 26208.

[21] A copy of the most recent version of the OpenSG use cases that have been submitted to NIST is available at http://osgug.ucaiug.org/UtiliComm/Shared%20Documents/Interim_Release_4/SG%20Network%20System%20Requirements%20Specification%20v4.0.xls. *See also* EPRI Smart Grid Use Repository at http://www.smartgrid.epri.com/Repository/Repository.aspx.

1. **Advanced metering infrastructure (AMI), including automated meter reading (AMR), direct load control (DLC) and real-time-pricing.**

Advanced metering infrastructure encompasses a range of functionality embedded into smart meters or their collection point devices. In addition to automated meter reading for a variety of services including electric, gas and water, these meters can also enable a host of other applications, such as direct load control and real-time pricing. As such the smart meters can route demand response signals to smart appliances within the premises in order to curtail power consumption during periods of peak or critical peak demand. Alternatively, these smart systems can carry real-time or dynamic pricing signals to customers, enabling them with the option to operate appliances within the premises during times of the day when the price of electricity is lower.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
AMR	High	14-100 kbps per node	99.0-99.99	20%-100%	2000 ms	0-4 hours
DLC	High	14-100 kbps per node	99.0-99.99	20%-100%	2000 ms	0-4 hours
Real-time pricing	High	14-100 kbps per node	99.0-99.99	20%-100%	2000 ms	0-4 hours

2. **Distributed Generation**

Distributed generation (DG) or Distributed Energy Resources (DER) includes solar, wind and other sources of power, including energy storage systems. These tend to be intermittent sources of power, and utilities need to monitor and integrate the flow of power back onto the grid. Utilities anticipate that DG and DER will become increasingly prevalent, representing a significant percentage of supply. A Federal renewable portfolio standards (RPS) that will cover all states is being considered that will accelerate the deployment of DG.[22] Many states are already implementing RPS standards that will be ramping up DG requirements.[23] As such, smart grid systems will need to be deployed to monitor and integrate DG, potentially all across the grid.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Distributed Generation	High	9.6-56 kbps	99.0-99.99%	90-100%	300-2000 ms	0-1 hour

3. PEV Integration, including at the home or at charging stations

Electric transportation represents a significant new source of demand coming online.[24] Utilities will need to implement smart grid systems to deal with two different scenarios: charging at home and charging at charging stations. Charging at home needs to be coordinated so that the load on the transformers in the neighborhood is does not damage existing transformers. It is expected that each high current charger could represent the equivalent of one or two additional new homes on the existing transformer. Charging at charging stations requires communications in order track

[22] *See e.g.* American Clean Energy and Security Act of 2009 (HR2454) and Clean Energy Jobs and American Power Act (S1733).

[23] See e.g., http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm.

[24] Pike Research, a Boulder, Colo., clean-tech market-research firm, forecasts that there will be 610,000 plug-in vehicles in the U.S. by 2015. *See* press release at http://www.pikeresearch.com/newsroom/17-million-natural-gas-vehicles-will-be-on-the-road-by-2015

customer consumption wherever the customer travels.[25] As PEVs become more prevalent in the future, utilities will need smart grid to integrate these large new loads on to the existing distribution grid and monitor and control PEV charging across the entire grid. This will require ubiquitous, reliable two-way communications networks to support PEV charging applications.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Charging PEVs at home	Medium	9.6-56 kbps	99.0-99.90%	20-100%	2000 ms – 5 min.	0 hour
Charging PEVs at stations	Medium	9.6-56 kbps	99.0-99.90%	20-100%	2000 ms – 5 min.	0 hour

4. Pricing signals to smart appliances

Utilities will need to be able to communicate pricing signals to smart appliances in the home in order to enable dynamic pricing and demand response These signals will enable smart appliances to respond automatically and adjust consumption, in response to fluctuations in the price of electricity. Not only does this save customers money, but it helps to reduce peak and critical peak loads.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Price	Medium	9.6-56	99.0-	20-100%	2000 ms –	0 hour

[25] The U.S. Department of Energy has awarded a $99.8 million grant to construct over fourteen thousand charging stations at five strategic point around the country. The initial phase of the project will start in the Summer of 2010 and the project is scheduled for completion in 36 months. For more information, visit the "EV Project" at http://www.theevproject.com/.

signaling		kbps	99.90%		5 min.	

5. In-home display of customer usage

Customers monitoring their electric consumption will use in-home displays, which will receive consumption data and other information, such as pricing and rebate information, from the utility. These in-home displays can also communicate with smart devices in the home to control their consumption.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
In-home displays	High	9.6-56 kbps	99.0-99.99%	20-100%	300-2000 ms	0-1 hour

6. Automated feeder switching

Automated feeder switching requires intelligent grid devices on pole tops and in underground infrastructure. These devices will use two way communications to control switches in order to optimize the delivery of electricity. This system optimization can improve operational reliability and service restoration, as well as operational efficiency.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Automated feeder switching	High	9.6-56 kbps	99.0-99.99%	20-100%	300-2000 ms	8-24 hours

7. Capacitor bank control

Capacitor bank control enables utilities to remotely monitor and control voltage and VAR by switching in capacitor banks to compensate for VAR losses when large inductive loads occur, such as when air conditioners, furnaces, dryers, and/or industrial equipment start. Using two-way communications, utilities can automate the process of switching in capacitor bands to maintain voltage levels and minimize VAR losses. This promotes system reliability and efficiency.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Capacitor bank control	Medium	9.6-100 kbps	96.0-99.00%	20-90%	500-2000 ms	0 hours

8. Fault current indicator

Fault current indicators enable utilities to determine the direction of a phase to ground fault on a distribution line, which helps to reduce the time to restore service. Using networked communications can enable utilities to monitor these devices remotely, thereby further improving operational efficiency and reliability.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Fault current indicator	Medium	9.6 kbps	99.00-99.999%	20-90%	500-2000 ms	0 hours

9. Transformer monitoring

Transformer monitoring is another smart grid application that can promote operational reliability and service restoration. Using networked communications, utilities can monitor transformers remotely, so that they know when and where a transformer has failed or is beginning to fail. This can dramatically promote system reliability and efficiency.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Transformer Monitoring	Medium	56 kbps	99.00-99.999%	20-90%	500-2000 ms	0 hours

10. Voltage and current monitoring

Voltage and current monitoring enables utilities to analyze power flows across feeders to improve efficiency. It can also promote reliability by alerting utilities to faults that are beginning to occur on the grid.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Voltage and current monitoring	Medium	56 – 100 kbps	99.00-99.999%	100%	2000-5000 ms	0 hours

11. Network protection monitoring

Network protection monitoring is another smart grid application that promotes reliability by enabling utilities to remotely monitor the health of the grid and isolate faults before they cascade.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Network protection monitoring	Medium - High	56 – 100 kbps	99.00-99.999%	100%	2000-5000 ms	0 hours

12. AMI network management

AMI network management enables utilities to efficiently monitor and control smart meters from remote locations for such applications as demand response, remote connect and disconnect and direct load control.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
AMI network management	High	56 – 100 kbps	99.00%	20-100%	1000-2000 ms	0-4 hours

13. Remote connect/disconnect

Remote connect/disconnect promotes operational efficiency and customer service by enabling utilities to turn power off and on without the need for additional truck roll, thereby avoiding cost and delay.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Remote connect/disconnect	High	56 – 100 kbps	99.00%	20-100%	2000-5000 ms	0 hours

14. Meter data management

Meter data management systems are essential to manage meter data in order to improve operational efficiency, customer service, energy forecasting, and outage restoration. These systems need two-way communications to enable these capabilities.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Meter data management	High	56 kbps	99.00%	100%	2000 ms	0 hours

15. Outage management

Outage management enables utilities to remotely determine when and where an outage has occurred, thereby enabling utilities to respond more quickly and restore power faster. Two way communications systems are used to automatically notify utilities about outages.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Outage management	High	56 kbps	99.00%	100%	2000 ms	0 hours

16. Distribution asset management

Distribution asset management enables utilities to monitor and control devices on the distribution network, thereby promoting system optimization and operational efficiency.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Distribution Asset Management	High	56 kbps	99.00%	100%	2000 ms	0 hours

17. Demand response

Demand response enables utilities to reduce demand by remotely controlling devices, such as hot water heaters, air conditioners and eventually high current EV chargers. This promotes system reliability by enabling utilities to meet demand during peak and critical peak periods. This also reduces costs for consumers by providing rebates to customers that participate in these demand response programs, and by deferring or avoiding major infrastructure investments that would have been needed to meet those peak or critical peaks. Two way communications are needed to activate demand response and to validate that the remote devices have received and responded to demand response signals.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Demand response	High	56 kbps	99.00%	100%	2000 ms	0 hours

18. Wide Area Situational Awareness (PMUs)

Wide Area Situational Awareness (WASA) represents the monitoring of the power system across wide geographic areas. These broad area perspectives are necessary to maintain system knowledge and decisions that go beyond conventions of individual companies or even regional transmission organization (RTO) boundaries. The requirements for WASA are architecturally significant from the standpoint of requiring uniformity across traditional systems operation boundaries. Enabling WASA based applications brings forward unique requirements and challenges for the Smart Grid infrastructure.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Wide area situational awareness	High	600 – 1500 kbps	99.999-99.9999%	100%	<200 ms	24 hours

19. Line protection and control

Line protection and control includes teleprotection systems that utilities use to isolate faults on the distribution grid. Due to the need to isolate these faults quickly and reliably anywhere on the grid, the communications systems that support teleprotection systems must meet stringent requirements for security, reliability coverage, latency and back-up power.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Line protection and control	High	600 – 1500 kbps	99.999 – 99.9999%	100%	<20 ms	24-72 hours

20. Billing

As smart grid enables dynamic pricing and access to consumption data at more frequent intervals, utilities must upgrade their billing systems to keep pace with these increased capabilities. This will require highly secure, reliable and ubiquitous coverage for these enhanced customer billing communications.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Billing	High	56 kbps	99.00%	100%	2000 ms	0 hours

21. Customer Information Management

Utilities will need to upgrade their customer information management systems, as they implement smart grid. There will be more data management requirements and greater privacy and security requirements for that data.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Customer information management	High	56 kbps	99.00%	100%	2000 ms	0 hours

22. Customer Web Portal

A customer web portal enables customers with access to their daily energy usage and cost information. This information must be posted in a timely and secure manner.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Customer web portal	High	56 kbps	99.00%	100%	2000 ms	0 hours

23. Emergency response

Utilities must have reliable voice and data communications to respond to emergencies, such as power outages. As such, there are stringent requirements for reliability, coverage, latency and back-up power for communications systems to support emergency response.[26]

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Emergency response	Medium	45-250 kbps	99.99%	95%	500 ms	72 hours

24. Routine dispatch

Utilities also need reliable voice communications for routine dispatch. As such there are stringent requirements for reliability, coverage, latency and back-up power for communications systems that support routine dispatch.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Routine dispatch	Medium	9.6-64 kbps	99.99%	95%	500 ms	72 hours

25. Workforce automation

Utilities are increasingly relying on data communications for workforce automation to communicate with their field crews. These communications can include

[26] While back up power requirements for voice communications are high for routine dispatch and emergency restoration scenarios, some utilities use higher requirements (e.g. 72-168 hours) for black start scenarios.

file transfers, which can require increased capacity on the network. These communications must also continue to operate during power outages and in remote areas. Hence bandwidth, back-up power and coverage requirements are high for workforce automation.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Workforce automation	Medium	256 -300 kbps	99.90%	90%	500 ms	8 hours

26. Water Production

Water production includes all aspects of source water infrastructure control and monitoring for potable drinking water supplies. These include water production wells, intake structures, collection pipelines, reservoirs, and treatment facilities. These are generally near real time processes that require automated supervision.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Water Production	High	9.6-56 kbps	99.99%	100%	300-2000 ms	8 hour

27. Water Distribution

Water distribution includes all aspects of remote control and monitoring of finished water infrastructure. These include critical infrastructure control such as pump station operation, remotely operated valve control, reservoir volume monitoring, distribution pipeline flow rates, pressure regulation control, and disinfectant residual monitoring. These mission critical systems are required to provide fire protection capability to the public, as well as safe and adequate quantities of drinking water for personal consumption, public health, and public sanitary services.

Application	Current Functional Requirements					
	Security	Bandwidth	Reliability	Coverage	Latency	Back-up Power
Water Distribution	High	56 kbps	99.99%	100%	30 s	8 hours

V. Technology Options

In its RFI, the DOE asks, "What are the technology options for smart grid and other utility communications?" [27] In response, UTC offers the following description of the different types of technologies that are available.

On the wireline side, utilities use fiber, commercial wireline, and other wireline solutions for their communications systems. Fiber includes a number of technologies, including Sonet based Ethernet, and MPLS based Ethernet. Commercial wireline includes old circuit switched leased lines or new fiber lines. Other wireline solutions include PLC and BPL, which use existing power lines for narrowband and broadband communications. Some of the advantages of using these wireline solutions include: reliability, security, capacity, point-to-point range, and low latency. Some of the disadvantages of using these networks can be (but not in all cases): cost, wide-area coverage, and the possibility of cable cuts.

On the wireless side, utilities use land mobile radio, microwave, unlicensed wireless, commercial wireless and satellite. Land mobile radio systems are analog or digital and operate using licensed radio spectrum in various bands including VHF, UHF,

---

[27] DOE RFI, 75 Fed. Reg. at 26208.

800 MHz, and 900 MHz. Microwave systems are analog or digital and operate using licensed radio spectrum in various bands including 900 MHz MAS, 2 GHz, 6 GHz, 11 GHz, 18 GHz and 23 GHz. Unlicensed wireless are digital and operate in various bands including 902-928 MHz, 2.4 GHz, and 5.8 GHz. Commercial wireless includes TDMA, CDMA and 3G cellular and unlicensed wireless services. Satellite systems are typically fixed VSATs that operate in various bands including the C-band (3-7 GHz), Ku-band (10-18 GHz) and Ka-band (18-31 GHz) band. Some of the advantages of using these wireless solutions include: coverage, cost, and reliability. Some of the disadvantages of using these solutions can be (but not in all cases): capacity, interference, line-of-sight issues, range and latency.

Different technology options will fit into different tiers in the network architecture. These tiers consist of the following:

> **Tier 1 –Core backbone**: The core communications network is the primary path to the utility data center and data processing infrastructure. The core may also be the transport for enterprise applications and will typically be architected in a self-healing ring topology or point-to-point with backup circuit redundancy. The core may have points-of-presence in substations and other company facilities.

> **Tier 2 – Backhaul Distribution:** The distribution tier will aggregate the field area network devices including collectors, RF access points, data concentrators, etc. from the field access tier of the network and provide a delivery transport bridge to the core backbone tier.

> **Tier 3 – Access:** At this tier end-point devices, typically meters, will gain access to the network. It is commonly referred to as the last mile communication or Field Area Network and will be relatively low bandwidth for hand off to the Backhaul Distribution Tier.

> **Tier 4 – HAN:** In home devices will typically communicate with the Access tier through various technologies. The HAN has not yet converged on a standard but is likely to consist of technologies like ZigBee or Home Plug which may connect directly with communication Tier 3, Tier 2 or Tier 1.

Note that some utilities may adopt a network architecture with additional tiers, and some utilities may adopt a network architecture with fewer tiers. These tiers are thus representative of a typical abstract network architecture.

Utilities will use multiple technologies on their communications network, depending largely on the network tier, but also depending on the criticality of the applications the communications network supports. For example, while relatively low capacity, low reliability systems can be tolerated for non-mission critical applications, such AMI, at the edge of the network, utilities absolutely need adequate capacity, low latency, and highly reliable communications for their core backbone networks and for their distribution backhaul networks for mission critical applications, such as Teleprotection and synchrophasor systems. The following analysis examines each tier of the network and the technology solutions that are generally used.

At the Tier 1 core backbone layer, utilities will generally rely on fiber or wireless microwave to carry data from the various smart grid applications back to the utility data center from Tier 2 backhaul distribution points. Fiber and wireless microwave provide high capacity, reliable point-to-point communications. These high capacity networks will be necessary because this is the part of the network where all of the data from the smart grid and other communications applications are aggregated. The amount of data is potentially enormous; one utility estimated that its head-end would collect 1200 MB of data per day from just 136,000 meters and 27,000 collector nodes on its AMI network. That is a relatively small deployment; other utilities are deploying over a million smart meters on their network. In addition to capacity, utilities need low-latency (i.e., less than 20 ms) networks for certain teleprotection applications to monitor and protect the transmission and distribution grids, as well as to support critical voice communications.

At the Tier 2 distribution layer, utilities will tend to use fiber or wireless microwave, but also to a lesser extent: unlicensed wireless, licensed wireless and other private wireline technologies to carry data from collectors to backhaul distribution points. Again, the primary requirement at Tier 2 is for fixed point-to-point capacity and reliability, which explains the use of these long range, robust technologies. However, there is also a need for broader coverage deeper into the network, which explains the use of some of the licensed and unlicensed wireless technologies in Tier 2 primarily for fixed point-to-point communications. These fixed wireline and wireless technologies consistently appear to be the preferred solutions throughout Tier 2 for most applications, whether it's to support AMI at the customer premises, capacitor bank control on the distribution grid, or outage detection at the operations level.

At the Tier 3 access layer, technology solutions become more varied. No longer are fiber and wireless microwave the preferred solutions; instead most utilities use licensed wireless, unlicensed wireless, and some commercial wireless, particularly for AMI (i.e., non-critical) applications. There are also some utilities that use PLC in Tier 3 for AMI and distribution asset management applications. But, most utilities indicated a strong preference to use licensed wireless for this last Tier in the network; followed by unlicensed wireless and finally commercial wireless. This reflects the need at Tier 3 for wide area coverage, generally.

At the Tier 4 home area network layer, unlicensed wireless solutions such as

Zigbee are the predominate solution. Utilities also use PLC as a HAN solution. Both technologies offer relatively slow speed connections, but are also cost-effective and flexible technologies. These technology choices reflect the fact that utilities will be communicating with millions of smart appliances and other HAN end points, which dictates for a flexible architecture that is relatively low cost and low capacity. Reliability is not as much a consideration for HAN applications, which also explains why utilities will use unlicensed technology solutions at the Tier 4 layer, even though they generally prefer licensed solutions at other higher layers of the network where there are more mission critical applications, such as line protection.

VI. Recommendations to Meet Current and Future Communications Needs.

In its RFI, the DOE asks, "What are the recommendations for meeting current and future utility requirements, based on each use case, the technology options that are available and other considerations?"[28] In response, UTC offers the following recommendations, based upon technology options, functional requirements and other considerations.

i. Overview

In order to meet their current and future requirements, utilities will need access to nearly 2 MHz of spectrum for the Tier 3 access layer of the network, at least 30 MHz of spectrum for the Tier 2 backhaul layer of the network, and approximately 900 MHz of spectrum for the Tier 1 core layer of the network. This is based on data provided to UTC by utilities.[29] Utilities provided their estimated throughput requirements at the

[28] DOE RFI, 75 Fed. Reg. at 26208.

[29] *See* Appendix A for the current communications requirements and Appendix B for future communications requirements.

collector or node to support various different applications. They also provided the number of collectors that would support those applications.

UTC estimated the throughput requirements for each tier of the network by taking the total throughput required at the Tier 3 access layer, and then aggregating that traffic upwards to the Tier 2 backhaul layer, and finally to the Tier 1 core layer.[30] UTC then calculated the estimated spectrum requirement to support these throughput requirements, based upon the spectral efficiency of LTE and WiMAX networks (i.e. 5 bits/Hz).[31] Finally, it adjusted the estimated spectrum requirement downward by 50% for the Tier 1 core layer of the network and 30% for the Tier 2 backhaul layer of the network to account for the estimated percentage use of other, alternative technologies besides private wireless for each tier of the network. Note that this methodology does not account for redundant networks which would potentially double the throughput requirements for each application and/or tier of the network. The following describes these estimates in more detail.

ii. Tier 3

UTC estimated the spectrum requirement for the Tier 3 access layer of the network by simply adding together the total throughput requirements for all of the applications. Thus, this is a worst case analysis which presumes that all of the applications would be communicating with the collectors at once. Although the reality

---

[30] *See* Appendix C for the methodology used to calculate the throughput and bandwidth requirements.

[31] *See e.g.* "Driving 4G: WiMAX and LTE," Motorola at p. 3 at http://www.motorola.com/staticfiles/Business/Solutions/Industry%20Solutions/Service%20Providers/Wireless%20Operators/Wireless%20Broadband/wi4%20WiMAX/_Document/StaticFile/a%20Driving_4G__WiMAX_and_LTE.pdf. *See also* Tae-Hyun Kim, "Taking the Journey from WiMAX to LTE" at slide 4 at http://user.juncotommy.com/20100104_agilent_DVD/PDF/2_Taking_the_journey_from_WiMAX_to_LTE_Apr_2009-full_version.pdf.

may be that certain applications would be communicating at regular or sporadic intervals, utilities must design their networks for such a worst case scenario. This is particularly true for mission-critical applications, which must be available when called upon by the utility. Based on this scenario, UTC estimated that the total throughput at the Tier 3 access layer would be approximately 2.2 mbps currently and 9 mbps in the future, and that this would require approximately .50 MHz of spectrum currently and 2 MHz in the future using LTE or WiMAX technologies.

The private wireless technologies used at the Tier 3 layer will consist primarily of licensed and unlicensed wireless. Licensed wireless will consist primarily of land mobile radio for all types of applications, particularly mission critical applications such as emergency restoration, line protection and control, and wide area situational awareness. Unlicensed wireless will consist primarily of wireless mesh for short range communications such as for metering, and other protocols for longer range communications, such as for distribution automation. As this layer of the network will require wide-area coverage, most technologies will rely on spectrum below 2 GHz, and as such wireless microwave will be limited to only a few fixed point to point applications, such as transmission line protection.

The wireline and other alternative technologies to private wireless at the Tier 3 access layer will consist of commercial wireline and wireless, and PLC or BPL. Commercial wireless is suitable in this layer of the network for certain non-mission critical applications, such as AMI and some of its associated applications, such as AMR and real-time pricing. PLC or BPL may also be used for these applications, as well as other mission-critical applications, such as demand response and transformer monitoring. The extent of the use of these technologies will depend in large part on the criticality of the applications, as well as other local and regional factors, such as customer density, grid topology, foliage and terrain. For example, PLC or BPL may be preferred in areas where lack of wireless coverage and/or high customer density and foliage are prevalent. Conversely, commercial wireless may be preferred in areas where terrain and low customer density would make it a cost-effective alternative for wide area coverage.

iii. Tier 2

UTC estimated the spectrum requirements for the Tier 2 backhaul layer of the network by multiplying the throughput requirement for each application by the average number of collectors for each application. That figure represents the total maximum throughput on the Tier 2 layer. UTC divided that total throughput figure by the average number of collectors for each segment of the network for each application (i.e., 36 collectors/segment), and concluded that each segment of the Tier 2 layer must be able to handle 8.8 mbps throughput currently and 252 mbps throughput in the future. From that, UTC estimated that approximately 1.2 MHz currently and approximately 30 MHz in the future would be needed at the Tier 2 layer of the network, using a LTE or WiMAX network.

The wireless technologies at the Tier 2 backhaul layer will consist of private licensed radio and microwave and unlicensed point-to-multipoint, and to a lesser extent, commercial wireless. Because of the need for high capacity communications and long range backhaul, wireless microwave and unlicensed topologies will be the primary technology choices for this layer of the network. Utilities currently use 900 MHz MAS channels and 2.4 GHz and 5.8 GHz channels for these technologies. In addition, private licensed radio can also provide long range, wide area coverage, albeit less capacity for backhaul. Utilities currently use a variety of spectrum bands for private radio applications at this tier in the network, including 220 MHz, 150-512 MHz PLMR, 700 MHz, 800/900 MHz and other private radio spectrum. While these bands provide relatively favorable propagation, they are limited in terms of capacity.

The wireline and other alternative technologies to private wireless at the Tier 2 backhaul layer will consist of fiber and to a lesser extent, commercial wireline and wireless. Fiber is ideal for backhauling traffic, and many utilities are using SONET architectures for network reliability, but it is also expensive compared to wireless alternatives and may not be cost-effective for providing wide-area connectivity to many collectors, such as for AMI or distributed generation. Conversely, commercial wireless can be suitable in this layer of the network for backhauling certain non-mission critical applications, such as AMI and some of its associated applications, such as AMR and dynamic pricing. Commercial wireline alternatives, such as leased circuits, can also be used at this layer for such applications as remote distribution substation monitoring; however such links will be limited to unique situations where they are cost effective and the impact of the loss of communications would be minimal. UTC estimates that utilities will use these alternative technologies for approximately 30% of their throughput requirements at this layer of the network, depending on such factors as whether sufficient private wireless capacity and coverage is available and whether loss of backhaul would affect the reliability of utility operations.

iv. Tier 1

UTC estimated the spectrum requirements for the Tier 1 core layer of the network by multiplying the throughput requirement for each application by the average number of collectors for each application. That figure represents the total maximum throughput on the Tier 1 layer, which is 316 Mbps throughput currently and 9.09 Gbps throughput in the future. From that, UTC estimated that approximately 32 MHz currently and 909 MHz in the future would be needed to support these throughput requirements at the Tier 1 core layer of the network, using a LTE or WiMAX network.

The wireless technologies at the Tier 1 core layer will consist almost entirely of private microwave. Utilities will need exceptionally high capacity fixed point-to-point communications at this layer, and other private wireless technologies may not be able to provide the same capacity. There may be some potential use of unlicensed wireless point-to-point at this layer of the network, and the extent of this use will be determined by the need for licensing flexibility and the availability of microwave spectrum. Utilities currently use 2 GHz, 6 GHz or higher spectrum for their microwave links, and they use 2.4 GHz or 5.8 GHz spectrum for their unlicensed point-to-point communications. Any future spectrum allocations for these technologies should be in similar spectrum bands, preferably lower frequency range for better propagation and lower LOS issues.

The wireline and other alternative technologies to private wireless at the Tier 1 core layer will consist almost entirely of fiber. Again, fiber is ideal for backhauling traffic, and many utilities are using SONET architectures for network reliability, and its use at the core layer of the network is particularly appropriate, given the exceptionally high capacity and reliability requirements there. UTC estimates that utilities will use these alternative technologies for approximately 50% of their throughput requirements at this layer of the network, depending on such factors as whether sufficient private wireless capacity and coverage is available and whether loss of backhaul would affect the reliability of utility operations.

VII. Commercial Networks

In the RFI, the DOE asks, "To what extent can existing commercial networks satisfy the utilities' communications needs?" It also asks, "What, if any, improvements to the commercial networks can be made to satisfy the utilities' communications needs?"[32] UTC offers the following assessment of commercial networks and suggestions for improvements.

A. Can commercial networks meet utilities' needs?

As explained above, UTC believes that there are applications that can be served by commercial wireline and wireless networks, particularly given that the growing demands for utilities to rely on two-way communications could quickly outpace utilities' own internal communications networks capabilities. Our members are eager to work with technology partners to help fulfill the advanced communication requirements posed by the smart grid.

However, the utility industry faces unique safety, reliability and security issues that any outside telecom carrier must take into account in order to ensure the stability and ongoing functioning of the nation's electric grids. In addition, these requirements vary across the different components of the grid. More stringent and exacting requirements apply for communications applications inside critical control networks than

[32] DOE RFI, 75 Fed. Reg. at 26208.

might apply, say, at the edge of the network where metering device communications occur. No one-size-fits-all approach applies across utility functional domains and any analysis of how carriers and utilities work together must take this central fact into account.

Telecom providers and utilities must team to ensure that minimum safety, security and reliability requirements are met for every communications application, regardless of where in the network the application resides. To the extent that these requirements, as discussed below in more detail, could necessitate upgrades in carrier communications capabilities in order for the carrier to meet minimum requirements, carriers should make informed and detailed business decisions regarding the level of investments they can cost-justify in order to serve the utility industry.

At the outset, one issue must be clarified. Utilities make their communications investment decisions on the basis of reliability, security, safety and cost-benefit factors. Some utility industry detractors contend that the nature of rate-of-return regulation inherently tilts the investment decision toward utility construction and ownership of communications networks and away from reliance on telecom providers. In the experience of UTC's members, nothing could be farther from the truth when it comes to the communications networks that drive the electric grid.

First, utilities must meet stiff technology mandates placed on the utility industry by regulators and other groups, such as NERC, and no amount of regulatory financial incentives or disincentives can alter this need. Secondly, state regulators keep tight reins on utility spending, forcing utilities to justify every capital investment or operating expense that can impact ratepayers, however large or small. To the extent that ratepayers might benefit from a non-owned communications infrastructure regulators will push to ensure that this alternative is explored. Finally, in comparison to the massive expenditures utilities make on building power plants and other core electricity generating assets, communications network spending is, indeed, a very small expense for most utilities. Therefore, few utilities are motivated to go through the burdensome process of recouping capital investments made in communications networks solely to earn a regulated rate of return on that investment, particularly given the more compelling safety, security, reliability and regulatory requirement needs that utilities must fulfill. In short, rate-of-return regulation is simply not a factor for the utility industry when deciding whether to build or outsource communications capabilities.

a. Survivability

Electric service is perhaps the most crucial link in the disaster recovery chain in the aftermath of a catastrophic event, such as a major hurricane, snow storm or ice storm. Communications networks are crucial to the survivability of electric systems during major weather and other events and utilities have built their communications networks to survive the harshest conditions. Communications link redundancy, multi-week diesel and oil power back-up facilities and extensive contingency planning are just some of the components that ensure the survivability of utility communications networks during crucial periods. To the extent that utilities can rely on carriers for critical communications functions, the telecom providers must be prepared to meet these and other requirements.

b. Availability

As discussed above, the continued functioning or quick restoration of the electric grid is critical during times of emergencies. To the extent that utilities rely on carriers to provide any form of communications service, the service must be available during times of crisis or emergency, or at the minimum must be made available to utilities on priority access terms once the communications service has been restored by the carriers. To the extent that this availability and priority access is not available, utilities will be reluctant to rely on a telecom provider for critical communications functions.

c. Coverage

One key characteristic of utilities is that service, particularly electric service, can extend to all portions of a service area, however sparsely populated. Utility communications services must therefore be available throughout the network, including remote areas with low populations. If utilities are to rely on carriers for any communications services that are central to operations in these remote areas, the carriers must have coverage to span the geographic territory. This is particularly true of wireless communications services, which are typically designed and built to hit the most densely populated portions of utility service areas but not necessarily the wide geographic expanses of these service areas.

d. Latency

Utilities need low latency communications, particularly for mission-critical voice and data applications, such as emergency restoration, teleprotection systems and substation monitoring and control. To the extent that utilities rely on telecom providers to deliver communications services on a contract basis, the telecom networks must be developed in a way to ensure the required levels of latency, particularly for core functions that involve emergency restoration, teleprotection systems and substation monitoring and control.

e. Security

Utilities need to meet stringent requirements for security, both physical and cyber security. As noted above, these requirements include regulatory rules that pose stiff fines for non-compliance. This raises two issues for security: control and liability. Utilities are frequently reluctant to rely on commercial carriers, because doing so puts them out of control over networks, which may be considered critical assets or critical cyber assets under NERC CIP standards. To the extent they may be willing to rely on commercial carriers, utilities need contractual provisions which would protect them against liability from regulatory penalties and legal damages.

f. Technological Obsolescence

Another factor that must be considered when supplying communications services to utilities is the length of time that most utilities keep technologies in place. Due to lengthy depreciation schedules typically mandated by public utility commissions, most utilities abide by longer-range useful lives for equipment and capitalized investments than do other institutional customers served by carriers. Moreover, maintaining stability and security in the electric grid often dictates far more gradual transitions to newer forms of technologies. Therefore, telecom providers, which typically keep pace with more rapid technological innovation developments, must consider relatively lengthy commitments to servicing and supporting technologies if they are to support the utility industry.

B. Suggestions for improvements of commercial networks.

UTC and the utility industry are working with carriers to identify the most fruitful areas of communications collaboration so that utilities can count on their telecom technology providers to help them transition into the smart grid area. As evidence of this collaboration, UTC is conducting a study, sponsored by Verizon, that will be published in September, 2010 and made available to all UTC members.[33] The study will be guided by focus-group discussions with top telecom technologists at UTC member utility companies, followed by in-depth questionnaires and background research into the business and technical issues shaping utility telecommunications. The study will provide "key recommendations and approaches on how utilities and the communications industry should approach critical infrastructure communications in the era of the smart grid."[34] As such, the study is a genuine effort to start the serious discussions with carriers and to open up a dialogue, recognizing that utilities will need to work with technology partners, such as carriers, in order to meet a variety of communications challenges facing the industry, including smart grid and emergency response requirements.

VIII. Evolution and Expansion of Communications Needs with Growth in Smart Grid.

In the RFI, the DOE asks, "As the Smart Grid grows and expands, how do the electric utilities foresee their communications requirements as growing and adapting along with the expansion of Smart Grid applications?"[35] In response, UTC offers the following assessments.

Utility communications needs for voice and data will increase over the next five

---

[33] *See* "Utilities Telecom Council and Verizon to Study Utility Communications Needs," Press Release, June 17, 2010 at http://www.verizonbusiness.com/about/news/pr-25557-en-Utilities+Telecom+Council+and+Verizon+to+Study+Utility+Communications+Needs.xml.

[34] *Id*.

[35] DOE RFI, 75 Fed. Reg. at 26208.

years, driven by the sheer volume of data from existing applications as networks are fully deployed and by new applications, such as PEVs, DG and AMI that will be increasingly pervasive across the grid. UTC estimates that data throughput requirements will increase by a factor of 20 over their current levels over the next five years. This is consistent with estimates by individual utilities. For example, James Ingraham, Vice President of Strategic Research, Electric Power Board of Chattanooga, (EPB) recently estimated that, "[w]e will go from eleven million data points per year to six billion data points per year," when EPB completes its smart grid network.[36] Therefore, as utilities build out smart grid and add new applications, they will need robust communications networks, including access to suitable spectrum to meet their requirements.

Utilities are building out their smart grid networks now and many will be fully deployed by 2015. According to GTM Research, the top 15 North American AMI deployments represent roughly 41.1 million smart meters scheduled to be deployed by 2015.[37] More than 250 million meters worldwide are expected to be deployed by 2015 representing a penetration rate of 18% of all electrical meters by that time, up from 46 million in 2008, according to Pike Research.[38] Cumulative global spending on smart grid technologies worldwide is expected to rise to $200 billion during the period from

---

36 Remarks of James Ingraham during the Department of Energy's Workshop on the Communications Needs of Utilities for Smart Grid, June 17, 2009, as reported in the UTC Insight at http://www.utcinsight.org/content/doe-roundtable-more-productive-dialog-needed-utility-communications-needs.

37 *Smart Grid in 2010: Market Segments, Applications and Industry Players*" GTM Research, (July 2009) at http://www.gtmresearch.com/report/smart-grid-in-2010.

38 *Smart Meters* Pike Research (November 2009) at http://www.pikeresearch.com/research/smart-meters.

2008 to 2015.[39]

In addition, new applications such as PHEVs, DG and AMI will become increasingly pervasive in the future, which will accelerate the growth in data over smart grid communications networks. As more fully described above, utilities will need smart grid capabilities to control the charging of PEVs in order to balance load and maintain electric reliability.[40] For similar reasons, they will need smart grid to control variable sources of distributed energy, such as solar and wind power, and NREL recently estimated that utilities could integrate up to 35% of their supply from wind and solar, if they implement wide area coordination and other smart grid capabilities.[41]

While increasing communications demands can be met in part by new technologies and increased efficiencies, access to additional spectrum will be needed as well. The FCC recently estimated that 10 MHz of spectrum would meet the routine needs of public safety for broadband communications, but that this would not be enough to meet their needs during emergencies.[42] This estimate was based on the build-out of a federally funded $5.5B nationwide LTE network composed of thousands of low-site cell towers designed to increase capacity using a minimum amount of spectrum. While this network would use spectrum efficiently, the infrastructure required would drive up the cost and complexity of the network significantly. It is unclear whether a similar

---

[39] *Smart Grid Technologies* Pike Research (December 2009) at http://www.pikeresearch.com/newsroom/smart-grid-investment-to-total-200-billion-worldwide-by-2015.

[40] Mike Rowand*, Plug-In Vehicles and the Smart Grid—Duke Energy Perspective* (Aug. 2009) at http://car.eng.ohio-state.edu/doc/smartatcar/PHEV_News_vol2_num3.pdf.

[41] Western Wind and Solar Integration Study, National Renewable Energy Laboratory (May 2010) at http://www.nrel.gov/wind/systemsintegration/wwsis.html.

[42] *See* "The Public Safety Nationwide Interoperable Broadband Network: A New Model for Capacity Performance and Cost," FCC Whitepaper, June 2010 at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-298799A1.pdf

network design would be cost effective or appropriate for utilities. Conversely, access to additional spectrum would enable utilities to deploy wireless networks that meet their requirements at lower cost.

As explained more fully above, UTC estimates that at least an additional 30 MHz of spectrum in bands below 2 GHz will be necessary to meet their communications needs in the next five years. This includes spectrum for both voice and data applications for emergency response communications, as well as smart grid. This spectrum would fill the gap that currently exists at the Tier 2 backhaul layer of the network for wide area, high capacity communications. Spectrum at lower frequency ranges (i.e., below 1 GHz) is particularly important at the edge of the network (e.g., Tier 3 access layer) to provide signal penetration into buildings and to overcome attenuation from other factors, such as foliage and moisture. Finally, more spectrum may be needed, particularly at the Tier 1 core layer of the network for fixed point-to-point communications to handle Gigabit speeds. These spectrum requirements may need to be increased further to account for network redundancies and additional traffic from HAN applications.

WHEREFORE, the premises considered, UTC thanks the Department of Energy for initiating this study into the communications needs of utilities, and looks forward to working with DOE to meet utility communications needs, including access to at least 30 MHz of spectrum for smart grid and emergency response communications.

Respectfully submitted,

Utilities Telecom Council

_ss____________________
Michael Oldak, Vice President & General Counsel
Brett Kilbourne, Director of Regulatory Service & Associate Counsel
Utilities Telecom Council
1901 Pennsylvania Avenue, NW
Fifth Floor
Washington, DC 20006
202-872-0030

July 12, 2010

APPENDIX A

CURRENT COMMUNICATIONS NEEDS				Estimated Number of Communications Nodes to be Deployed for Each Application (e.g. thousands of collectors)	Estimated Number of End Point Devices to be Deployed for Each Application (e.g. millions of meters)	Functional Requirements (See Definitions Below) — AC Independence	Bandwidth Throughput Estimated	Coverage	Latency	Reliability	Security
						Quantified Estimates					
Applications	Customer	Advanced Metering	Remote Meter Reading (based on hourly reads)	735	533,667	1	85	77.50%	1,667	99.40%	5
			Direct Load Control	735	733,333	1	55	70.00%	3,000	99.50%	4
			Real time pricing	735	335,059	1	78	73.33%	2,000	99.50%	4
		Distributed Generation		251	248	0	33	96.67%	1,150	99.33%	4
		PHEV Integration	At the customer premises	80	20	0	33	60.00%	2,000	99.45%	4
			At charging stations	81	24	0	33	60.00%	2,000	99.45%	4
		Pricing Signals to Smart Appliances		90	500,150	0	33	60.00%	1,500	99.45%	4
		in-Home Display of Customer		92	501,650	0	33	60.00%	1,500	99.45%	4
	Distribution	Automated Feeder Switching		1	136	16	78	48.50%	234	99.99%	5
		Capacitor Bank Control		81	2,325	0	40	68.33%	2,500	98.17%	3
		Fault Current Indicator		76	29	4	10	57.50%	1,100	99.50%	3
		Transformer Monitoring		75	250,029	0	56	100.00%	1,001	99.00%	5
		Voltage and Current Monitoring		130	250,541	3	78	98.33%	2,000	99.50%	4
		Renewable Energy/Distributed		1	103	12	25	73.00%	600	99.83%	5
		Network Protection Monitoring		76	250,057	4	55	99.67%	2,000	99.50%	4
	Operations	AMI Network Management		315	333,882	2	78	73.33%	1,500	99.30%	5
		Remote Connect/Disconnect		735	800,000	0	38	60.00%	3,500	99.00%	5
		Meter Data Management		150	1,000,000	0	56	100.00%	2,000	99.50%	5
		Outage Management		150	1,000,000	0	56	100.00%	2,000	98.80%	5
		Distribution Asset Management		150	250,000	0	56	100.00%	2,000	99.00%	5
		Distribution Network Management									
		Demand Response		150	502,500	0	38	99.50%	1,025	99.25%	5
	Transmission	Wide Area Situational Awareness		1	3	24	328	100.00%	200	100.00%	5
		Line Protection and Control		60	440	15	225	99.75%	72	100.00%	5
	Service Provider	Billing		150	1,000,000	0	56	100.00%	2,000	99.00%	5
		Customer Information		150	1,000,000	0	56	100.00%	2,000	98.50%	5
		Consumer Web Portal		4	1,000,000	0	56	100.00%	2,000	98.50%	5
									500	99.99%	
									500	99.99%	
	Other	Emergency Response		67	1,833	72	148	100%	2,000	99.83%	3
		Routine Dispatch		67	1,933	72	27	100%	1,000	99.87%	3
		Workforce Automation		110	1,533	28	252	100%	525	98.00%	4

Network Tiers	Throughput Requirement (kbps)	Bandwidth Requirement (kHz)	Bandwidth Requirement (MHz)
Tier 1	316,833	31,683	31.68
Tier 2	8,801	1,232	1.23
Tier 3	2,194	439	0.44

Definitions (please report your data based on the definitions below)

Functional Requirements	
AC Independence	After the loss of electric service what applications need backup power to provide restoration and for how long (measured in minimum hours)?
Bandwidth	Estimated or tested data rates are required to support this application during normal and emergency conditions (measured in kilobits per second (kbps) at the node or collection point)
Coverage	Geographic areas that these networks are required to operate (estimated percentage of service territory).
Latency	How quickly does field data need to be updated (measured in milliseconds (ms) from endpoint-to-endpoint (i.e. not roundtrip))?
Reliability	How many service interuptions are tolerated and how well must this network provide accurate data (as a percentage of overall traffic (e.g. 99.999%)?
Security	How secure must the network be from cyber and physical attacks (one a scale of 1-5 with 1 being low and 5 being high)?

APPENDIX B

FUTURE COMMUNICATIONS NEEDS

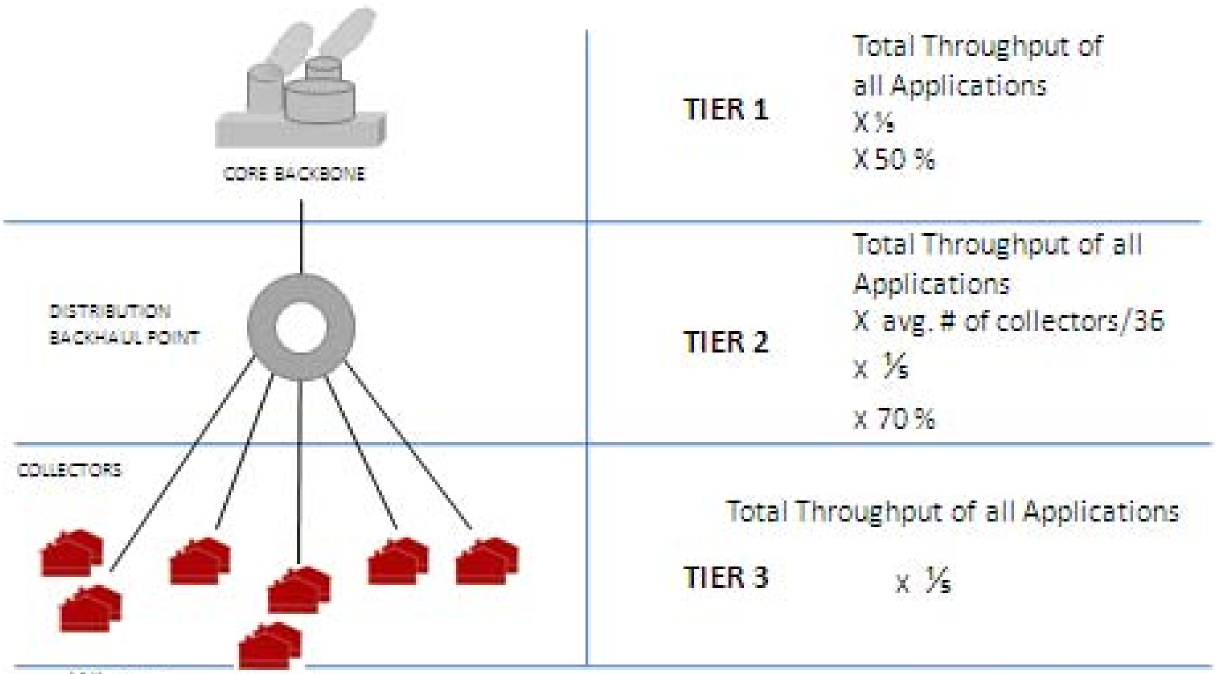
Applications	Area	Application	Estimated Number of Communications Nodes to be Deployed for Each Application (e.g. thousands of collectors)	Estimated Number of End Point Devices to be Deployed for Each Application (e.g. millions of meters)	Functional Requirements (See Definitions Below): AC Independence (hours)	Bandwidth Throughput Estimated per Node	Coverage (% of service area)	Latency (msec)	Reliability (%)	Security (1 low 5 high)
					Quantified Estimates					
Applications	Customer	Advanced Metering: Remote Meter Reading (based on hourly reads)	2,475	2,500,000	1	327	85.00%	1,500	99.68%	5
		Advanced Metering: Direct Load Control	2,350	1,428,400	1	304	85.00%	2,500	99.66%	4
		Advanced Metering: Real time pricing	2,633	1,232,000	1	327	85.00%	1,500	99.75%	5
		Distributed Generation Management	875	1,583	0	355	96.67%	1,100	99.50%	5
		PHEV Integration: At the customer premises	1,250	4,000	0	316	100.00%	1,333	99.60%	4
		PHEV Integration: At charging stations	867	667	0	316	100.00%	1,333	99.62%	5
		Pricing Signals to Smart Appliances	2,633	932,750	0	304	100.00%	1,333	99.25%	4
		in-Home Display of Customer Usage	2,633	1,104,000	0	304	100.00%	1,333	99.40%	4
	Distribution	Automated Feeder Switching	1,001	814	12	139	66.75%	450	99.99%	5
		Capacitor Bank Control	837	3,635	0	127	71.25%	900	98.50%	4
		Fault Current Indicator	834	1,033	3	105	71.25%	825	99.50%	4
		Transformer Monitoring	833	875,081	0	78	100.00%	2,000	99.50%	5
		Voltage and Current Monitoring	877	877,948	3	139	100.00%	2,500	99.62%	4
		Renewable Energy/Distributed Generation	1,001	3,343	9	341	80.00%	1,800	99.75%	5
		Network Protection Monitoring	867	877,025	3	116	75.75%	2,250	99.60%	4
	Operations	AMI Network Management	893	1,148,080	3	327	84.00%	1,250	99.68%	5
		Remote Connect/Disconnect	893	1,105,080	1	306	84.00%	2,250	99.50%	5
		Meter Data Management	1,250	1,900,000	3	402	100.00%	1,333	99.62%	5
		Outage Management	1,250	1,900,000	3	402	100.00%	1,333	99.62%	5
		Distribution Asset Management	835	586,667	2	103	99.50%	1,167	99.25%	4
		Distribution Network Management	1,002	3,403	18	103	62.75%	410	99.50%	5
		Demand Response	1,250	2,200,000	0	103	100.00%	1,333	99.50%	5
	Transmission	Wide Area Situational Awareness (PMUs)	100	54	15	800	100.00%	510	100.00%	5
		Line Protection and Control	1,000	793	15	552	100.00%	600	100.00%	5
	Service Provider	Billing	500	3,500,000	0	553	100.00%	600	99.95%	5
		Customer Information Management	500	3,500,000	0	553	100.00%	510	99.95%	5
		Consumer Web Portal	4	3,500,000	0	106	100.00%	2,000	99.45%	5
	Other	Emergency Response	67	1,400	51	502	97.50%	750	99.99%	3
		Routine Dispatch	67	1,453	51	422	97.50%	750	99.99%	3
		Workforce Automation	110	1,625	40	253	91.67%	3,000	99.90%	4

Network Tiers	Throughput Requirement (kbps)	Bandwidth Requirement (kHz)	Bandwidth Requirement (MHz)
Tier 1	9,087,033.38	908,703.34	908.70
Tier 2	252,417.59	35,338.46	35.34
Tier 3	9,083.67	1,816.73	1.82

Definitions (please report your data based on the definitions below)

Functional Requirements	Definition
AC Independence	After the loss of electric service what applications need backup power to provide restoration and for how long (measured in minimum hours)?
Bandwidth	Estimated or tested data rates are required to support this application during normal and emergency conditions (measured in kilobits per second (kbps) at the node or collection point)
Coverage	Geographic areas that these networks are required to operate (estimated percentage of service territory).
Latency	How quickly does field data need to be updated (measured in milliseconds (ms) from endpoint-to-endpoint (i.e. not roundtrip))?
Reliability	How many service interuptions are tolerated and how well must this network provide accurate data (as a percentage of overall traffic (e.g. 99.999%)?
Security	How secure must the network be from cyber and physical attacks (one a scale of 1-5 with 1 being low and 5 being high)?

APPENDIX C



Where:

- ⅕ = spectral efficiency conversion rate for throughput to hertz (i.e. 5 bits/hertz/second).
- Avg. # of collectors/36 = the number of collectors in a branch of the network for a given application.
- 70% = the percentage of traffic that is likely to be carried using wireless technologies at Tier 2
- 50% = the percentage of traffic that is likely to be carried using wireless technologies at Tier 1