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| **Radiocommunication Study Groups** |  |
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| Utility Communication Systems | |

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*{Editor’s Note: explicit review by the author needed related to (1) where to replace 5G by IMT‑2020 and (2) review of possible related market references*

TABLE OF CONTENTS

***Page***

[1 Scope 5](#_Toc56588484)

[2 Related documents 5](#_Toc56588485)

[3 List of definitions, acronyms and abbreviations 5](#_Toc56588486)

[3.1 Definitions 5](#_Toc56588487)

[3.2 Acronyms 7](#_Toc56588488)

[4 Utility modernization/digital transformation 8](#_Toc56588489)

[4.1 Electricity Utility Modernization 8](#_Toc56588490)

[4.2 Water and Gas Utilities Digital Transformation 8](#_Toc56588491)

[5 Overview of smarter electricity networks 9](#_Toc56588492)

[5.1 Distribution network assets 11](#_Toc56588493)

[5.2 Opportunities and challenges with connected power distribution grids 12](#_Toc56588494)

[6 Smart Network Applications & Services 13](#_Toc56588495)

[6.1 Supervisory Control and Data Acquisition (SCADA) 13](#_Toc56588496)

[6.2 Advanced Metering Infrastructure (AMI) 13](#_Toc56588497)

[6.3 Demand Response (DR) 15](#_Toc56588498)

[6.5 Distributed Generation (DG) 16](#_Toc56588499)

[6.6 Distributed Storage (DS) 17](#_Toc56588500)

[6.7 Electric Vehicle Charging Stations (EVCS) 17](#_Toc56588501)

[6.8 Synchrophasors 17](#_Toc56588502)

[6.9 Dynamic Line Rating (DLR) 18](#_Toc56588503)

[6.10 Utility Engineering and Operations 18](#_Toc56588504)

[6.11 Closed Circuit Television (CCTV) 18](#_Toc56588505)

[6.12 Mobile Workforce (MWF) 18](#_Toc56588506)

[6.13 Protection Applications 18](#_Toc56588507)

[6.14 Utility Business Voice 19](#_Toc56588508)

[6.15 Utility Business Data 19](#_Toc56588509)

[6.16 Digital Disturbance Recorder (DDR) 19](#_Toc56588510)

[7 Utilities Integrated Communications Network Architecture 19](#_Toc56588511)

[7.1 Traffic Aggregation at Network Endpoints 20](#_Toc56588512)

[7.2 Core Network (WAN) 21](#_Toc56588513)

[7.3 Access Networks (FANs) 21](#_Toc56588514)

[7.4 Power Line Communication 22](#_Toc56588515)

[7.5 Evolution of Substation LAN Architecture 22](#_Toc56588516)

[8 Utility Communications Objectives 25](#_Toc56588517)

[8.1 Introduction 25](#_Toc56588518)

[8.2 Communications Objectives of Smart Grid Communications Technologies 27](#_Toc56588519)

[8.3 Operational Requirements for Modern Utilities 29](#_Toc56588520)

[8.4 Utility Radio Communication Systems 30](#_Toc56588521)

[9 Utility Radio Communications Systems 31](#_Toc56588522)

[10 Spectrum Related Aspects 33](#_Toc56588523)

[10.1 Utility spectrum bands and applications 34](#_Toc56588524)

[10.2 Shared use of existing bands [and access to additional spectrum bands 34](#_Toc56588525)

[10.3 Suitable radio spectrum 35](#_Toc56588526)

[10.4 The Case for Sharing Spectrum 35](#_Toc56588527)

[10.5 Commercial Network Providers 35](#_Toc56588528)

[10.6 Socio-economic benefits 36](#_Toc56588529)

[11 Summary 37](#_Toc56588530)

[Annex 1 - General technical and operational characteristics of mission critical utility applications 40](#_Toc56588531)

[1 Introduction 40](#_Toc56588532)

[1.1 Protection Applications 40](#_Toc56588533)

[1.2 SCADA 42](#_Toc56588534)

[1.3 Operational voice and data 43](#_Toc56588535)

[1.4 Remote Metering 43](#_Toc56588536)

[1.5 Digital Disturbance Recorder (DDR) 44](#_Toc56588537)

[2 Description of Existing Communications Systems to Support Utility Applications 45](#_Toc56588538)

[3 Complementary Survey 47](#_Toc56588539)

[Annex 2 - An Overview of a smart water management system 50](#_Toc56588540)

[1 Introduction 50](#_Toc56588541)

[2 Smart water management components 50](#_Toc56588542)

[2.1 Digital output instruments (meters and sensors) 50](#_Toc56588543)

[2.2 Supervisory control and data acquisition (SCADA) systems 50](#_Toc56588544)

[2.3 Geographic information system (GIS) 50](#_Toc56588545)

[2.4 Application software 51](#_Toc56588546)

[Annex 3 - Natural Gas example: An overview of Transport, Storage and Distribution 52](#_Toc56588547)

[3.1 Transmission Pipes 52](#_Toc56588548)

[3.2 Compressor Stations 52](#_Toc56588549)

[3.3 Metering Stations 53](#_Toc56588550)

[3.4 Valves 53](#_Toc56588551)

[3.5 Control Stations and SCADA Systems 53](#_Toc56588552)

[3.6 Storage 53](#_Toc56588553)

[3.7 Distribution 54](#_Toc56588554)

[3.8 Delivery of natural gas 54](#_Toc56588555)

# 1 Scope

This Report describes radiocommunication systems and applications that can be used by electric, gas and water utilities, and highlights how utilities can utilize these systems to support their needs for mobile voice and data communications as well as fixed wireless access.

# 2 Related documents

**ITU-R Recommendations:**

ITU-R [F.755](https://www.itu.int/rec/R-REC-F.755/en) – *Point-to-Multipoint Systems in the Fixed Service*

ITU-R [F.701](https://www.itu.int/rec/R-REC-F.701/en) – *Radio-frequency channel arrangements for digital point-to-multipoint radio systems operating in the frequency range 1 350 to 2 690 MHz*

**ITU-R Reports:**

ITU-R [M.2014](https://www.itu.int/pub/R-REP-M.2014) – *Digital Land Mobile Systems for dispatch traffic*

ITU-R [SM.2351](https://www.itu.int/pub/R-REP-SM.2351) – *Smart grid utility management systems*

[ITU-R M.2440](https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2440-2018-PDF-E.pdf) – *The use of the terrestrial component of International Mobile Telecommunications (IMT) for Narrowband and Broadband Machine Type Communications*

[ITU-R M.2441](https://www.itu.int/pub/R-REP-M.2441) –*Emerging usage of the terrestrial component of International Mobile Telecommunication (IMT)*

[ITU-R M.2474](https://www.itu.int/pub/R-REP-M.2474) – *Conventional digital land mobile radio systems*

**ITU-R Handbooks:**

Land Mobile (including Wireless Access) - Volume 3: Dispatch and Advanced Messaging Systems

Land Mobile (including Wireless Access) - Volume 1: Fixed Wireless Access

**ITU-T Reports and Recommendations:**

ITU-T Technical Paper: Applications of ITU-T G.9960, ITU-T G.9961 transceivers for Smart Grid applications: Advanced metering infrastructure, energy management in the home and electric vehicles.

# 3 List of definitions, acronyms and abbreviations

## 3.1 Definitions

Table 1

Definitions

|  |  |
| --- | --- |
| [**Smart Grid**](https://www.cpqd.com.br/en/innovation/smart-grid/) | This platform comprises the technologies applied to electrical grids (generation, transmission and distribution) with the purpose of improving decision making, data generation and managing information based on the increased level of automation and communication |
| **Demand response** | Consists of methods and algorithms to minimize the energy load by reducing consumption during high demand peaks. |
| **Advanced energy measurement** | Technology to electronically measure energy consumption, allowing consumers to interact with the supply system (active participation in managing electricity). |
| **Power Line Communication – PLC** | Technology for communication over the electrical grid’s transmission and distribution lines. |
| **Electrical grid automation** | Algorithms and methods that allow the optimization and automatic restoration of power after power outages or load redistributions |
| **Alternative renewable energy sources** | Technology to generate electric energy using natural sources such as the sun, the wind and geothermal energy, which are alternative renewable (naturally replenished) resources. |
| **Energy efficiency** | Methods, equipment, and algorithms for improving the efficiency of electrical equipment and networks, minimizing technical losses (electrical) and increasing efficiency |
| **Power quality** | Monitoring and evaluating electrical parameters of energy networks to characterize the quality of the service and of the distributed energy |
| **IEC 61850** | International standard for power systems substations automation based on Ethernet LANs |
| **Monitoring of the electrical infrastructure and equipment** | Methods, sensors and algorithms used to monitor electrical equipment parameters to evaluate the operating conditions and useful life of assets |
| **Distributed Generation** | Generation of electricity located close to the load (or consumers) they serve, typically using renewable energy sources. |
| **Information and Communications Technology (ICT) Networks** | Telecommunications networks that carry data, video, and other services. Utilities provision these networks to underpin their transmission and distribution infrastructure for daily reliability needs, situational awareness, grid modernization, cyber and physical protection, Supervisory Control and Data Acquisition (SCADA) communications, storm response and recovery, and much more. |
| **Mission Critical Applications** | An application is mission-critical when it is essential to operation. Mission-critical applications should not experience any downtime when end users are likely to utilize them |
| **Business Critical Applications** | An application is business-critical when it is essential to business operation. Business-critical applications should not experience significant downtime and are expected to be available all time, resilient, redundant and secure. |
| **Supervisory Control and Data Acquisition (SCADA) System** | Often referred to only as its acronym, Supervisory Control and Data Acquisition (SCADA) Systems are computerized industrial control systems that connect large industrial pieces of equipment with centralized facilities to transmit data. For utilities, SCADA systems refer to the data networks that connect remote pieces of infrastructure to control centre, providing utilities with real-time situational awareness on the status of their systems. Utilities deploy ICT networks to run these SCADA systems. SCADA systems can include Energy Management Systems which optimize generation and high-voltage transmission of energy, for example. |
| **Resilient Communications** | The ability of a utility’s ICT network to prepare for, withstand, and recover from natural or manmade disasters. Utility ICT networks are essential for daily reliability along with the ability to safely restore service after an event. These networks are intended to be, and are, more reliable than those operated by traditional telecommunications providers. |
| **Synchrophasors** | Sensors and algorithms to provide additional information currently not available via standard SCADA installation allowing to operate the bulk electric system more efficiently |
| **Utilities** | Entities that provide electricity, gas and water services as public services. |

## 3.2 Acronyms

Table 2

Acronyms

| Abbreviation | Definition |
| --- | --- |
| 3GPP | The 3rd Generation Partnership Project |
| ADR | Automated Demand Response |
| AMI | Advanced Metering Infrastructure |
| AR | Access Router |
| BPS | Bits Per Second |
| BAN | Building Area Network |
| BR | Backbone Router |
| CCTV | Closed Circuit TV |
| C&I | Commercial & Industrial |
| CDMA | Code Division Multiple Access |
| CIP | Critical Infrastructure Protection |
| CEPT | European Conference of Postal and Telecommunications Administrations |
| DA | Distribution Automation |
| DMS | Distribution Management System |
| DCC | Distribution Control Centre |
| DDR | Digital Disturbance Recorder |
| DLR | Dynamic Line Rating |
| DNO | Distribution Network Operator |
| DNP | Data Network Protocol |
| DG | Distributed Generation |
| DR | Demand Response |
| DS | Distributed Storage |
| DSO | Distribution System Operator |
| ECC | Electronic Communications Committee |
| EEI | Edison Electric Institute |
| ER | Edge Router |
| ETSI | European Telecommunications Standards Institute |
| EVCS | Electric Vehicle Charging Station |
| FAN | Field Area Network |
| FCC | Federal Communications Commission |
| GPON | Gigabit Passive Optical Network |
| GPS | Global Positioning System |
| HAN | Home Area Network |
| IAN | Industrial Area Network |
| IEEE | Institute of Electrical and Electronics Engineers |
| IED | Intelligent Electronic Device |
| ISM | Industrial, Scientific and Medicine |
| ISO | International Organization for Standardization |
| LAN | Local Area Network |
| LTE | Long Term Evolution |
| MDMS | Meter Data Management System |
| MWF | Mobile Work Force |
| NAN | Neighbourhood Area Network |
| NASPINet | North American Synchrophasor Initiative Network |
| NERC | North American Electric Reliability Corporation |
| PMU | Phasor Measurement Unit |
| PLC | Power Line Carrier |
| PTT | Push-to-Talk |
| RF | Radio Frequency |
| RLAN | Radio Local Area Network |
| RTU | Remote Terminal Unit |
| SCADA | Supervisory Control and Data Acquisition |
| TDM | Time Division Multiplex |
| TSO | Transmission System Operator |
| TSS | Transmission Substations |
| UHF | Ultra-High Frequency |
| VHF | Very High Frequency |
| VoIP | Voice over Internet Protocol |
| WAMPC | Wide Area Measurement Protection and Control |

# 4 Utility modernization/digital transformation

## 4.1 Electricity Utility Modernization

*Electricity utility* grid modernization represents a fundamental change in the way that electricity utility networks currently operate; for example, dynamically responding to an isolated fault and rerouting power before it leads to a widespread and extended outage or anticipating the fault before it occurs and changing out a transformer before it fails. In addition to fixed operations for intelligent electronic devices on the electricity grid, grid modernization also envisions mobile data applications to trucks and personnel so that they can access files with information about utility infrastructure as they are restoring power and then communicate back remotely to the utility when the work is completed, and power has been restored. Such developments could dramatically reduce the time it takes to restore power and improve the safety and efficiency of operations overall.

## 4.2 Water and Gas Utilities Digital Transformation

To reduce costs and improve sustainability water/gas utilities are adopting digital transformation; towards smart water/gas management systems to provide resilient and efficient water/gas supply systems. The digital transformation by water/gas utilities involves the adoption of solutions such as digital meters and sensors, supervisory control and data acquisition (SCADA) systems, and geographic information systems (GIS).

The use of digital output instrumentation (meters and sensors) enables the collection and transmission of information in real-time. Continuous monitoring of the network’s status is critical and is made possible by using monitoring and control systems such as SCADA. These systems also provide remote operation capabilities and enhancement of decision making. The data gathered from monitoring and control systems can be analyzed and applied in asset planning and renewal, network operation and maintenance.

# 5 Overview of smarter electricity networks

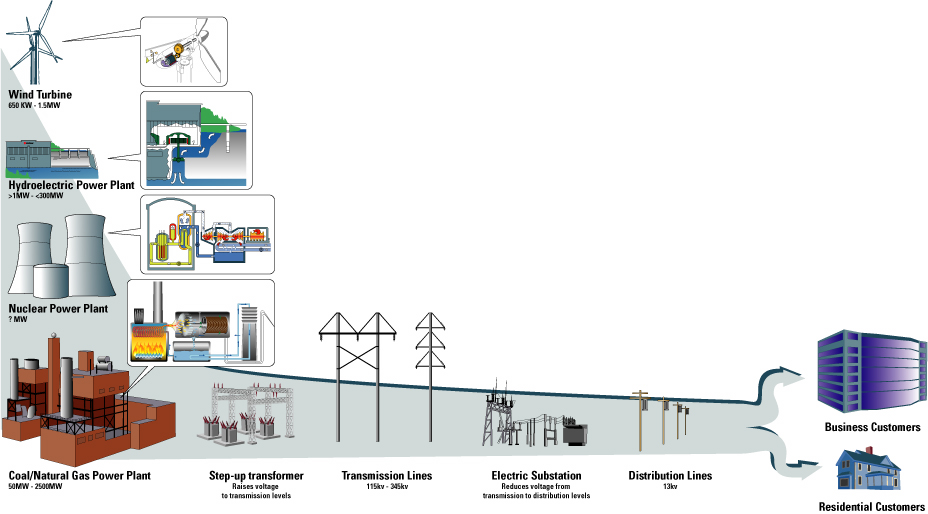
In general terms, the traditional electric network is divided into several parts. Power plants or bulk generation, using the high voltage transmission lines that send the power into the grid comprise the generation and transmission systems. The distribution network delivers power to homes and businesses using medium and low voltage grid and the points of supply where the customer is delivered the power; home area networks allow customers to control their energy usage and communicate with the utility.

The distribution system is characterized mainly by a combination of ring, networked and radial topologies, generally operated as a radial network where there is an identifiable single path to a source of power for every load. However, new grid configurations and the use of information and communications technologies (ICT) are beginning to change this model. This radial configuration simplified the engineering to account for one-way power flow in the monitoring, protection and control of the power grid.

Figure 1 below schematically illustrates the legacy electricity network configuration.

Figure 1

Electricity network infrastructure



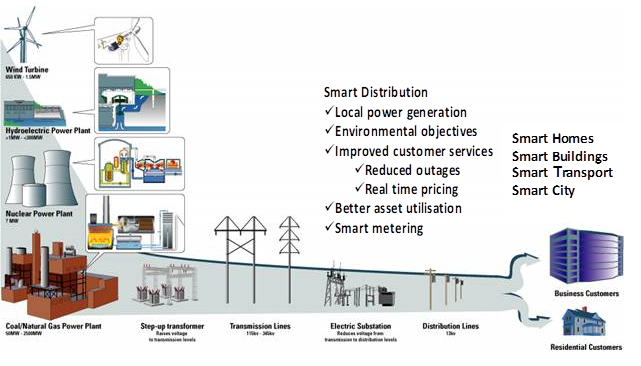
Today’s paradigm is vastly different, with the expectation that generation, storage, and mobile vehicle load, among other newer applications, create two-way power flows on those same lines, and that the end customer is extremely participative in the overall stability and functioning of that network.

Figure 2 below illustrates the major changes taking place in the energy sector as companies are required to develop smarter networks in order to accommodate very large numbers of renewable and low carbon energy sources. The traditional generation plants, very large power stations using fossil fuels are being replaced with much higher number of smaller units using wind, solar and natural gas. These smaller power stations are distributed over a large geographical area and connected not only to the transmission grid but to the distribution grid as well.

In addition, individual companies and individual homes can also generate power from wind and solar and this energy is fed into the energy grid. This has the effect of creating millions of small energy sources which utilities need to manage and control.

Figure 2

Smarter electricity network



The need to create smart distribution grids is universal across the world. Smart distribution energy networks will be integrated with smart homes, buildings, transport and cities. The key issue for the energy sector is connectivity to the many thousands of assets and energy sources in distribution networks. The information and communications technologies (ICT) needed to manage and control complex smart energy networks demands very high availability and reliability and needs to provide communications connectivity when the energy supply fails. The communications capacity and coverage required in the distribution network is not in place today and energy companies are planning new communications networks and services to meet the needs of smart grids. Many technologies will be used but the grid assets are spread over a large geographical area and in remote locations and therefore wireless communications will play a key role.

Specifically, utilities are deploying real-time, two-way communications networks that extend beyond the distribution substations all the way to the customer premises. These networks must be highly reliable and provide low latency communications. Moreover, the networks must support higher capacity to enable smart grid data traffic from a proliferation of devices that reside on the grid and in the home. Finally, the networks must provide high security to protect against cyber security and other external vulnerabilities.

The increase of renewable energy sources such as solar and wind will put new demands on DSOs to be active network managers with total control of the distribution network. Due to inherently increased volatility in renewable sources, there is a need for power grid protection measures which can respond more quickly. Additionally, there is a need to balance production and loads in a more dynamic way, as renewable energy sources have less inertia. Therefore, digitalization and connectivity are considered as key enablers in the transition to renewable power generation[[1]](#footnote-1).

*Power systems going digital*[[2]](#footnote-2)

Power systems all over the world are on the cusp of a transition from being highly centralized to supporting more distributed electricity generation and storage.

More connected sensors and smart meters will enable real-time network monitoring, including data about power quality, broken wires and consumption spikes. As a great amount of data is generated from electricity customers at the edge of the network, AI-powered predictive analysis and edge computing can be introduced to reduce costs and increase revenues.

Predictive maintenance based on machine learning and AI may also reduce power outages and improve investment decisions. This predictive analysis can include rapid detection and response to spikes in demand. One example is the mass charging of electric vehicles (EVs) that can be both a challenge and part of the solution.

Another application area, as mentioned earlier, is that of production compensation between many small-scale installations, where it would be possible to achieve an optimal production balance between distributed energy sources. This is done by measuring and compensating for imbalances in the grid.

The need to introduce smart ways to monitor, balance and predict power consumption and generation will thus continue to grow. The power grids of tomorrow will be digital infrastructures, meaning they will be highly connected and automated.

## 5.1 Distribution network assets

A study by consultants in the UK devised the following representation of utility asset management for a typical distribution company with 4 million customers serving an area of 29 000 km2 through a network of 80 000 km of underground cables and 48 000 km of overhead lines; see figure 3 below. Compared to 2011, the increase in connected end points was forecast to grow by 775% by 2021 and 1199% by 2031.

Although the degree of communications connectivity required at the 11 kilovolt (kV) level (or alternative equivalent Medium Voltage (MV) level) is still uncertain, most utility commentators consider it will have to be between 50% and 100% of all end points, plus monitoring in real-time of many distributed assets to deliver the capacity increases required by low-carbon energy solutions.

Since this model is typical of most electricity distribution networks across Europe, it can provide a first level approximation of the increase in connections that will be required. European data indicates approximately 200 million households across Europe, and although this does not precisely mirror the data above, it can be scaled to suggest 4.5 million assets at Medium Voltage level across the EU, indicating:

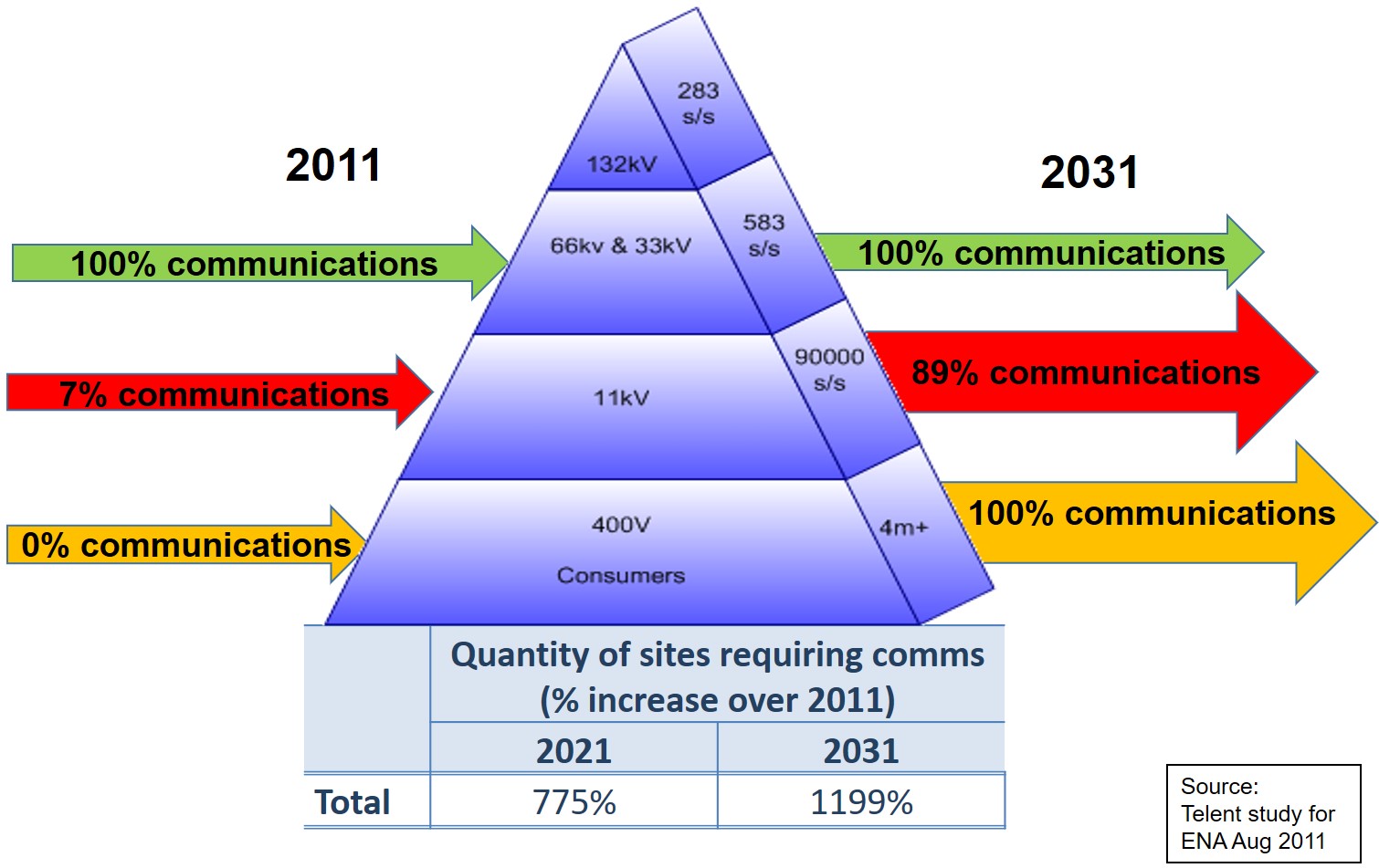
– 2011: connectivity of 315 000 units

– 2021: connectivity of 2.4 million devices

– 2031: connectivity of 4 million devices

Figure 3

Distribution network assets



## 5.2 Opportunities and challenges with connected power distribution grids

Enhancing data connectivity for power grids holds societal, regulatory and economic value. Connectivity and automation can deliver higher reliability and better protection of the electric power grid, unleashing great potential benefits for distribution system operators (DSOs) through the following[[3]](#footnote-3):

1. Enabling the scaling up of renewable, distributed energy sources.

2. Reducing the impact of interruptions to customers.

3. Minimizing damages and costs related to power grid equipment.

4. Lowering service costs and reducing the need for troubleshooting.

5. Protecting the power grid with peak shaving and frequency regulation

Terrestrial and satellite networks can be used in combination to ensure seamless connectivity to remote and urban locations[[4]](#footnote-4).

# 6 Smart Network Applications & Services

Smart Electric Network applications are briefly described below. We have included traditional power grid applications such as SCADA because the traffic for these traditional applications also has to be carried over the communications networks.

## 6.1 Supervisory Control and Data Acquisition (SCADA)

The SCADA (Supervisory Control and Data Acquisition) systems are aimed to supervise, to perform data acquisition and to enable the visualization of a particular process, with the objective of controlling it, providing a high interface level to the system operator, informing in real time about all events of importance occurred in Remote Terminal Units (RTU) distributed across industrial plants or geographically spread assets.

In this report, SCADA refers to communication between RTU or Intelligent Electronic Devices (IED) deployed in substations (or a generation plants) and other utility relevant assets with the SCADA Master (Control) in the utility DCC. As an example, a RTU in the substation collects measurement and status information from some or all measurement devices, relays, and other elements in the substation. In response to periodic polls received from the Master, the RTU sends measurement + status messages to the SCADA Master. In addition, events generated at the relays and other instrumentation are transmitted to the SCADA Master as they occur (asynchronously). The RTU also receives controls from the SCADA Master that are delivered to the relays, bay controller, or other devices for necessary action.

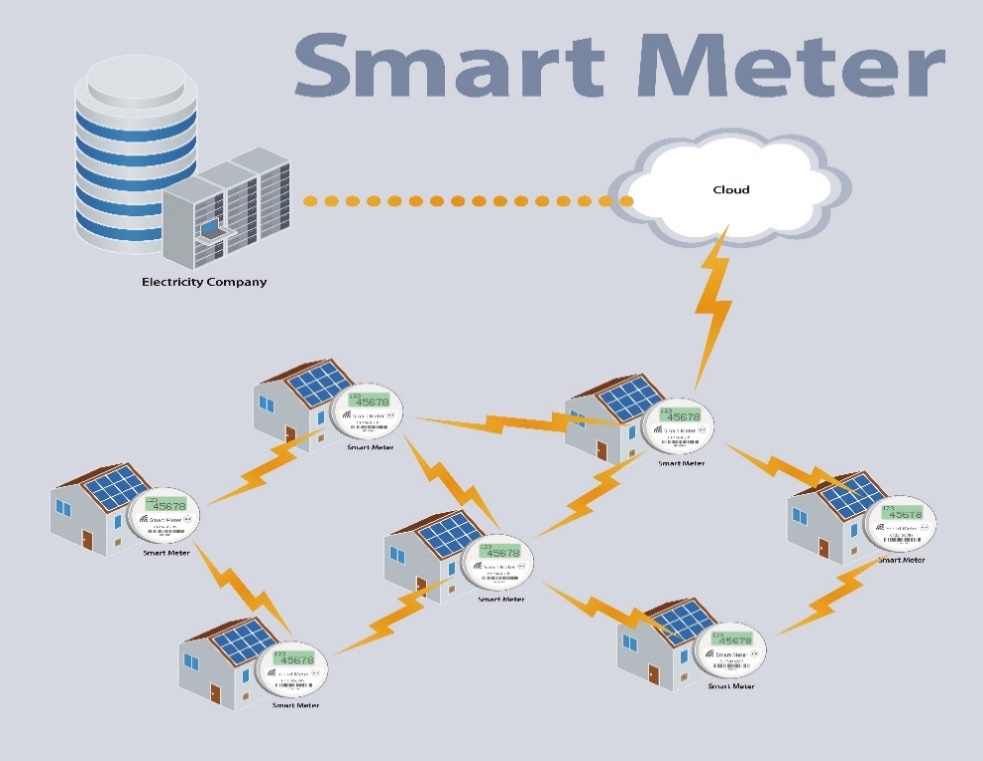
For substation automation based on IEC 61850 standards, IEDs deployed at the substation replace traditional relays, bay controllers, other measurement devices, and switchgear. In this case, each IED is capable of direct communication with the SCADA Master Control: direct communication is used for periodic polls from the SCADA Master, measurement + status responses, event reports, and control signals.

## 6.2 Advanced Metering Infrastructure (AMI)

Utilities are deploying smart meters at consumer locations, at their own substations, and at grid borders. Smart meters report electrical measurements (energy, voltage, power, etc.) at frequent intervals (e.g., once every 15 minutes). In addition to billing, these frequent meter measurements are used by many new and emerging applications including Automated Demand Response (ADR), energy management, rate management, power quality, and asset management systems.

Figure 4

Smart meter network configuration



In an AMI solution, meters communicate with the utility Meter Data Management System (MDMS) located at the utility DCC. Meters send periodic measurement + status information to the MDMS, often in response to periodic polling from the MDMS. Asynchronous events such as voltage alarms are also sent to the MDMS. The MDMS may also send control signals to the meters (e.g., disconnecting the meter). Currently, there are three different prevalent AMI solution architectures. A utility may deploy one or more AMI solutions in its service area (some of them are illustrated in Figure 5).

• Direct Meter Connection (Figure 5A)

In this approach, communication between each individual meter and the MDMS is carried directly over a communications network to the FAN (such as a 3G/4G wireless broadband connection, utility-owned wireless connections over licensed or license-exempt spectrum, and/or Gigabit Passive Optical Network – GPON – connection).

• Power Line Communication (PLC) Neighbourhood Area Network (NAN) (Figure 5B):

In this AMI architecture, meters at consumer locations connected to a distribution transformer communicate with a meter data concentrator located near the distribution transformer. The data concentrator aggregates traffic from the individual meters connected to it and connects to the AMI solution´s head end over a FAN connection. On the other hand, the MDMS sends control signals to the head end to be forwarded to the meters.

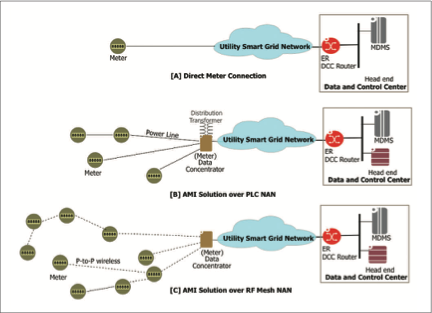
• Radio Frequency (RF) Mesh NAN (Figure 5C):

An AMI solution over RF mesh uses wireless communication between the meters and a meter data concentrator over licensed or license-exempt spectrum. The meter concentrator is usually deployed at a substation. However, it is not necessary that the data concentrator support only the meters at the customer locations connected to that substation. Communication between a meter and the data concentrator goes over zero or more intermediate meters with each intermediate meter forwarding data received from its neighbouring meter(s) to another meter or to the data concentrator.

To extend the range of an AMI solution (and thus increasing the number of meters in the RF mesh), data forwarder elements may also be deployed on rooftops or poles, for example, as intermediate mesh nodes. Like the PLC AMI solution, the meter concentrator connects to the head end through the substation router or over its own FAN connection. A data concentrator in these solutions can support a large number of meters (up to 10 000 or more).

Figure 5

AMI solution architecture



## 6.3 Demand Response (DR)

Demand Response refers to actions taken by a utility to adapt to changes in demand. Some DR methods, such as ADR, occur over the timescale of seconds. New Demand Response solutions require the deployment of new wireless infrastructure to facilitate the increase in generation, transmission, and/or distribution capacity.

Currently, ADR is most prevalently used for commercial and industrial (C&I) consumers. It is expected that use of ADR will be extended more prevalently to residential and small business consumers in the near future. In general, third-party data communication services or the Internet is used for ADR communication today. In the future, DR traffic will likely be carried over the Smart Grid communications network, possibly using the same links supporting communication between the utility’s AMI solution the meter.

## 6.4 Distribution Automation (DA)

DA refers to monitoring and control of IEDs deployed in the utility distribution system outside of the distribution substation. These IEDs may be deployed at reclosers, switches, and capacitor banks installed along feeders (distribution lines) and possibly, in the future, at distribution transformers. The DA IEDs are assumed to use DNP3 to communicate with the DA control system in the DCC. We will refer to this control system as the DA Master.

DA IED functions are similar to those of substation IEDs, possibly with larger interval between sending of the successive measurement+status message.

Each DA IED can connect directly to the DA Master over its individual FAN connection. An RF or a medium voltage PLC NAN can be used to connect the DA IEDs in a neighbourhood to a DA Data Concentrator, typically located at the distribution substation connecting the respective feeders. The DA concentrator, in turn, connects to the DA Master through the substation router or over its individual FAN connection.

## 6.5 Distributed Generation (DG)

Large-scale distributed generation (solar, wind, fuel cells, biomass and biogas, etc.) are an integral part of Smart Grid evolution. DG deployments that require monitoring and control by the utility generate network traffic. These DG sources will be equipped with IEDs. DG IEDs are assumed to use protocols such as DNP3 and IEC 60870-5-104 to communicate with the systems in the DCC. The DG IED functions are similar to those of substation IEDs, possibly with larger intervals between successive measurement + status.

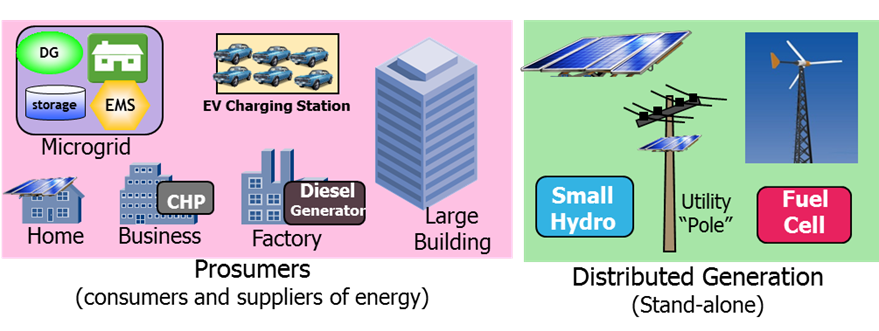
Figure 6

Solar and wind generation



Figure 7

Large scale distribution generation

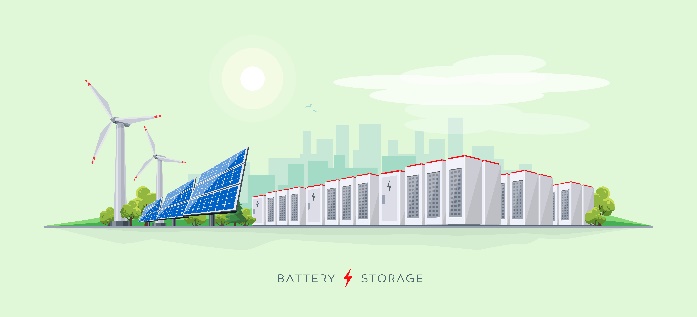


## 6.6 Distributed Storage (DS)

In addition to electric energy storage necessary at many DG deployments to mitigate voltage transients, the utility may deploy stand-alone storage facilities such as large batteries, flywheels, super capacitors, and pumped hydro systems. For the purpose of traffic estimation, the DS IED characteristics will be assumed to be the same as those for the DG IEDs.

Figure 8

Storage



## 6.7 Electric Vehicle Charging Stations (EVCS)

Electric Vehicle Charging Stations that allow EVs parked at the station to discharge energy from vehicle batteries into the grid (in addition to charging EV batteries) can be considered standalone DS deployments. For the purpose of traffic estimation, EVCS IED characteristics will be assumed to be the same as those for DG IEDs. Note that in addition to the periodic measurement+status traffic, there may be (asynchronous) traffic related to authentication (and billing-related) traffic between the EVCS and utility DCC for the vehicles parked at EVCS for battery charging and/or discharging.

Figure 9

Charging station



## 6.8 Synchrophasors

Synchrophasors are Phasor Measurement Units (PMU) that measure electrical properties (voltages and currents) of their respective phasor components as well as other quantities (such as line frequency deviation). PMUs are special purpose, state-of-the art IEDs that report measurement+status at very short intervals (e.g. 60 or 50 times a second).

These reporting intervals are significantly shorter than the several second long intervals used by SCADA IEDs. PMUs are deployed at transmission substations (TSS). PMU measurements from transmission substations are collected and analyzed to support wide area situational awareness and control of the regional power system. Each measurement+status message from each PMU carries a Global Positioning System (GPS)-derived timestamp. The North American Synchrophasor Initiative Network (NASPInet) is the first network deployed for Wide Area Situational Awareness in regions of North America. While Synchrophasor deployment is currently limited to transmission substations, their deployment at distribution substations (DSS) for management and control of distribution systems (including power quality control) is also possible in the future.

## 6.9 Dynamic Line Rating (DLR)

Increasingly, DLR systems are being deployed to monitor environmental conditions at transmission lines using IEDs deployed at or close to transmission towers. DLR IEDs measure ambient temperature, wind, solar radiation, ice accumulation, sag, and other parameters. By closely monitoring transmission lines, DLR helps utilities optimize power delivery and enhance operational safety. DLR IEDs are assumed to use DNP3 to communicate with systems in the DCC. DLR IED functions are similar to those of SCADA IEDs, possibly with a larger interval between sending of the successive measurement+status messages.

## 6.10 Utility Engineering and Operations

In addition to the periodic traffic and asynchronous control traffic between the sensors (IEDs, PMUs, or meters) and their respective operations and control systems at the DCC, other types of data transfer are required for operations and engineering needs. Examples of such data transfer include the retrieval of sensor data for analysis, software/firmware upgrades, remote programming, and configuration of sensors, and, in the case of meters, re-registration of meters after blackouts.

## 6.11 Closed Circuit Television (CCTV)

Utilities are increasingly deploying CCTV cameras at substations, DCCs, and other locations to support physical and operational security. Video feeds from cameras are typically stored in local Digital Video Recorders (DVR). At any time, several feeds are also streamed, as necessary, to the (security operations centre within the) DCC. When required (such as during an incident at a substation), one or more live video feeds may also be uploaded to the DCC.

## 6.12 Mobile Workforce (MWF)

Utility mobile workforce requires ubiquitous voice and data communications. Conversational (person-to-person) voice communication between MWF personnel, as well as between MWF personnel and anyone outside the MWF is assumed to have the mission critical communication characteristics. Similarly, the “data” needs (including video) of MWF will be assumed to have the same characteristics. MWF frequently uses Mapping and Geographical Information System applications. Finally, MWF personnel may need to stream live video (from an MWF camera) during an incident.

## 6.13 Protection Applications

Protection applications are designed to ensure electrical equipment safety and reliability in substations and transmission lines, acting quickly and accurately the detect and isolate faults and minimizing the possibility of spreading disturbances to the rest of the interconnected electrical system.

Protection relays in two transmission substations connected over a transmission power line communicate with each other to detect faults. When a fault is detected, a control signal is sent to trip a circuit breaker. While a fault may be detected and circuit breaker tripped locally at a substation, in many cases, the tripping of a circuit breaker will be triggered by a remote substation.

Protection is a very critical application requiring very short communication delays (about 10 ms). Further, for high reliability, two independent connections are used to support communication between the relays. Protection is also used between a DG, DS, and EVCS location and the connecting distribution substation. Protection relays at such locations communicate over a FAN. Protection is typically only used at high capacity DG, DS, EVCS locations.

## 6.14 Utility Business Voice

The Smarter Electricity Network architecture of Figure 2 supports voice traffic for utility personnel located in business offices, field offices, and other sites as well as for MWF personnel. Support of voice communication over the smart grid requires the use of IP-based interfaces.

## 6.15 Utility Business Data

The Smarter Electricity Network architecture of Figure 2 supports business data traffic for utility personnel located in business offices, field offices and other sites as well as for MWF personnel. Business video traffic (including videos over the Internet or corporate intranet and video conferencing from user data devices) are considered as a part of the business data needs.

## 6.16 Digital Disturbance Recorder (DDR)

Digital disturbance recorders register the operation of the electric system and its protection during important events, such as electric failures, frequency oscillations and operational failures.

Digital Disturbance Recorders (DDR), also known as digital oscillographs, are utilized in most of the installations of power electric systems and perform a constant surveillance of the system, recording significant disturbances, such as voltage and current out of the standard.

### 6.17 Precise Load Control

The precise load control system focuses on solving the problems of rapid frequency drop at the initial stage of grid failure, overrun of main channel power flow, over-utilization of inter-provincial tie line power, insufficient power grid spinning reserve, etc. According to different control requirements, it is divided into millisecond-level control system to achieve rapid load control and second-level or minute-level control system to be more user-friendly. The former meets the requirements of frequency emergency control to firstly cut off part of the load quickly. The latter secondly cut off part of the interruptible load to achieve the balance of power generation and consumption.

# 7 Utilities Integrated Communications Network Architecture

Currently, communication network needs for most utilities are supported by disparate networks, each supporting a utility application such as SCADA, physical security (CCTV), or mobile workforce communication. With smarter electricity network evolution as well as the expected growth with a large number of new applications supporting a large number of endpoints, creation of a purpose-built network for each application cannot be sustained. It is extremely important that the utility ICT needs including that of connectivity to distributed generation are supported by an integrated network.

There is literature covering the most suitable elements to achieve a telecommunication network and service architecture that can make the Smart Grid become real. By way of example, the publication Communication Networks for Smart Grids: Making Smart Grid Real (2014)[[5]](#footnote-5), provides a selection of telecommunications components; the publication Telecommunication Networks for the Smart Grid (2016)[[6]](#footnote-6) proposes a practical reference architecture that holds the value of having been deployed on the field. A practical, flexible, and scalable target communication network architecture supporting all smarter electricity network applications is illustrated in Figure 10.

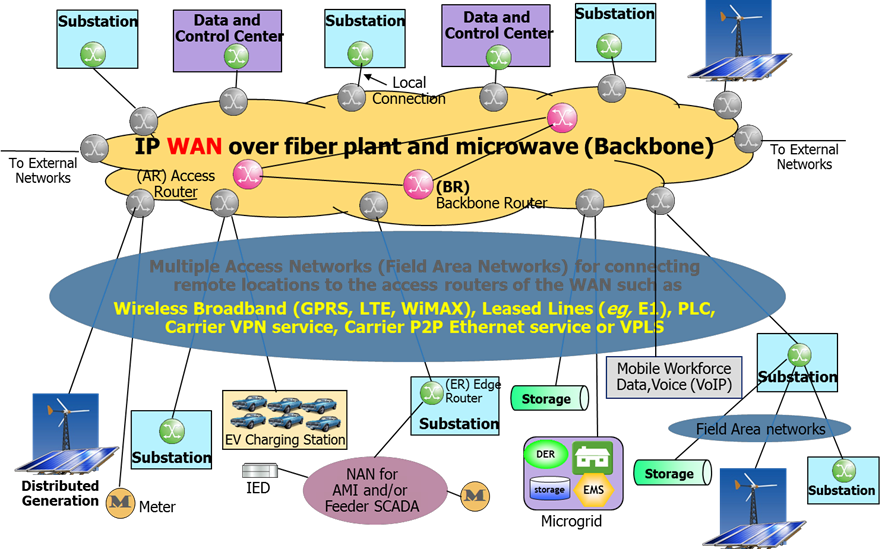
IP is assumed to be the underlying network protocol for the integrated network with support for connecting legacy endpoints and protocols (such as TDM) using tunnels, circuit emulation, and/or gateways.

Given the expanse of the utility service territory, the number of endpoints that need to be connected into the network, and since communications for most applications are predominantly between sensors and/or remote endpoints and the central application control or processing servers, an edge-core network architecture is preferred as illustrated in Figure 10. Another important aspect of this architecture is traffic aggregation at intermediate points in the network rather than direct communication between the endpoints, thus facilitating ease of traffic routing, reliability, QoS implementation, and reduced costs.

To avoid complexity in the figure, not every possible application or network connectivity option is included in Figure 10. In any case, the actual physical connections will be dictated by network design.

Figure 10

Architecture for Integrated Communications Network for the Smart Grid



While the enterprise voice and data applications or utility enterprise offices are not included in Figure 10, they can be easily supported by the architecture based on a utility’s preference about integrating the OpTel and business applications on the same network.

## 7.1 Traffic Aggregation at Network Endpoints

An Edge Router (ER) at an endpoint location aggregates traffic from multiple sources and applications at that location. For a location with a single endpoint or only a few endpoints, there may not be an ER at that location that aggregates their traffic and these endpoints may be connected directly into the network. Depending on network design, an ER may also be used to aggregate traffic from other locations in the vicinity. For example, an ER at a (large) substation may aggregate traffic from other (smaller) substations as well as traffic from other locations in the vicinity, in addition to the traffic generated at that substation itself.

## 7.2 Core Network (WAN)

Depending on the network expanse and end points, the core network (sometimes called WAN – Wide Area Network) may vary from a single router up to a mesh of (redundant) interconnection of backbone routers (BR) and access routers (AR). ERs not connected to other ERs and endpoints not connected to an ER connect to the ARs for network connectivity. Based on the reliability requirement, an endpoint (such as the data and control centre or a “important” substation may connect to two different access routers. An AR aggregates traffic to/from the endpoints that connect to the ARs, possibly through the ERs. The WAN must be a reliable network with very high reliability (e.g., there must be at least two physical paths between every pair of ARs). For that purpose, additional routers BRs may be deployed in the core network based on the network design.

Often, the core network will be close to the utility data and control centres as well as to the substations in metro areas. Thus, some of the ARs may be collocated with these utility sites. For such a collocated site, its endpoints may connect to the corresponding AR over the LAN in that site. If required for redundancy, ER at this site may additionally connect to an AR at another location over a FAN.

Based on security policies and security designs, firewalls and IDS/IPS systems are deployed at ARs and BRs.

In many cases the WAN will be owned and operated by the utility but that may not always be the case. Even the utility-owned WAN may lease or share basic physical resources such as fibre plants and spectrum.

Optical fibre is used extensively in the majority of Europe’s transmission system operator (TSO) companies. However due to the fact that they link the main electricity generators with the consumers centres, their capacity to contribute to distributed generation in medium voltage networks is limited.

However, not as many distribution system operators (DSOs), mainly in Western Europe, have any substantial amount of optical fibre. Nevertheless, most of them think they will need to install in the future as smart grids deploy, mainly in medium voltage networks. This will contribute to the deployment of highly reliable, cost efficient and secure networks.

## 7.3 Access Networks (FANs)

Access networks (often called Field Area Networks – FANs) provide connections between utility locations and the ARs. After presenting a brief overview of the wireline and wireless FANs, we present a few more details on the Power Line Communication (PLC) technology which is being increasingly used in smart metering access and being explored for deployment in FANs including connectivity to DG.

The utility may use multiple wireline and wireless technologies for FANs. The FANs may be owned and operated by the utility (self-provided) or service provider networks may be used as FANs. Wireline technologies may include PLC, private lines, Layer 2 technologies as Ethernet and Frame Relay, and MPLS, VPLS or VPN service. The wireless broadband technologies may include 2G and 3G 3GPP technologies (e.g. GPRS and HSPA) with a migration path to 4G (e.g., LTE and WiMAX).

In parallel to this activity, European utilities in particular had identified some specific limitations of products based on the existing LTE standard to satisfy some of their specific technical requirements (latency, prioritisation, power autonomy etc). As a result of concerted effort from EUTC, UTCAL and major utilities operators, a specific work item has been approved in 3GPP SA1 (approved July 2020). The intention of this work item is to drive development of utility specific functionality in future releases of the ~~LTE 4G~~ IMT-2020 standard (from release 18 onwards). The initiatives are supported by almost 20 global organisations from the vendor, operator and end user community.

The mix of utility-owned and service provider network FANs depends on the service level agreements (SLA) provided by the service provider networks consistent with utility requirements, networking technology availability in an area, costs and other considerations. The choice of FAN technologies and ownership mix can evolve over time depending on the emergence of new technologies, utility access to spectrum, and network expansion with new applications and endpoint.

While strictly not FANs, and based on AMI communication technology, local Neighbourhood Area Networks (NAN) such as over license-exempt spectrum or over PLC may be used for concentrating smart meter traffic at substations or near distribution transformers. The NANs may also be used for concentrating the SCADA traffic from the IED deployed over feeders to RTU/IED in the substation. Note that meters and feeder IEDs may also directly connect to the ARs, depending on the vendor product communication technologies.

## 7.4 Power Line Communication

Power Line Communication over the power lines themselves as communication medium has been in use since early 20th century, initially for voice communication. In the last fifty years or so, PLC was also used for low data rate communication over HV and MV lines for applications such as protection and SCADA. PLC was not considered a useful technology by many for data communication because of its low range, susceptibility for interference with other communication applications, costly solutions to overcome the problem of communication through transformers (requiring coupling equipment to bypass transformers), and very low data rates.

However lately, PLC technology has taken its roots in smart grid evolution as one of two Neighbourhood Area Networking (NAN) technologies for AMI. In the last several years, many countries (particularly in Europe) are looking to deploy PLC FANs connecting to DG, meter concentrators, and other smart grid endpoints. Many standards bodies (ITU and IEEE) and industry forums have developed and are developing standards for supporting PLC communication.

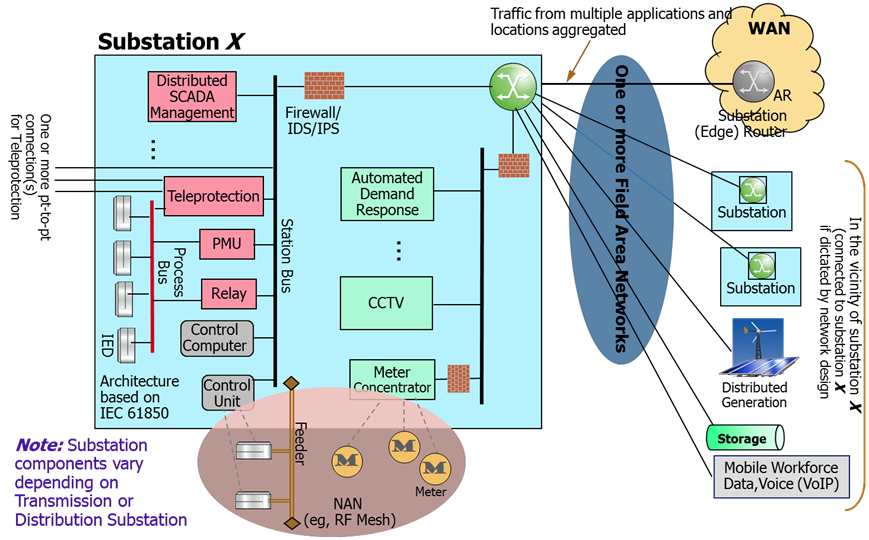
## 7.5 Evolution of Substation LAN Architecture

Currently communication within most substations is limited to SCADA. IEDs and RTUs in the substation use point-to-point communication between them, often through a “data concentrator”. Most protocols are proprietary. The SCADA communication link between the substation and the SCADA control centre are often point to point TDM connections. If there are other applications located at the substations (such as protection, synchrophasors, and CCTV), they each have a separate communication links to their respective counterparts.

The substation LAN evolution will be on two different levels. At one level, the substation architecture of the utility operations applications such as SCADA and protection will evolve to the architecture specified in IEC 61850 standard. On another level, traffic generated by many new smart grid and other applications that will be resident at the substation such as the meter concentrators and CCTV will be aggregated at the substation router along with the SCADA and other operations traffic. The substation router is an ER in our integrated architecture of Figure 11. The router at a (large) substation may additionally aggregate traffic generated in the vicinity of the substation.

Figure 11

Evolution of substation architecture based on IEC 61850 standards



IEC 61850 defines a *process bus* that is an Ethernet bus. All SCADA IEDs and optionally the protection IEDs and PMUs connect to the process bus. For legacy equipment gateways may be used to connect into the process bus. There may be more than one process bus.

The *station bus* is used to connect the process busses as well as other operation systems such as the distribution automation traffic concentration from the feeder IEDs (if thus designed).

Access to all these operation elements is protected by protecting the station bus behind firewall and/or Intrusion detection and protection (IDS/IPS) systems.

The substation may use another Ethernet network for connecting other smart grid and utility systems such as the CCTV, meter concentrators, and demand response systems; access to these systems is protected by another firewall and/or IDS/IPS system.

Finally, the substation router aggregates all traffic generated at the substation and possibly traffic generated at (smaller) substations in the vicinity as well as traffic from other endpoints in the vicinity – examples of which are shown in Figure 11.

Note that the utility may continue to use its existing TDM networks and/or possibly Ethernet connections for the protection traffic. The protection traffic may not be carried over the IP network for a period of time.

Connectivity to home area networks (HAN)is an important aspect of smart electricity network evolution in actively incorporating the consumer in energy management. Depending on the utility policies, the home networks *may* be allowed to be a part of the utility’s integrated communication networks either with the connection through the smart meter or through a “home gateway”.

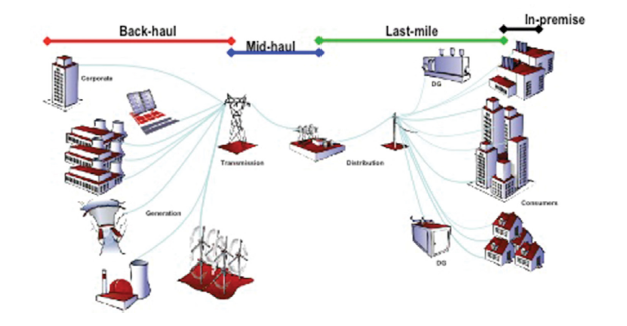
Utilities are implementing new systems to automate operations and enhance their monitoring and control capabilities. These systems support a variety of applications, including advanced metering, demand response, distribution automation, and wide area measurement, protection and control (WAMPC). Overall, these systems will improve operational efficiency, safety and reliability by extending communications further into the distribution network and improving their performance.

The network architectures for these systems are varied. Some utilities deploy networks using centralized network architecture, such as point-to-multipoint networks; while others rely on decentralized network architecture, such as mesh networks. There are also hybrid networks that include combinations of network architectures, as well. The FAN is expected to bridge the backhaul network to the field devices.

The Figure 12 below shows a combination of networks in a suburban configuration. A utility must manage the spectrum needs of its applications across the entire geographic footprint and account for the different device densities, geography, zoning regulations, and other technical and non-technical limitations.

Figure 12

Networks in a suburban configuration

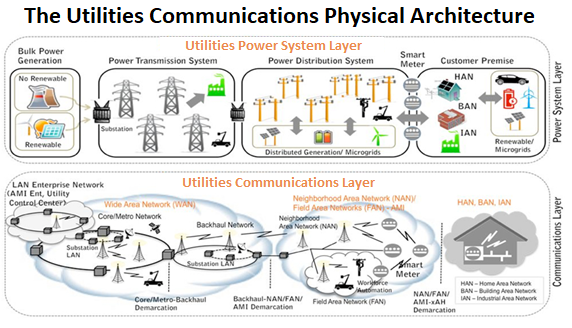


In Figure 13 below, we have mapped how the smart network applications and communications technologies can be layered onto the different elements of the energy network physical infrastructure. The communication requirements applicable to generation, transmission, distribution and customer premises have some differences and these are explained in greater detail in the following section.

Figure 13 also illustrates how the communications layer elements, the wide area network, neighbourhood and field area network and the home networks overlap the different power systems elements which make up the energy system.

Figure 13

Utilities communications physical architecture



There will be numerous applications, including several that require significantly greater bandwidth. While utilities may not implement all of these applications, they will need to design the FAN so that all of the applications that they do implement can be supported both now and, in the future, as demands increase.

In addition, the network needs to be designed so that it is reliable and provides coverage and low latency to meet their functional requirements effectively.

Flowing from the applications and their functional requirements, utilities may choose the network architecture that best supports their needs —and there are advantages and disadvantages to each.

# 8 Utility Communications Objectives

## 8.1 Introduction

Utilities involved in the generation, transmission and distribution of electricity, gas and water supplies, including waste water management, need reliable and secure communications to operate efficiently the business critical applications and improve workplace safety.

Utility systems are characterized by high reliability, high availability and low latency. Utilities typically operate their own operational communications networks in order to ensure communications reliability during extended power outages or other situations when public commercial communications networks may become adversely affected. This includes extended back-up power and diverse and redundant routing of backhaul communications networks at every wireless site. They also communicate in areas that commercial communications networks do not cover but where utilities may have critical assets, such as remote areas where generation or transmission infrastructure is located.

Utilities communicate with very low latency, depending on the type of utility application as low as 20 milliseconds or less. Some applications, as protection and synchrophasors, needs extremely low latency services to prevent faults on the grid from cascading and causing widespread outages and/or safety issues. Hence, utility communications networks can be characterized as highly reliable, available, and operate at low latency, as shown in Table 3 below.

Table 3

| Smart network communications parameter matrix | | | | |
| --- | --- | --- | --- | --- |
| Smart network sub-system | Coverage | Reliability | Latency Time | Security |
| Meter reading - AMI | Medium | Medium | High | High |
| Field area network | High | High | Medium | High |
| Phase measurement | Medium | High | Low | Medium |
| Protection | Medium | High | Low | Medium |

As utilities implement grid modernization more densely and deeper into their infrastructure, they are expected to need additional capacity and coverage as they shift towards two-way, real-time communications systems to provide increased control to turn systems on and turn off remotely, automatically and dynamically without the need to send out a truck and manually reclose circuits when breakers have tripped. Moreover, they will be able to automatically detect a power outage and restore power instantly by rerouting it, instead of having to attempt to triangulate a power outage based upon customer calls that a power outage has occurred and then sending a truck into the area to determine the exact location where a tree has fallen across a line or a transformer has failed. All of this automation would benefit from additional capacity and coverage.

### 8.1.1 Electricity utilities

In general, an electricity network or electricity grid is a network for distributing electrical energy from producers to consumers. It consists of:

– generating stations that produce electric power

– electrical substations for stepping electrical voltage up for transmission, or down for distribution

– high voltage transmission lines that carry power from distant energy sources to demand-centres

– distribution lines that connect to individual customers.

Many traditional electricity networks are not smart enough to meet today's requirements. A smart grid is an electricity network that enables a two-way flow of electricity and data.

### 8.1.2 Water utilities

In many countries water utilities manage the transmission of water from water sources, to treatment plants and to consumers and industry. A water supply system consist of:

– Water collection sources such as a lake, river, a dam, or groundwater from underground aquifers.

– Transmission network of aqueducts, covered tunnels or underground water pipes to transfer water to water treatment plants; underground pipes to carry treated water to water storage; and a pipe network for distribution to residential consumers and industry.

– Water treatment plants. Treated water is transferred using water pipes (usually underground).

– Water storage facilities such as reservoirs, water tanks, or water towers.

– Additional water pressurizing components such as pumping stations may need to be situated at the outlet of underground or above ground reservoirs or cisterns (if gravity flow is impractical).

– Connections to wastewater or sewers are generally found downstream of the water consumers.

– Waste water treatment could be part of the services that water utilities provide and includes collection and treatment of waste and rain water, processing and redistribution.

Annex 2 contains an overview of a smart water management system.

### 8.1.3 Gas utilities

The operations of gas utilities are, in some ways, similar to water utilities. Natural gas is transported from collection (storage) points at high pressure through (transmission ) pipelines to local distribution networks of smaller diameter pipelines, at lower pressure, to end users such as residential homes, offices, restaurants and factories.

Annex 3 contains an overview of an example in the transport, storage and distribution of natural gas in North America.

## **8.2 Communications Objectives of Smart Grid Communications** Technologies

The following tables list the various different utility applications and provide the requirements for latency as well as their relative priority. For example, protection applications, such as breaker reclosers and PMUs, which have extremely low latency and relatively high priority objectives, cannot generally be reliably supported using commercial wireless broadband networks.

However, advanced metering and some monitoring applications, such as AMI periodic measurements and fault recordings, could potentially be supported over existing commercial networks[[7]](#footnote-7).

Table 4

Application latency objectives

| Application | Minimum Delay Allowance  (ms) | Priority:  0 = Max to 100 = Min |
| --- | --- | --- |
| **Delay ≤ 10 ms** | | |
| (High Speed) Protection Information | 8, 10 | 2 |
| Load Shedding for Under Frequency (under 50-60 Hz) | 10 | 20 |
| **10ms < Delay ≤ 20 ms** | | |
| Breaker Reclosures | 16 | 15 |
| Lockout Functions | 16 | 12 |
| Many Transformer Protection & Ctrl Apps | 16 | 12 |
| System Protection (PMU) | 20 | 12 |
| **20 ms < Delay ≤ 100 ms** | | |
| Synchrophasor Measurements (Class A) | 60 | 10 |
| SCADA Data Poll Response | 100 | 25 |
| PTT Signaling (critical) | 100 | 30 |
| PMU Clock Synchronization | 100 | 20 |
| **100 ms < Delay ≤ 250 ms** | | |
| VoIP Bearer (inc. PTT) | 175 | 50 |
| VoIP Signaling (inc. PTT – normal) | 200 | 60 |
| Dynamic Line Rating (DLR) | 200 | 40 |
| Real-time Video (mobile WF) | 200 | 55 |
| On Demand CCTV video | 200 | 55 |
| Other SCADA Operation | 200 | 45 |
| Enterprise Data – Preferred | 250 | 70 |
| Most Distribution and SCADA Apps. | 250 | 65 |
| AMI – Critical | 250 | 60 |

Traffic for these applications is only between two substations connected with transmission line. This traffic should be designed to be only single hop. Thus, the corresponding delay objectives must be considered only single hop. All other delay objectives may have to be satisfied over multiple network hops.

Table 5

Application latency [specifications, objectives] (cont.)

|  |  |  |
| --- | --- | --- |
| Application | Minimum Delay Allowance (ms) | Priority: 0=Max to 100=Min |
| **250ms<Delay<1s** | | |
| AMI – Priority | 300 | 70 |
| CCTV Stream – Normal | 400 | 75 |
| PMU (Class C) | 500 | 80 |
| Some Transformer Protection & Ctrl Apps | 500 | 80 |
| Enterprise Data - Other | 500 | 80 |
| **1s<Delay** | | |
| Image Files | 1 000 | 90 |
| Fault Recorders | 1 000 | 90 |
| (Medium Speed) Monitoring and Ctrl Info | 1 000 | 90 |
| (Low Speed) O&M Info | 1 000 | 90 |
| Fault Isolation and Service Restoration | 1 000 | 90 |
| Distribution Applications | 1 000 | 90 |
| AMI Periodic Measurements | 1 000 | 85 |
| Text Strings | 1 000 | 90 |
| Audio and Video Data Streams | 1 000 | 78 |
| Fault Recorders | 1 000 | 90 |
| Best Effort, Default | 2 000 | 100 |

Ensuring that these systems are secure and can be delivered in a cost-effective way is a high priority within the industry.

Finally, some of the key characteristics the operational communications components of utility networks are highly ruggedized for extreme conditions within the substation environment and have traditionally used extended depreciation cycles; so that the equipment must last for an extended period of time.

These key characteristics to maintain utility networks and their functions are detailed in Table 6 below.

Table 6

Network requirements[[8]](#footnote-8)

| Application | Bandwidth | Latency | Reliability | Security | Backup Power | |
| --- | --- | --- | --- | --- | --- | --- |
| AMI | 10-100 kbps/node, 500 kbps for backhaul | 2-15 sec | 99-99.99% | High | | Not necessary |
| Demand Response | 14 kbps- 100 kbps per node/device | 500 ms-several minutes | 99-99.99% | High | | Not necessary |
| Wide Area Situational Awareness | 600-1 500 kbps | 20 ms-200 ms | 99.999-99.9999% | High | | 24 hour supply |
| Distribution Energy Resources and Storage | 9.6-56 kbps | 20 ms-15 sec | 99-99.99% | High | | 1 hour |
| Electric Transportation | 9.6-56 kbps, 100 kbps is a good target | 2 sec-5 min | 99-99.99% | Relatively high | | Not necessary |
| Distribution Grid Management | 9.6-100 kbps | 100 ms-2 sec | 99-99.999% | High | | 24-72 hours |

Getting the data from field devices to the electric utility’s back office system, or getting commands to devices from back office systems, relies upon a secure, reliable network covering a geographical footprint that can vary from dense urban areas to remote locations with virtually no population. This data is often critical in managing the power system.

Simultaneously being able to respond to events via central commands adds to the complexity needed to manage the communications network. Thus, the network needs to be able to support the increased bandwidth requirements, as well as ongoing wide-area coverage and low-latency communications requirements necessary to effectively monitor and control operations.

## 8.3 Operational Requirements for Modern Utilities

Since the 1950s, utilities have been using telecommunications to monitor and control their electricity, water and gas networks.

Electricity is at the top of essential services list to society, whose unavailability or even temporary interruption can negatively affect whole chain of other public services that are also essential to society, such as transportation, health, banking and telecommunications.

The chain that makes up the electricity system is composed of three important sectors: generation, transmission and distribution. These segments operate in an integrated way, being extremely important the management, control, automation and monitoring of the events resulting from human actions and nature that constantly impact the electrical system.

The electrical networks "intelligence" is mainly based on the exchange of real-time information on measurement, supervision and control data, installed in strategic positions in generation, transmission and distribution networks, as well as in homes, offices, companies, with the purpose of making it capable of automatically detecting, analysing, responding and restoring faults in the network.

Utilities around the world use communications networks in their operations to support the safe, secure and reliable delivery of essential electric, gas and water services to the public at large. Such operational communications networks facilitate utility networks and are desired to be resilient with low latency to enable the use of certain utility applications.

Utilities use wireless technologies, for voice, control and data communications to support the operation of their critical systems. However, as described more in detail below, a wireless solution would need to support the ever-growing demand for the utilities services and certain performance characteristics associated with utility’s system availability, operation and management, (e.g. performance requirements for smart grids).

Non-wireless telecommunications alternatives may be impractical for many applications that would need wide service area coverage and low-cost implementation. For example, it is usually difficult to enable fibre and wired technologies for millions of smart grid devices, many of which may be located in remote and otherwise inaccessible areas across the wide service area of a utility.

Suitable communications technologies can enable more efficient management and control to flow of energy onto the distribution infrastructure. Some utilities are also implementing newer distribution automation technologies thereby enabling utilities to maintain power resilience and restore power more quickly after an outage and protect the utilities’ critical assets against physical and cyber-attacks. These are just some of the utility applications that are creating additional demand for new wireless communications capacity and coverage.

## 8.4 Utility Radio Communication Systems

*Overview.*

Utilities utilize highly reliable and resilient communications in order to ensure operational safety, reliability and security of the underlying electric, gas and water services that they support. This includes extended back-up power and diverse and redundant routing of backhaul communications networks at every wireless site. In addition, energy networks utilize extremely low latency services in order to ensure that utility protection systems and synchrophasors operate to prevent faults on the grid from cascading and causing widespread outages and/or safety issues. Ensuring that these systems are secure and can be delivered in a cost-effective way is becoming a high priority within the utilities industry.

Finally, some of the key characteristics of the operational communications components of utility networks are highly ruggedized for extreme conditions within the substation environment and have traditionally used extended depreciation cycles; so that the communications network devices must last for an extended period of time.

These systems support voice applications, such as routine dispatch and emergency restoration, and for data applications, such as supervisory control and data acquisition (SCADA), distribution automation (DA) and advanced metering infrastructure (AMI). Collectively, these systems comprise the [field] area network, and they are characterized by wide area coverage, high reliability and availability, and redundancy/resiliency. Details of communication systems supporting those applications are described in Report [ITU-R M.2014](https://www.itu.int/pub/R-REP-SM.2014) Digital land mobile systems for dispatch traffic and Report [ITU-R SM.2351](https://www.itu.int/pub/R-REP-SM.2351).

While utilities also use fixed wireless access systems that provide point-to-multipoint communications with high capacity backhaul that operate across different platforms, access to higher capacity licensed spectrum in the mobile service could be better suited to offer wide area coverage, not just on a point-to-point or point-to-multipoint basis.

Many of the utility applications described in the previous section of this report would be accommodated under fixed service, but there are other applications that could also be accommodated under mobile service, as well.

Utility grid modernization represents a fundamental change in the way that utility networks currently operate; for example, dynamically responding to an isolated fault and rerouting power before it leads to a widespread and extended outage or anticipating the fault before it occurs and changing out a transformer before it fails. In addition to fixed operations for intelligent electronic devices on the grid, grid modernization also envisions mobile data applications to trucks and personnel so that they can access files with information about utility infrastructure as they are restoring power and then communicate back remotely to the utility when the work is completed, and power has been restored. Such developments could dramatically reduce the time it takes to restore power and improve the safety and efficiency of operations overall.

Grid modernization depends on the underlying communications systems that would support the operational requirements for this modernized grid. The introduction of grid modernization will increasingly require telecommunications networks capable of securing real-time traffic and meeting stringent security, ubiquity, resilience, reliability and availability requirements, inherent in the provision of mission critical services, essential to society. These new applications and intelligent devices, commonly referred to as smart grid, will require utilities to upgrade their existing communications networks. Existing communications systems are characterized by a variety of wireline and wireless systems.

# 9 Utility Radio Communications Systems

Electricity, water and gas utilities use a wide range of communications systems including narrowband land mobile radio systems to meet their instantaneous push to talk (PTT), data control and dispatch communications and operational needs. Broadband is becoming at the heart of digital transformation of utilities communications as the supply chain and operational command becomes completely digitized.

Electricity is at the top of essential services list to society, whose unavailability or even temporary interruption can negatively affect whole chain of other public services that are also essential to society, such as transportation, health, banking and telecommunications.

The chain that makes up the electricity system is composed of three important sectors: generation, transmission and distribution. These segments operate in an integrated way, being extremely important the management, control, automation and monitoring of the events resulting from human actions and nature that constantly impact the electrical system.

The electrical networks "intelligence" is mainly based on the exchange of real-time information on measurement, supervision and control data, installed in strategic positions in generation, transmission and distribution networks, as well as in homes, offices, companies, with the purpose of making it capable of automatically detecting, analysing, responding and restoring faults in the network.

Utilities around the world use communications networks in their operations to support the safe, secure and reliable delivery of essential electric, gas and water services to the public at large. Such operational communications networks facilitate utility networks and are desired to be resilient with low latency to enable the use of certain utility applications.

Utilities use wireless technologies, for voice, control and data communications to support the operation of their critical systems. However, as described more in detail below, a wireless solution would need to support the ever-growing demand for the utilities services and certain performance characteristics associated with utility’s system availability, operation and management, (e.g. performance requirements for smart grids).

Non-wireless telecommunications alternatives may be impractical for many applications that would need wide service area coverage and low-cost implementation. For example, it is usually difficult to enable fibre and wired technologies for millions of smart grid devices, many of which may be located in remote and otherwise inaccessible areas across the wide service area of a utility.

Suitable communications technologies can enable more efficient management and control to flow of energy onto the distribution infrastructure. Some utilities are also implementing newer distribution automation technologies thereby enabling utilities to maintain power resilience and restore power more quickly after an outage and protect the utilities’ critical assets against physical and cyber-attacks. These are just some of the utility applications that are creating additional demand for new wireless communications capacity and coverage.

Utilities depend on highly reliable and resilient communications in order to ensure operational safety, reliability and security of the underlying electric, gas and water services that they support. This includes extended back-up power and diverse and redundant routing of backhaul communications networks at every wireless site. In addition, energy networks utilize extremely low latency services in order to ensure that utility protection systems and synchro-phasors operate to prevent faults on the grid from cascading and causing widespread outages and/or safety issues. Ensuring that these systems are secure and can be delivered in a cost-effective way is becoming a high priority within the utilities industry. Finally, some of the key characteristics of the operational communications components of utility networks are highly ruggedized for extreme conditions within the substation environment and have traditionally used extended depreciation cycles; so that the communications network devices must last for an extended period of time.

These systems support voice applications, such as routine dispatch and emergency restoration, and for data applications, such as supervisory control and data acquisition (SCADA), distribution automation (DA) and advanced metering infrastructure (AMI). These systems are characterized by wide area coverage, high reliability and availability, and redundancy/resiliency. These systems have transitioned from analog to digital and have the ability to support machine type communications.

Details of communication systems supporting those applications are described in the following ITU-R Recommendations[[9]](#footnote-9), reports and handbook:

– Recommendation [ITU-R F.755](https://www.itu.int/rec/R-REC-F.755/en) – Point-to-Multipoint Systems in the Fixed Service

– Recommendation [ITU-R F.701](https://www.itu.int/rec/R-REC-F.701/en) – Radio-frequency channel arrangements for digital point-to-multipoint radio systems operating in the frequency range 1 350 to 2 690 MHz

– Report [ITU-R M.2014](https://www.itu.int/pub/R-REP-M.2014) Digital land mobile systems for dispatch traffic;

– Report [ITU-R SM.2351](https://www.itu.int/pub/R-REP-SM.2351) Smart grid utility management systems;

– Report [ITU-R M.2440](https://www.itu.int/pub/R-REP-M.2440)– The use of the terrestrial component of International Mobile Telecommunications (IMT) for Narrowband and Broadband Machine Type Communications;

– Report [ITU-R M.2474](https://www.itu.int/pub/R-REP-M.2474) – Conventional digital land mobile radio systems.

– Handbook: Land Mobile (including Wireless Access) - Volume 3: Dispatch and Advanced Messaging Systems

Utilities also use fixed wireless access systems that provide point-to-multipoint communications with high capacity backhaul that operate across different platforms, higher capacity mobile service could be better suited to offer wide area coverage.

Many of the utility applications would be accommodated under fixed service, but there are other applications that could also be accommodated under mobile service, as well.

# 10 Spectrum Related Aspects

The key ingredient to maintaining these Smarter Utilities Networks is radio communications. Energy and water providers operate mission-critical functions like Supervisory Control and Data Acquisition (SCADA) systems that are used to manage industrial control systems such as electric grids, protective relaying and smart grid applications. Additionally, utility workers use mobile radio devices to communicate when repairing lines or restoring service after an outage. The inability of utility personnel to communicate in the field could have catastrophic consequences for utility employees and public safety.

Utilities use a variety of wireless technologies to support their various mission critical applications. For protective relaying, utilities report that they use a mix of fixed wireless access and land mobile systems, as well as optical fibre and power line communications. Similarly, for SCADA systems, utilities report that they rely more heavily on wireless communications, using a mix of fixed wireless access and land mobile systems. For operational voice and data communications utilities report that they use a combination of fixed and mobile communications systems for substations, power plants, control centres and field staff, and they use land mobile systems to a greater degree for field area communications with staff compared to substations, power plants and control centres that predominately use fixed wireless access and wireline communications systems. Utilities also reported that they use wireless services from commercial providers as an alternative to private wireless communications. For remote meter reading, utilities reported that they mainly use a combination of optical fibre, fixed wireless access and land mobile radiosystems, and to a lesser degree they use cellular radio systems.

For DDR communications, utilities report that they mainly use fixed wireless access and optical fibre, followed by land mobile radio and other communications systems to a much lesser extent. For distribution automation, utilities report that they use a mix of optical fibre, , fixed wireless access and land mobile radio systems.

While some applications are non-mission critical and can be supported using license-exempt spectrum or commercial communications networks and services, many of the applications must meet higher standards for reliability and latency due to their impact on operational safety and security – and will need access to licensed spectrum for utility communications networks. Licensed spectrum is generally less susceptible to interference, operates at higher power and provides greater overall reliability. However, certain applications require greater bandwidth than can be supported using available licensed spectrum. For these applications, utility access to licensed spectrum with greater bandwidth is necessary to support increasing communications requirements.

The energy companies that were surveyed reported they are finding difficulties in expanding services of applications that use wireless solutions in land mobile service bands, using channel bandwidths of 12.5 kHz or 25 kHz. For each new requirement, especially in existing sites, utilities often require the licensing of a new channel. If the adjacent channel is unavailable, a new frequency should be requested to the telecommunication’s regulatory agency, which causes the use of a variety of frequencies that are not necessarily adjacent or contiguous to be reused for wideband or broadband. If frequency bands with a larger channel bandwidth were made available it could enable introduction of broadband applications. Because of the increase in the demand by applications for grid modernization, smart grid, distributed generation, IoT, demand management, etc., the availability of spectrum with higher bandwidths will be crucial to utilities.

## 10.1 Utility spectrum bands and applications

Utilities operate their fixed and mobile communications systems using licensed spectrum, and they use these systems to support various voice and data applications. Utilities also use license-exempt spectrum to provide additional capacity.

Many of the utility applications considered in this document are fixed, but some utility applications also are mobile. The fixed applications include remote terminal units and other devices that operate across utility transmission and distribution networks; and unlike older one-way relatively slow speed devices that utilities have used in the past, these devices enable two-way, real-time communications that would provide utilities with much better visibility and control over their entire critical infrastructure delivery networks.

In addition to fixed operation for intelligent electronic devices on the grid, grid modernization also envisions mobile data applications to trucks and personnel so that they can access files with information about utility infrastructure as they are restoring power and then communicate back remotely to the utility when the work is completed, and power has been restored. Such developments could dramatically reduce the time it takes to restore power and improve the safety and efficiency of operations overall.

Grid modernization depends on the underlying communications systems, which in turn are dependent upon access to sufficient and suitable spectrum, particularly for field area networks.

## 10.2 Shared use of existing bands and access to additional spectrum bands

The intent here is to make more effective use of existing land mobile service spectrum bands without disrupting incumbent operations (e.g. neither by interference nor relocation). Instead, sharing existing bands could facilitate more timely access to spectrum. Additional spectrum for utilities broadband applications is also required. In order to secure equipment at the lowest possible production cost, access to additional spectrum in bands where manufacturers offer chipsets are developed for the broader market is recommended.

In addition, sharing the existing bands could open up the potential for the development of shared systems that could allow existing passive network infrastructure, such as sites and active components such as fibre connectivity to be shared thus reducing overall costs relative to operating separate networks.

Research of current uses for international electricity, gas and water utility communication systems has identified a typical common set of spectrum characteristics as shown below:

– VHF spectrum– for resilient voice communications and distributed automation for rural and remote areas (PTT & SCADA).

– UHF spectrum for resilient voice communications, wide area tele-protection, control, automation.

– Lightly regulated or deregulated shared spectrum for smart meters including access to the new 6 GHz RLAN band as this band becomes available for license exempt use as well as other bands based on shared access with incumbents.

– L-Band for more data intensive smart grid, security and point-to-multipoint applications C-band for broadband mobile applications based on IMT technologies with bandwidth of 20 to 100 MHz within geographically limited areas including within utilities power generation or water/gas treatment and distribution facilities.

– Public microwave and satellite bands for access to the core fibre networks of utilities or strategic backhaul.

Although utilities make extensive use of copper and fibre-based communications systems – and in the case of electricity, communicating down the electrical supply cables in some instances, radio also plays an essential role. Radio is valuable in this role because:

– the communications network can be independent of the assets being managed;

– radio is flexible and can be deployed more quickly than fixed assets;

– if radio services are interrupted, they can usually be restored more quickly than wired systems; and

– radio is more cost effective in many applications.

Radio systems need spectrum in which to operate. Some services may be able to operate in license-exempt bands designed for short range devices (SRDs), but no protection is available for services in license-exempt spectrum bands if they suffer interference.

## 10.3 Suitable radio spectrum

Radio communications is undeniably important to running a Smarter Electricity Network. Smarter Electricity Networks will require communications as much as computerization to successfully monitor and control the electricity network and provide communications for personnel working on the grid.

Smarter Electricity Network communications are necessary for the day-to-day functionality and the administrative savings to be made, UTC citing regular functions in the Critical Infrastructure Industries (CII) as ‘voice and data, mobile applications, monitoring and control of remote facilities, the extension of circuits to areas unserved by commercial carriers, security, video surveillance and emergency response. Furthermore, the communications are highly valuable during a crisis.

## 10.3.1 The Case for Sharing Spectrum

An alternative to using dedicated spectrum for private networks would be for utilities to share spectrum with other network users. A solution such as this would alleviate the issues around finding spectrum and the difficulty for utilities to compete for access to spectrum at auction. However, sharing spectrum involves some trade-offs, because utilities would no longer solely control the network, and that may limit functionality and degrade the quality of service.

### 10.3.2 Commercial Network Providers

Another alternative would be for utilities to approach a commercial carrier to manage their utility telecommunication networks. Commercial providers would aim to reduce the cost of building and maintaining the network. While reducing the cost would be a benefit, key issues face commercial providers about the quality of service they would be able to provide, geographical coverage requirement, the security of the supply chain and maturity of new network virtualization and slicing to serve vertical needs. It might be cumbersome to meet all the security and operational service level agreements and data protection requirements that some of the utilities business-critical applications require. It is clear that certain utility applications will have higher requirements than what these commercial providers can offer to utilities, particularly around contractual commitments to high availability and reliability.

Firstly, the utility networks need to provide full coverage of their asset base with 99.999% availability, something that has proven to be commercially unviable for public mobile. Current utility networks are built to cover the entire geographic area with overlap redundancy, power redundancy, strict maintenance schedules and emergency group talk functions. Despite the poor financial case, a commercial provider would have to provide a network that fulfilled all of these criteria.

Secondly, another issue is reliability and resiliency during adverse conditions. Maintaining and re-establishing communications during crises has always been fundamental in recovery plans for utility providers.

Thirdly, concerns surround the level of cyber security of some commercial providers, given some commercial telecommunications providers may not be subject to rigorous requirements in national regulation.

In addition, future changes to global regulation- such as net neutrality and the way third-party/public communication networks may prioritise network traffic going forward.[[10]](#footnote-10)

Many of these aspects were analysed in the publication “Is commercial cellular suitable for mission critical broadband? (2014)”[[11]](#footnote-11), and the conclusion was that there are necessary and difficult actions needed to enable commercial network as feasible solutions for many utilities services.

## 10.4 Socio-economic benefits

In 2011 UTC/European UTC and JRC UK carried out a study to assess the socio-economic benefits of utilities use of radio spectrum to support the complex smart networks of the future. The Executive Summary of the report is included here for information.

– When commercial entities are faced with decisions on whether or not invest in assets, their decisions are based purely on an economic assessment of the value of such assets to the entity. Where those assets also have a social value, it is for society, through the proxy of government, to assess any additional societal benefits and attribute a financial value to them.

– Public safety organizations and elements of the critical national infrastructure have traditionally used radio communications to underpin their operations. The allocation of this spectrum has historically been made by governments who have implicitly taken into account the socio-economic value in making allocations of spectrum to these sectors.

– With the modern tend towards the application of market mechanisms for the award of spectrum to all entities, including the public sector, utilities will assess the economic value of radio spectrum to them in judging the amount of money to commit to spectrum access in any competitive award process, and the associated business risks. Any societal value will thus be ignored.

– The purpose of this study was to investigate whether there might be an element of socio-economic value attributable to radio spectrum deployed by utilities in the conduct of their business; and if this is the case, to place an indication of the amount of socio-economic value which might thus be overlooked if an award is made purely on the basis of the economic value of the radio spectrum to the utilities concerned.

– There are limitations due to the sources of data used in the report. The data is mainly based around research in the UK and USA and relates to power interruptions to electricity networks stretching back several decades in some cases.

– More study is required on the socio-economic value of radio spectrum used to support utility operations in Europe. This new study should look forward to valuations based on Smart Grid Deployment to facilitate renewable energy generation, greenhouse gas reduction and enhance security of supply.

– On the basis of the available data, the report concludes that the societal benefit of spectrum used by the electricity industry to ensure reliable operation of the electricity supply network may have a societal benefit 50 to 150 times the economic value of the electricity itself.

– Within the resources available for the study, it has not been possible to produce equivalent figures for the gas and water utilities, although it is probable that a similar situation pervades these industries. The impact of disruption to these industries is most probably at the lower end of the multiplier ratio due to much less economic impact from disruption to gas and water supplies, although the social impact of loss of gas and water may be greater under certain climatic conditions.

In addition, the Energy Networks Association, UK and Ireland in its report [[12]](#footnote-12) stated:

“Investing in operational telecoms to support the electricity networks, through appropriate spectrum allocation and use, would enable a continued growth in connections of distributed generation, energy storage and technology solutions to actively manage the network.

Continued growth of these connections and new technologies is key to the implementation of overall carbon reduction measures. Enhancements and growth in telecommunications would also assist electricity network operators in managing their networks to reduce losses and make more efficient use of assets”.

# 11 Summary

In conclusion, it is critical for policymakers and utilities to understand the enormous amount of data that Utility Communications Networks will need to carry in order to enable the vision of the next generation utility network. There will be numerous applications, including several that require significantly greater bandwidth. While utilities may not implement all of these applications, they should design their networks so that all of the applications that they do implement can be supported both now and in the future as demand increase. In addition, the network needs to be designed so that it is reliable and provides coverage and low latency to meet their functional requirements effectively. Flowing from the applications and their functional requirements, utilities may choose the network architecture that best supports theirs needs – and there are advantages and disadvantages to each. Thus, different utilities have deployed different network architectures and have gained lessons learned along the way. Key issues going forward include the need for radio spectrum to support these various network architecture and standardization/interoperability of utility networks – which must be addressed in order to ensure operational safety, reliability and efficiency.

To recap, the utilities services network, including the field area network (FAN), bridges the gap between energy consumers and energy providers by connecting monitoring and control technologies with robust command, control, and information processing enterprise applications. There is no single reference design for a FAN: the technologies cover a wide range of radio spectrum and designs philosophies, from mesh to star to hybrid. The choice between licensed or unlicensed technology is made based on traceable requirements, as is the one between private or public network infrastructures. There is little doubt that the multitude of new smart electricity applications will require greater use of radio spectrum, whether in existing frequency bands or in new allocations of different frequency bands.

Interoperable systems and their benefits to society can be seen in many of today´s technologies, including IMT networks[[13]](#footnote-13), Radio Local Area Networks[[14]](#footnote-14), and short-range devices[[15]](#footnote-15). The utility industry and the smart electricity networks have not reached this level of interoperability, though frameworks and standards are being refined daily. Before a utility assumes a vendor´s claim of interoperability for smart electricity products, the vendor should demonstrate test results that confirm any claims.

Many vendors will not be able to meet this requirement at this time, as smart electricity device testing for interoperability is in its infancy. In some instances, the utility´s one choice is creating its own test facilities.

Utilities that were early adopters of smart electricity applications and FAN connectivity are providing valuable insight from their experiences that should be leveraged by subsequent adopters. The industry learned that smart grid applications have a wide range of system requirements in the amount of data to be transmitted and the speed at which the data received and acted upon. Network designers must be familiar with detailed use case information in order to plan traffic load. The use cases must include normal, start up and emergency modes. RF modelling prior to final design and purchase decisions, often complex and tedious, is key to understanding the day-to-day operation of these systems. While no single network design will meet all requirements for the industry, let alone a single utility, the technologies are maturing and real-world experiences is being added into current standards activities.

Smart electricity applications are presented in a number of categories and the requirements of each of the categories are discussed. The backhaul FAN is critical in overall smart grid performance and this document includes a discussion of backhaul, the use of commercial or private back haul options and some guidelines for making these choices. Standards continue to play a role on FAN designs and a discussion of standards, a few examples of standard families are provided. Finally, a wireless FAN relies on radio spectrum, so a summary of spectrum options is also included.

There are different architectures, each with advantages and limitations. The design of the FAN communications network to support day-to-day grid operations must be completed with the same amount of care and diligence as the grid itself. The utility creates its vision of the smart electricity networks by selecting which applications to deploy. These applications have use cases that must be clearly understood. Use cases lead to FAN architecture options and ultimately data throughput needs. Data throughput will determine spectrum requirements and the choice between licensed and license-exempt spectrum. The bandwidth requirements are going to be different for each technology, depending on the applications and the functional requirements for those applications.

Utilities around the world share a common need for radiofrequency spectrum to support their mission critical applications to ensure safety, reliability and security of their operations and the public that relies on their essential electric, gas and water services that they provide. Without these communications systems, electric services are subject to brown-outs and blackouts which can extend over large areas if faults are not instantly isolated. Gas services also depend on communications to monitor and control pressure and the flow of gas so that services are also delivered safely and reliably. Similarly, water services use communications technologies to monitor and control the quality of the water and shut-off valves when there are breaks in the water mains. Not only are these communications systems critical for utility applications, they are also essential for communicating with personnel in the field, particularly in remote areas or when they are restoring service in the aftermath of storms, earthquakes, wildfires and other natural disasters where and when commercial communications networks may be unavailable.

The results of the surveys show that utilities currently use a wide variety of different spectrum bands, which is largely a reflection of the reality that there have been and remains to this day virtually no international policies to coordinate spectrum allocation for use specifically by utilities. As utilities increasingly rely on communications to support increasing automation of electric, gas and water services and as the world becomes even more dependent on reliable electric, gas and water services, the time has come for policy makers to work together to allocate harmonized spectrum that will provide sufficient capacity and coverage for utilities to support grid modernization using standardized IMT and LTE equipment.

This report is intended to serve as the foundation for this critical initiative, which will have far-reaching implications and long-lasting benefits for the world. This is a huge opportunity for the ITU, and utilities around the world need the leadership that ITU can provide to drive access to spectrum and in turn the development of grid modernization, which will ensure safety, reliability, and security of essential electric, gas and water services for the next generation.

Finally, given the critical nature of electric utility services, providers must make complex and sophisticated choices regarding the communications networks over which the various applications can run. Without flexibility to choose the nature of the technology and the structure of the networks, the continued stability of the power grid will be compromised. These choices are also influenced by the size of utilities and their consumers. Some smaller distribution utilities, for example, may consider reliance on commercial networks a necessity, due to their size, staffing requirements and trade-off between reliability and cost.

Therefore, any strategic decisions on the allocation of spectrum without consideration of the requirements of utilities is likely to have an adverse impact on the ability and cost of delivering electricity supplies to end consumers.

Annex 1

General technical and operational characteristics of   
mission critical utility applications

# 1 Introduction

Utility systems are composed of various applications that depend on communications. Some of these applications are mission critical, which means that they are used to guarantee security, quality, availability, resilience, and reliability in the provision of essential services to society, whose loss or unavailability can generate not only financial but also social disorders. Other non-mission critical applications help to support utility operations, but do not affect safety, reliability, and security. In general, utilities support mission critical applications using their own private internal communications networks in order to ensure meeting requirements for reliability, availability, and low latency. They may use commercial communications networks and services to support non‑mission critical applications.

Some examples of utility mission critical applications that require low latency and high reliability include protection, SCADA, remote measurement, mobile voice communications, fixed voice communications, digital disturbance recorders (DDR), synchrophasors, and distribution automation networks.

The following data was gathered in response to a recent survey of utilities presented in the following graphics. The survey was conducted by UTC/UTCAL with thirty-six (36) utility companies in the Americas, Europe and Africa. It encompasses information gathered from different types of utilities, namely generation, transmission and distribution companies.

The following graphics highlight the information gathered from utilities participating in the survey on communications reliability and acceptable latency for mission critical applications.

## 1.1 Protection Applications

When questioned about the maximum latency supported by the protection applications, 69% of the companies participating reported to accept delays of up to 10 ms (33% from 6 to 10 ms and 36% up to 5 ms), while 25% reported to accept delays between 11 ms to 50 ms. More details can be found in Figure 1. In the case of Brazil, the National System Operator (ONS)[[16]](#footnote-16) network procedures document, in its sub-module 13.2, establishes value smaller than or equal 140 ms as minimum requirement for the communication channels latency.

figure 1

Maximum Latency supported by protection applications

Concerning the minimum availability required for telecommunication systems for protection applications, most of the utilities surveyed reported that they require a percentage equal to or greater than 99%. As can be seen in Figure 2, twenty-four (24) companies consider availability of at least 99.99% for this type of application.

figure 2

Minimum availability for protection applications

To ensure such availability, the companies use redundant telecommunications solutions typically duplicated fibre optic routes, or a fibre route backed up by a radio link (SHF or UHF) or even a PLC connection.

## 1.2 SCADA

When asked about maximum latency supported by this type of application, 78% of the respondents stated considering a maximum of 100 ms. Among them, 39% claim that the maximum accepted is 10 ms. Figure 3 shows that 17% of the participants accept latencies higher than 100 ms in SCADA systems. Only one company informed (in “others”) that consider a latency of 2 ms as the maximum accepted to support this type of application.

figure 3

Maximum latency allowed by SCADA applications

In Figure 4, most of the participant companies consider adequate an availability higher than 99%, and 83% reported that an availability higher than 99,9% is required.

Figure 4

Minimum availability required by SCADA applications

## 1.3 Operational voice and data

When asked about the minimum availability required for operational voice and data applications, the answers were diverse. Thirty-three (33) of the companies do not accept an availability index lower than 99%. The answers can be seen in Figure 5.

figure 5

Minimum availability required by operational voice and data applications

## 1.4 Remote Metering

As it can be seen in Figure 6, most of the respondents (25 companies) informed that remote metering can work with a maximum latency of 3 minutes. Other eleven (11) companies accept latencies higher than 3 minutes.

figure 6

Maximum latency permitted by remote metering applications

When asked about minimum availability, 31% of companies answered that 99% is the required availability index and 22% consider 95% as the minimum. More details can be seen in Figure 7.

figure 7

Minimum availability permitted by this type of application

## 1.5 Digital Disturbance Recorder (DDR)

When asked about the maximum latency supported by DDR applications, participants responded a variety of answers. Nine (9) of them informed that 1 s is sufficient for this type of application. Six (6) considers that a latency no higher than 5 ms is necessary. More information can be seen in Figure 8.

figure 8

Maximum latency permitted by DDR applications

Regarding the minimum availability, most of the companies (22) work with an availability between 95% and 99,9% for their DDR applications, as it can be seen in Figure 9. One (1) company required availabilities above 99,999% for this type of application.

figure 9

Minimum availability permitted by this type of application

As utilities implement grid modernization more densely and deeper into their infrastructure, their communications networks are expected to need additional capacity and coverage as they shift towards two-way, real-time communications systems that would provide increased control, for example, to turn on/off systems remotely, automatically and dynamically without the need to send out a truck to manually reclose circuits, or when breakers have tripped for example. Moreover, those communication networks will be used to automatically detect a power outage and restore power instantly where, for example, a tree has fallen across a power line or a power transformer has failed. This kind of automation would benefit from additional capacity and coverage functions that would be provided by certain types of radiocommunication systems.

# 2 Description of Existing Communications Systems to Support Utility Applications

Figure 10 shows the different telecommunication solutions used by energy companies that answered to the survey conducted by UTC/UTCAL to support their mission-critical applications. It should be clarified at the outset that each utility may use multiple different technologies to support different utility applications. As a result, the number of utilities reporting about the technologies that they use for certain applications, such as protection or SCADA, may exceed the total number of utilities that responded to the survey.

Figure 10

Number of companies that use different telecom solutions to support their mission critical applications

Although optical fibre is widely used in the electrical sector to support utilities’ mission critical applications, the use of the wireless solution is also essential, so much in the backbone as in the access to power plants, substations, etc. Wireless solutions ensure that a great number of decentralized resources can be connected more easily and quickly. Wireless solutions are also essential for maintaining communication with the field team in activities related to maintenance and repair of the power grid.

Figure 11 shows the information gathered in the survey in regard to the various wireless technology solutions used by utility companies for each specific type of application.

figure 11

Wireless Telecommunication solutions by type of application

Use of the public mobile service was limited to supporting applications for distribution network automation and only one of the respondents reported that they utilized it. By contrast, use of a private LTE solution by utilities was considered by all respondents as an alternative to most of their utility applications, except for protection. Mesh, according to the respondents, was not used for protection or operational voice and data.

Figure 12 shows the minimum data rate, in kbps, required for various utility applications, according to the respondents.

Figure 12

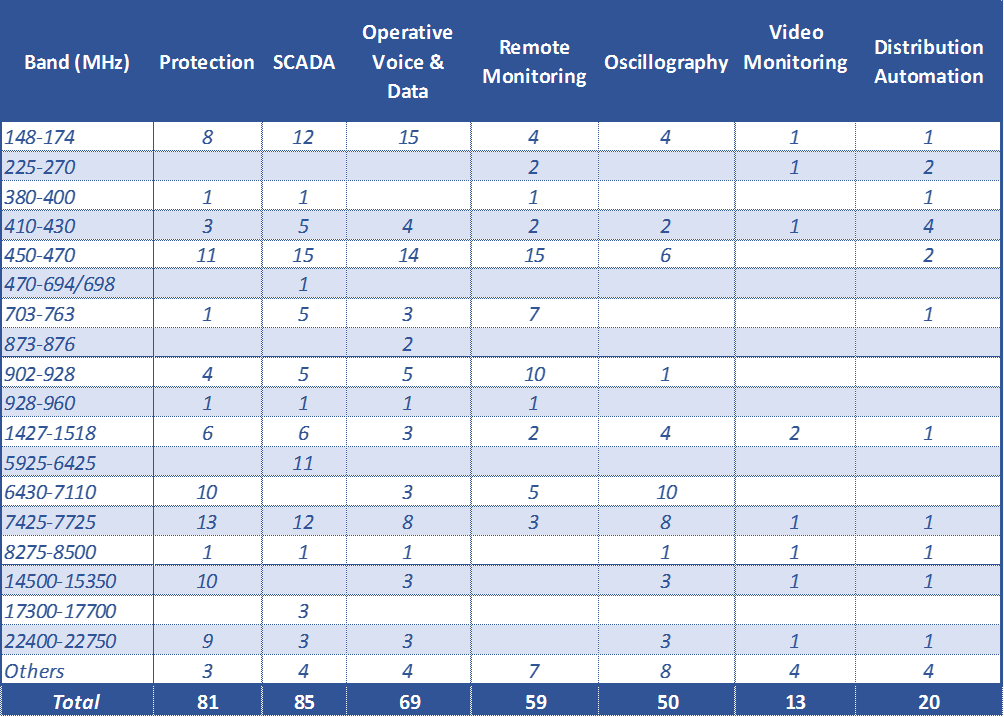
Data Rates required to each mission critical application – Energy companies’ vision

# 3 Findings of Survey on Frequency bands used by Utility Communications

A survey was conducted with the aim to gather additional information from utilities on the different frequency bands being used by those companies for the deployment of radiocommunication systems that support their mission critical applications. A total of forty-three (43) utilities in the Americas, Europe and Asia responded to the survey and the results obtained are depicted in the Table 1 and Figures 13 and 14 below:

TABLE 1

# of Answers x Application/Frequency Band



In China, part of the band 223-235 MHz was used for wireless smart grid applications. The band provides good propagation characteristics suitable to meet the wide area coverage requirement of many smart grid applications.

It is evident in this survey the diversity of spectrum bands used by utilities worldwide, certainly because there are no internationally agreed recommendations, to be considered by regulators, for allocating spectrum on a harmonized basis to utilities. There is broad recognition, however, that mission critical applications and services depend on the suitable choice of spectrum bands, on a primary basis, to ensure a better quality of service rendered to the population.

Figure 13

# of Answers x Application/Frequency Band

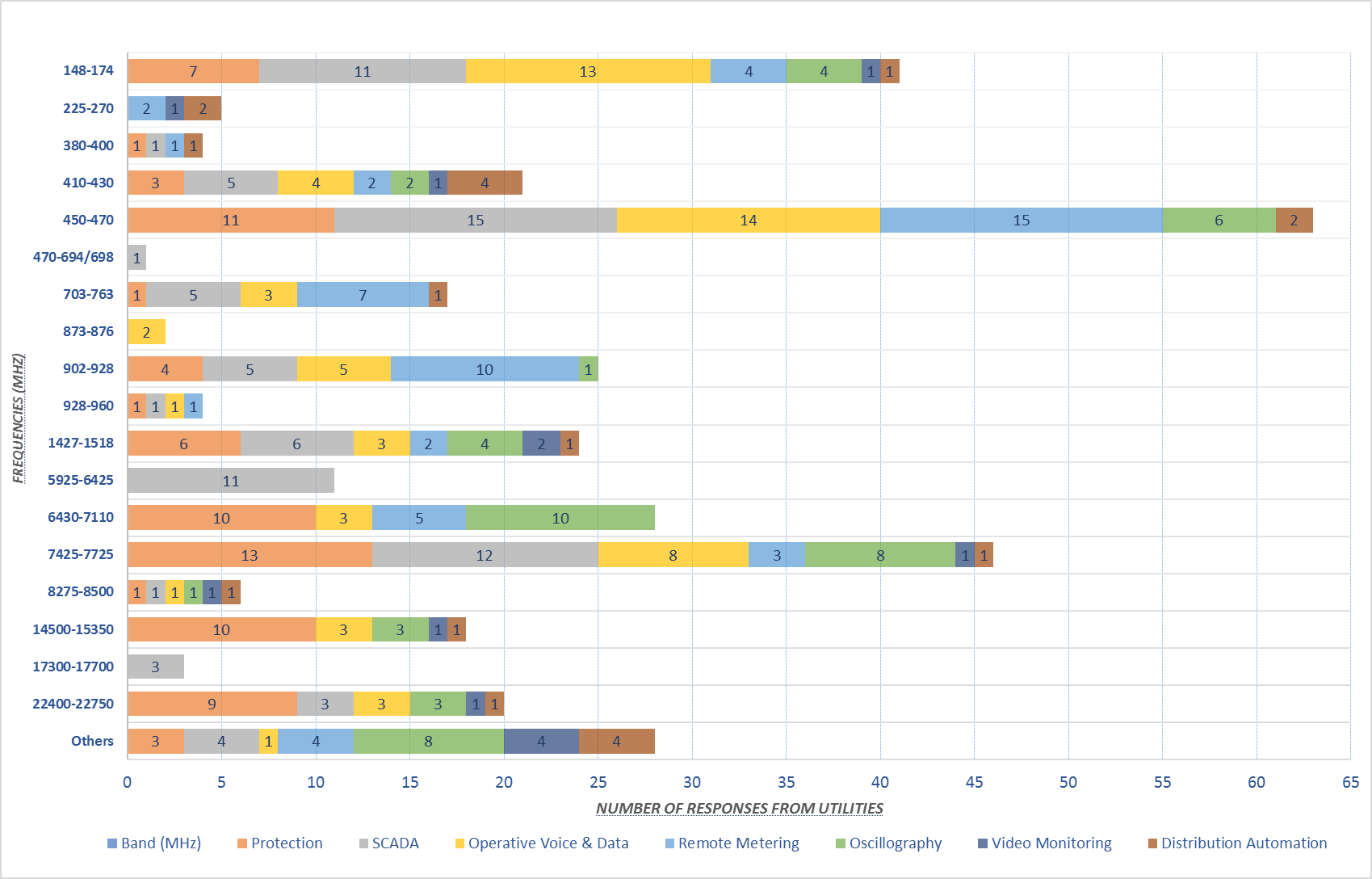
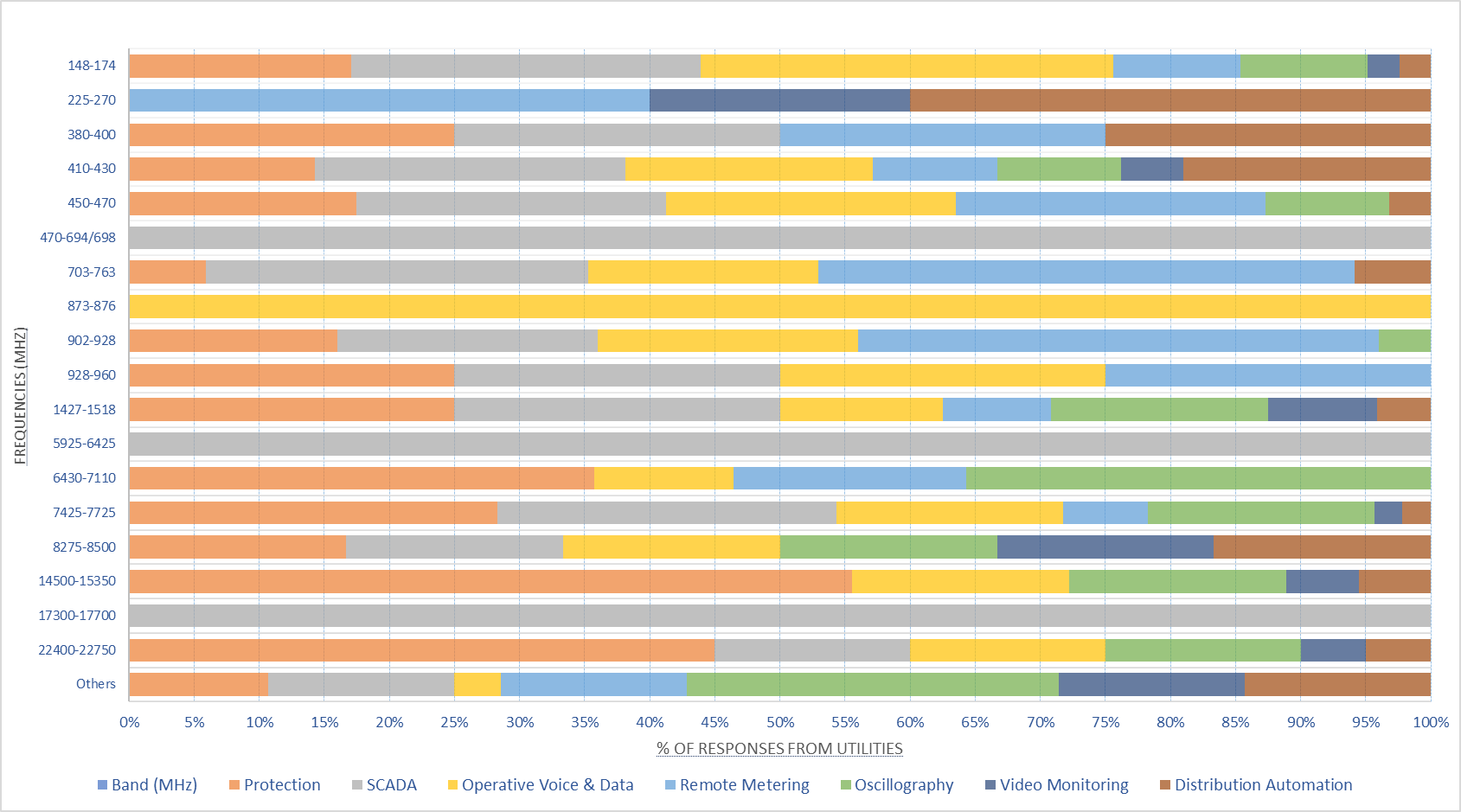


Figure 14

% Distribution of Answers x Application/Frequency Band



In Figures 13 and 14 above, it is possible to highlight the frequency bands most used by utilities, as well as those that support virtually all applications through the implementation of wireless networks capable of providing a wide range of fixed and mobile services. Certainly, they are frequencies with good propagation characteristics that enable the deployment of radiocommunication systems, with different channeling arrangements, to meet the bandwidth requirements of the different mission critical applications.

Additional considerations on spectrum for Utilities in certain countries

In Europe, the European Utility Telecom Council (EUTC) is proposing a portfolio of spectrum to address utility requirements, including a total of 16 MHz of licensed spectrum in the vital 400 MHz to 3 GHz range.

In UK and Ireland the ENA’s Strategic Telecommunications Group (the Energy networks association consisting of representatives from all UK DNO’s and National Grid) prepared position statement to raise awareness in Government, Regulators and the wider telecommunications industry concerning the changing needs of operational telecommunications for electricity networks highlighted that “Appropriate access to the radio spectrum by electricity network companies is the most cost efficient and technically appropriate option to facilitate dedicated and robust communications to support the volume of smart grid devices being deployed now and anticipated in the future.”

The ETSI technical report 103492 V1.1.1 (2019-01) estimates that the functionality of the Smarter Electricity Network could be facilitated within 20 MHz of spectrum, utilizing 4G technology. This provides a guarantee that will allow companies to make efficient investment decisions in appropriate technologies by removing the uncertainty in current spectrum-based planning.

As part of the wide area / field area network, many utilities have started to trial (and in some cases implement) LTE solutions in 3GPP band 31 (450-470 MHz). However, in some countries 3GPP band 31 is not yet suitable for LTE deployments due to existing incumbent narrow band users. As an alternative, such countries have turned their attention to the 410-430 MHz region. The creation of 3GPP bands 87 & 88 during 2018-2019 was driven almost exclusively by the needs of the Utility sector to be able to access 410-430 MHz for LTE based solutions. Developments in Ireland, Poland and Czech Republic are representative examples of band 87 and 88 use by the utility sector.

In China, both SWIN system (230 MHz discrete multi-carrier power wireless communication system: Smart and Wide-Coverage Industry-Oriented Wireless Network) and IoT-G 230 system (230 MHz discrete multi-carrier electric wireless communication system: IoT-G 230), have been used to achieve broadband transmission by aggregating multiple 25 kHz discrete carriers at part of the 223-235 MHz range (also referred here as band 230 MHz) to provide wireless service for smart grid. The 230 MHz spectrum provides good propagation characteristics suitable to meet the wide area coverage requirement of many smart grid applications.

Annex 2

An Overview of a smart water management system

# 1 Introduction

In a number of countries water supply infrastructures are not adequately funded. They are in need of repair, replacement and expansion to provide access to clean water for sustained economic development and public health.

There is a trend in legacy water management systems towards adopting digital transformation; towards smart water management systems to provide resilient and efficient water supply systems, to reduce costs and improve sustainability. The digital transformation by water utilities involves the adoption of solutions such as digital meters and sensors, supervisory control and data acquisition (SCADA) systems, and geographic information systems (GIS).

# 2 Smart water management components

Generally, the technology for smart water management consist of four components:

## 2.1 Digital output instruments (meters and sensors)

The meters and sensors provide digital outputs that are used to collect and transmit information in real time. Rain gauges, flow meters are used in water quality monitoring and other environmental data. Acoustic devices are for real-time leakage detection, video cameras for asset management and site security. Pressure monitoring for leakage detection and pump optimization and smart water meters for measuring consumption.

## 2.2 Supervisory control and data acquisition (SCADA) systems

To maintain high water quality requires constant and consistent measurement and oversight. Facilities and plants situated in remote locations must be monitored constantly. The processing and remote operation and optimisation of systems and processes is performed with advanced SCADA (Supervisory Control and Data Acquisition) systems. The applications of SCADA include: pressure management; pump station optimization; water treatment plant control; sewage treatment plant control; and environmental controls.

RTU[[17]](#footnote-17)s and PLC[[18]](#footnote-18)s are connected to sensors and actuators and a combination of radio and fixed lines is used to network the RTUs and PLCs to a supervisory computer system. Wireless SCADA systems using mission critical radios can be cost effective in covering multiple sites in remote locations over wide areas.

## 2.3 Geographic information system (GIS)

GIS is used to store, manage, manipulate, and analyse spatial information; to develop accurate baseline data. GIS can help provide understanding of assets and conditions. This baseline and monitoring systems will be important for determining realistic and achievable performance indicators. It will also be necessary to understand the hydrological baseline to prove water availability and understand future water availability and possibly quality.

## 2.4 Application software

Application software is usually integrated with GIS and/or SCADA systems to manage water networks, monitor sensors and control pressure and other attributes. It is used to improved decision making and risk management; build customer databases; enable smart metering, billing and collections; hydraulic design and optimization; water resources and hydrological modelling for water security; provide cloud-based data management and hosting options.

Smart systems can provide accurate and up-to-date information that enable informed and systematic decision-making in water management. These systems can, through automation, increase productivity and efficiency in the management of water supply systems.

A key requirement of smart systems is data: its collection, transmission and storage. In implementing the appropriate smart system there are some considerations regarding the data which will be generated:

– The amount of data: data traffic can range from a few bytes per day to megabytes per second:

• Timeliness of data: once a month, once a day, once a second; real-time?

• Criticality of the data – is it essential; is it mission critical; is it acceptable to lose a message occasionally?

• Security and privacy of the data: is the data business critical (for someone to steal), mission critical (for someone to take control).

Where appropriate existing communication networks can be used to carry the data traffic. Such networks include local area networks, cellular 4G/5G networks, fibre/copper networks, low-power wide area networks (LPWAN), and mission critical land mobile radio networks.

Annex 3

Natural Gas example: An overview of Transport, Storage and Distribution[[19]](#footnote-19)

The efficient and effective movement of natural gas from producing regions to consumption regions requires an extensive and elaborate transportation system. In many instances, natural gas produced from a particular well will have to travel a great distance to reach its point of use. The transportation system for natural gas consists of a complex network of pipelines, designed to quickly and efficiently transport natural gas from its origin, to areas of high natural gas demand. Transportation of natural gas is closely linked to its storage: if the natural gas being transported is not required immediately, it can be put into storage facilities until it is needed.

There are three major types of pipelines along the transportation route: the gathering system, the interstate pipeline system, and the distribution system. The gathering system consists of low pressure, small diameter pipelines that transport raw natural gas from the wellhead to the processing plant.

Natural gas processing consists of separating all of the various hydrocarbons and fluids from the pure natural gas, to produce what is known as ‘pipeline quality’ dry natural gas. Major transportation pipelines usually impose restrictions on the make-up of the natural gas that is allowed into the pipeline. That means that before the natural gas can be transported it must be purified. While the ethane, propane, butane, and pentanes must be removed from natural gas, this does not mean that they are all ‘waste products’.

## 3.1 Transmission Pipes

Pipelines can be characterized as interstate or intrastate. Interstate pipelines are similar to in the interstate highway system: they carry natural gas across state boundaries, in some cases clear across the country. Intrastate pipelines, on the other hand, transport natural gas within a particular state. This section will cover only the fundamentals of interstate natural gas pipelines, however the technical and operational details discussed are essentially the same for intrastate pipelines.

The interstate natural gas pipeline network transports processed natural gas from processing plants in producing regions to those areas with high natural gas requirements, particularly large, populated urban areas. The pipeline network extends across an entire country.

Interstate pipelines are the ‘highways’ of natural gas transmission. Natural gas that is transported through interstate pipelines travels at high pressure in the pipeline, at pressures anywhere from 200 to 1500 pounds per square inch (psi). This reduces the volume of the natural gas being transported (by up to 600 times), as well as propelling natural gas through the pipeline.

Interstate pipelines consist of a number of components that ensure the efficiency and reliability of a system that delivers such an important energy source year-round, twenty four hours a day, and includes a number of different components.

## 3.2 Compressor Stations

As mentioned, natural gas is highly pressurized as it travels through an interstate pipeline. To ensure that the natural gas flowing through any one pipeline remains pressurized, compression of this natural gas is required periodically along the pipe. This is accomplished by compressor stations, usually placed at 40 to 100 mile intervals along the pipeline. The natural gas enters the compressor station, where it is compressed by either a turbine, motor, or engine.

## 3.3 Metering Stations

In addition to compressing natural gas to reduce its volume and push it through the pipe, metering stations are placed periodically along interstate natural gas pipelines. These stations allow pipeline companies to monitor the natural gas in their pipes. Essentially, these metering stations measure the flow of gas along the pipeline and allow pipeline companies to ‘track’ natural gas as it flows along the pipeline. These metering stations employ specialized meters to measure the natural gas as it flows through the pipeline, without impeding its movement.

## 3.4 Valves

Interstate pipelines include a great number of valves along their entire length. These valves work like gateways; they are usually open and allow natural gas to flow freely, or they can be used to stop gas flow along a certain section of pipe. There are many reasons why a pipeline may need to restrict gas flow in certain areas. For example, if a section of pipe requires replacement or maintenance, valves on either end of that section of pipe can be closed to allow engineers and work crews safe access. These large valves can be placed every 5 to 20 miles along the pipeline, and are subject to regulation by safety codes.

## 3.5 Control Stations and SCADA Systems

Natural gas pipeline companies have customers on both ends of the pipeline – the producers and processors that input gas into the pipeline, and the consumers and local gas utilities that take gas out of the pipeline. In order to manage the natural gas that enters the pipeline, and to ensure that all customers receive timely delivery of their portion of this gas, sophisticated control systems are required to monitor the gas as it travels through all sections of what could be a very lengthy pipeline network. To accomplish this task of monitoring and controlling the natural gas that is traveling through the pipeline, centralized gas control stations collect, assimilate, and manage data received from monitoring and compressor stations all along the pipe.

Most of the data that is received by a control station is provided by Supervisory Control and Data Acquisition (SCADA) systems. These systems are essentially sophisticated communications systems that take measurements and collect data along the pipeline (usually in a metering or compressor stations and valves) and transmit it to the centralized control station. Flow rate through the pipeline, operational status, pressure, and temperature readings may all be used to assess the status of the pipeline at any one time. These systems also work in real time, meaning that there is little lag time between the measurements taken along the pipeline and their transmission to the control station.

The data is relayed to a centralized control station, allowing pipeline engineers to know exactly what is happening along the pipeline at all times. This enables quick reactions to equipment malfunctions, leaks, or any other unusual activity along the pipeline. Some SCADA systems also incorporate the ability to remotely operate certain equipment along the pipeline, including compressor stations, allowing engineers in a centralized control centre to immediately and easily adjust flow rates in the pipeline.

## 3.6 Storage

Natural gas, like most other commodities, can be stored for an indefinite period of time. The exploration, production, and transportation of natural gas takes time, and the natural gas that reaches its destination is not always needed right away, so it is injected into underground storage facilities. These storage facilities can be located near market centres that do not have a ready supply of locally produced natural gas.

## 3.7 Distribution

Distribution is the final step in delivering natural gas to customers. While some large industrial, commercial, and electric generation customers receive natural gas directly from high capacity interstate and intrastate pipelines (usually contracted through natural gas marketing companies), most other users receive natural gas from their local gas utility, also called a local distribution company (LDC). LDCs are regulated utilities involved in the delivery of natural gas to consumers within a specific geographic area. There are two basic types of natural gas utilities: those owned by investors, and public gas systems owned by local governments.

Local distribution companies typically transport natural gas from delivery points located on interstate and intrastate pipelines to households and businesses through thousands of miles of small-diameter distribution pipe. The delivery point where the natural gas is transferred from a transmission pipeline to the local gas utility is often termed the ‘citygate’ and is an important market centre for the pricing of natural gas in large urban areas. Typically, Utilities take ownership of the natural gas at the citygate and deliver it to each individual customer’s meter. This requires an extensive network of small-diameter distribution pipe.

## 3.8 Delivery of natural gas

The delivery of natural gas to its point of end use by a distribution utility is much like the transportation of natural gas discussed in the transportation section. However, distribution involves moving smaller volumes of gas at much lower pressures over shorter distances to a great number of individual users. Smaller-diameter pipe also is used to transport natural gas from the citygate to individual consumers.

The natural gas is periodically compressed to ensure pipeline flow, although local compressor stations are typically smaller than those used for interstate transportation. Because of the smaller volumes of natural gas to be moved, as well as the small-diameter pipe that is used, the pressure required to move natural gas through the distribution network is much lower than that found in the transmission pipelines. While natural gas traveling through interstate pipelines may be compressed to as much as 1,500 pounds per square inch (psi), natural gas traveling through the distribution network requires as little as 3 psi of pressurization and is as low as ¼ psi at the customer’s meter. The natural gas to be distributed is typically depressurized at or near the citygate, as well as scrubbed and filtered (even though it has already been processed prior to distribution through interstate pipelines) to ensure low moisture and particulate content. In addition, mercaptan – the source of the familiar rotten egg smell in natural gas – is added by the utility prior to distribution. This is added because natural gas is odorless and colorless, and the familiar odor of mercaptan makes the detection of leaks much easier.

ANNEX 4

The future of smart grids from an IMT perspective

IMT-2020 is more than the next generation of mobile technology; it will bring entirely new ways of using mobile technology that do not exist today[[20]](#footnote-20). Much as IMT-Advanced’s speed and capacity propelled us into the app economy and expanded the use of mobile video, IMT-2020 will be a platform for entirely new innovations. Imagine what can be done with a 100x increase in traffic capacity and network efficiency, a 10x decrease in end-to-end latency, and speeds that are over 600 times faster than the typical IMT-Advanced speeds on today’s mobile phones. IMT-2020’s faster, ultra-reliable, low-latency and higher-capacity wireless connectivity, combined with other emerging technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and Quantum Computing, will enable a whole new world of possibilities.

Smart grid technologies are considered an important enabler for dealing with the increasing demand for electricity, especially given the complexity of the electricity infrastructure. IMT technologies will be able to unlock further efficiencies in smart grids by supporting large numbers of low-cost, low-power sensors that extend monitoring for many of the grids’ unconnected areas. The densified coverage of IMT-2020-enabled sensors will allow unprecedented visibility for demand-side management that helps better forecast energy requirements, reduce electricity peaks, promote the consumption of renewable energy and ultimately reduce costs. In addition, the data collected can be integrated into consumer-facing systems to allow better visibility into residential energy use, enabling households to take more proactive roles in managing consumption. Densifying smart grids with IMT-2020 sensors will also enable the self-healing capabilities of future smart grids that can diagnose maintenance issues in real time, and automatically react to avoid outages. It has been estimated that IMT-2020-connected smart grids can enable a wide range of applications that can help reduce household energy consumption by up to 12% (Figure 1)[[21]](#footnote-21). Government investments, such as the Smart Grid Program in Canada[[22]](#footnote-22), will further encourage a shift to smart grids and cleaner energy production.

Figure 1

IMT-2020-enabled smart grids can reduce household energy consumption by up to 12%



Cities can also utilize IMT networks in the deployment of smart street lighting, especially as more vendors start to integrate IMT-2020 and advanced sensors into new lighting poles. Smart lighting systems consume 50% to 60% less energy than traditional lamps, due to the use of LED and the increased capability to adjust brightness. Connectivity also unlocks further cost savings of up to 80% by providing more visibility into maintenance operations[[23]](#footnote-23). For example, an increasing number of Canadian cities are building public-private partnerships focusing on smart city applications for energy management[[24]](#footnote-24). The cities may see significant annual cost reduction benefits from smart street lighting alone. In addition to annual cost savings, cities can see additional benefits from automatic adjustment of smart street lighting, which can reduce light pollution and increase the visibility of the night sky[[25]](#footnote-25). This is illustrated in Figure 2.

figure 2

IMT-2020 networks in the deployment of smart street lighting



Smart Street Lighting Systems can lead to significant annual cost savings.

Issues to be taken into account[[26]](#footnote-26)

With the increasingly pervasive need for communication, the focus is now switching to machines and sensing, commonly referred to as the “Internet of Things (IoT). This potentially expands the market to cover every conceivable device on the planet, and every imaginable parameter. In this environment, utilities are one of the prime targets for 5G applications as the energy sector has increasing requirements for monitoring and control driven by regulatory and commercial pressures given that the ways in which energy is generated and consumed are changing rapidly.

As with any new technology/evolution, much is promised but there is little evidence against which to judge these claims. The big issues for utilities are cost, reliability and confidence in the supply chain. It is important to note that the availability and resilience of a communications system is more a feature of network design, operation and maintenance than it is of the technology employed. There is nothing inherent in 5G to make it more reliable and resilient than previous generations of technology; on the contrary, there is the potential that the extra infrastructure – located closer to the end service points - needed to provide 5G promises will increase the cost of enhancing reliability. Since all modern communications networks are software controlled, this must also be recognized as a common-mode failure point, especially with the increasing complexity of modern software systems.

Another major issue is security. Any wireless network is open to monitoring over the air, interception and/or tampering. However, provided the security system is designed with this vulnerability in mind, the network could potentially be better secured than legacy systems.

We also have to look at 5G applications and markets, suggesting where utilities might fit into these ecosystems. Cognizance is taken of the international situation with different constraints on spectrum availability in different geographic regions and markedly different starting positions and customer densities.

Utilities will also wish to participate in the 5G world by acquiring spectrum in order to have the option to construct their own private 5G networks and integrate them into a 5G world. These private 5G networks will take a variety of forms but will need to be able to integrate and interwork with commercial 5G infrastructure operated by telecommunications providers. Reasons that utilities might want to operate private 5G networks might include the need to have:

• Networks able to operate for extended periods in the absence of primary power.

• Greater security than offered by commercial networks.

• Deterministic low latency services.

• Coverage into areas not served by commercial operators being either remote rural areas, industrial sites with poor coverage, underground locations, tunnels, etc.

• Redundant telecommunications provision.

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