# Smart Grid communication Technologies

## Smart Grid communication infrastructure challenges:

The design of the Smart Grid communication architecture faces several challenges as discussed below,

1. Dealing with huge volume of data,
2. Energy sources,
3. Highly varying traffic,
4. Interoperability,
5. Quality of service (QoS),
6. Security.

## Smart Grid Communication Technologies:

- Communication technologies utilized in smart grid can as mentioned be **wired or wireless**.

- Most power systems use a combination of different wired and wireless technologies, depending on the infrastructure. Several factor that has to be taken into account when deciding on communication technology used in SG and smart metering.

- Wireless communication alternatives have some advantages over wired communication, such as **low cost and connectivity** in inaccessible areas.

- A number of factors have to be considered for each different case to decide on communication technology. Requirement include aspects such as **geographical topography, technical and operational requirements and cost.**

Wireless communication is **less costly** to implement in a complex infrastructure and **ease of installation** in some areas.

Both types of communication are necessary in smart grid environment. The technology that fits one environment may not be suitable in a different environment.

# Smart Grid Communication Technologies

## Wired Communication:

I. Power line communication (PLC)
II. Fiber optical communication
III. Ethernet

## Wireless Communication

I. Cellular communication
II. ZigBee (IEEE 802.15.4)
III. Z-Wave (IEEE 802.15.4)
IV. WiFi (IEEE 802.11)
V. Satellite communication

## Power line communication (PLC):

Power line communication utilizes the power transmission lines to transmit data. High frequency signals from a **few kHz to tens of MHz** are transferred over the power line.

**Initial cost of PLC is lower** since it uses already existing power line infrastructure. The technology is mature, and has already been in use for decades for commercial broadband and is highly reliable.

PLC provide **high data rate and low latency** which makes it a suitable for SG communication in densely populated areas.

Power line communications divides into narrowband and broadband PLC.

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Narrowband PLC (**NB-PLC**) is operating at **300-500 kHz** with a data rate up to 10-500 Kbps and a range up to 3 km.

Narrowband PLC is further divided into Low Data Rate Narrowband PLC and High Data Rate Narrowband PLC.

Low data Rate Narrowband PLC is **single carrier based**, with a data rate up to **10 kbps**.
High Data Rate Narrowband PLC is **multi carrier based** with a data rate up to **1 Mbps**.

Broadband PLC (**BB-PLC**) is operating between **1.8 and 250 MHz** with a data rate up to **300 Mbps**.

There are some technical challenges due to the nature of the Power line networks.

The Power line transmission medium is a harsh and **noisy environment** that makes the channel difficult to be modeled. The **low-bandwidth characteristic** (20 kb/s for neighborhood area networks) restricts the PLC technology for applications that need higher bandwidth.

Furthermore, the network topology, the number and type of the devices connected to the power lines, wiring distance between transmitter and receiver, all, adversely affect the quality of signal, that is transmitted over the power lines.

The sensitivity of PLC to disturbances and **dependency on the quality of signal** are the disadvantages of PLC.

## Fiber optical communication:

Fiber optical communication is well suited for control and monitoring, and backbone communication in WANs.

Although **more expensive** than other alternatives it has the advantages of **long range, high bandwidth and high data rate**, and and not being susceptible to electromagnetic disturbances.

Limitations of fiber optic communication is the **number of access points.** Fiber optics are used to connect substations to the utility companies control centers.

## Ethernet:

Suited for communication in WAN between substations and control centers.

Advantages with this form of communications is its **high availability and high reliability.** Ethernet is also used in HAN for the communication between smart meters and home central.

# Wireless Communication:

## Cellular communication:

- Existing cellular networks can be a good option for communicating between smart meters and the utility and between far nodes.

- The existing communications infrastructure avoids utilities from spending operational costs and additional time for building a dedicated communications infrastructure. Cellular network solutions also enable smart metering deployments spreading to a wide area environment.

- 2G, 2.5G, 3G, Worldwide Interoperability for Microwave Access **(**WiMAX), and long-term evolution (LTE) are the cellular communication technologies available to utilities for smart metering deployments.

# Wireless Communication:

## Cellular communication:

Cellular communication can be used where continuous communication is not required.

It is used for communication in smart meters in rural areas.

Advantages with this technology is that is already existing, it has widespread coverage, low cost and high security.

One disadvantage with cellular communication is the fact that the network is shared with many other users, this can in some cases result in network congestion.

Universal mobile telecommunications system (**UMTS**), long-term evolution (**LTE**), LTE-machine type communication (**LTE-M**) and narrowband internet-of-things (**NB-IoT**) are technologies used for communication in smart grids

The last two specifically developed for IoT applications.

LTE-M and NB-IoT are both low power wide area networks. LTE-M offers higher data rate, but require more bandwidth.

The fifth generation mobile communication network (5G) utilizes wide frequency range including mm wave spectra and operate at higher frequencies than LTE/4G system, allowing for higher speeds and lower latency, and ability to connect a high number of devices. This makes it suitable for SG infrastructure.

**Advantages**: Cellular networks already exist. Therefore, utilities do not have to incur extra cost for building the communications infrastructure required for a smart grid.

Widespread and **cost-effective benefits** make cellular communication one of the leading communications technologies in the market. Due to data gathering at smaller intervals, a huge amount of data will be generated and the cellular networks will provide **sufficient bandwidth** for such applications.

When security comes into discussion, cellular networks are ready to secure the data transmissions with strong security controls. To manage healthy communications with smart meters in rural or urban areas, the wide area deployment capability of smart grid becomes a key component and since the cellular networks coverage has reached almost 100%.

**Lower cost, better coverage, lower maintenance costs, and fast installation features** highlight why cellular networks can be the best candidate as a smart grid communications technology for the applications, such as demand response management, advanced metering infrastructures, HAN, outage management, etc.

**Disadvantages:** Some power grid mission-critical applications need **continuous availability of communications**. However, the services of cellular networks are shared by customer market and this may result in **network congestion** or decrease in network performance in emergency situations.

Hence, these considerations can drive **utilities to build their own private communications network**. In abnormal situations, such as a wind storm, cellular network providers may not provide guarantee service. Compared to public networks, private networks may handle these kinds of situations better due to the usage of a variety of technologies and spectrum bands.

## WiMAX (IEEE 802.16):

Worldwide inter-operability for microwave access (WiMAX) is a short range wireless communication technology based on the IEEE 802.16 standards with a data rate up to 70 Mbps and a range of 50 km.

WiMAX operate on two frequency bands, 11-66 GHz for line-of-sight, and 2-11 GHz for non-line of sight communication.

Line-of-sight − service, where a fixed dish antenna points straight at the WiMAX tower from a rooftop or pole. The line-of-sight connection is stronger and more stable, so it's able to send a lot of data with fewer errors.

Non-line-of-sight − service is a WiFi sort of service. Here a small antenna on your computer connects to the WiMAX tower.

The physical and media access control (MAC) layer of WiMAX are defined by IEEE 802.16.

The physical layer uses orthogonal frequency-division multiple access (OFDMA) and 14 of 26 multiple-input multiple-output (MIMO) antenna system providing increased non-line of sight capabilities.

The MAC layer applies data encryption standard (DES) and advanced encryption standard (AES) encryption to ensure secure and reliable communication.

WiMAX is well suited for sensors and meters provided sufficient numbers of nodes in the area.

One limitation with WiMAX is that **coverage becomes highly limited due to signal losses** (e.g., rain attenuation, blockage, etc.)

## ZigBee (IEEE 802.15.4):

ZigBee is an open wireless mesh network standard based on the IEEE 802.15.4 standard.

It is a short range, low data rate, and energy efficient technology. ZigBee has mesh capabilities and a coverage range from 10 to 100 meters.

Mesh networks are decentralized, where each node are self-manageable, and can re-route, and connect with new nodes when needed.

This makes ZigBee well suited for use in HAN applications such as remote monitoring, home automation, consumer electronics and smart meter readings.

A ZigBee mesh network is constructed of three different types of nodes: coordinator, router and end-device.

ZigBee uses AES-128 access control to manage a high level of security.

Because of the low transmission power level, this technology is vulnerable to multipath distortion, noise and interference.

ZigBee operating on 2.4 GHz band is also affected by distortion from technologies such as WiFi, USB, Bluetooth and microwave ovens as these operate on the same unlicensed frequency band.

ZigBee is a wireless communications technology that is relatively low in power usage, data rate, complexity, and cost of deployment. It is an ideal technology for smart lightning, energy monitoring, home automation, and automatic meter reading, Advantages: ZigBee is considered as a good option for metering and energy management and ideal for smart grid implementations along with its simplicity, mobility, robustness, low bandwidth requirements, low cost of deployment, its operation within an unlicensed spectrum, easy network implementation.

Disadvantages: There are some constraints on ZigBee for practical implementations, such as low processing capabilities, small memory size, small delay requirements and being subject to interference with other appliances, which share the same transmission medium

**WiFi (IEEE 802.11):**

WiFi technology, based on the IEEE 802.11 family of standards, is a wireless networking technique that is being widely used for Internet access.

It can also be a good choice in the context of smart grid, which enables consumers to monitor the improve their energy use.

WiFi solution is already being utilized in a number of devices that contribute to the so-called smart home.

For instance, WiFi is used in thermostats, appliances, and new smart energy home devices that will connect them all together to help consumers manage their own energy consumption.

**Satellite communication:**

Satellite communication can play an important role in SG communication in rural areas without cellular coverage, or as a backup solution for other communication technologies.

Examples of areas of use for satellite communication are control and monitoring of remotely located substations.

## SMART GRID COMMUNICATIONS REQUIREMENTS:

The communication infrastructure between energy generation, transmission, and distribution and consumption requires two-way communications, interoperability between advanced applications and end-to-end reliable and secure communications with low-latencies and sufficient bandwidth.

Moreover, the system security should be robust enough to prevent cyber-attacks and provide system stability and reliability with advanced controls.

In the following, major smart grid communication requirements are presented.

Security

System Reliability, Robustness and Availability

Quality-of-Service (QoS)

# Challenges of smart grid communication

## Robust Transmission:

Robust transmission of information with high QoS is one of the most prioritized requirements for smart grid communications.

It will greatly improve the **system robustness and reliability** by harnessing the modern and secure communication protocols, the communication technologies, faster and more robust control devices, embedded intelligent devices for the entire grid from substation and feeder to customer resources.

As the use of communication systems in other scenarios, there are many challenges to achieve robust transmission because of limited bandwidth, limited power, adverse transmission environment (interference, high path loss, etc)

Both wireless and wired communication technique consists important parts of the smart grid communication with its own advantages and disadvantages. In many cases, a **hybrid communication technology** mixed with wired and wireless solutions can be used in order to provide higher level of system reliability, robustness and availability.

**Security:**

Cyber security is considered to be one of the biggest challenges to smart grid deployment as the grid becomes more and more interconnected, and every aspect of the SG must be secure.

Security measures must cover issues involving communication and automation that affects operation of the power system and the utilities managing them.

It must address deliberate attacks as well as unintended accidents such as user error and equipment failure.

Smart grids are vulnerable to cyber-attacks due to the integration of communication paths throughout the grid infrastructure.

Undetected cyber-attacks can lead to critical damage affecting thousands or millions of customers and life threatening infrastructure

**Privacy:**

Communication in smart grids are often linked to information related to individual customers and their lives. This is why securing authentication, authorization, and confidentiality is so important in a smart grid environment.

It is of greatest importance not to disclose private data to anyone other than consented entities. Private data include consumer identification, address, energy usage information.

Smart meters are expected to provide high accuracy reading of power consumption at defined time intervals to the utilities companies. This data is used for billing purposes and grid management.

Usage pattern analysis can be useful for power saving, but involves a significant risk. The data holds a great amount of information about individual consumers.

| Wired communication technologies | | | | | | |
|---|---|---|---|---|---|---|
| Technology | Data rate | Coverage | Application | Advantages | Disadvantages | Network type |
| Ethernet | Up to 100 Gbps | Up to 100 m | In-home communication, SCADA, backbone commnunication | Good on short distances | Coverage limitations | Premise network, NAN/FAN, WAN |
| Broadband PLC | Up to 300 Mbps | Up to 1500 m | SCADA, backbone communication in power generation domain | Existing infrastructure, standardized, high reliability | Noisy channel environment, Disturbance | NAN/FAN, WAN |
| Narrowband PLC | 10-500 Kbps | Up to 3 km | SCADA, backbone communication in power generation domain | Existing infrastructure, standardized, high reliability | Noisy channel environment, Disturbance | NAN/FAN, WAN |
| HomePlug | 4, 5, 10 Mbps | Up to 200 m | In-home communication, Smart appliances | Low cost, low energy | Coverage limitations, Disturbance | Premise network |
| Fiber optic | Up to 100 Gbps | Up to 100 km | SCADA, backbone communication in power generation domain | High bandwidth, high data rate. not susceptible to electromagnetic interference | Costly | WAN |

| Wireless communication technologies | | | | | | |
|---|---|---|---|---|---|---|
| Technology | Data rate | Coverage | Application | Advantages | Disadvantages | Network type |
| WiMAX | 75 Mbps | Up to 50 km | In-home communication Smart meter reading | Low cost, low energy | Not widespread, coverage highly reduced if loss in line of sight | NAN/FAN, WAN |
| ZigBee | 20-250 kbps | Up to 100 m | In-home communication, energy monitoring, smart appliances, home automation | Mesh capability, simplicity, mobility, low energy, low cost. | Low data rate, short range, interference | Premise network, NAN/FAN |
| Z-Wave | 9-40 kbps | Up to 30 m | Wireless mesh network | Mesh capability, simplicity, mobility, low energy, low cost. | Low data rate, short range, interference | Premise network |
| WiFi | 2 Mbps - 1.7 Gbps | Up to 100 m | In-come communication, smart appliances, home automation, SCADA | Good on short distances. | Security | Premise network, NAN/FAN |
| 3G | Up to 42 Mbps | 70 km | SCADA, Smart meter reading | Already existing network, high security, low cost, large coverage | Network shared with consumers may result in congestion. | NAN/FAN, WAN |
| 4G/LTE | Up to 979 Mbps | Up to 16 km | SCADA, Smart meter reading | Already existing network, high security, low cost, large coverage | Network shared with consumers may result in congestion. | NAN/FAN, WAN |