IEEE 802 Standards for Smart Grid

IEEE P802.24
Smart Grid
Technical Advisory Group

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The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

PDF: ISBN 978-0-7381-xxxx-x STDVxxxxx
Print: ISBN 978-0-7381-xxxx-x STDPDVxxxxx

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IEEE 802 Standards for Smart Grid

Introduction

History and values of IEEE 802

IEEE 802® is the leading standards development organization for networking. IEEE 802 is actively developing standards for both wired and wireless networks.

Smart Grid is defined as an evolution of the energy supply and consumption infrastructure that will enable providers and consumers with unprecedented levels of reliability and control while reducing the adverse environmental impact of energy generation and consumption. One of the key aspects of the Smart Grid is the underlying communication between the various network elements.

(JPKG to rewrite) The first IEEE 802 network standard, IEEE Std 802.3™ (Ethernet), was approved more than 30 years ago. The first IEEE 802 wireless standard, IEEE Std 802.11™, was approved in 1997. IEEE Std 802.15™ and IEEE Std 802.16™ were both initiated in 1999 and have achieved substantial success as well. Other standards in IEEE 802 series that are relevant to Smart Grid applications are as follows:

- IEEE Std 802.1™ for bridging, time-sensitive network, and security
- IEEE Std 802.21™ for media independent handover
- IEEE Std 802.22™ for wireless regional area networks (WRAN) in the TV white space (TVWS) bands

IEEE 802 has endorsed the OpenStand principles (see http://open-stand.org/), which include cooperation, adherence to principles, collective empowerment, availability, and voluntary adoption. These principles are part of the process IEEE 802 uses to create high-quality, widely-adopted standards.

Machine-to-machine (M2M) technology enables devices to communicate with each other. There are three general layers in M2M, as shown in Figure 1.

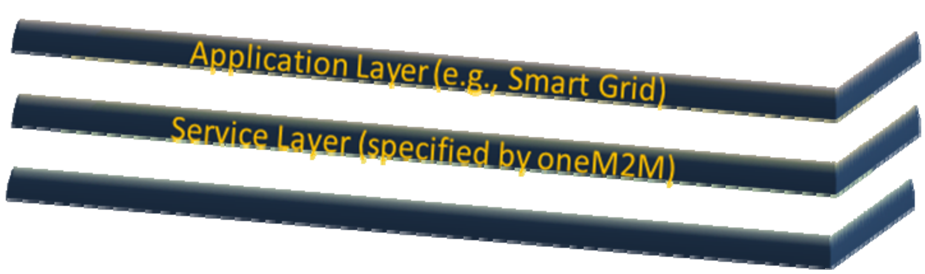

Figure 1: Layering of M2M technology

The application layer, which is the highest layer, provides the relevant application data. Organizations such as the Smart Grid Interoperability Panel (SGIP) and Continua (eHealth) are involved in the definition of this layer.

A middle layer called the common service layer enables the exchange of information between the application layer and the access independent underlying network or transport layer. Organizations such as oneM2M are leading the effort to standardize this layer.

Below the common service layer is the underlying network layer. IEEE 802 standards provide underlying networks with enhanced coverage and accessibility, quality of service, security (such as authentication and encryption), and reliability (high availability of network infrastructure). IEEE 802 standards can also provide additional capabilities for an ad-hoc self-organizing network, such as low cost, low power, low duty cycle, and low data rate.

Some IEEE 802 networking technologies offer the ability to bound communication latency of a link. IEEE 802 technologies that are not based on multi-hop networks will generally offer better ability to bound communication latency.

A list of Smart Grid standards that focus on PHY and MAC layer have been documented and approved by IEEE 802 [1].

Characteristics of IEEE 802 networks that support Smart Grid applications

(review by Beecher and Kinney) IEEE 802 networking technologies bring the following advantages to Smart Grid communications:

- Enterprise grade security compatibility
- Huge ecosystem (billions of products, hundreds of manufacturers)
- Long-term (20 year), battery-powered operation
- Continued operation during line fault events when using wireless media
- Wide choice of products across the spectrum of power versus performance
- Ability to be implemented in resource-constrained devices
- Ongoing development of standards to address changing environment and technology
- Wireless standards that operate in a licensed and license-exempt spectrum
- Possiblity of a rich set of data rate/range/latency tradeoffs
- Common upper layer interface to seamlessly integrate into existing IT systems

Operation in license-exempt spectrum offers an alternative for the lack of licensed spectrum for utilities. TV White Space (TVWS) is one example as a future source of spectrum.

Multi-hop mesh networks, such as those defined in some IEEE 802 standards, are widely used in the utility network. There are a number of characteristics that make the mesh topology favorable in some deployment situations.

Mesh topology extends the range of the network well beyond the range of a single radio link. Multi-hop delivery can assist in reaching endpoints in poor RF environments, as adjacent neighbors forward messages to the hard-to-reach node. This in turn allows greater network range with low-power radios that can operate from license-exempt frequency bands.

In dense deployment scenarios, mesh topology can allow reducing the transmit power and/or increasing the symbol rate, which are both measures that can reduce interface from and with other nodes by reducing the interference footprint. An inherent tradeoff in multi-hop network topologies is that forwarding will, in some cases, increase latency. In interference limited environments, use of mesh topology can improve delivery reliability, which will reduce retransmission delays. Similarly the resistance to interference improves delivery reliability, which can also improve the effective throughput, as retransmission caused by collisions increase the spectrum bandwidth required to deliver the message.

In a wireless system, rate (throughput) and range are inversely related if all other factors are equal. A lower rate can operate over a longer range. In multi-hop (relay or mesh networks), there is also an inverse relationship between latency and range. If range is extended by forwarding packets through a mesh or multi-hop network, the latency increases proportionally to the number of hops. This topic is presented in greater depth in NISTIR 7761 V2 (2013), Section 6.1 [2].

Applications for Smart Grid

The electric power system is logically separated by three main domains; these domains include Generation, Transmission, and Distribution. Among the categories of Smart Grid applications are Advanced Metering Infrastructure (AMI) and Distribution Automation (DA).

AMI

AMI improves utility metering and includes the following features: Utility service outage and restoration management, meter reading, Demand Response, Load Management, remote service disconnection/re-connection and service pricing capabilities that include Real Time Pricing, Time of Use pricing, and Critical Peak pricing. For more information, refer to NISTIR 7761 V2 (2013) [2].

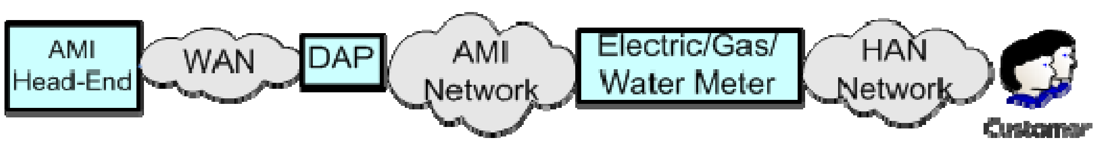

Figure 2: High level example of an AMI system

DA

DA extends intelligent control to the distribution system that includes the following capabilities: Voltage Optimization, Load Reduction/Optimization, system fault detection and remediation, and SCADA. For more information, refer to NISTIR 7761 V2 (2013) [2].

Application requirements for network communications

Security

The security of power grid communications is vital from a national security point of view. Security protocols and encryption need to be certified by international bodies. Security protocols need to be interoperable, widely deployed, and have years of testing and deployment in the field of IEEE 802 link layer security, which is based on FIPS approved technologies and ***… (add some 802.1X: Jeffree)***. IEEE 802 link layer security has been widely deployed in enterprise environments where security of corporate data is of utmost importance. These protocols have been vetted by a large number of security professionals.

Non-mains powered operations (for some devices)

There are many Smart Grid applications that require non-mains powered operation, for example, certain types of sensors may not have access to the mains power in a cost effective manner or need to operate during power outages.

Many IEEE 802 standards have been developed with energy-constrained devices in mind. This focus enables the implementation of networked devices that operate for years from small capacity primary cell batteries. Some IEEE 802 standards have been developed with the goal to work from energy harvesting as well.

Coverage requirements

In general, Smart Grid systems need to provide network services throughout the utility's service area. To do this, Smart Grid systems need to support a hierarchy of networks that have different link distance requirements. In addition, the network needs to be robust enough to allow end point devices to reach the gateways. There are a variety of IEEE 802 standards for the networks that implement these requirements.

To achieve the required coverage, IEEE 802 standards provide a variety of solutions as follows:

- Multi-hop, non-deterministic networks (e.g., wireless mesh networks and bridged wired networks)
- Star networks with a base station and relatively long distance wireless links
- A variety of physical layers with different data rates (e.g., modulation, coding, etc.)
- Fiber links when right of way is available

While 80% of the people lie within 20% of the service territory, AMI networks need to service 100% of the meters. Multi-hop networks can be used for hard to reach meters to get 100% coverage.

For resource-constrained devices, multi-hop networks provide connectivity with low power usage. In some cases, constraints on the allowed transmit power levels for wireless networks restrict the practical link distance, which multi-hop networks are applicable. Multi-hop networks, both wired and wireless, also allow resiliency during the failure of nodes in the system.

Communications over fiber or wireless gives resilience to induced voltage differences when operating in proximity to high voltages.

For connectivity within a single facility, e.g., intra-substation networking and the head end, IEEE 802.3 (Ethernet) provides a cost-effective solution.

Advantages of IEEE 802 networks

Utilities expect that the current deployment of Smart Grid networks will have a minimum lifetime of ten (10) to twenty (20) years. In general, IEEE 802 standards support backward-compatibility, as continuous improvements are adopted. This framework assists in preventing the need for "fork-lift upgrades" in the field. IEEE 802 has more than forty years of history in creating successful, backward-compatible standards.

Network and devices upgrades are achieved via incremental implementations that support multiple generations of IEEE 802 standards in the same network. In addition, the process in IEEE 802 includes the evaluation of coexistence with existing networking technologies to ensure good performance.

Conclusions

(Gilb will write once paper is done)

In summary, IEEE 802 standards provide a platform to enable diverse sensors, RFIDs, and other devices in support of the SmartGrid, eHealth industry, intelligent transportation systems, smart city applications, and general Internet of Things (IoT).

Citations

[1] "IEEE 802 recommendations on IEEE 802 related Smart Grid standards," https://mentor.ieee.org/802.24/dcn/12/24-12-0033-04-0000-package-of-802-smart-grid-standards.docx

[2] NISTRIR 7761 V2, Guidelines for Accessing Wireless Standards for Smart Grid Applications.