**IEEE P802.24**

**Smart Grid TAG**

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| Project | IEEE P802.24 Smart Grid Technical Advisory Group | |
| Title |  | |
| Date Submitted | [17 September, 2013] | |
| Source | [] [Tensorcom] [] | Voice: [ ] Fax: [ ] E-mail: [ ] |
| Re: | [] | |
| Abstract | [Whitepaper on 802 standards.] | |
| Purpose | [Draft white paper.] | |
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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.

The first IEEE 802 network standard, IEEE Std 802.3 (Ethernet), was approved over 30 years ago. The first IEEE 802 wireless standard, IEEE Std 802.11, was approved in 1997. Other standards in IEEE 802 that are relevant to Smart Grid applications are

* IEEE 802.1 for bridging, time sensitive network, and security
* IEEE 802.15.4 for home area networks and neighborhood area networks
* IEEE 802.16 for wide area and field area networks
* IEEE 802.20 for field area networks
* IEEE 802.21 for media independent handover
* IEEE 802.22 for wireless regional area networks (WRAN) in the TV white space (TVWS) bands

IEEE 802 has endorsed the OpenStand principles (<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 standard.

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 : 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 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 has been documented and approved by IEEE 802 [1].

## Characteristics of IEEE 802 networks that support Smart Grid applications

IEEE 802 networking technologies bring the following advantages to Smart Grid communications:

* Enterprise grade security
* Backwards 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.
* Can be implemented in resource constrained devices
* On-going development of standards to address changing environment and technology.
* Wireless standards that operate in licensed and license exempt spectrum.
* A rich set of data rate/range/latency tradeoffs are possible
* 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. TVWS spectrum is one example that may find application in rural areas.

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 in license exempt frequency bands.

In dense deployment scenarios, mesh topology can allow reducing the transmit power and/or increasing the data rate, both measures that can reduce interference from and with other nodes by reducing the interference footprint. An inherent trade-off 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 improve the effective throughput as well, as retransmission caused by collisions increase the spectrum bandwidth required to deliver the message.

In a wireless system, data rate (throughput) and range are inversely related if all other factors are equal. A lower data 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 proportional 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 organized as three domains: Generation, Transmission and Distribution. The domains of generation and transmission have been instrumented and networked with IEEE 802 technologies for years. These technologies are now being applied in the distribution domain through Smart Grid applications. Two such Smart Grid applications that benefit from IEEE 802 networking technologies are Advanced Metering Infrastructure (AMI) and Distribution Automation (DA).

## AMI

Some examples of AMI features are: Utility service outage and restoration management, on demand meter reading, Demand Response, Load Management, remote service disconnection/re-connection and service pricing capabilities that include Real Time Pricing, Time of Use pricing & Critical Peak Pricing. A high level example of an AMI system is illustrated in Figure 2. For more information, refer to [2].

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Figure : High level example of an AMI system.

## DA

DA extends intelligent control to the distribution system and may include the following capabilities: Voltage Optimization, Load Reduction/Optimization, system fault detection & remediation and SCADA. For more information, refer to [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
* Interoperable
* Widely deployed
* Proven by years of testing and deployment in the field

Security for the IEEE 802 link layer is based on FIPS approved technologies, which have been widely deployed in enterprise environments where security of corporate data is of utmost importance. IEEE 802 link layer security has been vetted by a large number of security professionals.

### Non-mains powered operations

There are many Smart Grid applications (e.g. water meters, gas meters, remote monitoring sensors) that require non-mains powered operation. These types of devices may not have access to the mains power in a cost effective manner or they may 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 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

* Multi-hop 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 customers are located 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 10 to 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 40 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).

# References

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. NISTR blah blah blah