Tropos GridCom™: A Wireless Distribution Area Network for Smart Grids

A TROPOS NETWORKS WHITE PAPER

This paper charts the evolution of electric utility communications requirements towards the vision of a Smart Grid: an automated two-way network for the delivery of power and broadband data, connecting together the various utility subsystems and applications down to the level of the consumer. It lays out the roles of the different communications technologies and standards within the context of the hierarchical organization of a Smart Grid communications network and describes the attributes of GridCom, a foundational network architecture for a distribution area network capable of supporting the broad array of Smart Grid applications and subsystems.

Evolution of Electric Utility Communications Requirements

In the last few years there has been a steady progression in communications requirements for utility applications as the applications themselves have evolved. One-way communications networks for reading meter data (drive-by, and then automated meter reading (AMR)) gave way to more advanced two-way communications down to the meter or automated metering infrastructure (AMI), supporting application such as demand response. Many utilities are in the process of implementing the next stage in that evolution that incorporates capabilities such as outage notification and remote connect/disconnect (AMI+). The Smart Grid vision represents a logical extension of these capabilities to encompass two-way broadband communications supporting a broader range of applications including distribution automation and control, power quality monitoring and substation automation.

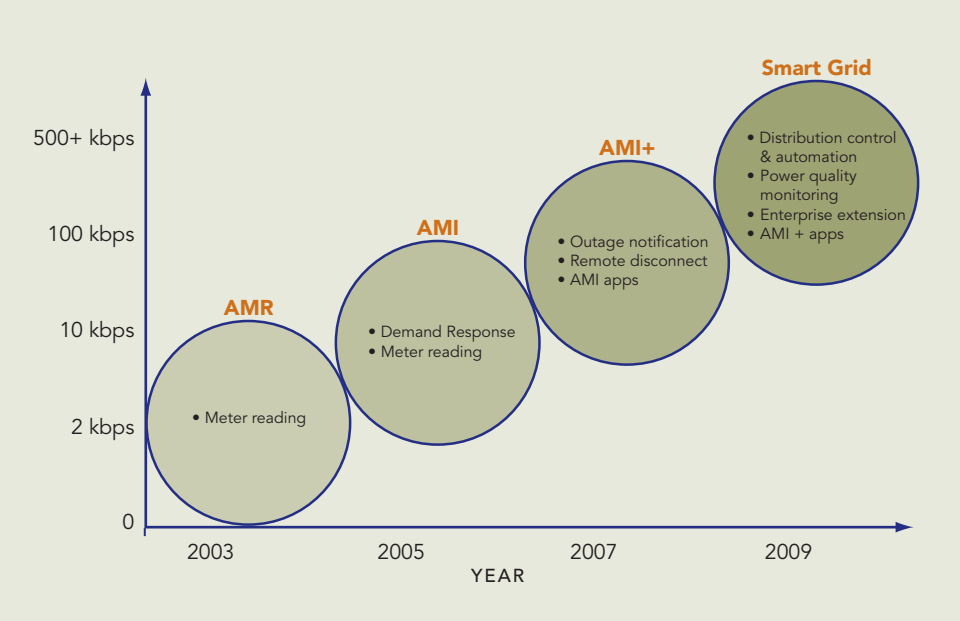

Figure 1: Evolution of utility communications requirements

The Role of Different Communications Technologies in the Smart Grid

This expansion in the range of networked applications is driving the evolution of communications system requirements, away from the one-way low bandwidth AMR systems of a decade ago towards two-way, real-time broadband networks. There has been much discussion of the merits of different communications technologies to meet this evolution in requirements. Technologies advanced by their proponents range from power line carrier (PLC) systems, broadband over power line (BPL), fiber, proprietary 900 MHz unlicensed radio networks, cellular data and WiMAX, 802.11 and Zigbee. To make sense of and to evaluate the competing claims, it is helpful to consider the overall network hierarchy extending from the utility core network out to the endpoints and evaluate the requirements at each layer of the network to understand where and how each of these technologies best fits.

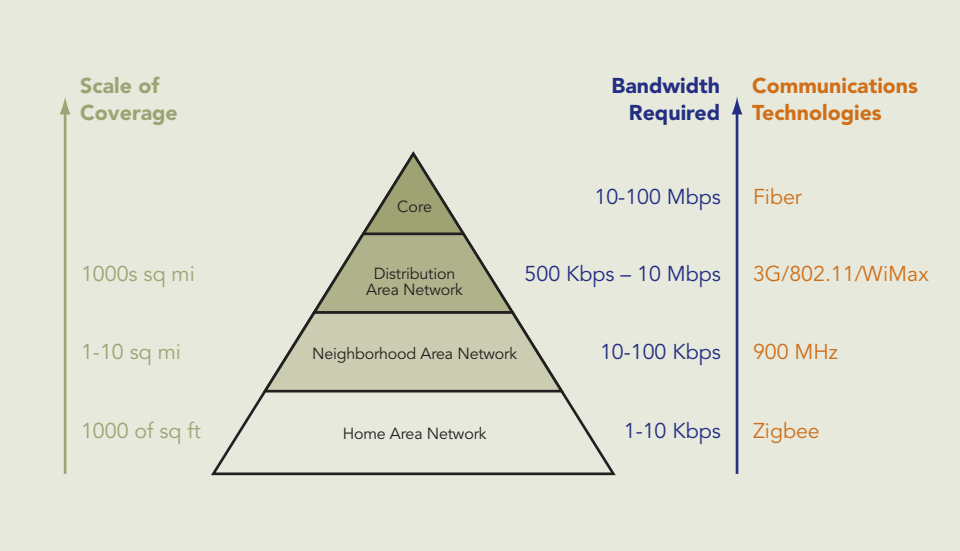

Figure 2: Communications technologies and the hierarchical organization of a Smart Grid communications network

There is, typically, a hierarchy of networks extending from the Home Area Network through the Neighborhood Area Network and the Distribution Area Network back to the Core. At each of these network layers there are distinct networking requirements and, correspondingly, different networking technologies that are most appropriate to meet those requirements.

- The Home Area Network (HAN) is inherently a multi-vendor environment composed of appliances and devices that need to network together seamlessly using open standards. Bandwidth requirements are low (1-10 Kbps) but ease-of-configuration, plug-and-play and low power consumption are essential. Home Area Networks cover areas of 1000's of square feet. Zigbee and HomePlug are examples of standards that meet these requirements.

- The Neighborhood Area Network (NAN) requires higher bandwidths (10-100 Kbps) and two-way communications capability (for meter reading, demand response, remote disconnect, etc.). The network needs to cover thousands of homes and businesses, typically offering coverage over a few square miles. The architecture needs to be resilient and the protocols need to support meshing between meters. Radio technology used at this layer needs to offer low latencies (<10s) and excellent propagation in challenging RF environments. 900 MHz mesh networks have emerged as a common way to meet these requirements at the metering network layer, in addition to such alternatives such as PLC and licensed fixed RF systems.
- The Distribution Area Network, since it is used to aggregate traffic from multiple applications including metering, distribution automation and control and SCADA, needs to support even higher bandwidths (500 Kbps-10 Mbps) and lower latencies (<100 milliseconds) and cover much larger areas, from the tens of square miles to thousands of square miles. It needs to extend the utility's fiber out from the substations into the broader territory to provide wide coverage at reasonable cost. It needs to offer standards-based interconnections to the diversity of applications and endpoints. It also needs to support Quality of Service guarantees for delay-sensitive applications and multi-layer security. 802.11, WiMAX and 3G data networks are mature proven technologies capable of meeting these requirements at the wide area network layer.
- The Core Network connects back to the utility enterprise network and is frequently backhauled today through utility-owned fiber or high-speed microwave point-to-point links at substation locations that offers 100+ Mbps of capacity.

Tropos GridCom: An Architecture for Distribution Area Networks

Tropos' GridCom is a wireless distribution area network architecture for Smart Grid communications utilizing open-standard radios and IP communications. Realizing the vision of a Smart Grid requires a broadband network that can create a solid foundation upon which multiple demanding smart grid applications such as distribution automation can be deployed. The foundation for GridCom is field-proven technology that includes Tropos' outdoor optimized routers; the patented Tropos Mesh OS built from the ground-up for large scale, mission critical outdoor network deployments; and a carrier-class centralized management and control system.

Tropos Networks has overcome the challenges of deploying wide-area wireless broadband networks on a large scale, making wide-area broadband coverage possible. Tropos has developed its innovative market-leading IP-based mesh architecture from the ground-up to deliver the scalability, reliability, performance and security that customers need.

Building on the Mesh OS system architecture, GridCom is a highly resilient, scalable, high-performance, and secure network architecture that seamlessly extends the utility's existing enterprise network and systems.

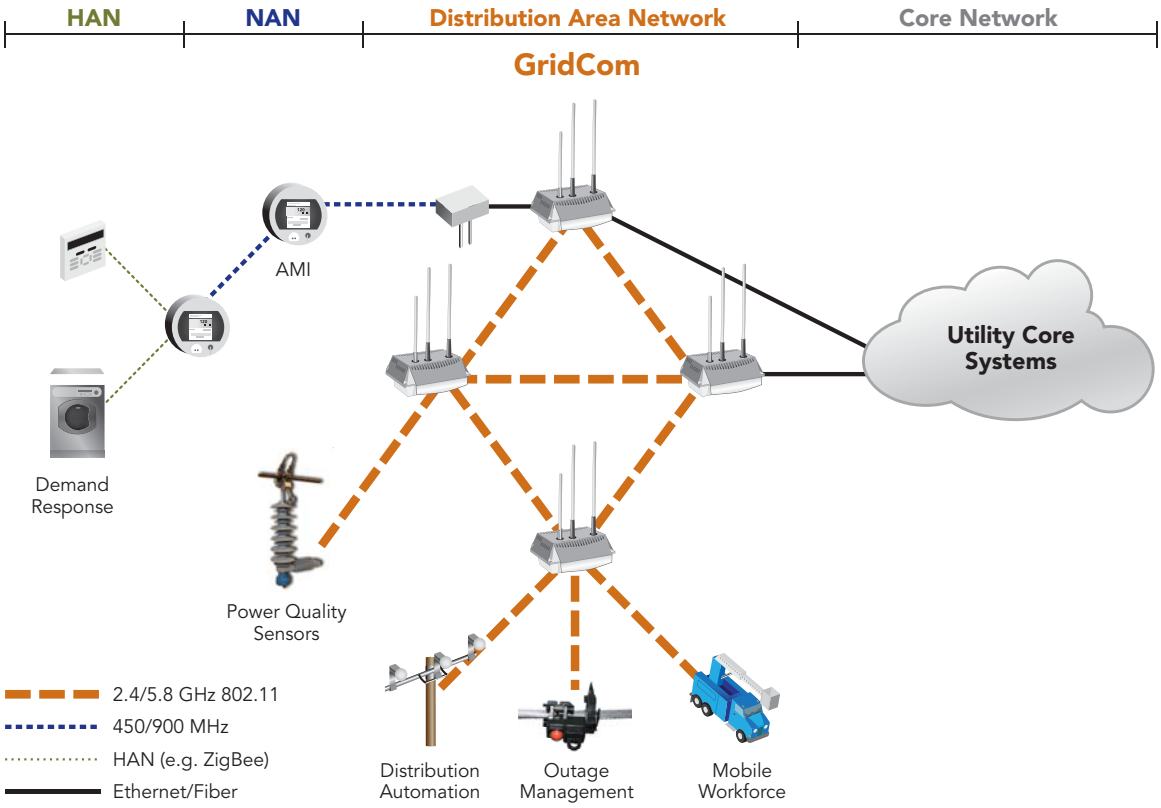

Figure 3: GridCom Network Architecture

Key Attributes of the GridCom Network Architecture for Distribution Area Networks

The GridCom architecture applies a modular approach to interconnecting a diversity of applications and endpoints. Multiple application subsystems from different vendors can be supported over a single distribution area network infrastructure through the use of standards-based interconnections (e.g., 802.11 or 802.3 Ethernet) at the system interfaces, such as that between the AMI subsystem and the wide-area network. This flexible approach allows for the selection of best-of-breed vendors for individual applications while consistently leveraging the overall communications infrastructure investment. The GridCom architecture has several key distinguishing characteristics, highlighted below:

Standards-based: The GridCom architecture is founded on the use of open standards at all layers of the protocol stack: 802.11 for mobile device support; 802.3 Ethernet interfaces to application subsystems such as AMI, SCADA, etc.; a networking layer built on TCP/IP; industry standard security specifications and guidelines such as FIPS 140-2 and the NERC CIP standards; and open XML APIs for network management systems.

Resilient and fault-tolerant architecture: The GridCom architecture is designed to be highly resilient, with multiple redundant communications pathways to ensure that there is no single point of failure. Tropos' mesh architecture self-organizes and is capable of automatically rerouting around failures, providing built-in resiliency and reliability. In addition, the ability to leverage multiple frequency bands (e.g., 2.4 GHz and 5 GHz) and to failover between them helps ensure that localized interference on any one frequency band can be routed around. Integrated battery backup protection allows Tropos routers to continue to operate for 8-12 hours in the absence of line power. Dynamic channel selection, adaptive noise immunity and other advanced RF resource management techniques provide added resiliency. Carefully designed networks achieve overall system reliability metrics of 99.999% availability in the real world.

Broad coverage: Utility footprints cover very large geographic areas, often several thousands of square miles. As stated in a recent presentation, 85% of PG&E's customers reside within 10% of the coverage area but, since the utility is required to provide 100% coverage, the remaining 15% of the customers (and the economics associated with serving them) drive the networking technology decisions. The GridCom architecture typically requires router densities averaging 1-2 per square mile, ranging from 1 every 5 square miles in sparsely populated areas to as much as 5-10 per square mile in dense urban areas. Tropos' high power radios along with the ability to mesh over 2.4 GHz as well as 5 GHz allows for the creation of broad coverage using much lower router densities (and at much lower cost) than is traditional in Tropos MetroMesh networks architected for municipal applications.

Millisecond latency: The most demanding real-time coordination and coordination applications target sub-cycle (<17ms) end-to-end latencies. Tropos' routers based on 802.11n technology deliver per-link latencies of a 1-3 milliseconds and the PWRP routing protocol that selects routing paths so as to minimize end-to-end latency can ensure end-to-end latencies under 17ms.

Interference-resistant: Since utility networks span very large geographic areas and encounter a broad spectrum of interference sources, the system architecture needs to be capable of avoiding and combating the effects of interference from a wide variety of sources. The GridCom architecture leveraging Tropos routers is highly resilient to interference through a combination of intelligent interference-minimization algorithms and highly-optimized radio hardware. Tropos routers have the best receive sensitivity and are capable of transmitting at the maximum FCC-allowed transmit power levels, providing a high link budget to counteract the effects of interference . They also have high-performance RF filters to reject out-of-band interference from neighboring transmitters in adjacent frequency bands. Advanced algorithms for dynamic channel selection, adaptive noise immunity and per-packet transmit power and modulation rate control allow the system to reconfigure its operating parameters to avoid the effects of in-band interference. Furthermore, the Tropos multi-radio routers possess frequency diversity, allowing mesh links to operate over multiple frequency bands with the ability to dynamically failover to a different frequency band if a particular frequency becomes congested at a particular location.

Security: The network needs to be designed from the ground up to be highly secure and follow evolving utility industry security guidelines to carry a range of data traffic types ranging from metering data to traffic from distribution automation devices as well as mobile GIS data. Tropos multi-use feature set allows for multiple virtual networks over a single physical infrastructure with traffic segregation across user groups. 802.11i-based link-layer security provides authentication using RADIUS and EAP and AES encryption for all control and data traffic. The network architecture and products comply with industry-standard security specifications including NERC CIP and FIPS 140-2.

High capacity: A distribution area network for aggregating traffic from a range of different applications, now and over the utility planning horizon, needs to be capable of carrying multiple megabits-per-second of data. The GridCom architecture, leveraging Tropos mesh routers, is capable of delivering multiple megabits-per-second of system capacity per square mile. In dense urban areas where the router densities might be higher than the average of 1-2 routers per square mile, higher capacities can be achieved. Many Tropos networks operating today transfer upwards of 10 GB/day per square mile of coverage.

Application QoS: Traffic from latency-sensitive critical applications such as distributed automation need to be prioritized relative to relatively delay-insensitive communications such as metering data. The GridCom architecture supports IETF (DiffServ) and IEEE (802.11e, 802.1p, 802.1q) QoS standards in addition to proprietary mesh extensions to deliver application-based QoS.

Mobility support: The wide-area network needs to support utility mobile workforce needs including broad coverage, seamless mobility and access to GIS and other databases in the field over standards-based wireless connections. The GridCom architecture delivers seamless access and mobility across a wide area to mobile devices equipped with standards-based 802.11 radios.

GridCom Deployments Today

Tropos broadband mesh routers and systems are deployed across multiple utilities in the U.S. and internationally, delivering a range of Smart Grid applications including AMI, substation automation, SCADA, video monitoring and mobile workforce automation.

Tropos is partnering with several of the leading vendors delivering Smart Grid solutions including Itron, Elster and Echelon, as well as with leading system integrators including Honeywell, Johnson Controls and IBM.

About Tropos

Tropos® Networks is the worldwide market leader in IP broadband mesh networks used to build smart communities and utilities. Its solutions create greener, safer, smarter IP foundations for deployment of high-value applications that increase efficiencies and reduce operational costs. Greener – smart grid, automated meter reading and intelligent transportation systems. Safer – mobile public safety communications and IP video surveillance. Smarter – enabling mobile workers to easily access the same information in the field as from their office. Tropos delivers the highest levels of reliability, scalability, and security in the industry with more than 800 customers in over 30 countries. Founded in 2000, Tropos Networks is headquartered in Sunnyvale, California. For more information, please visit www.tropos.com, call 408-331-6800 or send email to info@tropos.com. Tropos is a registered trademark of Tropos Networks, Inc.

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