Communications Technology for the Smart Grid *

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Supporting the multitude of Smart Grid solutions deployed or envisioned by utilities across North America requires a new approach to utility communication network design. Utilities have been among the largest creators of private communication networks, supporting varied corporate and operational information technology requirements. The result has been vast networks of copper pairs, leased analogue and frame relay circuits, fiber, microwave, and radio networks. Unfortunately, many of these solutions are not well equipped to support the requirements of the evolving Smart Grid landscape, and those that do rarely provide complete coverage across the utility's service territory.

New approaches are required for the communication networks that will support Smart Grid field devices. There is no single network capable of meeting all the requirements of the Smart Grid, but instead a network of networks can be combined to deliver necessary bandwidth and latency requirements for the wide variation of applications envisioned. Remote system monitoring, new distribution automation (DA) devices, expanded Substation Automation coverage, local distribution system grid control and smart meter solutions all have different Quality of Service (QoS) and performance needs.

THE RIGHT NETWORKS

While it is possible to use fewer networks to meet the vastly different service requirements of the various applications, doing so will entail either the use of networks with higher capability than required (resulting in unnecessary costs) or networks that are ill-suited or provide insufficient capabilities that impact performance and business value. In both cases, the utility will not have the optimum match of application to network and will not receive the maximum benefits of both.

As an example, there has been considerable discussion of using smart meter networks to support additional applications such as distribution system monitoring, automation, and local generation control. The various smart meter networks have vastly different capabilities in terms of bandwidth, deterministic latency, and network management capabilities. While this makes any generalized assessment difficult; the tier three smart meter networks may not be ideal candidates for a broad array of automation solutions. In some cases a smart meter network may suffice, but this might not be the ideal approach.

The various Smart Grid applications have many different QoS requirements. Figure 1 illustrates the varied bandwidth and latency requirements of different applications.

While not meant to be exact, the graph illustrates that AMI/smart metering and DR requirements are generally the lowest in terms of bandwidth and latency. On the opposite end of the spectrum is substation video security and transmission SCADA. In between are the DG, DA, RT switching and VVO solutions. Using a solution designed to meet the QoS requirements of AMI and DR to fulfill the communications needs of higher requirement applications may not be a good fit. It would be logical to take different communications networking approaches for this vastly disparate solution requirement set.

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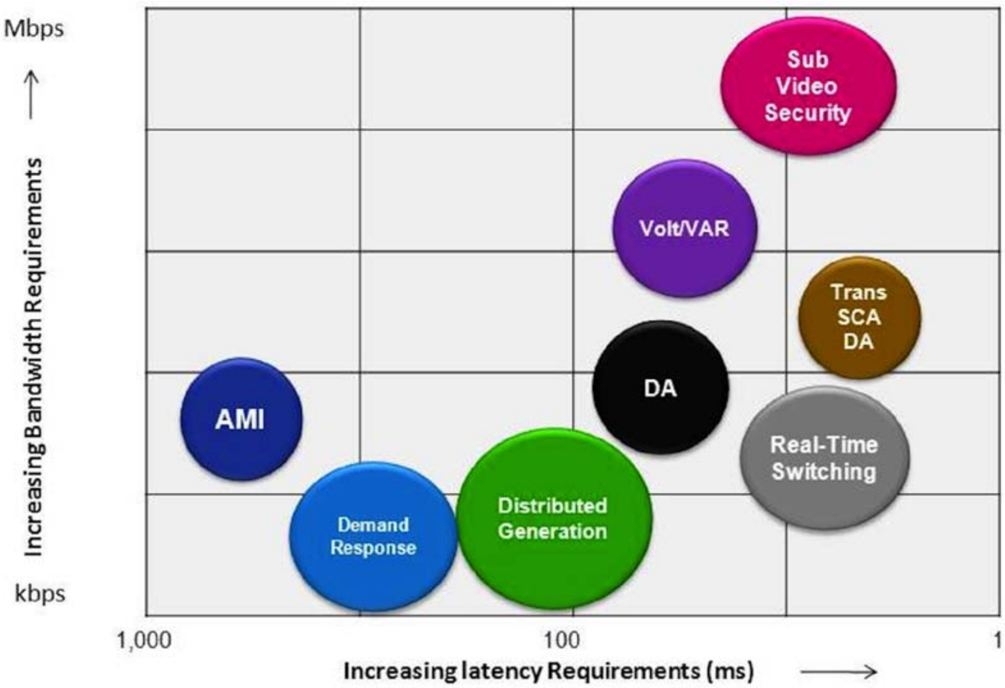

Figure 1. Varied Bandwidth and Latency Requirements of Different Smart Grid Applications

THE IMPORTANT CRITERIA

The end-state goal of an intelligent grid is one that monitors, senses, and takes action without human direction or intervention. By design it must collect, manage, analyze, and store vast quantities of data faster and more reliably than previous solutions. A view of the primary performance measures for Smart Grid communications solutions includes the following five categories: Bandwidth, Latency, Reliability, Security, and Standards. For each of these categories, the various Smart Grid applications have different requirements. Table 1 examines these categories and suggests performance ranges for each criterion.

In meeting the diverse needs of these five performance criteria, multiple and varied communications solutions are required. From an overall communications architecture perspective, the network of network approach can be viewed as a tiered network design. This is simplistic and, in actual practice, there are hybrid network designs and multi-use networks that blur the distinctions between the different layers. Conceptually, this approach allows the utility to identify available network options and capabilities, classify application requirements, and pair the Smart Grid applications with the most appropriate supporting communications infrastructure. In a four tier network design, focusing on just the first two criteria, the tiers are defined as follows:

- Tier 1: The high bandwidth, low latency backbone of the utility communications infrastructure – the information superhighway for the corporate Smart Grid initiatives.
- Tier 2: Still providing significant bandwidth and low latency but more focused in delivering backhaul solutions to connect specific applications to the Tier 1 network. These network level solutions also provide for direct connection for high value devices or those with more stringent requirements than can be served by Tier 3 and 4 solutions.

Table 1. Primary Performance Measures for Smart Grid Communications Solutions

Performance Measure	Scale	
Bandwidth	Low	Less than 200 kbps
	Medium	Between 200kpbs and 1 Mbps
	High	Over 1Mbps
Latency	Low	Withstands higher latencies and higher variability in latencies
	Medium	Requires moderate latency and some limits on latency variability
	High	Requires minimal latency and highly deterministic latency timing
Reliability	Low	No noticeably operational impact if communications lost for period of time from minutes to hours
	Medium	Operational impact if communications lost for even minutes but does not compromise ability to safely and reliably serve
	High	Significant potential impact to safety or ability to serve if communication lost for even minor amount of time
Security	Low	No operational impact if link compromised or data lost
	Medium	Moderate but limited impact if link compromised or data lost
	High	Significant operational or corporate impact if link compromised or data lost
Standards	Low	Minimal impact to use of non-standard proprietary communications solutions
	Medium	Moderate impact or workarounds required if non-standards based communications solutions used
	High	Significant impact to cost or operations if non-standard communications solutions used

- Tier 3: Include Local Area Networks (LAN) or Neighborhood Area Networks (NAN) that support applications such as Smart Metering networks, localized distribution automation, or internal substation communications networks.
- Tier 4: The least well defined level of the network but envisioned to support Home Area Network (HAN) solutions, providing connectivity between the utility and end-use customers.

Although not exhaustive, Table 2 provides examples of the physical approaches and applications for the suggested four network levels.

THE OPTIMUM APPROACH

Several factors influence a utility's approach to developing its telecommunications network and its plan to support Smart Grid solutions.

- Unique Starting Point. Every utility has a different starting point. Just as with some developing countries that have bypassed

Table 2. Physical Approaches and Applications in a Four Tier Network Design

Tier	Network Types	Applications
1 Backbone	Corporate fiber Microwave	Corporate information flow System protection Critical assets
2 Backhaul	WIMAX	Substation automation Video security Smart meter backhaul Distribution automation
3 LAN/NAN	Single purpose RF Smart meter networks	System monitoring Smart meters
4 HAN	Zigbee	In-premise devices

extensive copper phone networks to go directly to cellular, utilities that do not have extensive existing systems may be able to more easily jump to the desired end-state solutions.

- Evolving Requirements. How well defined are the utility's requirements? Because many utilities are still in the midst of developing their Smart Grid strategies and business initiatives, they do not yet know the extent of their communications requirements. These utilities might need to develop interim steps rather than move directly to the optimum end-state solution. These strategies would ideally allow for focused and incremental system upgrades without significant stranded asset concerns.

- Appropriate Solutions. Is it really necessary to have a ubiquitous solution that provides the same level of service and complete system coverage? Attaining this is often an expensive proposition. Geography, availability of public networks where the utility's private network is not cost effective, making due with lower level (but economically acceptable) solutions than ideal or spot solutions may be appropriate.

While much of the Smart Grid focus has been on the applications and business value derived, it is critical to understand the communications networks issues and options as well. A mismatch between application requirements and network capabilities can render an otherwise robust solution design unworkable.

About the author

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