

# Communications Networks: The Enablers of Utility Automation Success

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## Abstract

The common denominator for successful deployment of utility automation applications such as Distribution Automation (DA), SCADA, advanced metering infrastructure (AMI), Demand Response (DR), Mobile Computing (mobile data), Mobile Voice, and other utility applications is a well developed communications plan and infrastructure. Heavily involved in this type of planning project is a concept of deployment called “Smart Grid”.

In the past, a specific type of communications media was often selected for a given application. With the growth of TCP/IP Ethernet, the common use of DNP3 protocol and the proliferation of low cost, robust, reliable and secure private communications media, utilities are building private communication networks that are shared for many applications versus the piece-meal communications approach used in the past. Utilization of the Smart Grid technologies can assist a utility determine a highest and best use plan that will serve them well in the future.

The paper will provide information on many of the building blocks that need to be considered in developing a plan for the future as well as examples of different approaches taken by utilities for their communication infrastructure for AMI, DA, SCADA and mobile applications such as: WiMAX, Cellular 3G, IP/MPLS, software-defined radio (SDR), and many new microwave products. Many of these recent breakthrough “game changing” communication technologies have been successfully deployed at utilities.

## Introduction – Planning for the Smart Grid

What is a Smart Grid? The Smart Grid has been a popular subject matter over the last few years. A smart grid leverages existing assets and applications. Technology ranges from AMI, OMS, GIS, to SCADA, new electric distribution, and “smarter databases”. However, not one technology or strategy fits all utilities. The Smart Grid is not a purchased product, but a concept of deployment for a range of technology systems. Most Smart Grid definitions are user-specific, and can include:

- Automatic data collection from multiple applications
- Adaptive integrated communications mediums
- Integrated software suites that share databases

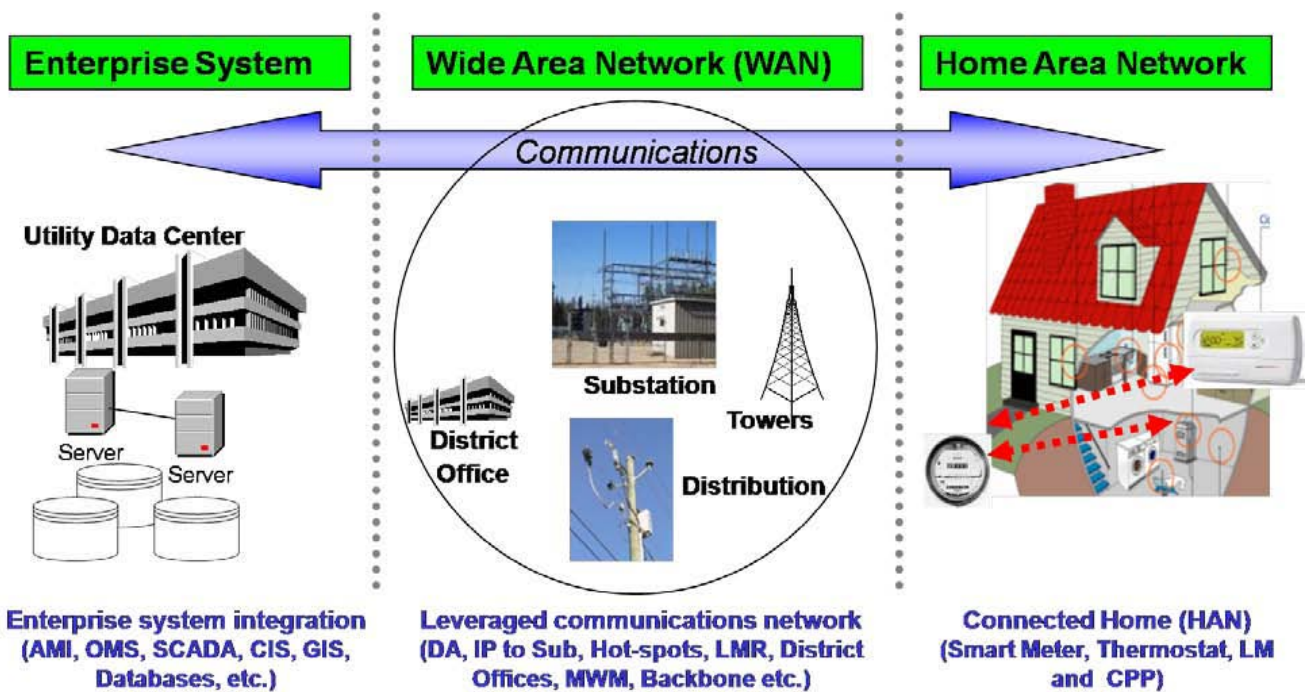


Figure 1: Smart Grid Communications

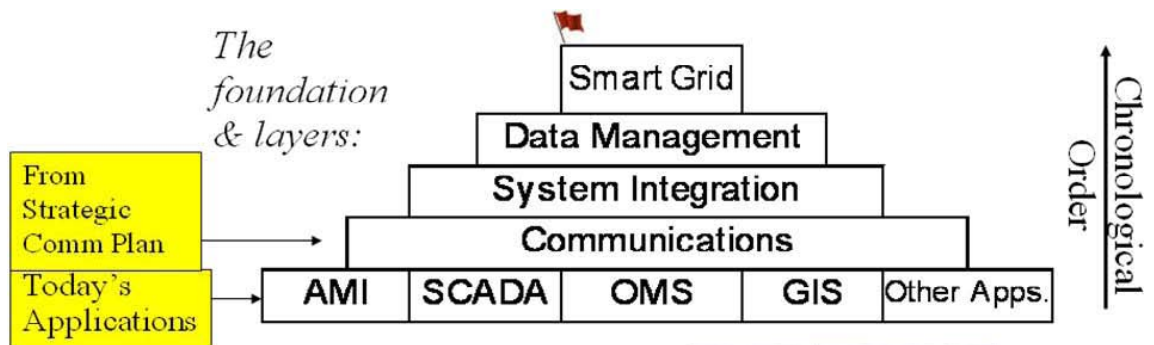
## Smarter Grid Building Blocks and Evolution

Generally speaking, the term “smart grid” refers to an advanced state of utility system infrastructure, operation, and processes. Discussion of the subject ranges from AMI, DR, feeder automation, and advanced grid optimization. The smart grid advances the level of intelligence in a utility’s operation to include not only traditional “grid” aspects of the field, but also enterprise systems and processes such as CIS, work management, rates, and other future applications.

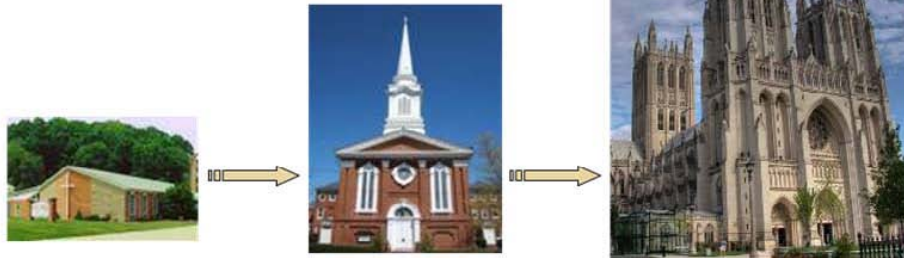
Smart grids vary in sophistication and intelligence levels, and are accordingly often referred to in terms of “smart,” “smarter,” and “smartest.” Highly automated, integrated systems, capable of self-healing, are ideal; nonetheless, more basic smart grids may be possible and within reach of some smaller utilities. Thus, the definition of smart grid is somewhat dependent on the utility’s present infrastructure, application needs, and vision.

The common themes of any smart grid design include:

- The need for automatic collection of data from multiple applications throughout the utility network, including end user premises. While the smartest grids will include end-user premises, this is not a prerequisite for a smarter grid.
- The need for adaptive integrated communication mediums that can handle data from multiple applications located throughout the utility infrastructure.
- The need for integration of application software suites so they share collected data in common dynamic databases.



*Somewhat like building a cathedral.*



## Need for Communications Infrastructure

In the past, utilities have different departments purchasing systems and applications. The operations department would typically purchase mobile voice (land mobile radios), SCADA and, possibly, mobile data products, the engineering department would purchase the software application suites for downloading recloser data from the field, and the billing department would focus on receiving meter data from the customers. Unfortunately, since a coordinated effort between utility departments would not often occur, the backhaul and backbone communications between field locations and the offices were often very expensive and, in many cases, ineffective.

Best practices for communications at utilities starts with an overall communications strategic plan developed with a goal for interoperability of applications using the same communications infrastructure. The question is how do you develop a Strategic Communications Plan that takes into account the current needs and the needs of the future?

## **Developing a Strategic Communications Plan**

Power System Engineering (PSE) has found that everything starts with cross departmental team of stakeholders, who are empowered to develop an overall utility strategic plan. This team should document the current state of the utility, the future state goal and then create a gap analysis that outlines the missing components between the current state and the future state goal.

The gap analysis will help define areas that need change to achieve the future state. In most cases, the future state cannot be achieved without adding new enterprise and/or operational technology applications. For instance, to further enhance the utility's customer relations and customer service, AMI may be identified in the strategic plan as a "needed gap technology". Typically, PSE finds our utility clients identify AMI, mobile workforce management, SCADA, distribution automation, IP communications to substations and district offices, and upgrades to their mobile voice system as the most common necessary technology improvements to support their overall utility strategic plan.

The identified gap application needs usually can be cost justified by creating business cases that outline the benefits for the new technologies, based on better system power quality or better personnel time management or both. When the operational applications that have positive business cases are identified, then the next step is to develop a technology roadmap that outlines the implementation of the utility strategic plan. Plans identify what technologies are going to be implemented at the utility over a given 3-5 year period.

Once the technology roadmap is complete, a strategic communications plan can follow. The communications plan focuses on how the different technology applications identified in the technology roadmap will interoperate. It should identify if a private communications backbone infrastructure can be justified versus using a commercial carrier. PSE has found that the key to a successful implementation of a utility strategic plan is usually a well thought out strategic communications plan, since all applications need solid communications. Unfortunately, for a true strategic communications plan to be developed, most often there needs to be a cultural shift away from past communications planning methods.

## **Culture Change Needed**

It starts with a strategic desire, shared by all functional stakeholders, to shift from the past. In the past, utility system plans developed a unique infrastructure for each application that was implemented. Given the Wide Area Networking (WAN) communication challenges and proprietary protocols of the past, this approach was understandable. New applications typically benefited one of the utility's functional groups more than others. This approach creates silos in the organization, meaning that each functional group has its own isolated information storage area.

However, although the system was designed with the expectation that only one functional group would need a particular type of information, often multiple functional groups end up gathering that same information and storing it in their isolated "silo."

Shifting the utility culture from a functional or “silo” organization to a shared infrastructure is the first step in implementing a smart grid. This step is probably the most challenging. However, it is the key to leveraging both the infrastructure and operational data. This step may need to be driven by the Board of Directors and the Executive staff at the utility.

## **Automation and Industry Trends Impacting Communication Planning - Strategic Technology Initiatives**

Technology buy-in costs used to be prohibitively expensive, but have become more affordable dependent on software, business process analysis, integrations, and user customization. The last 10 years have provided huge increases in hardware & software functionality at reduced costs. Providers have also rolled out the adoption of MultiSpeak and other integration approaches to reduce large costs in system changes. Many technologies developed for large utilities are now available for all sized utilities.

Smart grid is essential to utilities attempting to overcome the impending labor shortage. With 40-50% of the utility workforce eligible to retire in 5 years and increasing load growth, utilities will have to make do with less. Rural electric cooperatives may be especially hard hit given the challenges faced in recruiting young engineering and other staff to rural areas, and providing compensation in the tighter market available at larger utilities. Furthermore, co-ops face additional challenges in doing more with less due to their expansive service territories and remote locations. Simply put, a smart approach and use of automation can greatly reduce the “windshield time” of staff driving to remote sites. Smart grid automation and integration can reduce staffing requirements, optimize asset use, and enhance the productivity of available staff. Many vendors’ equipment life has become shorter – five years, seven years, etc. In order to work with the new technology, automation is the promise of improved reliability and staff efficiency.

Many utilities implemented an automated SCADA system in the past and are now in the process of upgrading or updating that system. This new system needs to include OMS and/or IVR (OMS, IVR GIS, and AMI integration). To reduce manpower the systems will have direct connections to substation IEDs.

New AMR/AMI technology can be used for much more than meter reading. Utilities have started to use AMI technology for demand response. Utilities with one-way AMR are in the process of developing plans for migrating to two-way functionality. The AMI vendor’s products are still quite immature in 2009 for two-way demand response and classical load management. PSE expects to see AMI demand response vaporware to migrate to field trials by end of 2009.

## **Communication Infrastructure**

Many utilities now approach their mobile communication planning while looking at the “bigger picture” of all of their communication needs. PSE calls this “developing a Strategic Communications Plan”. The mobile component is a key “spoke in the wheel” for these plans, but other spokes are equally important. PSE would go as far as saying it is a strategic mistake to ignore other applications and needs for communications. The key driver of this movement centers on the future need for a backbone network to enable dozens of applications, including the mobile applications. The figure below illustrates this concept.

## Approach for Communication Projects

### Communications Architecture Example With Shared Infrastructure

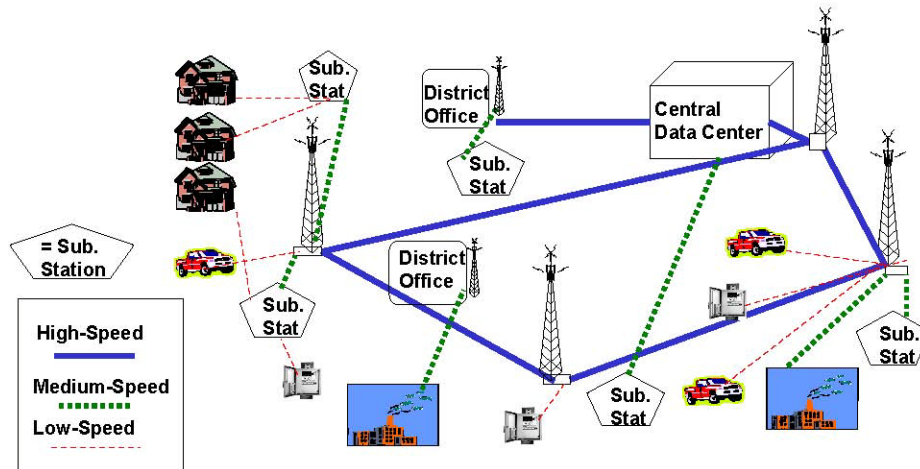


Figure 3: Communications Architecture

Listed below are the factors that have influenced the trend in developing a utility-wide communications plan:

1. There is an aggressive movement to retire proprietary SCADA protocols and replace with DNP3 or IEC 61850 with Ethernet interfaces and TCP/IP backhaul. This typically requires more base stations and/or a high speed backbone. This backbone is sometimes built with future applications like a new mobile radio system riding on it.
2. Aggressive migration to two-way AMR/AMI. In 2007, there was a breakthrough with new wireless AMI technologies. This also requires a backbone to transport the data from locations in the distribution network to the centralized node. Thus, this also requires a backbone network.
3. A movement to replace the aging VHF Load Management systems (often the former Scientific Atlanta and now ComVerge) technology or Cannon's Commercial Paging technology. Many utilities also migrated to commercial paging technologies for Load Management. PSE has found it is very typical to have Load Management failure rates of 20% or more with this technology.
4. A migration toward two-way DR in the homes with new programs such as Critical Peak Pricing and Smart Thermostat. Many utilities are faced with complicated and expensive challenges in this area; which are ultimately far more expensive than investing in a mobile radio system.
5. A replacement and/or an upgrade to the transmission level substation relay protection program where a circuit-switched < 4 ms requirement exists.
6. A deployment strategy to improve reliability with a "low-hanging fruit" DA strategy, whereas the worst-performing feeders would be set up with automatic sectionalizing strategies. PSE has completed business cases, designs, and deployments for this with great success. A fixed data

communications infrastructure is needed for this strategy.

7. If analog trunking is selected for the LMR, most often a circuit-switched backbone is needed. We have seen utilities deploy a new Ethernet backbone, and later wanted analog trunking like PassPort, only to find that, because of latency and the number of sites required, the backbone was not suitable for a particular type of analog trunking.
8. A migration to introducing or upgrading the mobile data infrastructure. Most utilities have concluded that 14.4 Kbps will meet many of the applications where coverage is critical, but will fall short of meeting future applications. Therefore, much analysis is being done with the use of various mobile data technologies versus a “one size fits all” approach. These answers come out of a Strategic Communications plan.

All of these points can be referred to as the Smart Grid. The common denominator is sharing of towers and the backbone network. The backbones are usually a combination of fiber, licensed and unlicensed microwave, and some small use of commercial telephone circuits.

## **Backbone Technologies**

In this paper backbone is referred to as the core high speed broadband network that connects tower sites, major data centers, and major network nodes together. Usually fiber and microwave are the technologies of choice. Backhaul refers to field applications like substation communications, AMI take-out points, DA sites, and other automation sites that typically require less than a megabyte of bandwidth. The move to Packet Switched Technologies (IP, UDP and TCP/IP) from Circuit Switched Technologies (TDM) has created the largest impact on Backbone Communication Designs.

### **Point to Point Microwave: 2.4 GHz and 5.8 GHz**

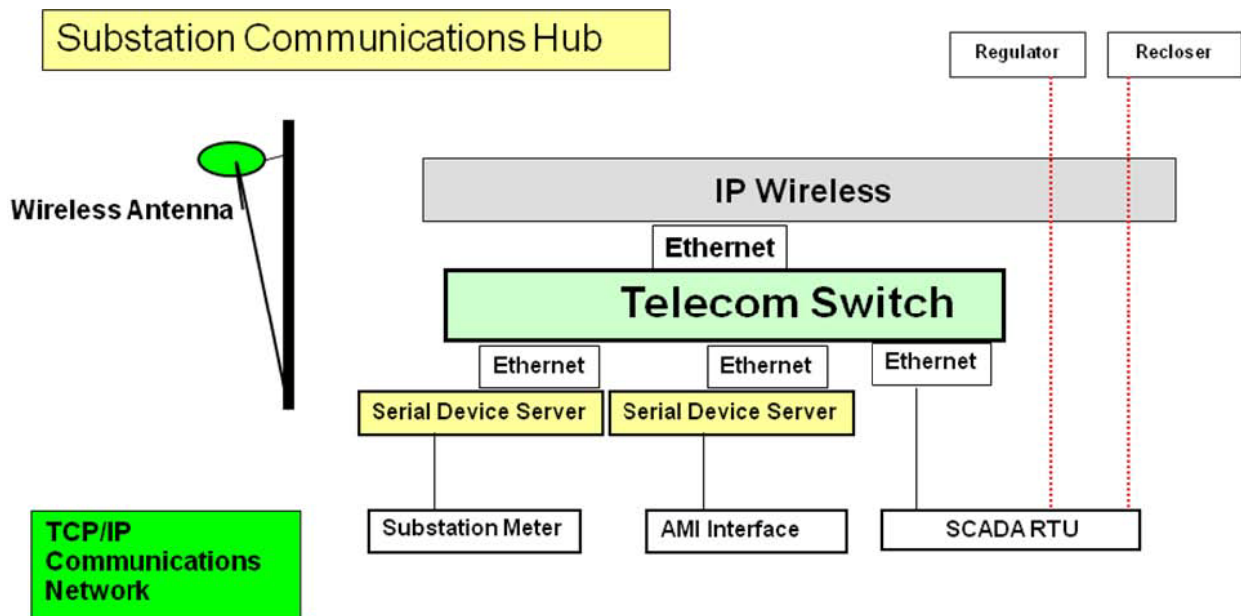
Proprietary spread spectrum products generally come with at least 4 wayside circuit-switched T-1s and 10 to 45 Mbps of Ethernet bandwidth. The wayside T-1s can be consolidated into Ethernet to increase bandwidth if needed. These products were not common five years ago. The price has steadily declined and the features/capabilities have improved. The actual radio cost is around \$8,000. Typical range is 15 to 20 miles. This system requires path and line of sight. There is some risk for spectrum “overuse” interference issues at 2.4 GHz in urban areas. This has become a very common communications media for utility backbone networks.

### **Point to Point Microwave: 6, 11 18 GHz**

Proprietary licensed radio technology products generally come with at least 8 wayside circuit-switched T-1s and 50 to 155 Mbps of Ethernet bandwidth. The wayside T-1s can be consolidated into Ethernet to increase bandwidth if needed. The price has steadily declined and the features/capabilities have improved. Typical range is 15 to 25 miles. This system requires path and line of sight. There is very little risk for spectrum interference. Price point per path for all cost involved is close to \$100,000.

## Fiber Options

Fiber is most often viewed as the very best communications media for transmission utilities. Most utilities would put in fiber nearly everywhere if costs were not an issue. Fiber is immune to ground potential rise and EMI. Reliability for fiber depends on the architectural design. Fiber has a very long life cycle (20 years plus). The utility will need to determine their transmission line build-out plan in next five years.



## SCADA, AMI, DA, and tower nodes

### Communication Requirements for Utility Automation and Substations

Communication requirements at tower sites are dependent on how many field locations and applications will feed into the tower site.

Distribution substations have become regional nodes for a variety of utility automation applications including:

- SCADA
- AMI via PLC or nodes for fixed wireless concentrators
- Direct connect via Ethernet into substation IEDs
- Video monitoring
- Concentration points for down-line DA
- Hot spots for mobile data

Smart Grid can offer dramatically enhanced monitoring, control, and processes affecting reliability, power quality, and the aging grid. Smart Grid can allow an integrated approach to prevention, rapid diagnosis, and restoration of power outages – via weaving together systems

(e.g. AMI, OMS, GIS, AVL, SCADA, DA, etc.) and programs (e.g. transformer management, voltage monitoring/modeling, etc.).

Smart Grid capabilities for monitoring and control can benefit utilities on the power side of the equation. Smart Grid offers load management and price signaling possibilities. Additionally it can support net metering and monitoring/control of renewable resource interconnections.

## **Fixed Wireless AMI**

AMI infrastructure has become one of the main drivers for the Smart Grid approach to monitoring the utility system. AMI is a system that gathers data on client consumption and transmits that information back to the utility on a systematic basis. However, the new AMI systems can also provide improved outage restoration process, improved voltage monitoring, critical peak pricing (CPP), Time of Use (TOU) metering, smart thermostat programs and replace the use of aging LM infrastructure. Therefore, choosing an AMI vendor has significant involvement with evaluating non-metering related functionality as well as metering capabilities. Currently, a large number of utilities have not utilized the full capabilities of an AMI system. An informed plan and vendor can assist with selection and utilization of AMI program that will serve many functions.

Classical AMI systems utilize 15-minute interval metering - data is sent back every 15 minutes once per hour. Classical load management includes water heaters and air conditioners as the top two applications. What is changing, however, is that load management is migrating to be run over the AMI network versus a private load management network. New CPP systems include connections into an In-Home Energy Use Display (IHD) in order to monitor usage. We look forward to installations of the Smart Thermostat and communications with other appliances.

Most utilities that have deployed two-way AMI technology in the last two years have done so with the intention of deploying many programs beyond basic meter reading. The utilities that have deployed one-way drive-by technology have limited potential to add advanced two-way functionality. It does not mean that the one-way drive-by technology is poor, but the technology may need to depreciate prior to advancing to AMI. For example, the business case for two-way AMI is much stronger for utilities without a present drive-by program. Many other automation opportunities exist in the near term for utilities that have one-way drive-by AMR such as SCADA, GIS, OMS, and new mobile data technology.

	Reduce Costs	Improve Customer Service	Productivity Improvements
Capturing individual load contribution during system peak conditions	X	X	X
Evaluate transformer loading	X		
Developing load shapes for customer classes		X	X
Voltage monitoring	X	X	
Identifying system blinks & power quality	X	X	
Monitor system conditions during load xfrs	X	X	
Track phase changes and phase verification	X		
Critical Peak Pricing (CPP)		X	X
DG & Net Metering	X	X	X
Reduce theft of service	X	X	X
Distribution Automation (DA)	X	X	
Time of Use rates (TOU)	X	X	X
Remote disconnect/reconnect	X	X	X
Load Management (LM)	X	X	X

**Table 1: AMI Benefits**

## What are In-Home Energy Use Displays (IHD)?

IHD are devices that show energy consumption, rates, and costs. Anyone can purchase an IHD to track kWh usage for appliances, etc. Utilities can use IHDs to notify consumers of Critical Peaks, operate Load Management & Demand Response programs, manage pre-paid consumer accounts, encourage energy-saving.



**Figure 5: In Home Displays (IHD)**

## Technology Alternatives – Fixed Network

Fixed Network AMI is a network that is permanently installed to capture meter readings. This method can consist of a series of antennas, towers, collectors, repeaters, or other installed infrastructure to collect transmissions of meter readings from AMR capable meters and send data to a central computer. Two-Way Fixed Network AMI is a way to expand coverage, depending on the vendor: meters will talk to meters, collectors will talk to collectors, or both collectors and meters will talk to each other.

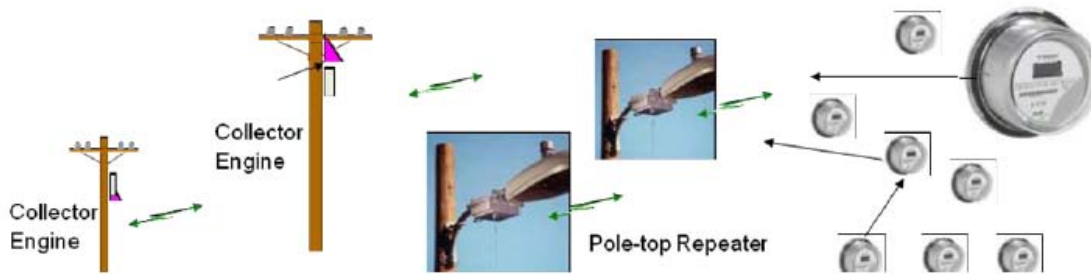


Figure 6: Two Way Fixed Network System

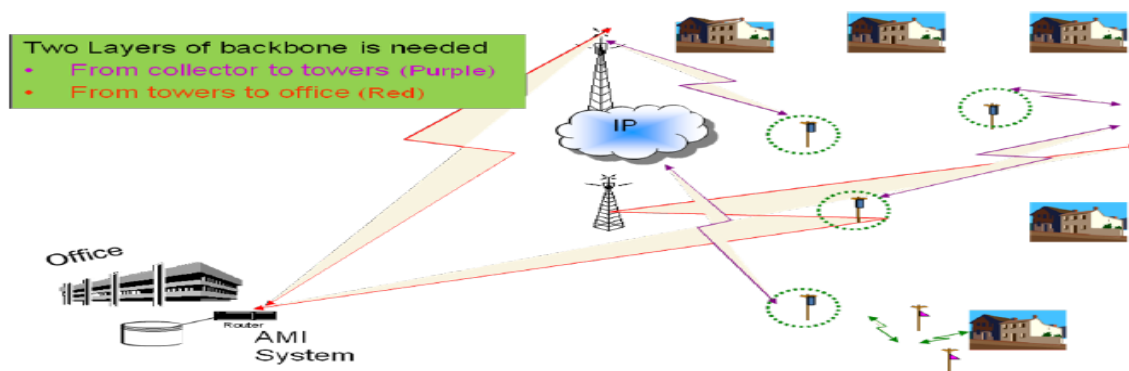


Figure 7: Fixed Network – Point to Multipoint

## AMI Backhaul WAN Options

Large amounts of data pass between gateways and the master station most often located in a utility's office. Media used for WAN communications typically use longer-range, high-power radios or Ethernet IP-based solutions. Some private options are 900 MHz spread spectrum point-to-multipoint, 2.4 GHz spread spectrum (mesh and point-to-multipoint), 3.65 GHz WiMAX, BPL, and fiber optics. Public options include: DSL or other Telco lines, and cellular.

Many utilities choose cellular to provide a WAN for their wireless AMI systems. Cellular is a "quick and easy" WAN solution. Disadvantages of cellular include monthly recurring charge – usually about \$45 USD per month (\$540 USD per year) per take out point. If the utility has 100 takeout points, this equates to \$54,000 per year. This is about \$800,000 dollars over 15 years not taking into consideration escalation factors. Cellular is typically not preferred for mission critical applications. With the dawn of the "Smart Grid" many AMI functions are now considered mission critical. This makes cellular a long term more risky WAN choice for AMI.

## Mobile Data Communications

Data-only systems can be built on licensed voice channels at 30-50 MHz, 150-174 MHz, 220-222 MHz, 450-470 MHz, 700 MHz, 800 MHz and the 900 MAS frequencies (in the 150 and 450 bands they are subject to the narrow-banding requirements). Some of the channels in these bands are exclusively for data and are listed in the FCC's Part 90 rule as such. According to Part 90, subpart J, "authorizations for non-voice emission on channels subject to coordination can be made".

Applications for data-only systems must be 75 miles from a co-channel licensee in the single mode of operation or 56 miles from a co-channel licensee in the two frequency mode of operation. These are nearly the requirements for FB-8 trunked operation and in urban areas are very difficult to meet but are usually possible in rural areas. Data-only operations on channels that do not require coordination are only on a secondary basis to voice. Nevertheless, although difficult to license, licensed data-only radio on existing channels is possible.

Functionality	VHF	UHF	900	Unlicensed
Radio System Coverage	Best	Good	Fair	Poor
Spectrum Availability	Poor	Better	Better	Unlicensed
Data Throughput	Good	Better	Fair	Best
Equipment availability	Poor	Fair	Poor	Best
Cost of system (assuming same coverage area)	Best	Better	Poor	Poor

**Table 2: Private Mobile Data Systems & Unlicensed Comparison**

Data radio systems come in several varieties; base to mobile, fixed point-to-point, and packet data. The base to mobile system business is shared by DataRadio and IP Mobilenet. Fixed point-to-point systems (other than SCADA) are usually integrated by local radio shops using any one of dozens of radio modems (with or without an integrated radio), various software packages and appropriate radios components. A few base-to-mobile systems are provided in this manner.

The final data technique is Amateur Teleprinting Over Radio (AMTOR) packet-data, developed by radio amateurs, and is similar to X.25 terrestrial data standards. There are many packet components available but they are usually integrated by local entities (usually "hams"). There are a few manufacturers of packet radios that specialize in meteor-scatter packet radio on low-band, which is specifically suited to extremely wide-area coverage using medium data rates that will accept relatively long latency times (over-the-road truck monitoring and railway payload monitoring), although the low-band hardware can be applied to any local low-band packet radio network.

Packet radio has one characteristic that may entice users and that is that each 256 byte packet contains a source address and a destination address and thus can be "digi-peated" until it arrives at its destination, thus not requiring a backhaul mechanism. Base to mobile systems usually require a backbone to connect from the tower, where mobile data is aggregated, to the office.

## Mobile Voice Communications

Mobile voice technologies include analog conventional, digital conventional (P25), analog trunking, digital Trunking (P25), and cellular. PSE has not seen a trend for commercial cellular to replace the utility private mobile voice radio. Trends have shown that current systems provide private voice radio coverage gap fill-ins between the vehicle and dispatch, private utility calls and calls with end-user customers. However, they cannot be depended on for tasks with safety ramifications, group calls or any dispatch related tasks.

Functionality	Analog Trunking	Digital Trunking
Separate Talk Groups	Many	Many
Status Messaging and AVL	Yes	Yes
Mobile-to-mobile across the service territory	Yes	Yes
Capability to roam to any tower site and use system with no manual intervention	Yes	Yes
Caller ID	Yes	Yes
Voice mail	Yes	Yes
Private calling	Yes	Yes
<b>Simultaneous voice and data</b>	No	Yes
Mobile data rate	2.4 kbps	7.2 kbps

Table 3: Analog vs. Digital Trunking Comparison

## Emerging DMR III Digital Trunked Radio Key Features

DMR is an open standard advanced by the European Telecommunications Standards Institute (ETSI). DMR II is the Conventional and Simulcast mode of the standard and DMR III is the trunking specifications. DMR III is being referred to as digital MPT-1327. It includes two Time Division Multiple Access (TDMA) voice channel slots in a single 12.5 KHz channel.

DMR III supports voice and short message handling similar to MPT-1327 with built-in 128 character status messaging and short messaging (including GPS) with up to 288 bits of data in a variety of formats. It supports packet data service in a variety of formats including support for IPv4 and IPv6 and data at up to 3600 BPS per virtual voice path (or 7200 if both voice paths are used simultaneously).

From a propagation standpoint, while Nextel or iDEN works with a 40 watt base station and a 0.6 watt portable, DMR III seems slated to work with a 100 watt base station and a 25 watt mobile. This can have millions of dollars of impact from a propagation standpoint. iDEN presently is only supplied at 800/900 MHz while DMR seems to be slated for operation at 150, 220 or 450 MHz; frequencies that could further widen the installed cost gap.

A feature of DMR III is the spectrum efficiency of two communication sessions over a single 12.5 KHz frequency channel. As frequency channels are already scarce, this feature helps to engineer a system with fewer channels than what would be needed with the existing analog trunking technology. This feature also includes a migration path from a 12.5 KHz analog technology to DMR in terms of fewer channels of the same kind required. It may also be viewed as a doubling of channel capacity when accomplished using the same number of channels.

Most importantly, as PSE understands, in both the stated 6.25 KHz FCC rules and the various DMR III product development strategies, if the user operates two voice paths over a single 12.5 KHz channel, then by definition it will meet the 6.25 KHz narrow-banding equivalent requirement. Therefore, DMR III will be set up for the eventual 6.25 KHz FCC further narrow-banding mandate when it is required by law.

## **Hottest Trends in Last Six Months**

### High-Rate Bandwidth Applications

- 802.16a – (Fixed WIMAX). Products now available.
- 802.16e (Mobile WIMAX).
- Software Defined Radio – Low band to GHz range.
- Carrier Grade Ethernet (PBB-TE)
- Mesh Radio Technologies with better QoS Latency Predictions
- More product choices at 2.4 GHz & 5.8 GHz, products working well, many vendors to choose from.

Most products or user attempts that try to combine high-speed fixed and mobile products fall short of reaching expectations. Many utilities are seeing the need to build a robust backbone to facilitate communications for a variety of applications.

## Conclusions

As utilities face the loss of manpower and degradation of older systems, new infrastructure can revolutionize how they gather and use data and information. Planning can assist with reducing customer costs, solve a utility's business challenges, and realize value and potential in their infrastructure. While the learning curve can be steep, the benefits can be invaluable as a utility plans their future.

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### About Power System Engineering

Power System Engineering, Inc. (PSE) is a full-service, independent consulting firm for electric utilities. Our clients include distribution cooperatives, generation and transmission cooperatives, investor-owned utilities, municipal utilities, public utility districts, and industry associations. The professionals at PSE include engineers, IT and communication experts, economists, and financial analysts. The PSE team has extensive experience in all facets of the utility industry. PSE is employee-owned and 100% vendor independent, with offices in Minneapolis, MN; Madison, WI; Indianapolis, IN; and Marietta, OH.

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Charles is currently facilitates the evaluation, procurement and implementation of strategic infrastructure technologies for PSE utility clients following smart grid technology roadmaps. Charles has been working in the electrical utility industry for 15 years in various communications and application technologies. He has a Bachelor of Science degree in Electrical Engineering from the University of Wisconsin – Madison.