MakaMesh

The Case for Using Wireless Mesh Technology in Smart Grid Communication Networks

With the passage of the 2009 American Recovery and Reinvestment Act (ARRA), interest has surged in smart grids and the potential $227 billion in anticipated benefits they can bring over the next forty years. With $4.5 billion directly and $24.6 billion indirectly allocated to the automation of the nation's antiquated electrical infrastructure, it's no wonder that researchers, vendors, and consumers are intently monitoring developments and considering their role in this latest technological land grab.

Technological Stacks

Smart grids offer the potential to change the way we live, work, and play by facilitating active consumer participation in energy usage, delivering quality power, and accommodating the generation of power by alternative sources. So pervasive and achieveable is this potential that Morgan Stanley predicts 8% annual growth in smart grid related investments taking the market from $20 billion to $100 billion by 2030. Driving this positive growth will be innovations in three smart grid technological strata or "stacks".

The Home Area Network

The first stack is the "Home Area Network" or HAN. These networks connect home or business power-consuming devices--smart appliances, light switches, and the like--with smart meters and other energy service portals. The result is a powerful demand response system that allows consumers to dynamically measure their real-time energy usage.

HAN information can be read by utilities and integrated into demand management schemes that turn off non-essential appliances during peak power demand periods. This capability allows utilities to optimize the management of power loads against available transmission and distribution facilities. So managed, utilities can decrease or defer the building of new power generation capacity.

Adding wireless technology to the HAN expands this efficiency. Battery powered devices--thermostats, security sensors, water and gas meters, and various remote controls and displays--can be monitored through wireless sensor networks (WSN) such as Zigbee, WiFi, and HomePlug. Using these proprietary networks, as many as fifteen million WSN nodes will be installed within the next five years to automate applications as diverse as vaccine inventory tracking, data center monitoring, and home lighting control.

Advanced Metering Infrastructure

The second stack is "advanced metering infrastructure" or AMI. This is the most economically vibrant smart grid stack and involves the replace-

A Smart Grid: integrates communications networks with the transmission and distribution power grid to create an electricity communications superhighway capable of monitoring its own health and performing self-healing as well as more efficient trouble notifications.

--Jay Stinson, Intergraph Corporation

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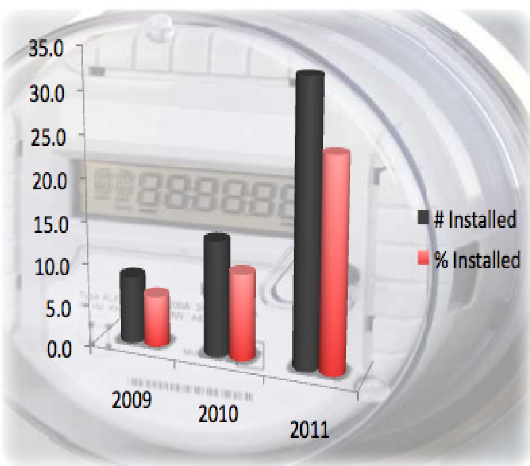
ment of vintage electromechanical meters wtih electronic "smart" meters. Remotely readable, these meters connect to a communications network to measure and report an individual location's electrical usage on a room-by-room or on a device-by-device basis.

Individual smart meters are distinguished by their communication capabilities. Meters can be equipped for one-way or two-way transmissions and can differ in data storage capacities. It is this combination that determines both the individual meter's functionality as an energy usage monitor and its cost; a cost that represents the largest portion of the smart grid budget.

Despite this expense, the demand for smart meters will, as with most products, drive their cost down with time. And demand is building to create this result.

In Boulder, Colorado, 50,000 smart meters will bring 100,000 homes and businesses on to the smart grid. Additional modernization will occur at substations to enable near real-time monitoring of network distribution and performance. Similar efforts at California's Pacific Gas & Electric will replace five million legacy meters.

Nationwide, ARRA awards which will finance the rollout of eighteen million smart meters, one million in-home energy management displays, and 170,000 smart thermostats. Beyond this effort, projections are that almost one quarter of the 140 million existing electromechanical meters installed throughout the United States will be replaced by smart meters by the end of 2011.



Smart meters as a number installed and a percentage of the installed U.S. electric meter base. (Park Assoc. 7/09)

The Communications Network

The third stack is the back haul network. These high capacity, low latency broadband networks work bidirectionally to extend the enterprise network to remote areas and to bring data from the access network back to the utility. In terms of cost, these networks represent ten to fifteen percent of overall smart grid costs.

To date, the technology footrace in this stack has been between:

- Broadband over Power Lines (BPL)
- Cellular
- WiMAX
- Wireless mesh

Each technology has its pros and cons but one thing seems certain: given the variety of environments over and the diverse sizes of the electric utilities through which the grid will be deployed, there will be no one size fits all solution. Instead a custom hybrid network will emerge.

This situation is driven by the reality that communications technologies that work well in rural areas don't work well in densely populated urban areas, and vice versa. Consequently, keeping business options open seems to be the right strategy at this point. As observed by Jeffrey Taft, global architect for smart grid at Accenture, it is important to avoid "falling in love with a particular device or system or technology."

Duke Energy is one U.S. utility that is keeping its smart grid communications choices wide open. The company anticipates using one technology for its backbone and using another for the roughly twenty percent of situations where the primary solution may not be suited for the task. Says Todd Arnold, Duke's Senior Vice President of Smart Grid, "Basically, both can coexist. Both are important ... it's another alternative as to how we reach spots and how we connect."

Luke Clemente, General Manager of Smart Grid for GE Transmission and Distribution, apparently agrees. Until the company is certain about which LAN technology among RF mesh, WiMAX and others will win out, it is not making major investments.

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In the U.S., the average power station was built in the 1960s using long established technology. Today's substation transformers average 42 years of age, years beyond their expected life span.

Decision Time

With the October 2009 award of billions of dollars in ARRA stimulus monies for smart grid deployment, market watchers anticipated receiving the first signs of an emerging consensus regarding the development of smart grid standards.

They were disappointed.

The awards spanned the marketplace's available technologies and delivered no definitive answers. The market was left to work out and wait for an answer.

So what's a manager to do? One thing's for sure, sitting tight is not an option.

Nationwide, peak demand has been exceeding transmission growth by almost 15% per year. Summer peak demand is expected to increase by almost 20% during the next ten years. In New York City, current grid capacities will be outgrown by 2019.

The problem is compounded the digitization of the economy. The 1980 electrical load from sensitive electronic equipment and automated manufacturing was limited. In the 1990s, chip share grew to almost 10%. Today, it's 40% with a 60% load expected by 2015 ... and growing.

In addition to growing demand, reliability has been increasingly inconsistent. Of the five most severe blackouts in the last 40 years, three of them have been experienced since 2000. The largest, the Northeast Blackout of 2003 resulted in a $6 billion economic loss to the region.

Beyond these cataclysmic events, everyday power outages cost big money: $150 billion to U.S. businesses each year. To appreciate the impact of this number consider that Sun Microsystems calculates the cost of one minute without power at $1 million to its operations.

Failure to plan for this growing challenge has tangible economic costs that will only mushroom in the future. Prevailing technologies and standardized approaches may not yet be determined, but forward thinking companies need to develop a plan to incorporate them when, not if, they do emerge.

Standards-Based Solutions

One approach is to adopt solutions that are standards based, non-proprietary, and interoperable. Such designs offer the greatest opportunity to future proof current investments without being hamstrung by proprietary solutions.

As necessary as standardization is to the acceleration of smart grid adoption, the electric industry has been slow to agree on what the common solutions are and who should issue them. State-by-state regulation and 1930's era business models supporting "natural monopoly" service have provided additional disincentives to investing in the smart grid vision.

Fortunately, a confluence of technological, economic, and societal pressures are rapidly realigning the agendas of utilities, regulators, and automation vendors. The vision is gaining velocity and coalescing to identify and adopt workable standards.

The U.S. Department of Energy has started the development of standards by publishing the Smart Grid Policy Statement (July 2009). According to this statement, Smart Grid Standards must:

- Provide two-way communication among grid users, e.g. regional market operators, utilities, service providers and consumers

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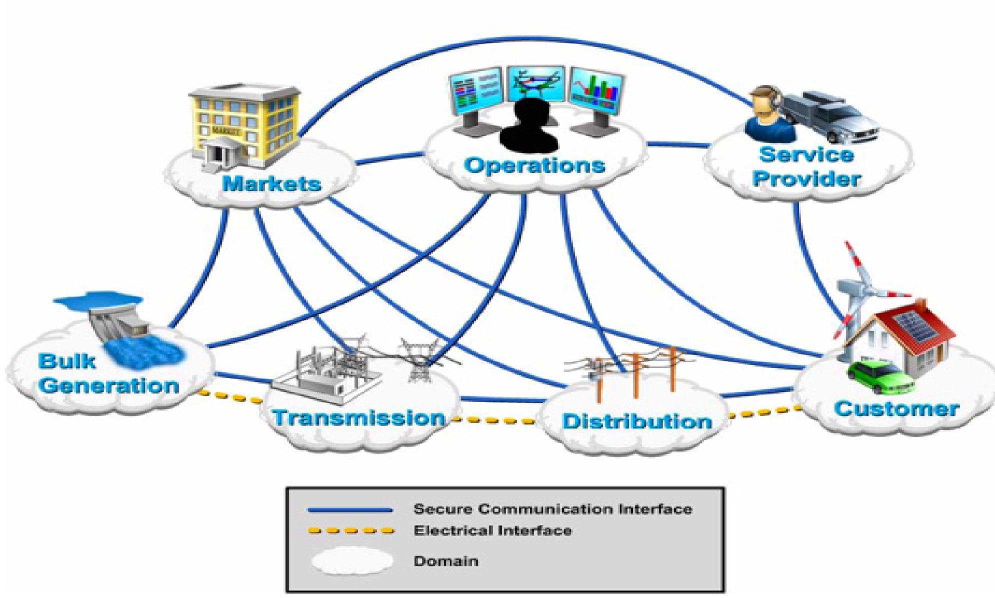

The National Institute of Standards and Technology's
Smart Grid Conceptual Framework

- Allow power system operators to monitor their own systems as well as neighboring systems that affect them so as to facilitate more reliable energy distribution and delivery
- Coordinate the integration into the power system of emerging technologies such as renewable resources, demand response resources, electricity storage facilities and electric transportation systems
- Ensure the cyber security of the grid

The ARRA has also accelerated the smart grid timeline by providing funding for standards development. In April 2009, it gave the National Institute of Standards and Technology (NIST) "primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems." This work was to be undertaken by engaging utilities, equipment suppliers, consumers, standards developers and other stakeholders to achieve consensus on Smart Grid standards

In September 2009, NIST offered its first Smart Grid work product: a document listing priorities for interoperability and cybersecurity standards, an initial set of standards to support implementation, and plans to meet remaining standards needs. In all, 77 proposed standards were listed for review. Targeted deployment of the final report is set for early 2010.

Communications Options

As noted earlier, BPL, cellular, WiMAX, and RF mesh are the communictions technologies currently being tested for the smart grid. Each has its pros and cons with the ultimate winner being the technology best able to satisfy existing infrastructure constraints, limited budgets, and varying technical capabilities. The solution also must operate from a basis that offers the greatest potential for plug and play interoperability.

Broadband over Power Lines

With its robust capabilities and ability to integrate commuications throughout the grid and HAN environments, BPL has become the leading technology in Europe. But, as with many implementations, what works well in one place may not work well in another. True to this form, U.S. utilities have largely ignored BPL in favor of Internet-based communications technologies.

BPL has also failed to achieve meaningful penetration for a number of reasons. Signalling is one. Switches, relays, transistors, and rectifiers create power lines that are inherently noisy.

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BPL must be engineered to work around these disruptions. Second, PLC signals cannot readily pass through transformers and require repeaters at each device. Third, BPL signals need these repeaters on runs greater than one mile.

The upfront cost of this equipment and its maintenance is magnified by the huge size of the U.S. grid. With 5.4 million miles of transmission lines, 300 major control centers, 22,000 substations, and 140 million individual meters, U.S. utilities face an installation budget hurdle of billions of dollars--even without the overhead of additional repeaters and engineering work--that dwarfs costs encountered by their European counterparts.

BPL is also challenged by its dependence upon the electrical grid. While this feature makes the technology facile to implement, it makes it unavailable during blackouts and disasters, just the time when it is needed the most. For power utilites whose performance is measured by the availability of its product, this failing is both a service and a political nightmare that will predictably occur with this technology choice.

Cellular

Cellular has been the technology of choice for pilot projects conducted throughout the U.S. It is ideal for these often brief and limited implementations because its networks are in and working over a wide footprint, can be quickly configured and, for a next to zero upfront cost, can be rented or leased without making a long term financial commitment.

But once the pilot is over and large scale installations are contemplated, the equation changes. With operating and maintenance expenses that grow with the installation of each network connection, cellular system costs grow geometrically--even at only a few dollars per month. Add this recurrence to Public Utility Commission requirements that typically classify it as an unrecoverable overhead or operational expense, and you have a system that is cost prohibitive for most utilities.

Cellular network coverage can be spotty especially in challenging terrain such as valleys, isolated mountaintops, and among variable cityscape structures and landscapes. Correcting these deficincies can be difficult and subject to the whims of individual communities and governing boards that can allow or block the placement of the towers that drive coverage expansion.

The lack of direct utility control over the network is also of concern. As one of many customers utilizing this shared resource, utility service levels can be equal only to the level provided, delivered, or allowed by the telco. The power

Option	Application	Pros	Cons
Broadband over Power Lines: 256kbps-10Mbps, variable range, 1.6-80MHz	Substations, smart meters, premise monitoring, distribution automation	Robust, integrated communication across grid and HAN, low recurring costs	High capital cost, expensive chips and equipment, not widely adopted
Cellular: 200-800 kbps, 1 - 2 mi. range, 700 MHz – 2.1 GHz	Smart meters, mobile work force management	Leverage existing networks, low upfront capital investment, short time-to-market, low module cost	Recurring cost per megabyte, lack of direct utility network control
WiMax: 3Mbps, 1-2 mi. range, 2.3 – 3.5 GHz	Smart meters, mobile work force management	High bandwidth capabilities, low latency	Not widely deployed or proven for smart grid deployments, high equipment cost
RF Mesh: Up to 1 Mbps, variable range and frequency	Smart meters, distribution automation	Customizable for specific deployments, self-organizing and healing	Proprietary, lack economies of scale, equipment can be expensive

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company does not control the resource chain and is vulnerable to the triage decisions made by and the repair capabilities of the telco. Given inherent differences between the missions of these utilities, this may lead to a misalignment of goals in challenging situations.

Privacy is yet another concern. Smart grid technology can let utilities know who, what, when, where, and how much electricity is being used as well as power quality data. This is all well and good and can encourage energy conservation: as long as the information is in the right hands. In the wrong hands, it lets the bad guys know when a home is unoccupied, where you're watching television, and other future exploitations that have yet to be imagined.

Running private energy usage data over the shared public cellular network increases its accessibility to burglars, terrorists and others who seek to disrupt service delivery, create blackouts, disrupt load balancing commands, or create fear and panic. As with Internet security, this is an unpredictable area of concern that will evolve with the deployment of smart grid technology over time.

WiMAX

WiMAX offers utilities the ability to deploy a smart grid over a private network. This option improves the security of the design and, because many of the costs are capitalized, ensures lower long run costs.

The greatest reason for considering WiMAX for the smart grid is its high bandwidth. Speeds of 100 Kb may be fine for reading smart meters but 1-2 Mb speeds may be what are needed for the split-second automation of the smart grid. WiMAX can also be used around major grid assets, such as substations. There, they can amalgamate voltage, current, and frequency data from phasor and other units. Additional servies such as mapping information and video services could also be accommodated.

WiMAX's open standards interoperability is another benefit. Over time, it could result in lower costs as equipment vendors develop hardware running on the technology.

But will these vendors appear? WiMAX is still a relatively small market. Equipment and device sales in the fourth quarter of 2008 were $275 million with 3.9 million subscribers. This number is larger than the 5,000 households served by BPL but, when measured against cellular and wireless penetration rates, pales in comparison.

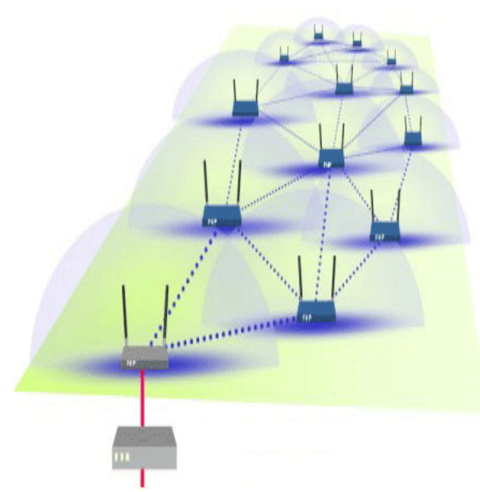
The WiMAX fight for market acceptance may be a reason that it has not yet been deployed nationally. Clearwire and Sprint have been attempting this feat but it has been slow going. Because of their inherent public nature, some of the same security concerns outlined for celular networks have slowed technology adoption.

Overall, WiMAX is still in the testing stage for many utilities and is not yet considered ready for prime time deployments. Anssi Vanjoki, Nokia's head of sales and manufacturing, believes that WiMAX will meet the same fate suffered by Sony's Betamax:

> I don't think the future is very promising [for WiMax]. This is a classic example of industry standards clashing, and somebody comes out as the winner and somebody has to lose. Betamax was there for a long time, but VHS dominated the market. I see exactly the same thing happening here.

The Case for Wireless Mesh

While BPL, cellular, and WiMax have attracted their share of supporters, the majority of U.S. utilities have chosen to pursue wireless, wireless mesh systems in particular, for their smart grids. As estimated by earth2tech's Katie Fehrenbacher,



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wireless mesh holds a 96% market share of existing smart grid network instalations.

Mature Technology

Utility favor for the technology is driven by its status as a mature, proven technology that is manageable, robust, capable of high performance, and secure. Most importantly, wireless mesh is ready to meet the evoloving needs of future smart grid applications through an ongoing innovation roadmap and established collaborative mechanisms (e.g., the Wi-Fi Alliance and IEEE).

Tested in the Real World

One area in which wireless mesh has been proven is in the HAN. An estimated 100 million households and more than one billion devices are embedded with the technology. Flexible enough to handle low data rate/low power applications as well as high definition video, wireless coexists with a variety of technologies and is ready to be the HAN standard for the Smart Grid.

Wireless mesh can also collect information from hundreds of neighborhood households and connect them to a utility's Wide Area Network (WAN). This backhaul can be implemented using point-to-point or point-to-multipoint links covering large areas and thousands of devices. Minneapolis, for example, has used WiFi for both Neighborhood Area Network (NAN) and WAN connections.

Wireless mesh supports both autonomous and centrally admnistered problem diagnosis. Visibility can be extended into individual devices to generate historical, threshold, and event reports as well as device configuration and reconfiguration. Radio link and traffic characteristics can also be measured to optimize both local and long haul performance.

Keeping Costs Under Control

Wireless mesh equipment is rapidly gaining in economy as deployments and production volumes increase. Under most PUC accounting schemes, these networks also have the benefit of being classified as capital investments thus allowing utilities to recover upfront investment costs over time.

Wireless Mesh is Utility Ready

Coverage Efficient and affordable, even in remote areas. Inherent self-organizing and self-healing intelligence keeps networks running.

Capacity Scalable high bandwidth capacity that accommodates networks of thousands of devices.

Control Bypasses private access points and prying eyes. Full network command that keeps utilities in command during disasters.

Capability Secure, reliable, portable equipment in a variety of form factors and ready to customize.

Cost Capital expenditures are recoverable; non recoverable recurring costs are minimized.

The benefit of this recoverability makes wireless mesh increasingly price competitive as network sizes increase. Compared with pay per location solutions such as cellular, wireless offers narly a 8:1 five year price benefit and an exceptionally low Total Cost of Ownership.

Interoperability

Wireless mesh networks have been largely deployed as proprietary solutions but this situation is changing with the emergence of solutions such as Concentris Systems' MakaMesh wireless technology.

MakaMesh is delivered on an open source platform with Linux at its core. Enhanced iwth OLSR support, an updated codebase, and Java 1.5 compliance, MakaMesh is ready-to-embed wireless mesh capability. Complete with built-in sensor interfaces, data processing intelligence, and communication-ready capabilities, it's a powerful development tool that speeds product development cycles and shortens time-to-market.

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Innovative technologies like MakaMesh are smashing preconceived notions that wireless mesh is a proprietary-only solution. By driving wireless mesh into the plug and play arena, MakaMesh is a choice that future proofs technology selections and grows with applications moving forward.

Putting Wireless Mesh to Work throughout the Smart Grid

Wireless mesh can be positively used in a variety of Smart Grid applications. Here are some examples:

- Wireless mesh can provide **IP-based NAN capability** from smart meters to data collection devices in support of AMI. Use of high gain antennas and other antenna technology can provide line-of-sight to pole-top access points more than kilometer away.
- Wireless mesh can be layered atop legacy grid elements to **increase two-way communications capabilities and distributed intelligence.** Proactive measures can be taken to reduce operational expenses and increase service delivery.
- Low-power battery operated mesh nodes can **extend smart grid assets** to gas and water metering and to accommodate the addition of new power sources such as solar and wind. Recent advances in battery technology have extended the service life of such devices to ten years or more.
- Private wireless mesh networks can carry both voice and data to **support mobile applications** for service technicians and field personnel. Los cost interoperable wireless clients are available and already integrated into mobile phones, laptops and computers.

Taking Today's Power Companies to the Future ... and Beyond

Few could have predicted the sweeping changes that the Internet has made upon the daily lives of people throughout the world. The availability of affordable, rapid, and flexible universal communication has created entirely new business models that have made it easier to work more cost effectively and productively.

The Smart Grid will have a similar impact on the way that we receive, use, and manage power. One cannot be certain of how this impact will be manifested but one thing is sure: the greater the flexibility and the universality of the smart grid, the greater its potential.

Wireless mesh technology will be a part of the smart grid. Its profound flexiblity, infinite scalability, and power of private control will coalesce thousands of disparate elements into a cohesive whole. It is a solution that makes sense today and deserves consideration as we design the power grid of tomorrow.

Smart Grid Spotlight Idea: Single Payer Installations

For communities such as college campuses, office complexes, and military housing complexes, individual users are not directly billed for the power that they use. With no negative--or positive--consequence for individual power usage, such communities often experience rising utility bills ... with no end in sight.

If you can measure it, you can manage it, ... and smart grids help facility managers accomplish this. Individual usage tracking can pinpoint problem areas and reward conservation improvements. Non-power devices, such as water meters, can also be monitored through the grid to provide unified utility management and control.

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