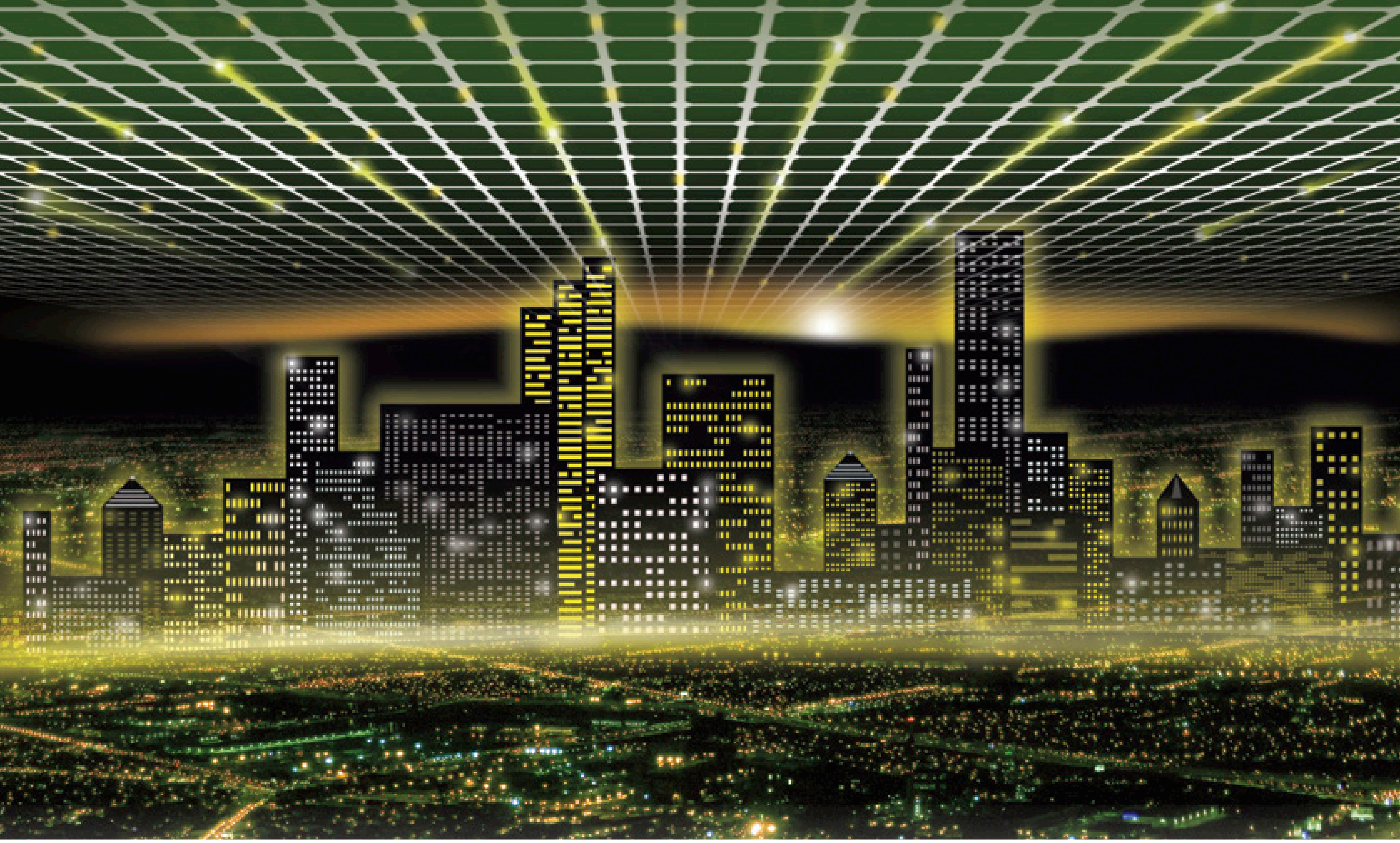


The Role of AMI Communications in Grid Intelligence

By H. Britton Sanderford, Sensus Chief Technology Officer

If timing is everything, then the time of the smart grid has come. Increasingly sophisticated AMI requirements have intersected with communications reliability (once only afforded by high-end distribution automation SCADA/controls systems) and with the announced objectives of the incoming White House administration: namely, to stimulate the economy by investing in energy and smart meters. This government support will likely lead to further tax incentives, funding and regulatory acceleration of smart grid initiatives.

The term "smart grid" is not formally defined, but for the purposes of this article, consider these six key objectives:

1. **Extend the service life of existing utility assets such as distribution and generation equipment, aging transformers, switch gear, capacitor banks and infrastructure. This is especially important in today's capital-starved economic cycle.**
2. **Improve efficiencies to enable delivery of more power, with greater up-time.**
3. **Promote current and future technologies to reduce dependence on foreign oil and to overcome delivery bottlenecks during critical peak events. Such technologies span from electrically powered vehicles, and distributed generation, to carbon nanotube solar cells, all of which require more sophisticated net metering capability that will account to rate payers for energy provided to the grid.**
4. **Support conservation programs in anticipation of the coming fuel scarcity and inevitable rationing.**

The concept of rationing will also introduce issues of social fairness as price per kWh, and the dynamics of supply and demand, may not be the only metrics for access to United States energy.

5. **Reduce exposure to malicious attacks on the power grid.**
6. **Empower rate payers to control their individual consumption by providing timely information and choices regarding use, energy choice and utilization timing.**

These objectives must be addressed in an environment where utility operations are evolving and becoming increasingly complex. Examples of this complexity include net metering pushing energy onto the grid as well as plug-in hybrid electric vehicles (PHEVs) connected to the grid and the related use of incentive plans, alternative gas highways tax and dispersal of recharge loads.

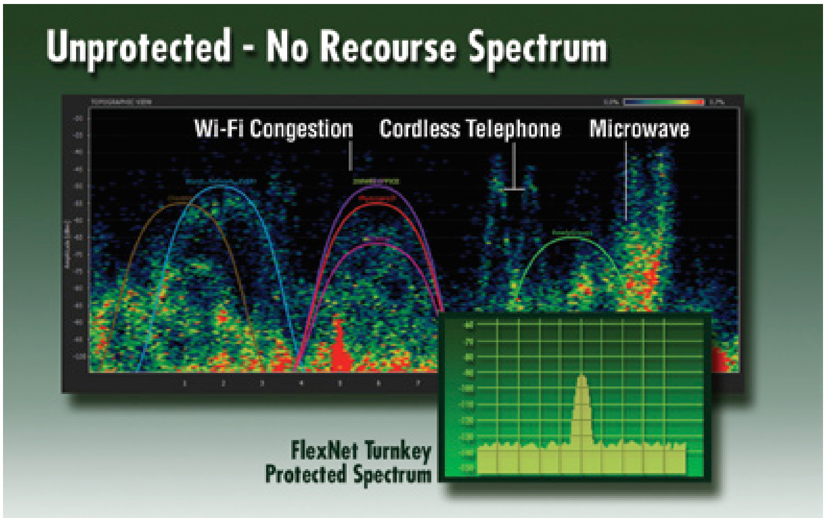
Attainment of intelligent grid objectives can only be achieved through highly coordinated communications between elements in the smart grid that are secure, ubiquitous and unobstructed. Unlike cellular telephone communications, where a user may be willing to step outside to make a telephone call or to wait until reaching a better coverage area, lapses in communication are unacceptable where the energy grid is concerned. If a response is required to a critical peak event, such as operation of a distribution line sectionalizer, that message must be received by load controllers regardless of location, coverage zone, or time of day. In short, communications to support a smart grid must be always on at all times, in all places.

Generation Avoidance via Demand Response (DR)—Security and Open Access

The AMI community is developing open standards for metering endpoints, home area networks which support DR, communications and other elements of the smart grid. This is a respectable goal as we journey into the future, but caution is warranted, as openness itself can be at odds with security.

Security practices should be layered, including restriction of information, not all product details should be on the Internet. Product development should be based on best practices driven from physics, creativity and solution diversity.

Overreaching standards can stifle innovation and diversity whereas insufficient standards can delay mass adoption in a market. Demand response is a case in point. As long as vendors and utilities are uncertain about what communication methods will become dominant for the home area network, HAN, decisions will be delayed in deploying capital for those future applications. For instance, there are 15 different choices that have surfaced over two decades, from X-10 to Smart Plug to 3 versions of Zigbee to most recently 802.11 (low-power version) and Bluetooth (high-power version).



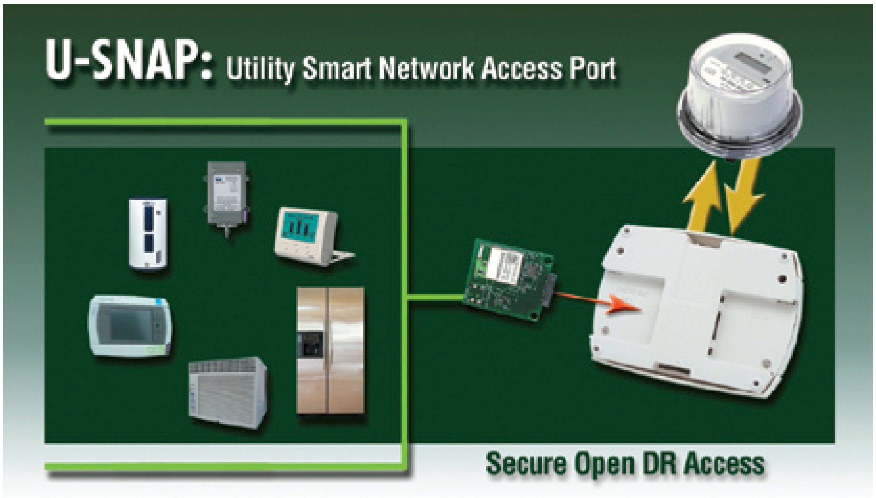
And the problems don't end there, all of these devices operating simultaneously cause self-interference. This is now being detected in utility deployments across the country, as larger volumes of unlicensed spread spectrum equipment compete for the very same radio spectrum that some utilities have become dependent upon. It is analogous to talking during a party once the guests arrive, the only way to hear is to get closer (reduce range) and talk louder (more power)—but endpoints can't move and the FCC limits their power output.

Establishing a HAN Solution

There is an inexpensive way to eliminate this uncertainty utilizing a secure format that is available to all AMI suppliers, all thermostat suppliers and all suppliers of other related in-home display and load control equipment. Sensus is strongly supportive of this innovative solution called U-SNAP (Utility Smart Network Access Port).

The genesis of the idea originated in California. In late 2007, the California PUC recommended that instead of mandating a particular HAN communications IC be built into a thermostat, it would be more effective to have thermostats outfitted with a generic circuit card connector where any vendor's communications card could be inserted. The utility would therefore remain the best judge of HAN communications technology.

This plug-in U-SNAP card provides a powerful, low cost solution. It solves a key utility issue—having to choose a HAN communication technology and pay for it, in all meters, up front and often well before the utility knows the scope and timing of a demand response deployment. It does this by using the communications hardware that is



already imbedded in every AMI meter, to communicate with a HAN controller embedded in a U-SNAP device such as a thermostat. Large IOUs can save tens of millions in capital since meters will not have to bear the cost of a HAN communications card.

In order to support U-SNAP, every vendor can supply inexpensive communications cards, roughly 1.5 inches x 1.5 inches, that will fit into a standard card slot in load controllers, thermostats, in-home displays, etc. The standard becomes very simple: an 8-cent card connector, an SPI bus (virtually in every microprocessor), and some simple rules (for more information go to www.U-SNAP.org).

Since each one of the circuit cards will be shipped with a unique IP MAC address, and affixed with a bar-code, the utility is able to address, bind and mail the tiny U-SNAP card with a monthly statement. The customer simply snaps the card into a compatible device and the card registers on the network. U-SNAP is open to all HANs. Some vendors are offering thermostats with two U-SNAP ports where the first links to the meter and the second is a gateway to 802.11 or ZigBee and in the future any popular HAN. U-SNAP also has the strongest security of any HAN alternative. Besides having a unique IP address, it is also embedded with a PKI stack where the Private Key Certificate is solely held at the back-end under the utility's control. Key's are not distributed, the meter gateway cannot be cloned to illegally gain access to rate payers loads.

U-SNAP also provides a strong business advantage to thermostat and load control manufacturers. By making a single U-SNAP interface, they can support any AMI vendor's technology. This provides scale to thermostat and load control manufacturers, which in turn increases availability and drives down load controller costs while addressing all of the objectives of demand response.

Always-On Communications and Connectivity

Presently, there are three key communications methods that allow connectivity between smart grid and AMI elements: power line carrier, unlicensed "free" spread spectrum, and licensed protected FCC spectrum.

The advantage to power line communication is that it operates on the utility's infrastructure, but a disadvantage is that it has slow data rate or requires a large infrastructure of repeaters. In addition, power line carrier is unavailable during power failures, abnormal substation, feeder or phase switching events or when protective switch gear has opened the power lines, therefore making the communications path unavailable.

The advantage to (and ironically the disadvantage of) spread spectrum is its free usage and availability to all users. Free use attracts hundreds of millions of products but with it comes no FCC protection or assurances. Products that operate using spread spectrum must bear a label that states: "(1) this device must accept harmful interference from others including that harmful interference which may cause miss-operation; and (2), this device must not cause harmful interference to others." The result is that a utility communication system has no recourse to interference, not even critical smart grid products. Worse, the utility is liable for interference that smart grid products would cause to other products, including home area network equipment, baby monitors, telephones, wireless video games and the like.

> **"One of the most important infrastructure projects that we need is a whole new electricity grid."**
>
> *- Barack Obama*

The advantage of FCC-protected licensed spectrum is its exclusive availability to a utility. The FCC provides that a primary use license holder has the presumption of perpetual license renewal providing that spectrum is being used for the public good (smart grid clearly counts). The downside to licensed spectrum is its expense. Sensus has acquired nationwide protected spectrum and supplies it turnkey to its customers; the utility has no FCC forms to fill out.

So why not eliminate this cost hurdle to other AMI vendors? If the government makes smart grid a priority, as is widely assumed under the new administration, the FCC could make primary-use protected spectrum available to all utilities for smart grid applications. There is already precedent for this under FCC part 90, where certain portions of protected spectrum are preferentially made available for utility's critical control applications.

The advent of digital signal processing and advanced digital modulation, such as those employed by the Sensus FlexNet solution, have enabled cost parity with lower-end radio equipment such as spread spectrum. If the FCC allocated 100-200 kHz of primary-use spectrum it would empower any smart grid application by providing data rates higher than any AMI product on the market today. This high-quality, low-interference spectrum would improve the performance of any AMI vendor's product, RF Single-tier or mesh, and even enhance standards such as ANSI C12.22. Radio chips that support HAN and mesh AMI communications could be adapted to this new channel. In short, the FCC could reduce the entry barrier to AMI providers, significantly increase reliability and support the objectives of the smart grid.

How Does FlexNet Meet Industry Needs

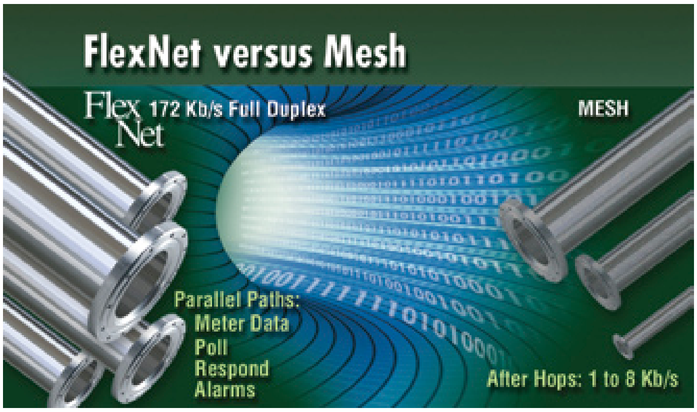
The first and most important point is the philosophy of continual improvement. This philosophy is essential in considering the historic path from drive-by to fixed-based networks to AMI networks to the demanding requirements of the future smart grid, which are still not fully defined today. That path may be similar to the mind-boggling array of Internet applications that were developed once engineers and managers realized that ubiquitous data resources had become a reality.

To support the Sensus vision of continual improvement, every FlexNet endpoint is equipped with the ability to securely accept downloadable code upgrades. Additionally, this capability is inherent in the data collectors in the communications network, called TGBs (Tower Gateway Base Stations). In addition to metrology and communications processors being downloadable, the actual communications core is software defined. This means that modulations, protocols, frequency of operation, and even data rate are defined in digital signal processing firmware, meaning endpoints can be fully upgradeable as future requirements and features are developed.

FlexNet is a minimum infrastructure network, which has the benefit of reducing ongoing O&M costs, and allowing a utility to use all utility-controlled assets if desired. In addition, a utility can roll out 100 percent territory coverage at the onset of a smart grid project. FlexNet is modeled after the cellular industry's proven tower base stations which use easy to upgrade 19" equipment racks. Even though cellular began with a modest number of early adopters, it has been able to seamlessly increase capacity and features not conceived of 30 years ago. During hurricanes Katrina and Ivan this modular, redundant minimum infrastructure paid off. After the greatest natural disaster this country has seen, the FlexNet Gulf Coast systems were reading water, gas and electric meters, including remote disconnect, when no land lines or cellular lines were accessible.

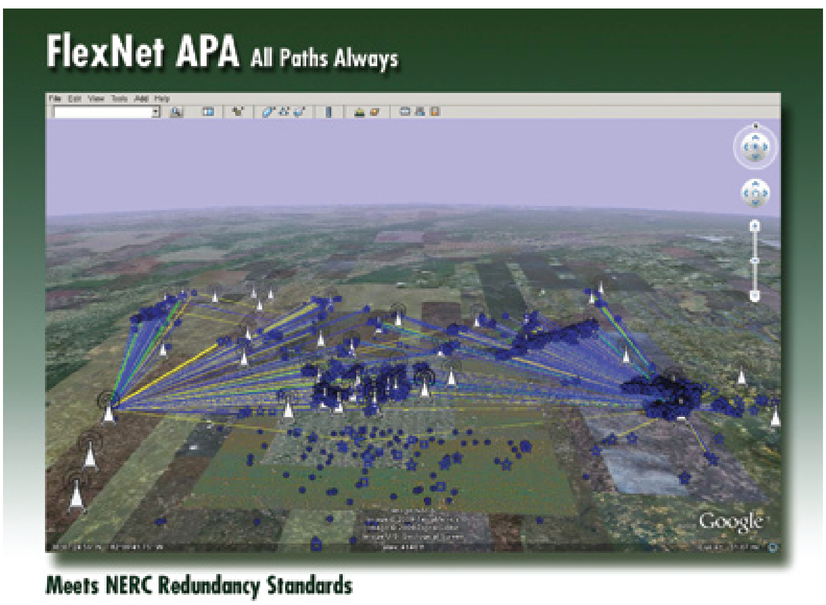
Sensus recently announced that it delivered a 2X increase in data rate by increasing the FlexNet modulation constellation from 7 to 13. This is now operating reliably in more than 150,000 electricity meters, each of which is providing hourly reads. Just as importantly, this was accomplished without a single field visit. Software was downloaded to the TGB collectors and software was enabled in the metering endpoints. Future plans include making additional data rate capacity increases.

The FlexNet system is optimized for both dense urban and rural applications. Rural ranges of over 40 miles are possible because of the 2-Watt power output allowed in the FCC licensed band, highly sensitive, digital signal processing-based modulation in the endpoints, and because background radio noise is extremely low in these licensed channels. In urban applications, a single TGB (full duplex 172kb/s or X-3 510 Kb/s) can communicate with up to 150,000 endpoints. Multiple TGBs, located on downtown towers or roofs, can provide coverage to any number of meters, while the surrounding long distance rural TGBs inherently provide overlapping coverage to urban smart meters.



A communications network must have fast, reliable response times in order to meet the latency requirements associated with operation of automated switching devices such as sectionalizers to reroute power and isolate problem spots on the distribution system before the main breaker at a substation trips the feeder resulting in a blackout affecting a large number of customers. The FlexNet single-tier communications network also means that the communications latency is short (sub-100 ms LAN) with a predictable delay. Mesh hopping systems inherently have variable delays (several to many seconds) proportional to the number of hops required and indefinitely based on the amount of interference sustained.

encryption and state-of-the-art digital certificates of PKI, secure handshaking and authentication. As with any secure regime, key generation and management have strict processes that must be followed, including the ability to rotate keys in a preventive and proactive manner. Sensus recommends that two layers of authentication be used, one internal and one external. In this manner, one element may be known only to the utility controlling entity while the second may be used for generic authentication for items such as firmware validation. In addition, Sensus does not publish its protocols nor offer



FlexNet uses APA™ (All Paths Always) technology; an ultimate form of self-healing that ensures critical messages are delivered without re-routing delay. This means that every tower and every meter listens for every transmission on every frequency in parallel and all paths are used at all times simultaneously. A mesh system uses a different philosophy of serial communications and serial path recovery. This serial approach takes time in order to "heal a wound" and find an alternative viable path. This healing time potentially delays time-critical messages when time-to-cure matters the most.

FlexNet supports a seven-layer security scheme that includes AES256 a development kit which would give access to a broader attack.

In conclusion, the Sensus commitment to continuous improvement supported by minimum network hardware infrastructure and software-defined radios are ideal to meet the present and future goals of the smart grid. FlexNet can bring utility executives closer to the domestic objectives of extending the service life of present assets, improving efficiency, reducing dependency on foreign oil, lowering the carbon footprint, reducing exposure to attack and putting the rate payer into the driver's seat. Perhaps one of the most important things that FlexNet can make available to the utility executive is the ability to act now and accelerate the realization of benefits, even in the face of uncertain times. FlexNet can be initially deployed with minimum capital commitment and yet provide virtually limitless expandability and features still undreamt of to support tomorrow's smart grid today.

Mr. Sanderford was appointed to the position of Chief Technology Officer in July of 2006 when Sensus Metering Systems Inc. purchased the assets of Advanced Meter Data Systems LLC, (AMDS), which he had founded. In 1985 Mr. Sanderford founded Axonn Corp, which was the first U.S. company to be granted FCC spread spectrum equipment approval under FCC unlicensed Part 15 rules. This innovation led to the first fielded fixed base AMR devices in 1992, which grew to over 13 million endpoints. In 2001 Mr. Sanderford gave the keynote address to the ISA, Instrument Society of America, on the economics and impact of wireless industrial sensors. Since 1974, Mr. Sanderford has published articles on multiprocessing computing, RF, protocols, modulations, telemetry and applications related to Smart Grid. He holds over 80 related patents, pending and granted.