Licensed versus Unlicensed Spectrum for Utility Communications

WP-100

White Paper

A side-by-side comparison of infrastructure, performance and cost

The emerging Smart Grid will redefine power transmission and distribution with new levels of transparency, intelligence and control. From utility substations to end users, the grid will be more secure, resilient and efficient. Monitors on transmission equipment will sense trouble conditions and automatically trigger corrective action. Smart meters will communicate power data throughout the day—both power consumed *from* the grid and returned *to* the grid by customers who generate alternative energy. In-home devices will inform customers of their utility usage patterns and intelligently shift loads to reduce overall and peak demands. In the process, the power grid will be transformed from one that simply broadcasts power from a few central power generators to a large number of users into one that can intelligently route and manage power to respond to changing conditions and to bill customers differently according to their usage patterns.

New Expectations for Utility Communications

As the Federal administration presses forward toward the Smart Grid vision, the requirements for utility communications are being fundamentally redefined by the following trends:

- The imperative to use energy more wisely throughout the grid
- The increasing incidence of renewable energy being pushed back into the grid
- Growing number of smart devices at customer endpoints, such as smart meters and controls
- Desire for more granular information, such as more frequent and detailed meter sampling

Utility networks will have to provide higher performance, range and availability for communications, both to receive monitoring and consumption data and to send control commands and system firmware upgrades.

The initial focus has been on smart meters that can be read from a distance of up to 50 feet by receivers in drive-by trucks. However, given a choice, many if not most utilities would prefer a fixed network for meter reading.

With a fixed network, data can be gathered at any time—even several times per hour—not just when a truck is driven past the meter. Day-to-day delivery of meter information enables the utility to better manage the entire power system. Continuous communication will be essential for the more advanced applications that are part of the Smart Grid plan, such as the ability to send consumers information about their energy use and to manage in-home devices over the utility network.

Therefore, fixed-based networks have been widely perceived as the Holy Grail of automatic meter reading (AMR) technology, especially for utilities with wide-ranging service territories. However, fixed based networks have historically had difficulty competing with the inherently lower-cost drive-by systems, primarily due to high infrastructure costs and associated support implications. New options are changing that picture.

The Inevitable Shift to Wireless Communication

Three key communications methods are presently used to enable connectivity between Smart Grid and Advanced Metering Infrastructure (AMI) elements:

- Power line carrier, using the utility's power lines for connectivity
- Wireless networks based on unlicensed "free" spread radio spectrum
- Wireless networks based on radio spectrum licensed from the U.S. Federal Communications Commission (FCC)

Power line communication offers the advantage that it operates on the utility's existing infrastructure and rights of way. One-way and two-way systems have been successfully used for decades.

However, the disadvantages are slow data rates and the need for a large number of repeaters. Options for higher data rates require adding high pass filter hardware infrastructure at every transformer and substation node.

Furthermore, the network is unavailable during power failures; during abnormal substation, feeder or phase switching events; or when protective switch gear has opened the power lines, making the communications path unavailable. Smart grid applications require higher availability and throughput than power line carrier systems can provide.

Some utilities have installed fiber-optic cables on existing towers to create a parallel broadband communication network (perhaps with power line carrier as a backup), but that option is costly—and cost-prohibitive for remote or lightly populated areas.

These realities, along with new technology and standards, have ushered in the wireless communications era. "Two-way, real-time communications among critical utility assets can be accomplished efficiently and economically with wireless technologies," states the Utilities Telecom Council in its January 2009 report, *The Utility Spectrum Crisis: A Critical Need to Enable Smart Grids*. "These technologies support machine-to-machine communications that form the backbone of energy distribution."

Almost immediately, unlicensed spread spectrum radio was widely touted as the technology that would finally free utilities from wires and meter readers altogether. However, a spate of new problems, including range limitations, spectrum interference and reliability issues—compounded by a utility workforce still firmly rooted in the business-as-usual mindset of electromechanical metering—kept the wireless revolution at bay for the better part of a decade.

There were obstacles to overcome. Until recently utilities have not had a viable wireless network approach that could satisfy their business cases, due to high initial and lifecycle costs for networks based on unlicensed radio spectrum.

Those wireless networks have typically needed hundreds (sometimes thousands) of cellular pole-top or meter-based data concentrators, collectors or repeaters to adequately cover a large metropolitan area. Mountainous terrains and densely built metro areas further compounded connectivity problems. The extra equipment needed to mitigate those problems was usually quite expensive and difficult to install and maintain.

Utilities and companies are now looking more holistically at the real costs associated with "free" unlicensed radio spectrum for wireless communication. They are asking whether Smart Grid wireless networks would be better run on licensed wireless spectrum, in which the airwaves are owned by the customer and protected by federal law.

Let's take a look at the two options—unlicensed and licensed radio spectrum—comparing infrastructure costs, bandwidth and performance for each.

Wireless Communications on Unlicensed Radio Spectrum

Unlicensed wireless devices on the Smart Grid operate in one of the bands set aside by the FCC for Industrial Scientific or Medical (ISM) applications—for the most part either 902-928 megahertz (MHz) or 2400-2483 MHz. Devices can operate in these radio bands license-free but must adhere to FCC rules set out for the ISM bands, most notably requiring that devices:

- Transmit one watt or less of power
- Not cause harmful interference
- Accept any interference received without causing undesired operation

The interference requirements are addressed by the use of "spread spectrum" techniques, which essentially disallow transmitting in a single channel and instead "spread" the energy out using one of two techniques:

Direct sequence, where a high-speed sequence is used to greatly spread the radio energy over a large band.

Frequency hopping (more common), where the radio channel changes or "hops" to a different channel for every message or several times during a message.

As long as the receiver knows the code used to spread the radio energy, it can use the same code to un-spread or tune to the correct frequency channel.

Unlicensed Spectrum—Pros and Cons

The advantage to (and ironically the disadvantage of) spread spectrum is that it is free and available to all users. Free spectrum attracts hundreds of millions of products, but without 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 misoperation; and (2), this device must not cause harmful interference to others."

The result is that utility communication devices, even critical Smart Grid elements, have no recourse to interference. Worse, the utility is liable for interference that Smart Grid products would cause to other products, such as home area network equipment, baby monitors, telephones and wireless video games.

As more and more ISM-band devices are added to the environment, the level of "noise" from incidental interference continues to rise. The basic law in radio telemetry is that the communication signal must be stronger than the background noise by a specified amount—an acceptable *signal-to-noise ratio*—in order for messages to be correctly received. 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).

However, a utility cannot move its customers closer together, and devices operating on unlicensed ISM bands are constrained to one watt of output. That means the network must contain many more concentrators and repeaters arranged in a mesh configuration. Messages go through a series of hops from one device to another to reach their destination. A single message could easily take half a dozen hops on its way. This scenario presents three key problems.

Higher infrastructure requirements—Because the range of a signal is limited, the network requires a high number of intermediate nodes, which adds greatly to the cost of deploying, operating and maintaining the network. In rural areas, or anywhere there is a long distance between endpoints, or for large-footprint systems (such as state-wide), a mesh network is generally not an economically viable option.

Higher bandwidth requirements—Each hop requires a slice of radio spectrum. A communication path with two hops consumes spectrum twice. Every additional hop is essentially another message on the network, consuming more bandwidth from a limited supply.

Slower communications—Each hop requires additional processing, so latency can become an issue, particularly if the network is used for real-time communications, such as voice.

As more and more Smart Grid services roll out, utilities will need a better business case and more bandwidth than unlicensed spectrum can provide.

> "Unfortunately, many highly critical utility control networks currently operate on radio frequency bands that must be considered suspect. Far too many have only secondary (interference-accepting, non-interference causing) status on the 150-512 MHz bands allocated primarily for mobile voice systems. Many more operate on unlicensed spectrum, mostly in the 900 MHz band, sharing it with hundreds of millions of other devices, from cordless phones to wireless Internet service providers and RFID tags. These are not the best environments for such mission-critical networks."
>
> ***—The Utility Spectrum Crisis: A Critical Need to Enable Smart Grids,***
> Utilities Telecom Council, January 2009

Wireless Communications on Licensed Radio Spectrum

Licensed spectrum devices operate within the portion of the radio spectrum designated by government regulators (the FCC in the United States) to be reserved for organizations that have been granted licenses. Licensed operators have exclusive use of part of the radio frequency (RF) band over a designated geographic area.

With exclusive rights, a license holder operates without interference or spectrum crowding. The FCC provides legal protection and enforcement to prevent other operators from transmitting over the same frequency in the same geographic area.

Devices on the Smart Grid operate in a variety of channels and frequency bands originally used for SCADA (supervisory control and data acquisition), paging and other services. Communications in these bands tend to be "narrowband" in nature, using a single frequency carrier and do not have the power limitations of ISM-band devices.

Licensed Spectrum—Pros and Cons

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 (the Smart Grid clearly counts).

Operating on a dedicated frequency, utilities have clear advantages over unlicensed spectrum for maintaining an excellent signal-to-noise ratio:

- Higher signal power—Devices operating on licensed spectrum can transmit more power, potentially 10 to 100 times more power in the case of a central collector, for example.

- Low noise floor—Since the spectrum is protected by the FCC, and a designated band is reserved for the utility's exclusive use, the noise in licensed bands is usually nearly non-existent, typically at least a 30 to 40 dB advantage.

Strong signal and low noise combine to dramatically increase the range, throughput and performance of communications. Instead of a fraction of a mile between endpoints, a wireless network can transmit 20 miles between endpoints, up to

100 times farther than on unlicensed spectrum. Towers and endpoints can communicate directly without intermediate network equipment to buy, install, maintain and repair.

On the downside, available licensed spectrum is a scarce resource, difficult and expensive to acquire. Available bandwidth can be an issue.

For example, a basic system might have only 100 kilohertz and a few channels available, perhaps one for outbound communications from towers, one that meters use to send data back to towers, one reserved for private conversations between the tower and a radio, and another reserved for alarms, power restores or emergency messages. The utility could max out available channels unless additional spectrum is acquired.

Sensus addressed these issues by acquiring nationwide protected spectrum that it supplies turnkey to its customers. Utilities currently have access to 325 kilohertz of bandwidth, plus the highest RF power in the industry. Sensus continues to aggressively pursue the acquisition of additional spectrum as well.

Summary Comparison—Licensed versus Unlicensed Spectrum

	Unlicensed Spectrum	Licensed Spectrum
Availability	Widely available at no cost	Limited to license holders
Signal-to-noise ratio	Variable, diminished by one watt limitation on devices and high potential for interference	Excellent, due to exclusive use of the band (virtually no interference) and higher signal power collectors
Range	Limited and variable depending on network conditions, typically up to 0.25 miles between network nodes and endpoints	Extensive, consistent and predictable Up to 20 miles between network nodes and endpoints
Infrastructure requirements	High number of repeaters needed	Minimal due to long range Direct tower-to-endpoint communications
Bandwidth	1-8 kbps per channel after hops Channels freely available	Up to 172 kbps per channel full-duplex Limited to licensed spectrum/channels
Latency	Potentially high and variable (several seconds to many seconds), proportional to the number of hops required and interference sustained	Low and predictable (typically sub-100ms LAN), due to direct tower-to-endpoint communications and no interference
Reliability	Can be compromised in high-interference environments and by network complexity	High, due to exclusive access to spectrum and streamlined network architecture
Security	Network-agnostic; provided by encryption, physical controls and security policies	

The Sensus Approach

With the acquisition of AMDS in 2006, Sensus also gained the expertise of the team that designed the first fixed-based AMI system ever deployed. This pioneering system used direct sequence spread spectrum technology in the 900 Mhz, license-free band. Field experience with unlicensed spectrum throughout the 1990s cemented the team's conviction that the Smart Grid requires nothing less than licensed, protected spectrum.

So when Sensus developed the FlexNet™ utility communications solution, the company bet on licensed spectrum and focused on five key criteria that would provide exceptional range without the high infrastructure costs previously associated with wireless utility networks:

- Use the tallest existing radio towers and efficient high-gain antennas;
- Acquire clear nationwide primary use licensed radio spectrum with a low noise floor;
- Design of high power endpoints (two watts) with all-digital modulation techniques;
- Design of highly sensitive receiver base stations using all digital signal processing (DSP);
- Development of a meter-to-meter "buddy" relay mode for hard to reach meters (such as those in basements or behind line-of-sight barriers).

As a result, FlexNet wireless networks cover a large area with minimal infrastructure. One tower can cover tens of thousands of meters. For example, the city and surrounding suburban areas of Birmingham, Alabama, are completely covered by only three tower gateway basestations (TGBs). The FlexNet system in New Orleans, Louisiana, regularly delivers two-way communications ranges of more than 15 miles from tower to meters. Rural ranges of more than 40 miles are possible.

Through an arrangement with USA Mobility, FlexNet systems have access to more than 4,000 tower sites covering more than 90 percent of the U.S. population.

> "We discovered years ago that there was a fair amount of interference for unlicensed spectrum. Licensed spectrum is yours alone to ensure a 'right of way.' It is like having a private highway, compared to having to share traffic with other devices."
>
> **—Britton Sanderford, Chief Technology Officer, Sensus**

Where Does the Industry Go From Here?

Spectrum requirements will continue to expand, due to increased expectations for security of critical utility resources, more sophisticated power network communications and intelligence, and more reliable emergency communications in disaster conditions.

As a step toward achieving those objectives, the Utilities Telecom Council (www.utc.org) is calling for the federal government to make 30 MHz of contiguous bandwidth available directly to utilities, as it did previously for the public safety community.

Evolving standards are the other factor that will influence the future direction of the Smart Grid. The National Institute of Standards and Technology (NIST) and the Institute of Electrical and Electronics Engineers (IEEE) are working on interoperability standards to drive universal availability of these devices. The IEEE Working group (P802.15) for wireless personal area networks (WPANs) has drafted an amendment for that proposes interoperability standards for the next generation of Smart Grid equipment.

The new standard, known as 802.15.4G, will have provisions to support both licensed and unlicensed radio equipment. That means utilities will still have choice in their wireless network deployments. However, utilities would be wise to consider all the costs associated with "free" unlicensed radio spectrum and consider not just today's communications requirements, but also the requirements of tomorrow's optimized and intelligent utility grid.

About Sensus

Sensus leads in innovative and evolving technology solutions that enable intelligent use and conservation of critical energy and water resources. Sensus has led the discovery, development, and implementation of technologies for the energy and water industries for more than a century. Water, gas, and electric utility customers around the world benefit from the company's open, flexible products and solutions to help them optimize their resources – today and tomorrow. Headquartered in Raleigh, N.C., USA, Sensus serves customers from locations throughout the Americas, Europe, Africa and Asia. For more information, visit www.sensus.com.

8601 Six Forks Road, Suite 700
Raleigh, NC 27615
1-800-638-3748