Cellular Communications and the Future of Smart Metering

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Introduction

The "Smart Grid" era is upon us, as energy suppliers around the globe invest in new technologies to optimize antiquated grids. With an end-to-end digital, two-way intelligent communications infrastructure, utilities will be able to capture details about how energy is transmitted and consumed in real time. As a result, they will be able to enhance electricity generation and distribution, reduce peak consumption by shifting demand loads and boost efficiency through improved diagnostics. The end result: the ability to serve more customers with less energy supply.

The Smart Grid concept encompasses a continuum of technologies, including:

- Energy generation (renewable energy, distributed generation sources, etc.)
- Transmission and distribution (load management, demand response)
- Smart metering (residential, commercial, and industrial)
- Electrical vehicles (charging station management)

This paper focuses on Smart Metering as one of the cornerstones of the Smart Grid vision. It explores the drivers and benefits of Smart Metering in an intelligent energy grid and examines the role that cellular technology is playing in these projects. The paper also discusses the critical success factors for Smart Metering communications infrastructures and details the best practices that should be kept in mind when designing wireless Smart Metering solutions.

Smart Metering Global Trends

- *ABI Research projects that about 212 million smart meters will be deployed worldwide by 2014 (up from 76 million in 2009).*
- *European Union member countries are required to have smart meters across 80 percent of their metering infrastructures by 2020.*
- *The American Recovery and Reinvestment Act of 2009 included approximately $11 billion for Smart Grid and Smart Metering projects, with $7.1 billion earmarked for 2010.*
- *Asia-Pacific has the largest and fastest-growing smart meter population, now approaching 1 billion units, according to Berg Insights.*
- *Berg Insights also reports that State Grid Corporation of China (SGCC), the power utility covering 80 percent of the population, will invest $200 billion annually in Smart Grid infrastructure through 2020.*

Smart Metering: An Overview

Smart Meters help modernize the power grid by providing the ability to remotely monitor and transfer energy consumption and power quality information more frequently and reliably. This allows utilities to work both behind the scenes and with their customers to manage the distribution network more efficiently. By collecting real-time energy consumption information, Smart Metering infrastructures empower suppliers to:

- Reduce operating expenses by managing manual operations (meter reading, service disconnection) remotely
- Improve forecasting and smooth power-consumption
- Improve customer service through profiling and segmentation
- Reduce energy theft (a serious problem in some markets)
- Simplify micro-generation monitoring and track power generated as well as consumed

Smart Metering also benefits end customers in the form of energy savings, reduced carbon emissions, improved service reliability and improved customer service and responsiveness.

To make all of these benefits a reality, however, utilities need a secure and flexible two-way communications infrastructure to connect and communicate with Smart Meters. Several options are available, including Power Line Communications (PLC), low-power radio frequency (RF) mesh solutions and cellular wireless wide-area network (WAN) technologies.

Wireless Communications in the Smart Grid

Energy suppliers have long used wireless WAN solutions to communicate with concentrators monitoring large numbers of meters in neighborhood-area networks (NANs). Increasingly, they are using cellular solutions for point-to-point communications with individual meters as well. As a result, cellular technologies are becoming an important part of Smart Metering deployments and the Smart Grid as a whole.

Energy suppliers have two primary WAN/cellular technology options: second-generation (2G) and third-generation (3G). Most cellular point-to-point Smart Metering infrastructures today are part of Global System for Mobile Communications (GSM) networks and use the General Packet Radio Service (GPRS) data service, a low-cost 2G solution. New 2G cellular Smart Metering infrastructures, however, are more likely to use the evolution of GPRS, Enhanced Data Rates for GSM Evolution (EDGE). EDGE technologies offer more bandwidth and higher connection speeds than GPRS, and are now comparably priced. EDGE is also the preferred 2G technology from the carrier's standpoint, as its higher bandwidth allows more devices to be connected over the network. In North America (especially in the United States), Code Division Multiple Access 1 times Radio Transmission Technology (CDMA 1x RTT) is also a very popular, reliable, and widely available 2G connection option.

With its much higher bandwidth and data rates, 3G technologies also play an important role in Smart Metering deployments. 3G solutions have traditionally been reserved for the NAN level – connecting wireless concentrators that send large amounts of data. For point-to-point metering communications consisting of very small messages, 3G has often been viewed as an unnecessary additional expense. However, as today's mobile carriers seek to move more customers to 3G networks for their own cost and capacity reasons, they are now more likely to work with energy suppliers to make 3G networks more attractive and cost-effective for Smart Metering projects. As a result, energy suppliers may have a surplus of wireless bandwidth available in their metering deployments, presenting opportunities for additional revenue-generating services such as consumer-targeted HAN equipment, and even reselling of wireless capacity to other utilities as part of HAN deployments.

As with GPRS and EDGE, suppliers have a choice of data services over 3G networks, including Wideband CDMA (W-CDMA), High-Speed Downlink Packet Access (HSDPA), and Evolution-Data Optimized (EVDO) Revision A. Newer HSDPA technologies can now be acquired at comparable cost to W-CDMA and have become the preferred solution. In CDMA networks, EVDO devices are more widely available than 1x RTT technologies, however 1x RTT remains the preferred option for Smart Metering applications due to its lower cost and the fact that higher data speeds are typically unnecessary.

Requirements for Successful Smart Metering Deployments

Regardless of the communication technology employed, the Smart Metering communications infrastructure must meet several core requirements. These include:

- **High reliability and long lifespan:** Smart meters (and the communications technologies supporting them) should be able to stay online for 10, 15, or even 20 years without requiring that components be replaced or directly maintained. Therefore, metering communications technologies must be highly reliable and designed with industrial-grade specifications to meet extreme environmental conditions of shock, corrosion, temperature, vibration and humidity.

Smart Metering Communication Success Factors

- *High reliability*
- *Low maintenance*
- *Interoperability*
- *Cost-effectiveness*
- *Strong security*
- *Low power consumption*
- *Low installation costs*
- *HAN interoperability*

- **Low maintenance:** During the 10- to 20-year life span of a Smart Meter communication device, the communication module's firmware will likely be upgraded – for example, to add new features, enhance security, or maintain compliance with the latest wireless communication standards. Utilities need to be able to remotely manage, configure, test, validate and upgrade firmware over the air using secure wireless device management services that the utility or service provider can easily deploy. Smart Metering solutions should also employ modular designs so that, for example, a WAN module can be changed without having to replace the entire meter.

- **Interoperability:** Smart Metering solutions need to employ standard metering protocols to assure interoperability with changing energy supplier equipment – as well as consumer equipment – over the life of the meter.

- **Cost effectiveness:** Smart Metering communications technologies that will be deployed on a massive scale must be designed to minimize those costs and provide excellent value.

- **Security:** When two-way command and control systems are embedded into energy management systems, several security threats must be addressed. These include consumer privacy, data integrity and maintaining continuity of service throughout the grid.

- **Low power consumption:** In a modular design, the WAN or other communication module will rely on electricity provided by the meter, which means that certain design requirements must be met. First, the communications module must be designed to operate using the low supply of current that the meter can provide. Second, suppliers need to ensure that communication systems are extremely power-efficient for cost reasons. After all, even when Smart Meters and their communication systems are consuming a relatively small amount of power, that consumption adds up when millions of meters are connected point-to-point.

- **Low installation costs:** Beecham estimates that installation makes up 30 percent of the total system cost of any Smart Metering project. Suppliers need solutions that simplify installation and reduce the time and expertise required to deploy Smart Meters. For example, in a low-power RF deployment, installation technicians require an advanced skill set and a variety of equipment to verify that the Smart Meter communication system and antenna are properly deployed and functioning as intended. Indeed, one reason that many energy suppliers are now looking to

cellular communications is the lower installation costs involved. Cellular communication modules can be designed with built-in network analysis technologies that make them quicker and easier to deploy.

- **Support for Home-Area Networks (HANs):** Energy suppliers and analysts expect HANs – home networks linking "smart" thermostats, appliances, electric vehicles, etc. to the metering infrastructure – to play an important role in influencing consumer behavior. With HANs, consumers will be able to respond on a minute-by-minute basis to energy pricing changes and remotely shift demand into off-peak periods, when energy is more available and less expensive. To enable these benefits, however, Smart Meters and their communication systems must be designed to interoperate with HANs. That means having the ability to support multi-utility configurations (i.e., to integrate water, gas and other services) and having IP routing capabilities.

Advantages of Cellular Technology in Smart Metering Deployments

In the past, while many utilities relied on cellular technologies to connect concentrators and industrial sites, they often used other communication networks to connect the meters themselves. Now, as cellular technologies have advanced and carriers have introduced more attractive rate plans, more and more suppliers are deploying wireless WAN solutions all the way to the meter.

Why Cellular?

- *Outsourced network deployment, operations, and maintenance*
- *Low installation costs*
- *Fast implementation*
- *Global coverage*
- *Proven and secure technology*
- *Several networks available at most locations, allowing backup capabilities*

Cellular WAN solutions offer a number of advantages for Smart Metering deployments. First, when a utility chooses cellular communications, they can rely on the mobile operator to provide the network – instead of having to bear the cost of deploying, operating, and maintaining the entire communications infrastructure themselves. By outsourcing the communications network to a mobile operator, energy suppliers can radically reduce both installation costs and implementation times for their Smart Metering projects. In addition, mobile operators increasingly view machine-to-machine (M2M) communications as an important and growing subscriber market and are implementing new service offerings and billing approaches to compete for this business. As a result, data rates for WAN-based Smart Metering communications are now extremely competitive.

Today's cellular coverage also extends literally everywhere, covering approximately 99 percent of the addressable population for Smart Metering infrastructures. Indeed, most areas are covered by multiple cellular networks, allowing utilities to deploy Smart Meters using the best cellular network available depending on location, and maintain backup network capabilities.

Finally, cellular WAN is now a proven technology that is more than capable of supporting Smart Metering infrastructures. Cellular technology has existed for more than 20 years, and the security and flexibility of wireless communications is no longer debated. In fact, 1 billion machines already use cellular networks today, and data communication (typically IP-based) now makes up 20 percent of all cellular communications worldwide.

Best Practices for Wireless Smart Meter Design

As more suppliers incorporate wireless WAN technologies as part of their Smart Grid initiatives, the industry is establishing a number of "best practice" design guidelines for cellular Smart Metering infrastructures, described in the following paragraphs. By following these guidelines, energy companies, meter manufacturers, and other stakeholders can help assure that cellular Smart Metering technologies deliver high performance, high value, and long service lives.

Intelligent Communication Modules

The most fundamental best practice now widely accepted in the industry is that smart meter designs should build intelligence into the communications module, rather than the meter. In this design, the meter is responsible only for metering. The communication module handles all of the more sophisticated decisions related to the management of metering information, such as:

- Opening the connection with back-end servers
- Monitoring signal strength
- Managing the security of the connection
- Acting as gateway between the WAN and HAN
- Selecting alternative communication paths if the primary path is unavailable
- Detecting a jamming attack on the meter

Cellular Smart Metering Best Practices

- *Build intelligence into the communication module, not the meter.*
- *Employ strong IP-based security mechanisms.*
- *Allow for software upgrades via patches – not just complete firmware upgrades.*
- *Use embedded SIMs to meet industrial-grade specifications.*
- *Choose a solution with a robust development platform to continually add value.*
- *Be sure that backup communication paths are available.*
- *Simplify installation with modules that include network quality analysis tools.*
- *Use power-efficient features and design.*
- *Design to integrate with HANs.*

This model offers a number of benefits for energy suppliers. First, it allows them to use a modular architecture, in which the same meter can be used with any communication technology (cellular, PLC, RF mesh, etc.).

Building the intelligence into the communication module rather than the meter also makes the solution more "future-proof." Suppliers retain the flexibility to change communication technologies and even complete modules over time (for example, migrating from 2G to 3G cellular technology in the future) without having to replace the meter itself. By avoiding hard-coding functions into the meter itself, they also retain the ability to add new capabilities or meet new requirements (such as complying with new security standards) via software updates.

In order for the communication module to deliver this level of adaptability and intelligence, the module should be built with operating system-like processing capabilities, and potentially with an actual lightweight operating system.

Information Security

Wireless and cellular infrastructures must include strong and proven security technologies. They should incorporate mature defense mechanisms employed by critical public safety and government wireless applications today, as well as Smart Metering-specific security measures. These security measures include:

- **Secure connectivity and encryption:** In any communication system, it is essential to ensure that sensitive information reaches its intended recipient and that it cannot be intercepted or understood by an individual or device attempting to intercept it. This is especially true when the information is contractual data used for billing purposes. Strong authentication processes are also mandatory to prevent hackers from accessing sensitive data, uploading malicious software or turning meters on and off. Wireless communication systems should employ strong and mature encryption protocols such as Secure Sockets Layer (SSL) – which is already widely used to protect retail and web-based payment card transactions – or Internet Protocol Security (IPSec) encryption, which is already widely used to secure virtual private network (VPN) connections.

- **Jamming detection:** In some higher-risk environments, defensive systems are needed to thwart deliberate network attacks. Modern smart meters should be equipped with wireless technologies that quickly detect such attacks and take appropriate actions, such as triggering an alarm, sending an alert through another communications channel, recording the event for further investigation and so on.

- **Autonomous operation:** In the event that the meter loses connectivity with the wireless communications network, the meter must be able to continue operating.

Additional Best Practice Design Considerations

Other best practices for successful Smart Metering projects include:

- **Software patch upgradability:** Everyone agrees that the ability to upgrade firmware, software, and capabilities remotely is essential for any Smart Metering communications technology. Support for basic firmware upgrades, however, is not efficient enough for large-scale deployments. After all, if a utility has to replace the entire 1-Megabyte firmware file on millions of Smart Meters to perform a minor upgrade, the cellular data costs quickly become enormous. With the ability to roll out software changes as patches, suppliers can upgrade only those parts of the firmware code that have changed, using a software package of just a few kilobytes. In general, software patches are often a tenth the size or smaller of upgrading the entire firmware package.

- **Embedded SIM:** Today, the removable plastic Subscriber Identity Module, or SIM cards, used in some cellular networks are designed for the mobile phone market and have a projected lifespan of just a few years. Smart metering communications, which must meet industrial-grade specifications, should use SIM cards that are embedded into the wireless module.

- **Robust and comprehensive development platform:** To enable the intelligent communications modules energy suppliers need, cellular modules should be programmable and allow energy suppliers and meter manufacturers to add capabilities and value as they see fit. Along those lines, cellular communications vendors should offer a mature and comprehensive development platform that encompasses all of the elements necessary to build customized solutions. The platform should also allow meter manufacturers to take advantage of proven, mature technologies for every aspect of wireless communication and management, without having to reinvent these capabilities from scratch.

- **Backup communication paths:** The Smart Metering communications system should provide the capabilities and intelligence to employ alternative communications paths if the primary mechanism is unavailable. For example, if GPRS IP communication is offline for some reason, the meter should be able to communicate via Short Message Service (SMS), i.e., a text message.

- **Network quality analysis capabilities:** To simplify deployments and reduce installation costs, the communication module should be able to analyze wireless network quality and clearly communicate results to installers. For example, instead of technicians having to check multiple SIM cards on their cell phones to measure signal strength, as is commonly done today, the module could scan and assess the signal strength of the different networks available and convey this information to the technician. Even a simple tool such as this can make it much easier and quicker for installation technicians to determine proper meter placement, which cellular network is best for the location, when an external antenna is required and where it should be located, etc.

- **Low power consumption:** Communications modules should be designed to optimize power efficiency at all times. For example, modules should include a low-power mode that allows them to switch off the cellular communications module when it is not in use. This is particularly important when the communication module is operating on battery power (such in a Gas or Water smart metering deployment).

- **HAN interoperability:** The communication module should be able to act as a HAN gateway, with the ability to communicate with other home devices, collect information from gas and water meters, and transmit data to remote displays in the home. To do this, the communication module must be designed with embedded support for IP protocols and routing. It should also support common low-power wireless communication standards such as IEEE 802.15.4, Zigbee, and Wireless M-Bus.

Sierra Wireless: A Strong Partner in Smart Metering Communications

Sierra Wireless is leading the way in wireless WAN communication technologies for Smart Metering deployments. Sierra Wireless' AirPrime™ intelligent embedded modules, AirLink™ intelligent gateways and routers, embedded SIMs, and the AirVantage™ Management Services Platform provide a comprehensive portfolio of solutions for energy suppliers and meter manufacturers that meet today's demanding Smart Grid communications requirements.

Sierra Wireless provides:

- *More than a decade of experience in wireless data communications for utilities*
- *Leadership as a financially strong and well-established technology vendor that will support smart metering technologies throughout their lifespan and beyond*
- *Energy industry expertise, including membership in key industry associations*
- *Established relationships with cellular network operators and technology approval bodies*
- *Broad-based technology solutions that accommodate a variety of wireless technologies and platforms, and service all regions*
- *Proven reliability with a track record of delivering industrial-grade communication solutions*

Looking Toward Tomorrow's Wireless-Enabled Smart Grid

For a variety of reasons, wireless WAN technologies are becoming a compelling choice for Smart Metering communication and will continue to play an important role in these projects. Suppliers seeking more flexible, adaptable, and cost-effective Smart Metering deployments are increasingly seeing the value of outsourcing their network operations to established wireless WAN operators, and incorporating intelligent cellular communications infrastructures into their Smart Metering projects.

To take advantage of the installation cost savings, flexibility, fast implementation times, and other advantages of wireless solutions, energy suppliers and meter manufacturers should be carefully evaluating those areas where cellular technologies can provide the most value in their Smart Grid initiatives. They should seek out solutions that provide robust, pre-packaged wireless management, configuration, and security capabilities, without requiring them to build these capabilities from scratch. And, they should ensure they are working with cellular technology partners capable of meeting the key requirements and best practices for modern wireless Smart Metering design.

To find out more about how wireless communication technologies can empower Smart Grid deployments, visit .sierrawireless.com/energy