ECHELON

MAKING THE GRID SMARTER

The existing electricity grid offers key, long-term advantages over add-on meshed RF communications for smart metering, AMI, and smart grid solutions.

This white paper summarizes the advantages utilities gain by building their smart grid solutions using the existing, reliable electricity grid. A comparison to meshed RF solutions shows why embedded solutions in the grid offer greater cost savings, fewer risks, and higher performance than other available solutions. Leveraging a key asset already owned and managed by a utility delivers proven reliability and performance, increases grid intelligence, and provides a foundation for open smart grid solutions.

WHITEPAPER

MANAGE THE NETWORK YOU KNOW

Utilities already own and manage a vast network: the electricity grid that delivers power to their customers. Through decades of investment and operations, they've become experts at managing their electricity distribution network. As a result, they have extremely reliable networks that reach 100 percent of their customers.

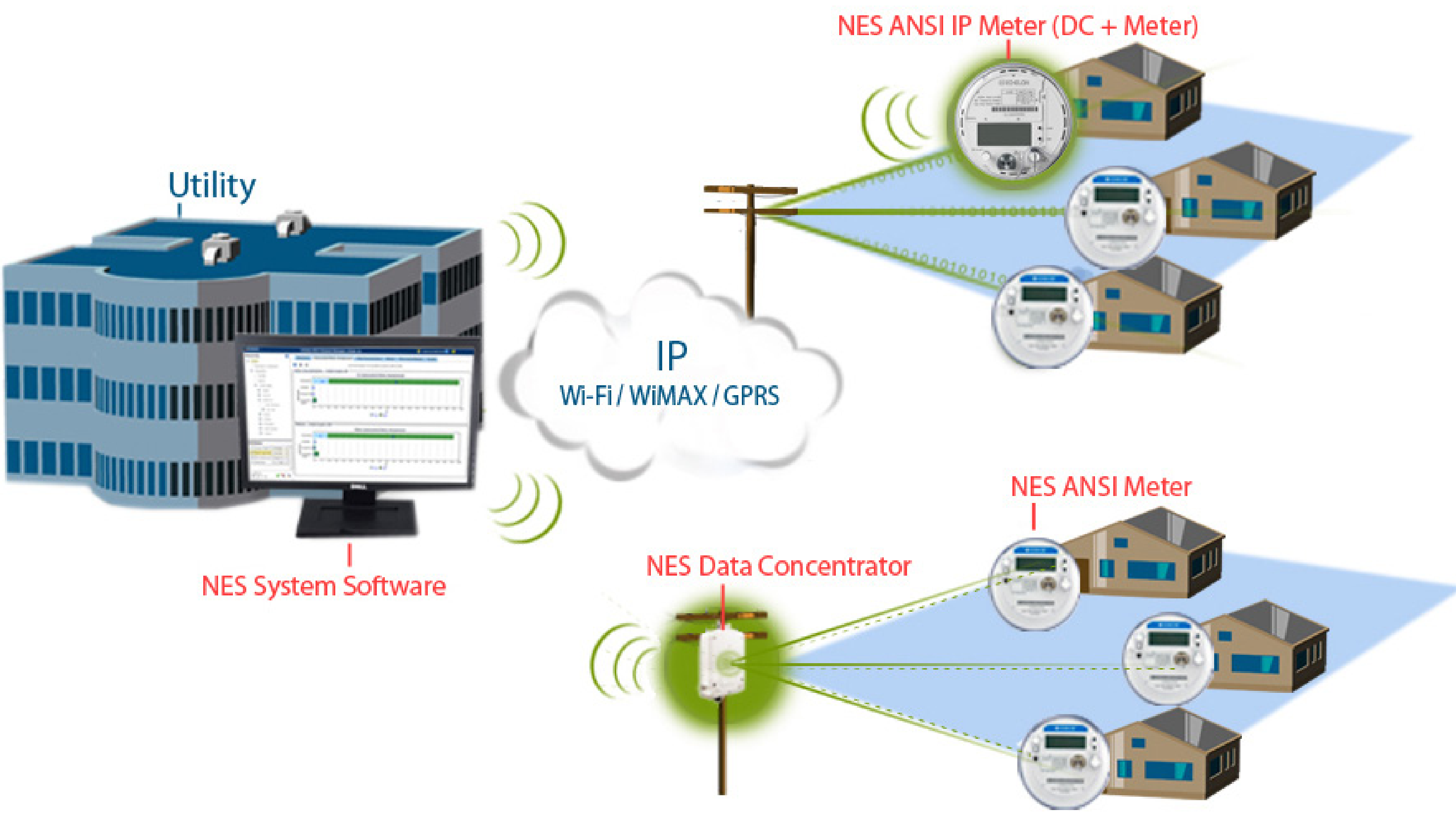
Echelon's NES System uses the power lines that run between the utility's low-voltage distribution transformer and the customer's meter. Unlike the old, slow power line systems designed for rural AMR applications or the expensive broadband power line systems designed for data networking, the NES System is optimized for AMI and smart grid applications. The NES meters' and concentrators' power line network topology maps exactly to a utility's electricity supply assets. The system creates a reliable, high-speed neighborhood network among all the meters on a given low-voltage transformer to share a single IP WAN connection. The WAN (backhaul to the central office) may be of any type, as long as it's IP-based.

Typically, the NES System is deployed by leveraging a community's existing IP network or using a cellular carrier, such as T-Mobile North America, to provide a backhaul for the data. This complementary architecture of neighborhood networks communicating over utility-owned electricity wires and an RF-based backhaul lets the domain experts manage their respective system elements: the utility manages its grid and the telco manages its wireless network. As a result, the entire system is less costly to deploy, operate, and maintain. Utilities can deploy smart grid systems incrementally without having to build out any new networking infrastructure.

- **Neighborhood meter network.** This network, from the transformer in the neighborhood to the meters in homes, is owned and managed by the utility. Maintaining and operating the network is already a primary focus of the utility, as well as one of its core competencies. The resources and expertise used to maintain the electricity grid itself are all that are needed to maintain the NES meters and smart grid system. In fact, the utility can use the performance data collected by the NES System to help improve grid reliability and reduce the costs of maintaining the low-voltage network.
- **IP-based WAN.** By using an established technology for the WAN and sharing an existing communications infrastructure, the utility gets more security, more reliability, and better coverage than it would by using a WAN it created itself. For example, a cellular network provider such as T-Mobile operates and maintains a high-bandwidth communications network designed for tens of millions of end points. By using an established WAN provider, the utility can also offload network maintenance, management, and development costs to the provider.

Conversely, utilities that employ proprietary meshed RF networks to reach their meters are faced with a new system with additional costs and risks. It's a potentially quirky management and maintenance endeavor that creates significant unknowns:

- No evidence of long-term scalability.
- No field proof that it can meet utility reliability standards.
- Unknown performance and maintenance costs over decades of use, especially with regard to changing environmental conditions such as inclement weather, tree growth, home remodeling, and neighborhood construction.



The NES advanced metering infrastructure consists of a family of highly integrated, advanced electronic electricity meters accessed via a Web services based network operating system over an IP networking infrastructure.

ESTABLISHED PERFORMANCE, RELIABILITY, AND SCALABILITY

Many utilities have experience with power line carrier-based metering systems. These systems fall into one of two technology camps, neither of which is well suited to today's smart grid.

The early-technology power line systems (lumped together as PLC) are limited-function solutions that communicate over long distances, through transformers, all the way from an electricity meter to a substation. In order to accomplish this, the connection speed is extremely slow — so slow, in fact, that anything resembling AMI services is impossible.

Broadband over power line (BPL) systems are almost the exact opposite: They are hugely expensive with unlimited (at least as far as metering applications are concerned) bandwidth at every meter. However, along with the high bandwidth come high operating expenses, very high initial capital and installation costs, and lower reliability. Most, if not all, BPL-based metering systems are no longer moving forward for these and other reasons.

Given their experience with PLC, some utilities feel they have no choice but to use meshed RF solutions for their smart metering pilot projects. They've made this decision despite the technology's unproven reliability and scalability. And they've made this decision despite the extra cost and complexity that operating and maintaining a proprietary communications network would entail — an expense on top of operating their own electricity network.

However, a lot has changed in power line technology.

Distribution Line Carrier/Power Line Networks

The latest generation of PL technology is vastly superior to early-technology PLC — so much so that it would be more accurate to refer to it as distribution line carrier (DLC). And power line (PL) technology still holds a dramatic edge over RF solutions because it embeds communications and intelligence directly into the electricity grid. The key advances in these types of PL-based systems are the following:

- Power lines are used for communications only from the low-voltage power distribution transformer to the meter. This effectively creates a meshed neighborhood meter network for every transformer.
- Bandwidth is measured in kilobits — literally many thousands of times greater per meter than early-technology PLC.
- Because the technology resides at the neighborhood meter network and offers high bandwidth, it provides utilities with all the bandwidth necessary for AMI and smart grid applications for the future.
- The power line communication technology itself has already proven to be reliable, economical, and scalable in tens of millions meters, smart appliances, and smart homes.
- The backhaul network uses the domain expertise of existing IP-based carrier networks.
- Using the power grid eliminates the need for an additional proprietary wireless communications network with additional long-term maintenance and management needs.

Radio Frequency Networks

Early-generation RF solutions for utilities were not networks, but point-to-point transmissions between a single meter and a single handheld receiver or drive-by vehicle. Later generations featured more sophisticated paging technology that allowed utilities to poll meter reads from customers' homes. These early generations were neither scalable nor reliable; the reliability of a meter read was only about 80 percent on a day-to-day basis.

Today's latest-generation RF networks are called meshed RF. Since these solutions are just being deployed — none have been in wide-scale operation for an extended period of time — they are unproven under real-world conditions. It's unknown, for example, how long-term environmental changes such as tree growth, new construction, or dramatic increases in consumer RF devices (such as Wi-Fi-enabled smart phones) will affect meshed RF performance, capital expenditures, or operating costs. There is no proof yet that meshed RF networks can maintain their test-bench performance estimates under real-world conditions over the long haul. And there is no proof that RF networks can be easily restored and reconnected after a power outage.

Conversely, there is evidence from other RF systems that constant expense is required to maintain reliable performance. Cellular providers are constantly adding infrastructure to maintain performance in the face of changing environmental conditions. In our personal lives, many of us have experienced RF systems that degrade over time as more and more devices around us clutter the airwaves.

The Reliability and Scalability of the NES System and Its Technology

The NES System, with its DLC neighborhood meter network, is the most proven, reliable, and scalable of any smart grid solution available today:

- Over 30 million electricity meters using the underlying Echelon power line communications technology are in operation today.
- Over 1.5 million more NES meters are operating in homes throughout the world and in harsh communications environments, successfully operating for multiple years.
- Because it uses the low-voltage network for communications, the NES System detects individual meter outages as well as problems with the electricity grid itself.
- The Swedish utility E.ON has seen a 50-percent drop in meter-related customer service calls since deploying its NES-based AMI solution.
- The Swedish utility Vattenfall has been able to read 99.7 percent of its 600,000 NES meters every day and 100 percent of its meters within 48 hours. The Vattenfall deployment has been operating for over two years. (Generally, the communications problem is not in the power line network but in the public RF network.)

EMBEDDED GRID INTELLIGENCE

The NES System embeds its underlying power line technology into a utility's core asset: the electricity distribution infrastructure. This gives solutions built on the NES System a level of grid intelligence that cannot be matched by any wireless solution. For example, because meshed RF solutions are physically separate from electricity lines — a network unto itself — they can't receive any information about electricity lines or power quality. Their data is limited to only what the meter can provide.

Grid intelligence provided by the NES System includes:

- **Line management intelligence.** Utilities can better monitor outages, reduce service restoration time, and verify that service has been restored.
- **Power quality.** Though it's not yet widely regulated, power quality is an important aspect of the smart grid. The NES System measures and detects events related to voltage surges and sags, over-current conditions, phase changes, long and short outages, and total harmonic distortion. The system can profile these and other parameters such as voltage, current, and power factor at configurable intervals. These are all key indicators of the health of the distribution network.
- **Power line communication statistics.** This diagnostic data can alert utilities to potential faults or fatigue in distribution lines.
- **Transformer status.** Since the NES network is attached to each transformer, it can provide unique information about the transformer, as well as aggregate information into circuit models that identify substation-, capacitor-, and transformer-related issues that would otherwise require explicit monitoring (through costly additional hardware and networks). In some cases, this information alone almost pays for the system within a few years.

CREATE AN OPEN SOLUTION

Utilities must be able to make smart grid decisions today that don't hamper their flexibility tomorrow. Future services like residential demand response, incentive pricing, prepay service, alternative energy buy-back plans, and intelligent electric vehicle charging are very real possibilities.

To ensure the maximum level of flexibility to utilities, Echelon's NES System is based on open international networking standards:

- ISO/IEC14908.1 for the communications protocol.
- IP for the WAN backhaul.
- SOAP/XML (Web services) for the system software API.

The signaling technology underlying the NES System is widely deployed in numerous applications worldwide, including smart metering/AMI, home area networks (HANs), and smart appliances.

The NES System itself is open at the meter, the WAN, and at the system software. This lets utilities modify and evolve their smart metering networks to keep pace with new market opportunities and changing regulatory requirements.

Created as a Service-Oriented Architecture (SOA), NES System Software is designed for rapid integration with new and existing enterprise software applications using IT standards. The NES Web service interface helps ensure competitive software services by multiple suppliers.

NES smart meters have multiple interfaces for extending services within a residence through a combination of hardware and software:

- ZigBee or 6LoWpan radio for RF-based touch panels, wireless smart thermostats, or in-home displays, as well as RF-based HANs.
- Open serial interface for home networks or services.
- M-Bus for water and gas meter management (Europe).

In addition, the NES System tracks more than 100 meter, concentrator, and software data points to support the features that are most in demand by utilities around the world. So, even if a utility's initial plans don't include all of the advanced features such as prepay, load profiling, power-quality measurement, residential demand response, remote disconnection and reconnect, and net metering, they can be added to a utility's smart metering system at a later date without changing the meter hardware. And when new features are developed, they can be downloaded as new software into the system from the central office, as has already happened a number of times in the life of NES systems. To use an analogy from the world of telephony, NES provides carrier-grade reliability and an expandable "dial tone" to every customer; over time, the utility can download new features and functions as they are needed and discovered.

CONCLUSION

The NES System's underlying technology helps make the smart grid smarter. Smart metering/AMI solutions built on the NES System are the only truly feature-rich, proven, and future-proof smart grid solutions on the market today. Because the NES System is based on open, international networking standards, an ecosystem of hardware and software suppliers has been developed to support and provide additional products and services to support the needs of every utility — now, and in the future.

The NES System's wide adoption and deployment proves the reliability and effectiveness of DLC technology in smart grid and smart metering applications. It also establishes a performance threshold that meshed RF solutions have yet to attain. While some utilities may have fallen into meshed RF solutions, these solutions are nonetheless extremely risky, presenting a number of uncontrollable variables related to deployment and operational costs, technology, and business opportunities. The NES System eliminates these risks.

DISTRIBUTION LINE CARRIER OVER PL VS. MESHED RF SOLUTIONS

	NES System DLC PL Communications	Meshed RF Network
Reach	Each meter acts as a repeater and the signal path is managed automatically by a data concentrator.	Each meter acts as a repeater, but the path cannot always be predicted. This leads to greater unpredictability in delays and reduced bandwidth due to time spent recomputing the mesh. Reducing the number of hops reduces reach and further increases cost.
Signal Propagation	Not affected by concrete, masonry, or other obstructions.	Works better in wide open spaces and in line of sight. RF must contend with tree growth, new construction, and presence of hills and valleys.
Interference	Echelon's proven power line communication is very robust in the presence of most interfering sources.	Interfering sources (such as Wi-Fi, phones, and HAN) could necessitate RF mesh reconfigurations that take time to propagate through the mesh, thereby reducing effective data rate.
Per-node Cost	Less expensive (less than $5).	Could be two or three times as much with software.
Installation Cost	Very low. Utilities already have the installation expertise. No new training or personnel required.	Higher. Requires new training, skill, and knowledge.
Network Ownership	Utilities already have a primary task of maintaining and optimizing the electricity grid. No new skills, training, or personnel required.	Unknown performance and reliability compounds the already high risk of maintaining a new network with new tools and personnel.
Cost of Repeaters	Every meter can be a PL repeater. Automatically handles repeating.	A few dedicated repeaters must be installed, powered, and maintained.
Largest Proven Installation	30 million in Italy (DLC) 600,000 in Sweden (the NES System)	260,000 (Gothenburg, Sweden)
Maintenance	Automatic topology management in data concentrator automatically handles changes in line conditions.	May have to deal with tree growth and new construction. Network may need periodic power measurements and relocation of repeaters. Mesh network connections, including repeater paths, must be re-established after power outages.
Performance	Proven collection of daily reads from millions of meters.	Disturbances can cause mesh reconfigurations and reduce the effective data rate. Scalability has yet to be proven.

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