Wireless Mesh Network

Applications in the Energy Industry

A Technology White Paper

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1.0 What is Wireless Mesh Networking?

Wireless mesh networking is an innovative technology used to enhance wireless communications. Historically, traditional wireless networks suffered from the same limitations imposed on wired networks. The information path was limited to one single route back to a central data point. If that one route was unavailable, then the entire network was unusable. The network was entirely dependent upon every node on the network being active at all times. Given the vagaries of weather, technical problems, user error, or malfunctioning equipment, maintaining a single route wireless network was very difficult. Users of single route wireless networks found them complex to install, very difficult to maintain, and subject to low transmission rates with unacceptable performance levels.

Wireless mesh networks overcome these weaknesses by providing multiple paths for data traffic. Wireless mesh networks such as those using patented AES-IntelliNet technology; use two-way smart transceivers for communicating data between remote locations and the Central Server (CS) also known as a Central Receiver. A Remote Monitor (RM), also known as a Transceiver, an intelligent device that acts as a transmitter, receiver, repeater and router, links each remote site to the Central Server.

In a mesh network every remote monitor is capable of sending and receiving data from another remote monitor or the Central Server and sending it to its final destination. Data is transmitted directly to the Central Server if the Remote Monitor is within radio range, or if not, is relayed through one or more Remote Monitors. Data always follows the shortest, most reliable route available.

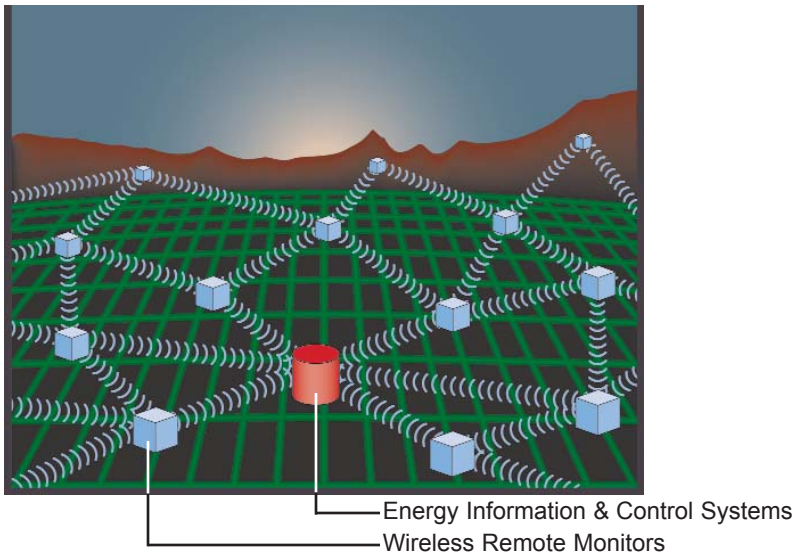

Figure 1: A Typical Wireless Mesh Network

In *Figure 1* above, the Central Server is the primary receiving location of the data for the network. The Central Server is a computer platform that integrates network management software and related applications. Each box indicates a remote monitor in a remote location that sends and receives data from the remote monitors to insure a dynamic data path, which optimizes information flowing reliably across the network on a continual basis.

There are three primary benefits that a wireless mesh network yields for users:

1.1 High Reliability

If data cannot be sent by one route, the intelligent RM automatically selects the next best route. From any given RM there are many different routes the data can take. The dynamic process of polling the network to find the quickest, most reliable, data path is a continual process. If any RM in the network is unable to store and forward the data, then the network immediately analyzes and selects an alternate route insuring that the communications gets through to the Central Server. The network is constantly self-adjusting to optimize the flow of information. This “smart routing” means the network is continually optimizing the pattern of communications to ensure the quickest, most reliable path to the Central Server.

1.2 Self Managing

RMs installed at remote locations dynamically adapt themselves to changes in the network, continually optimizing the system for best performance. The two-way RMs communicate constantly with the Central Server and other remote units to ensure connectivity. Every message received is authenticated, acknowledged and forwarded. If an RM fails to check in, the Central Server alerts the system operator who can assess problems from the console utilizing the network management software.

Wireless mesh technology is resistant to environmental disturbances and equipment problems that plague PLC, phone, cellular or radio tower based solutions by continually optimizing multiple signal paths. Mesh networking offers high reliability in data flow so that messages are received quickly and accurately. The redundant nature of the network ensures that messages always find a path to the Central Server.

1.3 Low Cost of Ownership

The two-way sending and receiving capability of every RM, dispersed over a geographical area, means that mesh networks can be managed remotely from the Central Server. This reduces the number of service calls that need to be made to remote locations.

Adding additional RMs expands and strengthens the network. As new units are added, the network dynamically reconfigures itself to incorporate the new unit exploiting the new paths created by the added RM. This allows network expansion without upgrading system components. Mesh networks can grow to cover thousands of square miles through the addition of RMs while traditional systems would require expensive expansion of physical plant and equipment to expand into larger territories or even fill in coverage holes in existing territories.

And with wireless mesh networking, there are no monthly communications costs paid to telephone or cellular network operators.

2.0 Primary Components of a Wireless Mesh Network

A wireless mesh network, typified by an AES-IntelliNet network, is composed of two basic elements: the Central Server (CS) and the Remote Monitors (RM). The CS is housed at a central location, monitors data sent by the RMs and manages the overall network. The RMs are installed at multiple remote locations.

These primary elements utilize common radio components that allow them to send and receive wireless data on a single radio frequency. The frequency is private and known only to the operator as opposed to cellular radio-based systems where the frequencies are publicly known. Elements include a 2- or 5-watt FM radio transceiver (VHF or UHF) and a Communications Controller made up of a microprocessor and a modem. The Communications Controller is the interface between the radio transceiver and the integrated computer based software, which interprets the data and manages the network.

2.1 Central Server

The Central Server is the primary computer platform to which data from the RMs is received and from which outgoing data is sent. It receives the data and converts the data from the wireless format to the digital format via the Wireless Concentrator, which then interfaces with the software and peripherals.

The Central Server is the hub of a wireless mesh data communications network and provides the following:

- Receives all data packets from the remotely distributed monitoring modules;
- Acknowledges all data messages from the network;
- Annunciates inbound delays, systems faults and warnings;
- Outputs system activity to a printer;
- Manages the Network Management Software and related reporting and analysis software.

2.2 Remote Monitors

Geographically dispersed at remote locations, the Remote Monitor is connected to the monitored device. If the RM is in geographic radio range (typically up to 1/2 mile per hop for residential and 4 to 6 miles for commercial meters but often quite a bit greater) then it communicates directly with the CS. If not, the RM relays its message to another RM closer to the CS. This second or intermediary RM unit acts as a store-and-forward message repeater for other RMs that are beyond direct radio reach of the central receiver. Each RM dynamically evaluates and stores information on all possible “routes” through which it can send messages to the CS.

Wireless mesh networks such as the AES-IntelliNet based system, can grow to cover thousands of square miles, thanks to its patented store-and-forward technology. The range from one radio to the next depends on antenna location, building structures and terrain. It is important to note that range is not the only factor, and that the multi-routing structure allows every radio to have multiple paths by which to send data packets.

3.0 Wireless Mesh Networks for the Energy Industry

Energy data collection and control systems have traditionally been labor intensive or have large up front infrastructure related capital costs and ongoing monthly expenses. New offerings have continued to evolve over time, reducing overhead costs associated with collecting and collating data and have seen technological improvements that have reduced the costs associated with manual energy information collection and control methods. But not enough to serve all of the market's needs.

The Energy industries central needs for AMR and Energy management:

- AMR — Reducing the cost of meter reading;
- Load Control — Reducing energy consumption;
- Load Profiling — Reduce peak demand to save on energy costs;
- Measurement and Verification of energy cost reduction programs;
- Demand Response programs for accurate usage pricing;
- Reducing the energy outage response times;
- Reducing the energy rates.

3.1 Industry Communications Requirements

These energy conservation and cost reduction needs have communications requirements essential to successfully meet these needs. These communications requirements include:

- Low cost for infrastructure and no or low monthly recurring costs;
- Frequent intervals of reading energy usage (often > 1–4x/hour);
- Real-time, immediate transmission of information or controls;
- High reliability;
- High accuracy;
- Small size of communicators (in-the-meter or alongside-the-meter);
- Web-based reporting and analysis;
- Low maintenance, self-managing networks;
- Communications coverage of long distances and varying meter density;
- Serving both Commercial and Industrial as well as Residential needs;
- Working with existing meters.

Driving down the cost component of AMR has been an evolving solution for decades. Various methods have been deployed to improve upon the previous meter reading methods including walk-by and drive-by AMR. These systems still carried with them high infrastructure and lifecycle costs due to the cost to support the communications network. As AMR evolved, so did the need for more information than just once a month billing. As a result, systems that support real time data acquisition, higher interval data reads, and energy controls have become requirements too.

3.2 Alternative Communication Options

Currently, the following communication options are on the market as the communication vehicles available to serve the industry's needs:

3.2.1 Unlicensed Peer-to-Peer Wireless Network — This includes Spread Spectrum and 900 MHz frequency products. The initial appeal is that there are no monthly recurring communications costs and low wiring expenses. However, the range of unlicensed wireless is measured in feet, whereas a licensed wireless system, such as with Advanced AMR Technologies, has a typical range

of up to 1/2 mile per hop for residential meters and 4 to 6 miles per hop from meter to meter. Furthermore, the limited range of unlicensed wireless requires more reliance on expensive communications infrastructure (i.e., repeaters, concentrators) that quickly adds to the price of the system.

3.2.2 Power Line Carrier (PLC) — PLC-based systems use existing power lines as the communication medium so there are no monthly recurring communication costs. However, PLC offers limited advanced AMR capabilities because at speeds of only 60 bits per second, communications is very slow and prone to power line noise that can interfere with communications. Furthermore, while the end device costs may be reasonable, the infrastructure costs can be very expensive.

3.2.3 Telephone — Telephone line based communication is available in most places except some remote areas but has high monthly recurring costs relative to the value of the meter data. Furthermore, installation may take weeks and there is no redundant communications path unless two phone lines are used.

3.2.4 Cellular — Similar to telephone lines, it is convenient to sign-up with a cellular company, but communications costs can increase dramatically depending on frequency of querying meter data. Communication coverage can also be spotty based on geographic area, network traffic, and varying levels of reliability.

3.2.5 Wireless Mesh — Wireless mesh networks as described in *Section 1.0* (page 3), offer a communications solution that requires no infrastructure costs as the data acquisition monitors provide the communications medium. The network operates without third party costs and provides a real time data monitoring function for AMR and the added benefit of two-way communication addresses energy control and management functionality. In addition the network will support AMR, device control, load profiling and an array of monitors for different needs without requiring the need for a separate network.

3.3 Energy Industry Primary Needs Summary

AMR and Energy Management have a unique set of requirements for both initial infrastructure and ongoing life cycle costs. These needs can be summarized in the following chart for technical requirements of the network and monitoring devices and the business requirements of the total solution offered by wireless mesh network-based platforms.

	Technical Needs	Business Needs
AMR	Power Sources: AC, Battery Solar Cover Long Distances Avoid RF Interference 2-Way Communication Eliminate Wiring/Cabling Conduit High Reliability and Accuracy Meter Reads as Often as 15 Minutes	Low Cost Data Collection Minimal Infrastructure Low Total Cost of Ownership Integrate with Billing Software On-Demand Reads Within Seconds
Energy Management	2-Way Communication Real-Time Interval Data On-Demand Meter Readings Ability to Control Devices Remotely	Minimal Infrastructure Costs Analysis Tools Usage Reporting Tools Fast Deployment Low Cost of Ownership

Table 1: Energy Industry Needs Comparison

4.0 Advanced AMR is Wireless Mesh Technology

Advanced AMR Technologies (AAT) is the leading provider of wireless mesh technology products based on patented AES-IntelliNet wireless mesh technology. This field-tested, proven, technology is utilized in security applications, energy management, vending, vehicle tracking, and telemetry monitoring applications in thousands of high value facilities in over 130 countries worldwide.

AAT's products provide innovative solutions to AMR and energy management and control requirements. Prior to the introduction of Advanced AMR, energy data collection systems still relied on a significant investment in infrastructure requiring large capital outlays and ongoing costs of ownership in order to support data collection. Advanced AMR sets a new standard by eliminating almost all the infrastructure needed to collect data and replacing it with an innovative approach that provides a number of benefits.

4.1 Advanced AMR Uses Patented IntelliNet Technology

Advanced AMR Technologies utilizes two-way wireless mesh network technology. By providing a self-managing wireless network that utilizes the remote monitors as the communication medium, Advanced AMR allows energy organizations to quickly implement monitoring programs for energy data collection, control and energy savings. The data collection system also has the inherent advantage of being able to coordinate a variety of different types of monitors within the same architecture. Data collection and energy management solutions for electricity, water, gas, and other utilities could all use the same systems without having to duplicate the network.

4.2 Benefits of Advanced AMR

The primary benefits of Advanced AMR Technology meet the industry's need for fast, real time, and low cost AMR and Energy Management services on a single network. The AAT features that support these benefits include:

- **Data Collection/Control** — Wireless monitoring provides fast, reliable, accurate data collection without high infrastructure costs.
- **Internet Reporting** — Collected data is transmitted from remote monitors via the Internet to an Energy Information and Control System that allows for remote monitoring and control from anywhere.
- **Speed** — Wireless data transmission is up to 30 times faster than telephone line based systems.
- **Real Time** — Real time data acquisition allows users to read on-demand and have immediate feedback on load profiles and energy usage. Systems that currently provide data like PLC systems or data loggers for monthly energy bills have significant lag times. With no means of actively making energy management decisions except over long periods of time and by having to manually visit the site to implement them, the ability to act to reduce costs is severely limited.
- **Interval Data** — The ability to read data in 15-minute intervals means users can make informed decisions regarding energy management by looking at where the energy usage is happening rather than looking at it in the aggregate.
- **Low Cost** — Systems that require a significant investment in communications infrastructure face a price performance curve that generally negates any savings that might be realized except for a very long return on investment period. Advanced AMR wireless systems, which can be easily implemented, and operate at significantly reduced costs compared to alternative methods provide fast, reliable data collection at a cost that provides an ROI of much shorter duration.

- **2-Way Controls** — Since each remote monitor acts as a transmitter and receiver, the system can not only remotely monitor and collect data, forwarding it to a central collection point for analysis, but the network management platform can also send control signals back to each individual monitoring module to turn the device on and off. This has inherent advantages in large geographically disbursed systems like multi-building campuses or large apartment houses where a remote manager may want to disconnect electricity in a vacant apartment and turn off selected devices at periods of peak energy demand. In addition remotely distributed devices such as sewer pumps or irrigation pumps can be controlled from a remote location.

5.0 The Advanced AMR Network Platform

The following diagram and system components provide an overview of the Advanced AMR Energy Information and Control System (EICS) platform and Remote Monitors available for energy management.

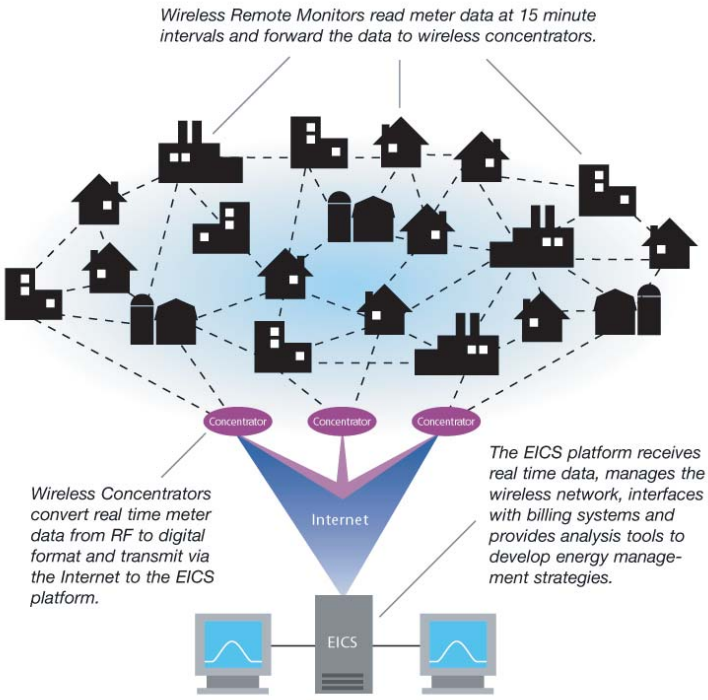

Figure 2: Advanced AMR Remote Wireless Network

5.1 Energy Information and Control System

The EICS platform is an open source Linux based server, which manages the wireless data network and makes extensive logs of radio traffic, meter data and wireless concentrator performance for remote troubleshooting.

The EICS also contains a MySQL database supporting a number of specially designed energy management software solutions:

- A Network Administration Program;
- A Light Duty Billing Program;
- A Dynamic Charting Program for Generating Meter Analysis;
- An Apache Web Server to View Live Information from the Internet.

Each remote monitor at the meter site self-configures into the network when installed, and is also a repeater site for other remote monitors to communicate with the EICS via the wireless concentrators. The remote monitors send data at selected intervals to the wireless concentrator and then every minute the data is sent via the Internet to the EICS. The EICS manages, stores and graphically presents energy management information via a Web browser.

The data can then be exported to any billing or energy management system as a flat file, text file (tab-delimited), Excel spreadsheet, and other formats.

5.2 Wireless Concentrators

The wireless concentrators collect the remote monitor's data packets and then convert the wireless data to digital format and upload the data via the Internet to the EICS where it can be collected, analyzed and viewed in graphical format. This allows wireless networks to cover large geographic areas. Advanced AMR can also support a variety of different monitoring modules in one system thereby significantly enhancing the ability of the network to address multiple requirements.

5.2.1 *7170* Wireless Concentrator — The 7170 concentrator collects long-range wireless data and converts it for transmission over the Internet.

5.2.2 *8850* Wireless Concentrator — The 8850 concentrators collects longer-range analog signals and converts the data to digital data for IP communication.

5.2.3 *8851* Local Concentrator — The 8851 collects short-range digital signals from clusters of remote monitors and forwards the data to the 8855.

5.2.4 *8855* Internet Concentrator — The 8855 concentrators collects shorter range digital signals and forwards the data to the Internet. The data is then sent to the EICS platform.

5.3 Remote Monitors

Designed to support a wide variety of energy and utility monitoring needs, these small, intelligent monitors collect data regarding electricity, water, sewer, heating, cooling, and provide information in real time to the EICS. Some specialized modules are designed to remotely turn processes off/on for remote management of distant processes. Examples of AAT remote monitors include:

5.3.1 *8650* Commercial AMR Monitor — An "outside the glass" remote monitor. These monitors are available in different configurations and read universal KYZ pulse output. These monitors collect energy usage data in up to 15-minute intervals at the meter and forward the data to the EICS system via wireless concentrators and the Internet.

5.3.2 *8810* Device Controller — The 8810 Device Controller can interface with several types of end-point equipment and perform remote on/off control. Hot water heaters, irrigation pumps, sewage pumps, refrigeration, boilers, and HVAC units are examples of end-point equipment that can be interfaced with the 8810 Device Controller. The device reports performance and implements demand response logic based on signals from energy managers.

5.3.3 *8811* Hot Water Controller — Designed with four sensors to monitor supply and return temperature on two pumps and two relays to manage hot water conservation programs. The 8811 has system logic that learns the consumption pattern of hot water heaters. The monitor then reduces the stand-by temperature of the system during periods of low demand and ramps up temperature in anticipation of high demand. The device can reduce stand-by heating costs by approximately 50% and report performance to the EICS via the Internet.

5.3.4 ***8840*** **UTG Monitor** — An “under the glass” remote monitor that collects meter data. Several different types of collection modules are designed to fit most industry standard meters available in the market.

5.3.5 ***8841*** **OTG Monitor** — An “outside the glass” remote monitor that collects meter data. Several different types of collection modules are available to fit most industry standard meters available in the market.

5.3.6 ***8842*** **Water Monitor** — This remote monitor provides AMR for water meters located in places without AC power. A capacitor charged by solar power eliminates the need for batteries. A solar cell also provides alternative DC power for more frequent meter reads. The benefit of the meter is that water consumption data will automatically load into the database on a timely schedule without manual data entry.

The following chart summarizes the type of remote monitors available and their primary applications.

Table 2: End Unit Device Selection Chart

	Remote Monitors				Remote Controllers	
	AAT 8650	**AAT 8840**	**AAT 8841**	**AAT 8842**	**AAT 8810**	**AAT 8811**
Commercial	**X**		**X**	**X**	**X**	**X**
Industrial	**X**		**X**	**X**	**X**	**X**
Residential		**X**		**X**	**X**	**X**
AMR Plus	**X**	**X**	**X**	**X**		
Load Control			**X**		**X**	**X**
Demand Response			**X**		**X**	**X**
SCADA Lite/M&V	**X**		**X**			
Electricity	**X**	**X**	**X**		**X**	
Water				**X**	**X**	**X**
Gas			**X**	**X**		

6.0 Conclusion

The implementation of wireless mesh networks offers significant advantages to the Energy Management and Utilities industry:

- The ability to implement AMR or Energy Management solutions at the lowest infrastructure cost ever available.
- The ability to install multiple remote monitors without running wires, cables or conduit.
- The ability to integrate multiple types of monitoring devices in one integrated system without having to duplicate separate systems for different types on monitoring.
- The ability to cover large geographic areas easily and economically.
- The ability to utilize two-way communication for network management, reduced service calls, and allowing remote on/off device controls.
- Advanced network management software offers ease of use, easy expansion and low-cost of ownership.

Advanced AMR provides a wide variety of unique energy management monitors that can utilize a single system to address the energy management needs of both energy suppliers and energy consumers. The installation of remote monitors reporting real time data combined with the powerful network management and application software analyzing the incoming data stream, yields the most advanced tools available today for those who monitor, manage, and conserve energy usage.

Utilities, Energy Co-Operatives, Municipalities, ESCO'S, facilities managers, and schools can all benefit from the ability to install and operate a low cost Advanced AMR EICS energy management platform that allows them to monitor energy usage on a real time basis and develop fast response, high impact, strategies for meter reading and reducing energy costs.

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