Wireless multipoint energy submetering

Tim Thompson, Chief Engineer, Communications, Eaton

Abstract

The Eaton Power Xpert™ Multi-Point Meter enables facility managers to track and accurately allocate energy usage among tenants or departments within commercial, industrial, and institutional facilities. The meters are designed to be factory-installed and easily retrofitted into existing applications.

This paper describes several scenarios that use wireless communications with the Power Xpert Multi-Point Meter. Sometimes running communications wiring is impractical, costly, or otherwise difficult. For example, in an old building it may be impractical to run communications wiring between the location of the meter(s) and the location of the supervisory system, which could be on different floors or in different buildings.

Introduction

Interest in energy efficiency has increased dramatically in recent years. The Energy Policy Act of 2005 (EPAct 2005) requires federal agencies to install advanced electric metering in every building by 2012. The Energy Independence and Security Act of 2007 (EISA 2007) requires all federal government agencies to reduce energy consumption by 3 percent per year through 2015. Similar initiatives in the private sector for energy efficiency have also driven demand for the ability to monitor and trend energy consumption at the level of individual loads in distribution panelboards and switchboards.

The Eaton Power Xpert Multi-Point Meter provides a cost-effective, scalable approach to meter energy in assemblies or power distribution equipment with a high density of metering points. A single device can handle up to 20 three-phase and/or up to 60 single-phase circuits and is compatible with most three-phase industrial, commercial, and single-phase residential low voltage electrical power systems. **Figure 1** shows a Power Xpert Multi-Point Meter with three meter cards, two digital input/output (I/O) cards, one Energy Portal Module, and four empty card slots for future expansion.

The 10-milliamp (mA), 100-mA, and 333-millivolt (mV) meter modules can be mixed and matched in one Multi-Point Meter, and each meter module can be configured for six single-pole, two three-pole, or three two-pole meter circuits. The Multi-Point Meter's PIM pulse input module can be configured for up to eight pulse inputs from other water, gas, air, or steam meters. For detailed information on the Multi-Point Meter and available option cards, see the literature available at www.eaton.com/meters.

The Power Xpert Multi-Point Meter supports Modbus® RTU over RS-485 directly from the meter base, and BACnet/IP, Modbus TCP, and SNMP over Ethernet using the Energy Portal Module. The module provides the additional functionality of a local embedded Web server, which enables Multi-Point Meter configuration support from a Web browser and support for cost allocation software.

The cost allocation software allows a facility manager to assign meters directly to individual tenants and add monitoring for additional utility sources via digital input modules. The user can then allocate energy costs to tenants and aggregate data from single-pole loads into a common tenant such as "lighting" or "HVAC." This allows building owners to understand where energy is being used. In addition, many state and industry energy codes now require metering of individual loads.

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Figure 1. Power Xpert Multi-Point Meter

The Power Xpert Multi-Point Meter is designed for distribution panelboard and switchboard installation, which makes it an attractive, integrated, factory-installed option. The Multi-Point Meter is also designed for enclosure installation, as shown in **Figure 2**, which makes it an attractive choice for retrofit applications. Sensors include both solid-core and split-core, the latter facilitating retrofit installation using existing power cables.

Figure 2. Enclosed Multi-Point Meter

Scenario 1: Wired communications

In applications where it is feasible to run communication wires from a supervisory system to the Multi-Point Meter, such as an energy management system or a building automation system, wired communication is likely to be the most cost-effective and simplest communications architecture. This is especially true if the building already has a local area network (LAN) in place. **Figure 3** shows a simple example of a Multi-Point Meter communicating with a supervisory system through an Ethernet switch. The meter's optional Energy Portal Module is the Ethernet interface, and it supports Modbus TCP and a local embedded Web server for configuration and energy cost allocation, as well as other protocols and functions. More sophisticated examples would replace the switch with a LAN, including routers, firewalls, other managed switches, and so on, but the basic concept of the Multi-Point Meter communicating to a supervisory system over Ethernet through the LAN is the same.

It is important to note that a supervisory system can collect data from the Multi-Point Meter via BACnet or Modbus at the same time that a local facility manager is accessing tenant energy consumption information from the Multi-Point Meter's Web server.

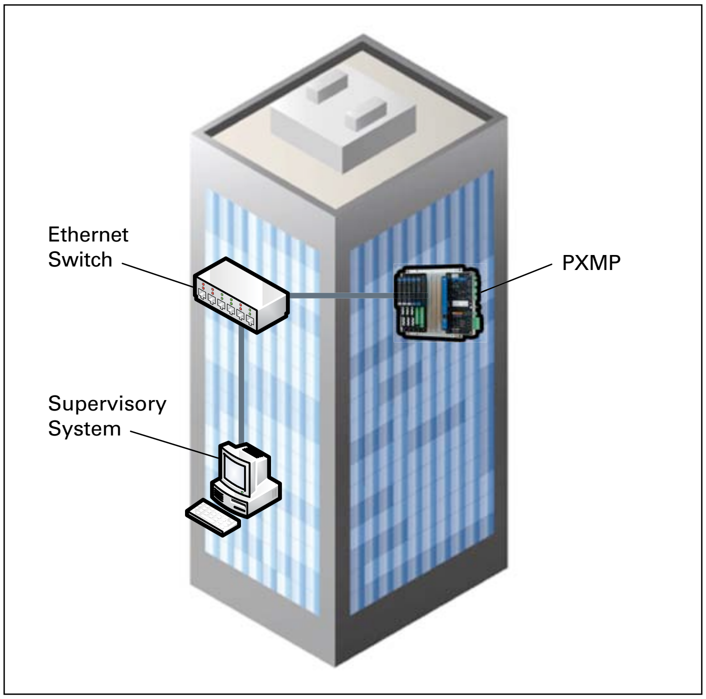

Figure 3. Building with Wired Communications

In some retrofit applications, particularly old buildings, it may not be feasible or desirable to run communication wires throughout the site. For these applications, there are a number of wireless options to consider.

Scenario 2: Wireless communications—Wi-Fi

The Institute of Electrical and Electronics Engineers (IEEE) standard 802.11 is a popular and very cost-effective means of wireless communications that is prevalent in many commercial and institutional buildings today. While there are several different approaches to 802.11, they are generally characterized as operating in either the 2.4G Hz or 5G Hz frequencies and with an indoor range from about 60 to 200 feet. The outdoor range is roughly 300 to 800 feet, with no physical obstructions between antennas.

In cases where a LAN does not exist (for example, in very old buildings), another option, as shown in **Figure 4**, is to use Ethernet Wi-Fi modems to create a completely wireless network within a building.

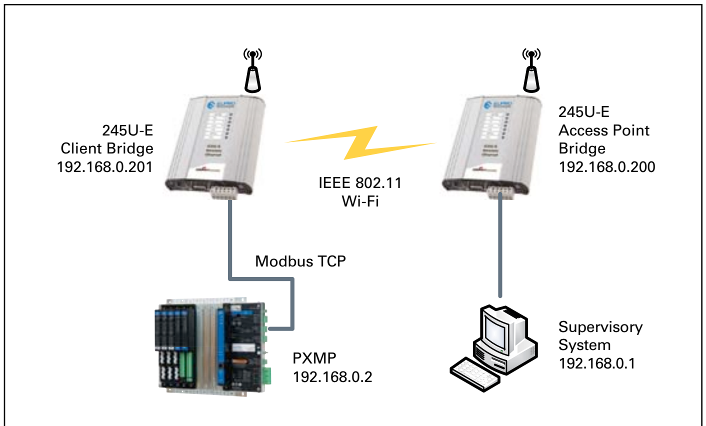

Figure 4. Wi-Fi with 245U-E Ethernet Modems

In this scenario, a LAN is not assumed. Rather, ELPRO 245U-E Wireless Ethernet modems by Bussmann can take the place of the wired LAN and communicate directly with each other using Wi-Fi.

In this arrangement, one 245U-E is connected via a CAT6 cable to the supervisory system, and is configured as an access point and bridge. The second 245U-E is connected to the Energy Portal Module installed in the Multi-Point Meter via a CAT6 cable, and is configured as a client and bridge. From the supervisory system, the "ping" command can be used to verify communication with both radios and the Energy Portal Module. After verifying communication, the next step is to open a Web browser on the supervisory system and enter the IP address of the module (which is 192.168.0.2 in this example). This will launch the module's user interface application, which will enable monitoring and configuration of the Multi-Point Meter.

Scenario 3: Wireless communications—longer range

Although IEEE 802.11 is commonly used in residential and commercial applications, it does not propagate well through obstructions such as walls and floors. **Figure 5** shows another option: using ELPRO 905U-E wireless Ethernet modems by Eaton's Bussmann business, which use 900 MHz radios. In addition to the lower frequency, which propagates through obstructions more effectively than the higher frequencies of IEEE 802.11, the 905U-E radios also implement a spread spectrum frequency hopping scheme that is able to cope effectively with radio interference as well as physical obstructions.

The distance that may be reliably achieved with 905U-E radios will vary with each application, depending on the transmit power (user-configurable), type and location of antennas, degree of radio interference, and physical obstructions to the radio path. It is possible to achieve reliable communications with 905U-E radios for distances of up to 15 miles.

To achieve maximum transmission distance, antennas should be raised above intermediate physical obstructions so that the radio path contains a clear line of sight. Because of the curvature of the earth, the antennas will need to be elevated at least 15 feet above ground for paths greater than 3 miles. The radios will operate reliably with some obstruction of the radio path, although the reliable distance will be reduced. Obstructions close to either antenna will have more of a blocking effect than obstructions in the middle of the radio path. For example, a group of trees near the antenna can be a larger obstruction than a group of trees between two antennas. The 905U-E modules provide a diagnostic feature that displays the radio signal strength of transmissions.

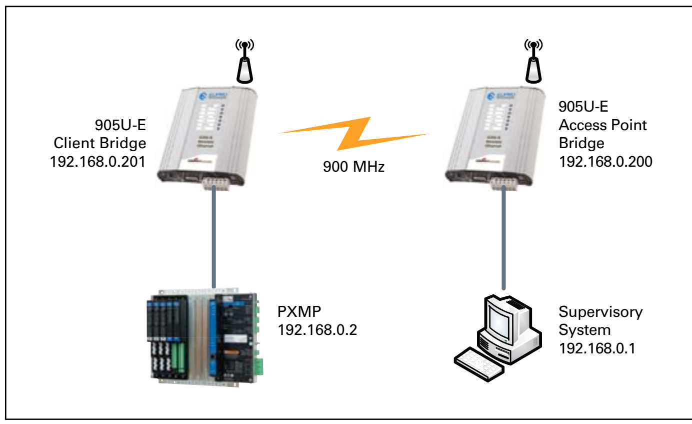

Figure 5. 900 MHz Wireless with 905U-E Ethernet Modems

As shown in **Figure 4**, in this scenario, the Ethernet modems also take the place of the wired LAN, enabling the supervisory system to communicate directly with the Energy Portal Module through the Ethernet modems.

In both scenarios, one 905U-E is connected via a CAT6 cable to the supervisory system, and is configured as an access point and bridge. The second 905U-E is connected to the Energy Portal Module installed in the Multi-Point Meter via a CAT6 cable, and is configured as a client and bridge. From the supervisory system, the "ping" command can be used to verify communication with both radios and the Energy Portal Module. After verifying communication, the next step is to open a Web browser on the supervisory system and enter the IP address of the module (which is 192.168.0.2 in this example). This will launch the module's user interface application, which will enable monitoring and configuration of the Multi-Point Meter.

Scenario 4: Wireless communications—Modbus RTU over Wi-Fi

The ELPRO 245U-E Wireless Ethernet Modem has two serial ports: an RS-232 port and an RS-485 port. The 245U-E can be configured for Modbus serial communications over either serial port. The two serial ports, in addition to the 100 Mbit Ethernet and Wi-Fi radio, give the 245U-E a high degree of flexibility for a wide variety of configuration needs. **Figure 6** shows one typical configuration example, in which the Multi-Point Meter communicates via Modbus RTU to a 245U-E, which translates to Modbus TCP and communicates wirelessly to a supervisory system via a second 245U-E.

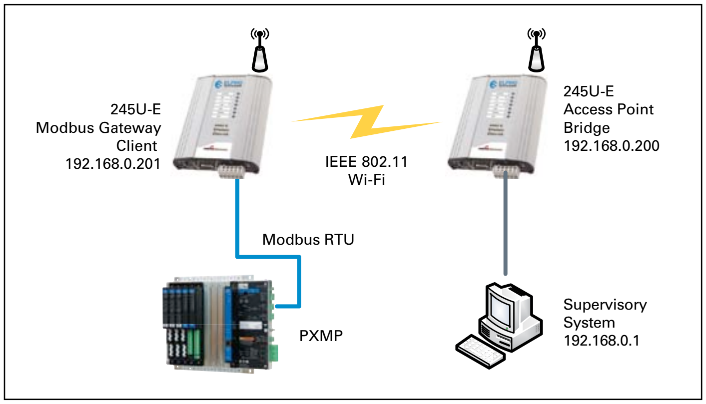

Figure 6. Modbus RTU over Wi-Fi

As in previous scenarios, in this scenario the Ethernet modems take the place of the wired LAN, enabling the supervisory system to communicate directly with the meter through the Ethernet modems.

The Multi-Point Meter supports Modbus RTU via RS-485 directly from its base unit. In this example, one 245U-E is configured as a Modbus TCP to a Modbus RTU gateway and a client. A second 245U-E is configured as an access point and a bridge. In this example, the second 245U-E is connected to the supervisory system via a CAT6 cable to enable Ethernet communication.

The supervisory system acts as a Modbus TCP master, and sends Modbus queries to the Multi-Point Meter through the Ethernet modems. The modem that is configured as a gateway converts the queries from Modbus TCP to Modbus RTU and forwards them to the meter. The Modbus RTU response from the meter is converted back to Modbus TCP and forwarded back to the supervisory system through the second Ethernet modem.

It is important to note that although this example shows one Multi-Point Meter Modbus RTU slave device, the gateway can serve as a link for up to 32 Modbus RTU devices over one daisy-chained twisted pair RS-485 network.

In addition, the access point can serve multiple client gateways, each of which may manage multiple Modbus RTU devices on different RS-485 networks. ELPRO 245U-E Ethernet modems can be used to easily scale from simple to very sophisticated systems.

Antenna selection

Antenna selection and usage is a complicated subject, and is described in detail in the user manuals for the ELPRO Ethernet modems. The 245U-E and 905U-E radios support a variety of external antennas. A basic omnidirectional antenna will be adequate for most applications. In applications that require long distances or that have to penetrate substantial physical obstructions, a Yagi antenna may be used. The following is a brief overview of the basics of antenna selection.

A basic omnidirectional antenna transmits in all directions, essentially in a three-dimensional spherical pattern, and also receives in all directions. An advantage of the omnidirectional (collinear) antenna is that the transmitting and receiving antennas do not have to be oriented exactly the same way. The disadvantage of the omnidirectional antenna is shorter range.

Figure 7.

A dipole antenna transmits in more of a two dimensional plane and receives in a two dimensional plane. The advantage of a dipole antenna is greater range than an omnidirectional antenna. The disadvantage is that some care must be taken during installation to ensure correct orientation and alignment of the antennas.

Figure 8. Dipole Antenna

A Yagi antenna produces a more focused transmission, and is sometimes referred to as a unidirectional antenna. As illustrated in **Figure 9**, a Yagi antenna has additional reflector and director elements that increase the strength and narrow the focus of the transmission into more of a one-dimensional beam. A receiving Yagi antenna similarly listens in roughly a one-dimensional beam. This highly focused transmission means that the transmitting and receiving Yagi antennas must be correctly oriented and aligned. The advantage of the Yagi antenna is longer range and better penetration of physical obstructions, due to the unidirectional transmission. The disadvantage is the care that must be taken in installation to ensure proper orientation and alignment.

Figure 9. Yagi Antenna

The ELPRO 245U-E and 905U-E Ethernet modems are available with a choice of antennas, as shown in the tables below.

Table 1. 245U-E Compatible Antennas

Elpro Model No.	Antenna Type	Net Gain (dBi)
MD2400-EL	Dipole	2
SG2400-EL	Collinear	2
Z2400-EL	Collinear	4
Y2400-EL	Yagi	6

Table 2. 905U-E Compatible Antennas

Elpro Model No.	Antenna Type	Antenna Gain (dBi)
WH900	Omnidirection whip	–2
DG900	Dipole whip	–2
CFD890EL	Dipole whip	0
SG900EL	Collinear	+5
SG900-6	Collinear	+8
YU6/900	Yagi	+10

In any given application, the most reliable way to determine if desired radios and antennas will work as desired is to test them in the intended application. Engineering services from Eaton's Bussmann business can provide on-site studies, as well as guidance on specific applications. As a general rule, the 905U-E Ethernet modems will transmit farther than the 245U-E Ethernet modems due to their lower radio frequencies, and the Yagi antennas will transmit farther than omnidirectional antennas. Also, physical obstructions near the midpoint between two antennas cause less interference than obstructions near either antenna. A clear line-of-sight between the antennas will result in best performance, though this is not always possible, especially within a building.

Also note that if range or physical obstruction remains a problem for the chosen radios and antennas, both the 245U-E and the 905U-E support a repeater function, in which additional radios may be placed between the end points to extend range. **Figure 10** shows an example of using an additional Ethernet modem to extend range.

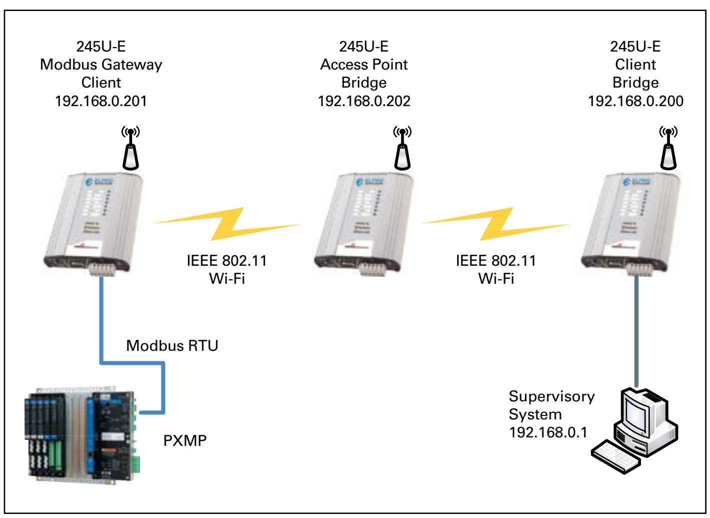

Figure 10. Multiple Ethernet Modems to Extend Range

Further, it is important to consider that another Modbus RTU network could be connected to the additional Ethernet modem that acts as a range extender. The 245U-E can communicate through a wireless and hardwired system simultaneously.

Security

For many wireless applications, secure communication is a key issue. This is particularly true with wireless communication, where eavesdropping is easier to accomplish than in a wired system. A key defense mechanism to ensure secure communications is to encrypt messages between the supervisory system and the meter. Both the 245U-E and the 905U-E have communication encryption capabilities (turned off by default).

The 245U-E supports several different radio encryption schemes. All modules in the system that communicate with each other will need the same encryption method and encryption keys.

The available encryption methods in the 245U-E are as follows:

- WEP (Wired Equivalent Privacy) encryption is the weakest encryption method, defined by the original IEEE 802.11 standard, and uses a 40-bit or 104-bit key with a 24-bit initialization vector to give a 64-bit and 128-bit WEP encryption level. WEP is not considered an effective security scheme, and should only be used if it is necessary to inter-operate with equipment that does not support more modern encryption methods.
- WPA (Wi-Fi Protected Access) is a subset of the IEEE 802.11i Security Enhancements specification.
- WPA2 (Wi-Fi Protected Access 2) replaced WPA and provides significant security improvements. In particular, it introduces CCMP, a new AES-based encryption mode with strong security.
- WPA/WPA2-PSK (Legacy Support) enables the modem to communicate with all WPA methods, including TKIP, AES, and WPA2 AES. Generally, it is only used if the network has older devices that do not support the higher-level encryption methods. Enabling this option will lower the security level of the network down to the weakest configured encryption level (WPA TKIP).
- WPA-Enterprise (802.1x) removes the need to manage the pre-shared key (PSK) by using an external server to provide client authentication. Clients who are not authorized will be prevented from accessing the network. Once a client has provided the correct authentication credentials, access is permitted and data encryption keys are established, similar to WPA-PSK. Fine-grain (user level) access control can be achieved using this method.

The 905U-E provides a choice of 64-bit proprietary encryption or 128-bit AES encryption. AES is a superior encryption scheme accepted by most users as one of the most secure encryption schemes available. For users who prefer not to use a "public-domain" encryption scheme, a proprietary scheme is available. Both encryption methods provide an extremely high level of wireless data security.

Conclusion

The Power Xpert Multi-Point Energy Submeter is a very powerful and cost-effective way to measure energy consumption at the load level in distribution panelboards and switchboards. A common application of the meter is in retrofitting existing buildings in order to understand and manage energy efficiency. A significant challenge, especially in old buildings, is running communications wiring between floors from a supervisory system to the meters. Fortunately, this problem can easily be solved through the use of the Multi-Point Meter in conjunction with ELPRO Ethernet modems from Eaton's Bussmann business. A variety of radios and antennas are available that will work in virtually any situation, from communication on the same floor, to communication between floors in a building, to communication between buildings.

Author

Tim Thompson is chief engineer for communications in power components solutions at Eaton. He has held positions in design engineering and engineering management, and has over 20 years of experience in developing electronic power distribution products, including power quality meters, protective relays, electronic trip units, communications gateways, and enterprise software. He holds four patents, with several pending. Tim received his BSEE from the University of Pittsburgh, and his MSEE from Carnegie Mellon University.

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Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
Eaton.com

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