Practical AMI/Demand Response Applications Using Wireless RF Technologies

Michael Sharp, P.E.
Eaton's Cooper Power Systems
505 Highway 169 N., Suite 1200
Plymouth, MN 55441
763-543-7662
MichaelSharp@Eaton.com

Paul Heinl
Eaton's Cooper Power Systems
910 Clopper Road, Suite 201 S
Gaithersburg, MD 20878
240-750-3829
PaulHeinl@Eaton.com

Mark Scheibe, P.E.
Maquoketa Valley Electric Cooperative
109 North Huber St.
Anamosa, IA 52205
319-462-5838 ext. 285
MScheibe@mvec.com

Abstract

An increasing number of utilities are starting to take advantage of the benefits of wireless-radio frequency (RF) Smart Grid technologies. This paper will cover several utility applications of this technology in Advanced Metering Infrastructure (AMI) and Demand Response (DR) roles. An overview of how the RF technology works will also be given.

Introduction

Over the last 10 years, AMI and Smart Grid communication network technology has seen rapid innovation, growth, and expansion across the U.S. and internationally. Utility service providers including not just electric, but water and gas also, have more options than ever for connecting to their infrastructure and customers. Options include power line carrier (PLC), cellular, wireless radio frequency (RF) using tower or mesh networks, and hybrids using a combination of these technologies.

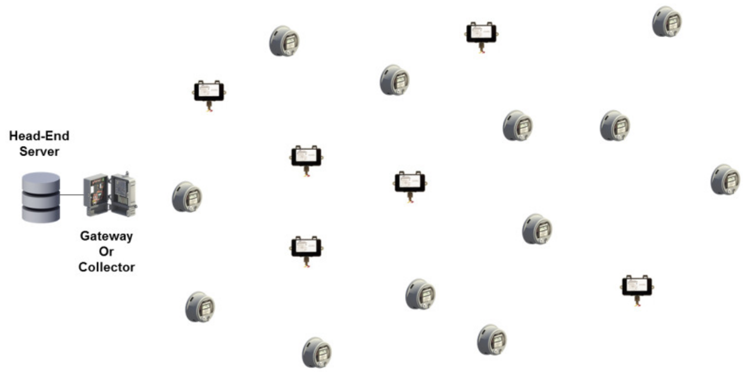
This paper will focus on the RF Mesh technology, including a brief overview on how these networks work, some case studies from existing users, and how improvements in the technology allow utilities to target high value Smart Grid features over a sparser than normal area without the initial expense of a full AMI implementation.

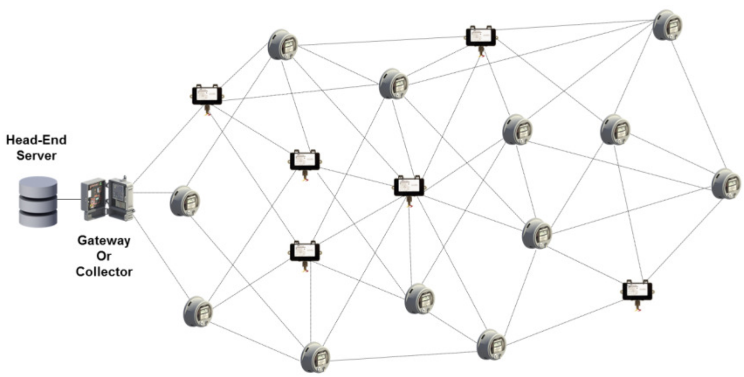
RF Mesh Overview

Typical RF Mesh Networks today are auto configuring and fully self-forming, self-optimizing, and self-healing. A head-end server either at the utility or hosted by a vendor provides the software to handle network management, user interfaces, graphical displays, useable data outputs, and third party software integrations to billing/customer information systems (CIS), outage management systems (OMS), geographic information systems (GIS), engineering analysis (EA), SCADA, and meter data management systems (MDMS).

The head-end server uses a high bandwidth communication channel such as fiber, backhaul radios, or cellular to communicate to gateways (also referred to as collectors). These are the primary access points into the RF mesh and act as centralized brains of the network. Several gateways are spread across the coverage area.

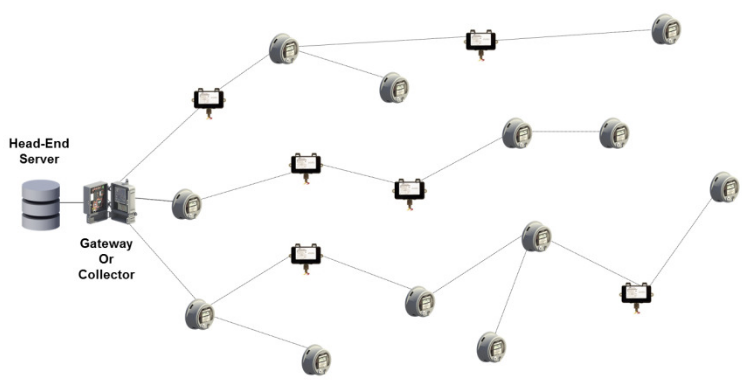
From there, end points such as electric meters, water meters, demand response switches, and distribution automation equipment are installed where needed. A propagation study is typically done ahead of time to ensure network connectivity at each specific GPS coordinate.





Once installed, each network device immediately begins listening for network traffic and broadcasting its own information including device specific information as well as other neighbors and routes available to it from surrounding devices in the mesh network. In this way, each node builds a full table of neighbors it can communicate to and possible routes back to a gateway. The network is self-forming.

Each network device constantly evaluates the possible routes and link costs associated with each route in order to determine the most efficient path to reach a gateway. That path is identified as the primary route, secondary routes and other routing and neighbor tables are also maintained in case of an interruption of the primary route or a newer, more efficient option appears. This provides the self-optimizing and self-healing nature of RF Mesh Networks; no outside intervention is required to account for addition or removal of network devices for them to continue performing at the highest level possible. It also ensures built-in redundancy at every level in the network for highly reliable systems.

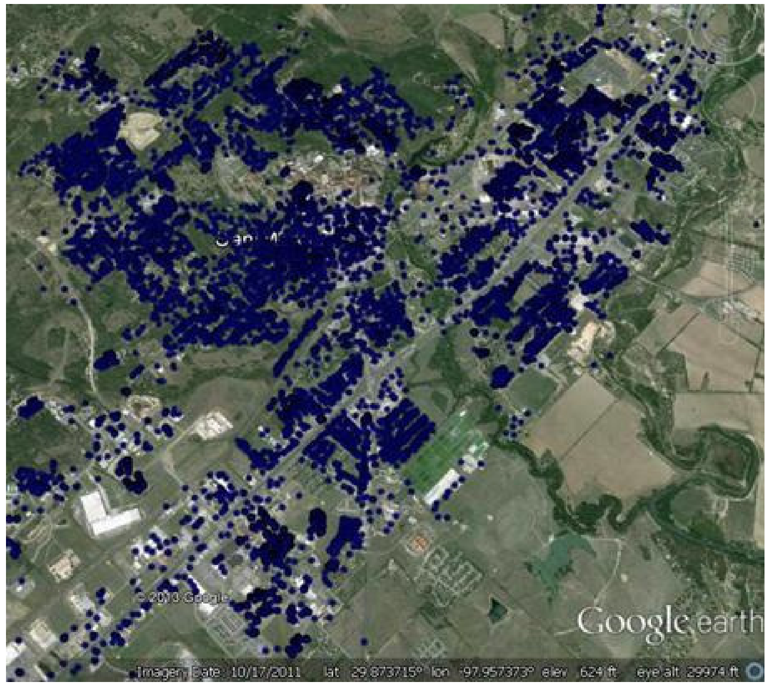


Case Studies

Voltage Regulation

One electric and water municipal utility with a deployed Cooper Power Systems RF Mesh Network for AMI primarily intends to use the low cost residential meter for collecting billing meter readings. However, an additional benefit of these meters is their capability of collecting interval voltage readings.

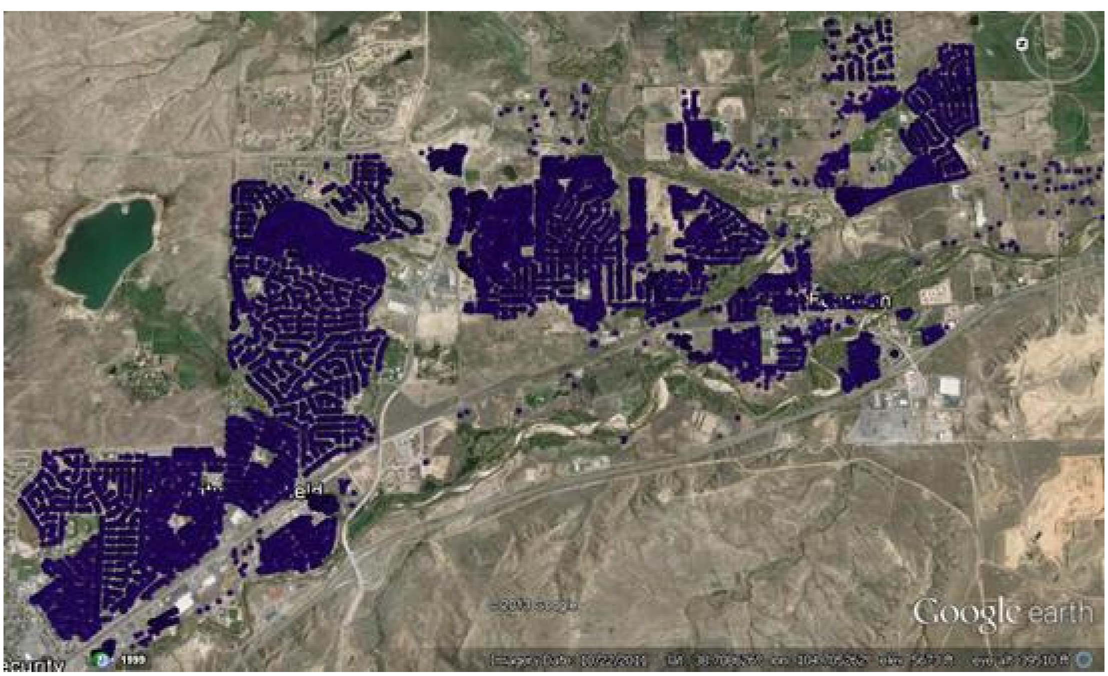
A plot showing the 20,000 plus AMI meters that are deployed with the capability of collecting voltage readings is shown to the right. They intend to use hourly voltage data collected from both their commercial and residential meters to monitor voltage sags and peaks along their power lines. This hourly voltage data will then provide a means to determine the consistency of the voltage levels anywhere along their power distribution lines. If need be, the meters can even be remotely configured to collect voltage levels at much shorter intervals. The meters will then provide the data to determine if additional voltage regulating equipment is needed, which is especially important now that the utility is experiencing a tremendous growth in new apartment complex construction.



Plot of voltage regulation area where blue dots are meters.

First Responder Safety

Recently, a full RF Mesh AMI deployment was completed with 100% remote service disconnect meters over an electric and water municipal utility’s 17,000 electric services in an area where wildfires are a large concern. This utility intends to use the service disconnect feature to disconnect groups of meters at a time in wildfire zones to help provide safety to first responders. The plot below shows the locations of all the installed disconnect meters.



Plot of disconnect meter area where blue dots are meters.

AMI Verification for One-Way DR

The goals of one city's current electric, water, and DR RF Mesh pilot include using information collected from new AMI meters to determine customers that are currently enrolled in their existing one-way Demand Response (DR) program with inoperative relays. By identifying and replacing these DR devices with new two-way Cooper Power Systems RF Mesh Load Control Relays (LCRs), they expect to see significant peak reduction benefits from the new LCRs. As an added benefit, the new LCRs include two-way data to provide even further Measurement and Verification (M&V) assistance. These cost saving benefits will then be used to pay for a large portion of the RF Mesh AMI and DR implementation going forward.

Drought Water Usage Monitoring

Another utility installing a pilot RF Mesh Network project for electric and water AMI is looking beyond just collecting monthly billing readings. They plan on using interval readings from their 16,000 AMI water meters to monitor high water usage customers during times of extreme drought conditions. They will use the readings to verify compliance with mandatory water usage restrictions.

Maquoketa Valley Electric Cooperative (MVEC)

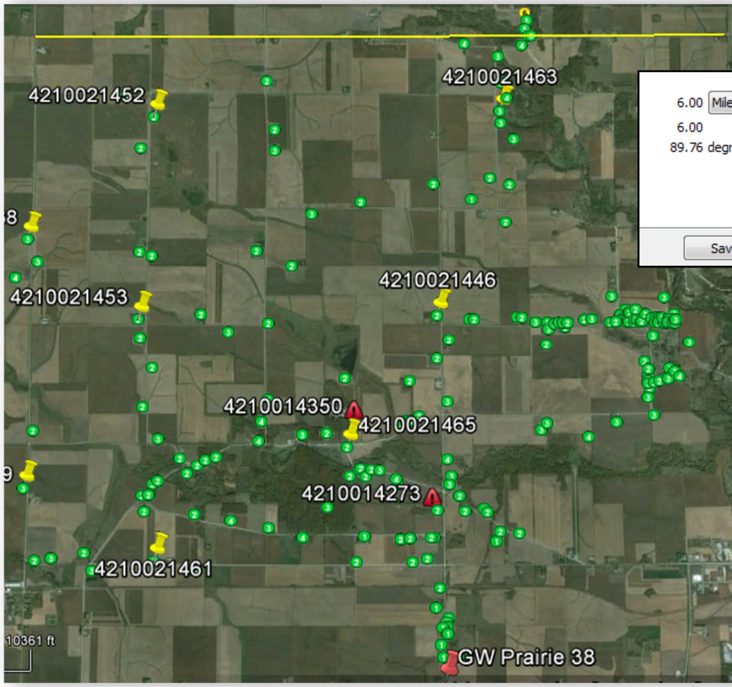
Maquoketa Valley Electric Cooperative installed 16,500 PLC based Cooper Power Systems AMI meters in 2008 and has invested significant time to make the system operate successfully, achieving a 99.4% read rate for billing. The existing power line carrier technology has been integrated with numerous technologies within the cooperative, including SCADA, OMS, CIS, GIS, and engineering analysis software. Tying the metering information to so many systems allows for the data to be beneficial to both the cooperative and the members and not just stored in a database.

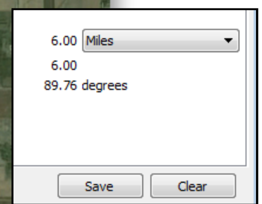
AMI technology has changed significantly in the last five years since the Cooperative made the decision to go with a PLC based system. When evaluating different technologies in 2008, RF was thought to be unavailable or unreliable in a rural setting. With newer, stronger radios inside of the meters and the ability to create a mesh, RF meters are now an option.

There are certain areas on Maquoketa Valley's system where receiving accurate, timely meter readings and engineering data from the PLC meters was a struggle. When Cooper Power Systems purchased a wireless meter vendor, MVEC became interested in the technology because it would allow the Cooperative to obtain meter information more efficiently. Since both the PLC and RF technologies utilize the Yukon platform, only one vendor would be needed to use both technologies.

Cooper approached Maquoketa Valley Electric Cooperative about doing a RF mesh pilot to test their new meters in a rural setting. After evaluating the technology, it was decided to proceed with the pilot since it was another tool that could be used to get the metering and engineering data. The main deciding factors were data bandwidth of the RF vs PLC meters, reduced amount of continued maintenance of the system to obtain reliable reads, outage detection and notification by the meters, and that the PLC equipment that is removed can be re-used elsewhere on the system. Only 93.5% of the meter readings were able to be obtained daily using PLC.

The first week of July 2013, all of the meters on one feeder out of a substation were changed from PLC to RF. To help the network form initially, Cooper completed a path study and recommended the placement of 10 relays to help ensure that the mesh network would form as expected given the variable terrain and distance between meters. As the meters were recognized by the collection gateway, they were automatically populated on the system and became a part of the larger mesh network. Throughout the week, the count of returned meters would increase hour by hour until all of the meters were communicating successfully. The image to the left shows a map of the pilot area.





Plot of MVEC RF Mesh pilot area

The system has lived up to the claims of having very low maintenance requirements. Since the initial installation, MVEC has only added one additional relay to receive data from 3 meters that were located in a valley with lots of tree cover. The day to day monitoring and tweaking that was experienced with the PLC system in this area has been eliminated and the RF meters are responding with 100% of the interval data.

Going forward, Maquoketa Valley plans to purchase RF metering equipment when buying new meters. This will allow for areas that have PLC communication challenges to be targeted and converted to the RF technology and the Cooperative will run a hybrid system for the foreseeable future.

High Value Applications

The Maquoketa Valley case study demonstrates one example of an RF Mesh network applied to an area with a device density much lower than the typical characteristics for where these networks have been installed in the past. Advances in network intelligence and the ability for each link in an RF Mesh network to negotiate its own data rate and transmit power for optimal performance allow the network to expand to these sparser areas with minimal sacrifice on speed and without unnecessarily using high power transmitters at every location.

Not only can this sparse network topology be used to deploy AMI systems in more rural areas, a sparse network can also be created right in town by only installing Smart Grid network devices that provide the most up-front value to the utility. The full AMI system is no longer needed, or can be added into the network later as budgets allow.

Commercial &Industrial Metering

Commercial &Industrial (C&I) metering for large customers is one example of a targeted high value application. An RF Mesh Network can be used for high profile customers to collect and provide interval data through a web portal without the need to install AMI metering at surrounding residential customers. The most important customers to the utility can receive some special attention with extra tools to login to a consumer portal and view their usage as needed.

Disconnect / Reconnect Capability

Remote meter disconnects are another AMI application that's often used to help cost justify a full AMI network. With this deployment methodology, remote disconnect AMI meters can be installed on an as-needed basis only to minimize cost and maximize the benefits of the Smart Grid network.

Prepaid Program

Along with remote disconnect meters comes the option to implement a prepaid electric program for your customers. Although this type of program may not sound appealing at first, many studies now have shown the popularity of these programs among consumers. Many users site the benefits of not having to open a bill for an unknown amount at the end of each month, eliminated or reduced service deposits, smaller and more frequent payments, no reconnection fees, and the option to choose a payment style that works best for them as reasons they like prepaid systems that have been implemented so far. There are also clear benefits to the utility, the largest being a solution to the constant struggle of collections and costs of manually connecting and disconnecting customers that usually can't fully be reclaimed even through reconnection fees.

New Rate Structures

Another option that targeted deployments allow is for customers to sign up for special rate structures such as time of use (TOU), real-time pricing (RTP), critical peak pricing (CPP), or peak time rebate (PTR) programs. These programs are designed to help flatten the utility's load curve similar to a demand response (DR) system or to at least charge rates that more closely reflect the price of energy for the utility. Customers can potentially pay less and save the utility money at the same time by shifting their electric usage from peak times of day when energy is most expensive, to other times of the day.

Voltage Monitoring

In addition to customer related activities, there are also high value engineering benefits which can be achieved through spot deployments of point of interest meters. Voltage profiling and monitoring is a great example. End of line meters and meters immediately following down line equipment such as voltage regulators and capacitor banks can be used to ensure that voltages are maintained at the target levels along each feeder. Meter voltage profiles, min/max daily voltages, or voltage alarms for crossing specified thresholds can be used directly by engineering or to facilitate SCADA, integrated voltage/var control (IVVC), or conservation voltage reduction (CVR) operations.

At the same time, these "point of interest" meters will facilitate outage management to improve restoration times for consumers and help improve CAIDI, SAIFI, and SAIDI reliability performance metrics for the utility.

Although low end residential meters might not have all the voltage profiling capacities that commercial, higher cost meters do, almost all residential meters do have the ability to collect voltage to the meter giving a utility and added benefit of collecting interval voltage data from almost all meters in their Smart Grid.

Distribution Automation (DA) Applications

An RF Mesh Smart Grid Network can be used solely for the purpose of DA in order to add the most intelligence and automation into the distribution network itself. DA applications can range from basic capacitor control to IVVC, CVR, and automated feeder reconfiguration (self-healing grid). While basic capacitor control focuses on minimizing VARs, IVVC systems incorporate voltage regulators and load tap transformers and allow the utility to set preferences in order to manage volts and VARs in balance according to the needs of each feeder.

CVR uses control of this same equipment to lower voltage at peak times as a form of DR. Field observation across the industry has shown that even a 1% reduction in voltage results in 0.5 to 0.8% reductions in kW.

Automated feeder reconfiguration uses smart sensors across the distribution network to detect outages, software intelligence to determine the scope, and controls on reclosers and relays to then allow software to isolate an outage and back-feed the circuit where possible, thus providing a self-healing grid.

Demand Response (DR)

DR systems have been around for a long time, typically using a one-way communications platform with a high power transmitter and receiver on the end device. These are still quite common using PLC, flex paging, and VHF systems. Two-way data being returned from the control devices is becoming a more common requirement now for PLC and RF systems, and a sparse RF Mesh Smart Grid Network is a fitting topology for this type of application since it's usually a low customer penetration type of voluntary program.

The two-way data returned is valuable in several areas. It allows utilities to confirm device programming and configuration, to ensure that separate control groups are correctly addressed for example. It also helps save time and money during measurement and verification (M&V) of the DR program by providing information on the appliance runtime and device control periods without visiting each location. With one-way DR systems there is very limited feedback outside of viewing the utility system load levels and often devices are uninstalled or disconnected and go unnoticed for years. The operator can now rest assured that an event will be successful on a control day by checking availability ahead of time, confirm that control is occurring by receiving immediate confirmation from the field, and do a full audit on device participation following each event.

Conclusion

As RF Mesh Smart Grid Networks become more prevalent with a high level of success and reliability, innovations in technology and deployment methodology are expanding the boundaries and making it possible to use the technology in new areas and for more specific, targeted high value applications to allow utilities to realize their return on investment faster than ever.