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Masters in Geographic Information Systems

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Capstone Project

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Introduction:

The term ‘smart grid’ is starting to permeate societal consciousness. Once confined to the boardrooms and engineering circles of the electric utility industry, the concept of a ‘smart grid’ is now common in popular journals and books, on utility bills, and even as a subject of movies and television commercials. Popular attention is not surprising, as the smart grid represents the arrival of ‘the future’ of electrical transmission and distribution systems. Technically speaking, the term smart grid refers to electrical generation, transmission, and distribution systems, which are capable of real-time communication and automated responses to load demands and outage events through advanced information and communication technology. The goal of any electrical system is to maintain uninterrupted delivery; a smart grid accomplishes this task with programmed responses to system adversity.

Metering, specifically demand metering, is arguably one of the two most critical developments of the electric grid, along with the ability to transform electrical voltages for transmission and consumption (Carr, 2008). Automated Metering Infrastructure (AMI), otherwise known as ‘smart meters’ and hereafter referred to interchangeably as smart meters or simply AMI, is one of the most critical components in a smart grid. Metering points exist throughout an electrical grid as a means of maintaining fair and equitable electricity for all levels of use. Furthermore, metering ensures that the electric company can accurately forecast peak demand while also measuring and billing for total usage at each service location. The more accurate and available this information is, the better a utility can monitor and react to demand and events at the service level. The accuracy and effectiveness with which AMI are able to perform these functions is partly dependent on their location and on the legibility of information that is relayed back to system operators.

The need for this project arose in response to hurdles encountered during a small utility’s implementation of a local radio frequency (900 MHz) based Advanced Metering Infrastructure (AMI) deployment. This project was inspired by a simple question from the metering manager of a small utility: “Can GIS help me find a location for a collector meter?” The answer to that question grew into this large project which develops and applies a methodology to facilitate an organized and informed approach to site selection, replacing a trial and error process. In other words, the purpose of this project is to develop and apply a geospatial methodology that will help metering managers make more informed decisions for installation of key equipment for smart metering systems. This project contributes to the planning, siting, and interactivity of AMI to enable utilities to deploy AMI in (cost) effective ways, and to gain full advantage of the benefits of increased monitoring and control at the system metering points provided by the next generation of metering technology. Furthermore, utility operators need timely information about the status of their network. As such, this project develops and applies a geospatial methodology for analyzing and configuring a web mapping system that will help metering managers visualize the layers of communication within their own system of existing metering points.

This project review has five sections. In the following section, the benefits of AMI and smart grid technology are discussed in greater detail. Second, relevant literature on mesh networks (the 'local' communication topology by which many AMI systems are designed to communicate), the use of GIS in designing such networks, and the use of GIS in electrical delivery system planning and operation in general is reviewed. Third, the methods used in this project are described. Fourth, the findings and outputs of this study are summarized. The paper concludes in the fifth section with a discussion of the extent to which the method and findings of this project can be extrapolated to other geographic areas.

Benefits of AMI:

The network of wires and cables that deliver electrical power from generation sites to consumption sites is commonly referred to as the electric grid. Electric grids are organized in the same manner as a flow chart or a grove of aspen trees (a grove of aspen trees is often one organism tied together through the root systems). The structure can be viewed as simply the main trunk lines that provide energy through the branches to meters, but below that surface view is interconnectivity, akin to the root system, which ties small local systems together to the larger grid. A smart grid is one that has some degree of technology influencing and interacting with the control and monitoring of the system.

Smart grid technology is not new. As early as the 1920's, primitive supervisory control and data acquisition (SCADA) systems were used by the electrical utility industry (Smith, 2010).   Early remote monitoring was as simple as gauges and switches wired to control rooms which were located short distances away from transformers and electrical devices. As computing capabilities along with speed and reliability of communication progressed, SCADA systems have blossomed into the dynamic asset they are today. Modern SCADA systems allow electric utility operators to view critical information in a snapshot, or dashboard view, which is fully customizable and can display anything from the temperature and oil levels of substation transformers to current system voltage and amperages. The purpose of SCADA systems is to transmit detailed information to a central computer screen, providing the same or greater information and control as if the operator were standing at the device in the field.

A quality SCADA system could be described as being greater than the sum of its parts because the information can be modified before reaching the graphic interface. Calculations can be performed using multiple values which are not always readily available from the limited interface of the device in the field. The majority of these systems also allow control messages to be sent to remote locations to manage the operation of the system, such as rerouting power during times of outage or high usage. Fiber optic and wireless communication networks have been harnessed to maximize speed, and now automation, of many aspects of the electric grid. In fact it is automation that most defines current electric grids as smart. These highly automated 'smart' electric grids have 'self-healing' capabilities whereby the underlying program of predicted actions and reactions are initiated by the SCADA system itself and merely monitored by the operator.

Smart grid technology represents the evolution of SCADA systems, with benefits extending beyond operation and control. Framing smart grid technology as an ongoing program within the electrical industry, there are stakeholders at every level with varying interests and goals. Utilities and customers benefit from increased reliability due to automation. Executives are able to monitor their electrical systems in a dashboard view and gain access to reports faster than with traditional information systems. Operators have been provided a level of control and monitoring that far exceeds past capabilities. Line workers can be armed with system information on a device as portable as a tablet or smartphone. Office employees are now more informed than ever with system operation, usage, and outage information displayed on their desktop workstation. The utility can monitor specific metering points for outage information, or groups of meters for general trends, load reporting, and system forecasting. Smart grid technology even allows consumers to monitor and participate in their own energy usage and habits. Appliances and other household device electric usage can be visualized through a real-time application, allowing the consumer to monitor their own household or business. Prepaid electricity is one of the fastest growing business model concepts in the utility industry and is fully dependent upon the presence of AMI. Embracing this technology also saves time and fuel because the meters can be turned on and off remotely from a desktop computer program.

Generation facilities are using smart technology to monitor production levels that are more precisely aligned with demand, thereby reducing excess electricity. Perhaps more importantly, smart grid technology offers a way to design a system that is amenable to intermittent sources of energy production – i.e., it adds the capability of the system to automatically respond across the network to fluctuations in wind or sun, as well as the ability to coordinate multiple generation locations and schedules. As Sioshansi and Fereidoon (2013: 367) note, smart-meters are "bi-directional" and able to measure "a) total electricity consumption and b) energy production of each household", which is a crucial need in the wake of increased distributed generation such as rooftop solar energy systems. Indeed, automation has a great impact at the retail metering point.

As mentioned, AMI systems are a critical part of smart grid technology. The Electric Power Research Institute (EPRI) asserts that the most basic characteristic of an AMI system is "two-way communication to exchange energy usage, price and curtailment signals, and operational control signals" (EPRI, 2011). This is the critical distinction between conventional Automated Meter Reading (AMR) systems and AMI. AMR is a highly desired solution for cost-minded organizations and is useful in saving time and money when retrieving in situ meter reads, but does not allow for the control and monitoring associated with AMI. Electric meters are shut off for a variety of reasons from load balancing (peak usage control) to outstanding account balances; the remote disconnect function within AMI brings this ability into the office through a simplified Graphic User Interface. These capabilities are wonderful functions for everyday operations of the utility, but AMI brings much more to the table. System analysis, outage management and prediction, along with load forecasting benefit all stakeholders within a smart grid program. These key functions are not provided by AMR systems.

Literature review:

Geographic Information Systems (GIS) serve as the organizational medium for smart grid data. GIS provides a framework to build models to represent electrical flow and build relationships between all elements of an electric grid. The specifics of using GIS to manage electric flow models and electric utilities as a whole are outside of the scope of this project but necessitate a short discussion. Bill Meehan makes the case for GIS being the driving force and backbone of a modernized utility. "GIS, integrated with corporate systems, SCADA, crew dispatch, and customer systems, helps with decision making, provides better coordination and communication, and lowers costs" (2007, p. 35). Among the benefits of combining GIS and field devices he lists are:

- Combining load forecasting and planning processes in a single GIS view
- Allowing multiple planning scenarios to exist within the same database
- Easing visualization of projected loads to current system capability
- Providing one consolidated view of all active projects in their varying stages of development
- Building a framework for engineering decision making based on data from within and outside the utility, using location as the common denominator

Meehan continues to make a case for utilities, large and small, to embrace GIS. Specific benefits exist based on the nature of the database structure. First, GIS can be used for general operation and maintenance. Many aspects of electricity generation, distribution, and use can be mapped and visualized in ways that facilitate informed decisions by industry managers. Equipment and assets have more important attributes than simply their identification, size, and location. Recording information such as manufacturer, performance ratings, and installation year will allow users to not only project life cycle, but also find the unique locations when a trend of failure is discovered. Too often utility companies are reactive: "What happened? Where are we at right now? How is our system currently performing?" These questions are common in utilities large and small, in fact, the concept of 'right now' may even be a *goal* at smaller utilities. GIS plays a key role in assessment in addition to planning and forecasting. Second, GIS provides a common platform to improve (the communication of) planning and forecasting, by tracking proposed and planned projects and highlight any common areas of scope or requirements. This allows management and users alike to avoid costly overlap in resource allotment (human or physical) and find common goals between projects which may be accomplished in tandem. Without a common communication platform it is possible that two separate staking engineers may be designing power lines to neighboring locations requiring the same resources, such as an empty conduit for the underground cable. With GIS, the overlap of resource allocation will be known before it becomes a problem and may even provide an avenue for a cost saving solution (Meehan 2007).

During times of emergency GIS and AMI systems can greatly reduce outage triage and response times. As Allen Cousins of Avista Corporation illustrates in Figure 1, an Outage Management System (OMS) using a GIS based electric connectivity model empowered by a quality AMI can predict root causes of outages before a customer even reports the lights out. When an individual AMI meter reports it has lost power the other meters connected to the same transformer are pinged. If the other meters have power, the outage is reported as a service outage. If this is the only meter on the transformer or the other meters are out of power, it is reported as a transformer outage. Transformer outages can be a localized issue or can be a symptom of a line outage. Electricity flows from a central location, such as a substation, to endpoints on a system. If there is a disruption along that path all devices, transformers, and meters past the point of interruption will not have electricity until the system reacts by restoring or rerouting power flow. An isolating device can 'open', or cut power, to stop electrical flow to a small area. The rest of the system maintains normal functionality, thereby containing the outage. Once a transformer outage is reported, meters associated with the next 'up line' transformer are pinged. An outage management system can use preset thresholds of verified outages (generally meter outages that have been stepped up to transformer outages) to predict problems with isolating devices that do not have direct communication, such as a fuse or relcoser. The system then begins to ping meters up line from that isolating device until meters are found to have power. All of this pinging and logic can be performed within seconds to provide the best location to send a field crew to check for problems. When SCADA enabled isolating devices operate or sense a lack of power, an outage report can be reported faster than the AMI system will predict the device is out. Not all outages affect a SCADA enabled isolating device so the systems each have value in different outage situations. While dispatchers and system operators are focused on field reporting devices, line crews can use mobile GIS to travel to the precise problem location. These field crews can access all of the data discussed above in order to make informed decisions and then update the central database after they have performed their restoration work. These complimentary systems can be integral parts of an organization's Outage Management System.

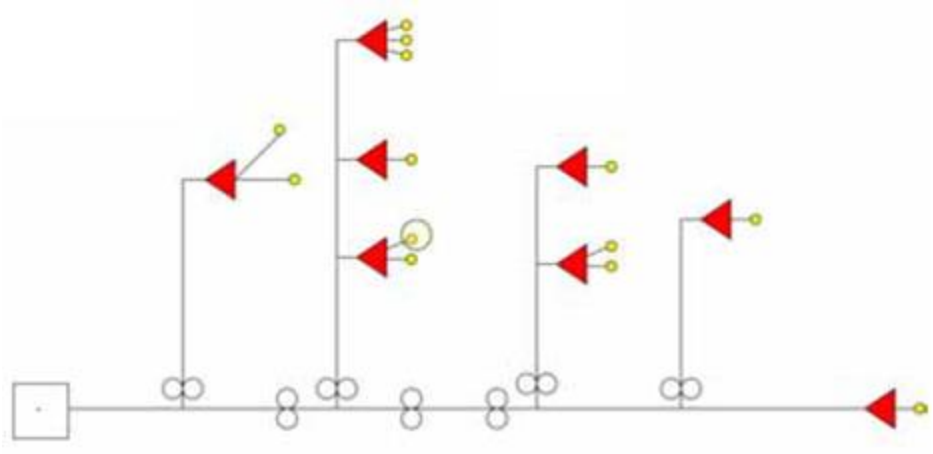


Figure 1: Conceptual model of an AMI-enabled electricity system. The large square at left represents the substation, the yellow circles are AMI meters, the red triangles are transformers, and the circles on the lines represent isolating devices on the power lines. Source: Cousins (2009)

Once implemented, AMI systems enable the consumer to take full advantage of this technology within their homes. Home Area Networks (HAN) can be created to bring appliances and electronics together as one operational system. Each consumer can build a dashboard view of the energy use within their home and enable control of their devices. This may be loosely considered SCADA on the local consumer level. As Greg Baird (2011, p. 37) points out in reference to in-home monitoring of water use, "it would be nice to imagine these activities are all motivated by resource conservation-oriented attitudes and behaviors, the main motivation is usually the price signal issued each month in the form of a water bill." Consumers have two-way communication with their electric company. In addition to this detailed view of their electric consumption behavior, consumers are armed with GIS based applications which can allow for problem reporting. Volunteered Geographic Information (VGI) can help inform the utility of small problems before they become large problems. A consumer can snap a picture with a location enabled smart phone of an area of concern anywhere on the system and notify the utility in moments.

Some metering systems employ a 900 MHz communication mesh network. Within these systems all meters can relay information through neighboring meters ultimately reaching a central aggregate device, which may be collector meter or a device that only collects aggregate data. These collector meters then transmit all gathered meter information to the central data acquisition server through an aggregate point via a variety of backhaul communication solutions. This process involves individual meters (end points) and collector meters (gathering units), communication portal (aggregation points), the central server and the user interface. A 2009 white paper by Patel, et. Al. describes this relationship:

> "The aggregation point, often called a Cell Relay (CR), is equipped with a cellular modem. The radios in the device (e.g. meter) end points transmit to the CR over a private RF network, primarily over unlicensed spectrum. It has the capability to aggregate multiple end-points and transport the information over the WWAN (wireless wide area network) to the backend systems" (p. 2).

Although this definition assumes that cellular technology is used for communication between the collector meters (or an aggregation point) and the central data acquisition server, other methods exist such as fiber optic, radio and satellite communication. Cellular communication is a very common method where service is available. The overall structure of these communication types working together to return reads to the central server is shown in figure 2.

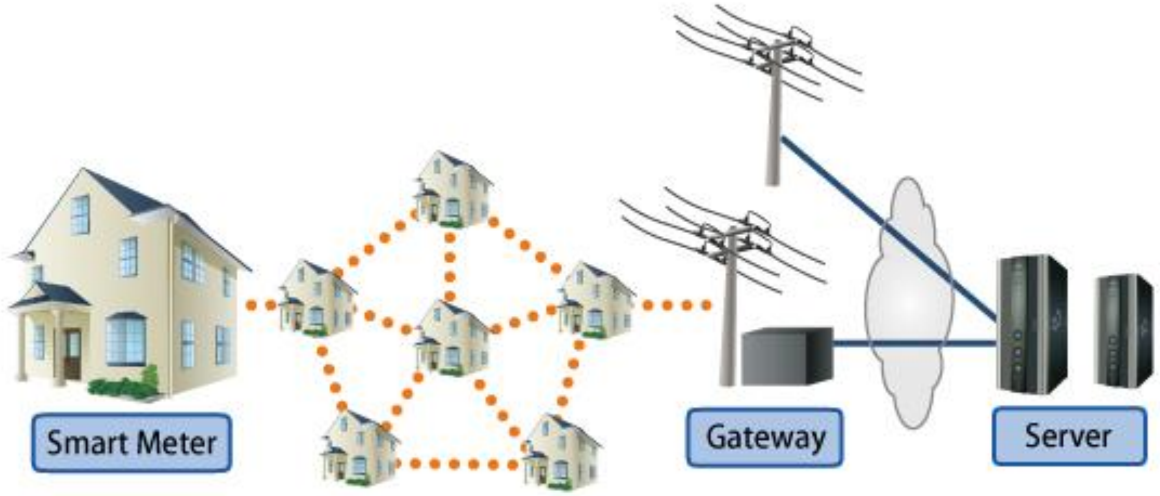


Figure 2: The basic structure of a local mesh network communicating to an aggregate point (Gateway in this image) and then to a central data acquisition server. Image retrieved from the AMI section of Fujitsu's website (http://www.fujitsu.com/global/services/solutions/sensor-network/ami-solution/).

Mesh networks are designed so that the flow of information is adaptive rather than fixed. In this RF network the individual meters operate as a 'mesh networks' which, according to Capehart and Capehart (2007, p, 322-323), have four basic characteristics:

1) *Self-configuring nodes:* These meters have open communication between all other meters allowing new meters to sense local communications and begin transmitting without configuration upon installment.
2) The individual meters can follow *multiple routing paths* to reach any collector meter. The read information simply has to reach any aggregate point. The read from neighboring meters may relay their information through the mesh network to the same or different collector meters. Depending upon system capabilities, this data may be relayed more than 15 times.
3) A mesh network will use *spread spectrum radios* allowing the meters to automatically change frequencies to avoid interference.
4) All frequencies used will be part of the *ISM (instrumentation, scientific and medical) band*. The FCC has designated these bands for local use and do not require a license.

The self-healing concept of a local AMI mesh network brings to mind the automated response of smart grid functionality to shift load to balance demand and respond to outages. AMI communication is somewhat symmetrical to the overall system in which it plays a key role.

A municipal utility in a small city outside of Chicago, Princeton, has recently reaped the rewards of GIS. The utility manages water systems and a fiber optic communication network in addition to electric distribution facilities. A critical element of a utility GIS is a detailed inventory of all utility equipment and facilities. In a surprisingly short period, Princeton completed a field inventory, with GPS locations, detailed attributes, and photographs of more than 2,500 features. During this three month period hard-copied data was scanned, geocoded, and organized. The city now has detailed records of their facilities, complete with an online presence, all in a searchable format which helps daily operations and future planning (ESRI, 2014). Server based solutions and an online presence are helping usher in the benefits of interdepartmental, interagency, and public sharing and communication provided by GIS.

As a result of the interconnectivity of servers and Web Mapping Services (WMS), a connected GIS can display live data that may or may not be streamed in map form. Web Mapping Services allow for a simple connect and display approach, whereas streaming of xml data can require a bit more creativity to produce a map. There are many examples of data streams that are not made readily available in WMS form. Lightning data for example contains x, y locations. ESRI's ArcGIS GeoEvent Processor enables data from nearly any source to be streamed through a server and projected in map form. While the data is being processed filters can be employed to focus on desired data. Once the data is streamed in the mapping environment all traditional functions, such as symbology and definition queries, will enable the data to be manipulated and presented in an easily digestible manner. ESRI's GeoEvent Processor allows live system information to be streamed into the desktop environment. This is the marriage of GIS and SCADA. For years SCADA has brought live data to and from remote locations. Live metering data can also be monitored through GIS using the GeoEvent Processor. This new capability of ArcGIS creates an environment where the age of data behind a map is no longer the limiting factor; with access to live data the user is armed with more information for their decision. Servers are now able to keep up with live data returning from the field. GIS can now add geographic relevance and modeling to this data. Projections based on equipment attributes combined with live system information will help forecast problems and opportunities (Cousins, 2009).

Map symbology is one of the most basic functions of communicating the message of your data. It is the basic foundation that makes a map useful; a map is inherently a symbolization of a real world area or phenomena. In a 2007 lecture outline to an introductory geography class, Dr. Rodrigue of California State University states that "symbols not only identify something and show its location, they also tell us something about the amount of that something in that location. The need to represent values as they change across space…" This applies directly to symbolization of AMI analysis. In the planning phase, symbolization will be used to represent how many neighboring meters meet the parameters at each metering point. During installation and maintenance phases symbolization will help the user visualize system operation. Symbolization brings the data to life.

The Arcpy module within Python scripting, selection queries, and map document preparation are areas of interest for data processing within this project. Backend database connections between a GIS database and other data management containers are also critical for AMI system visualization. The programming language Python has become the preferred user programming language in ArcGIS products. Python is free and open source. Scripts written in Python can be used across all of the common computing platforms, including Windows, Mac, and Linux. The object-oriented nature of Python lends itself nicely to use with ArcGIS data because ESRI is designed specifically to work with object-oriented programming languages (Zandbergen, 2013).

Case Study and Methodology:

The most challenging aspect of implementing smart grids and smart meters is configuring the communication channel between the individual meters and devices and the central server. Navopache Electric Cooperative northeastern Arizona offers a service area that is both vast and diverse. The small utility serves customers over an area of approximately 10,000 square miles. The service territory has sections of fairly dense population and large rural areas too. The terrain ranges from high plateau desert dominated by scrub brush with little communication interference to mountainous areas with rapid changes in topographical relief and dense vegetation cover which greatly affect communication performance. This project leverages the analytical and communicative power of GIS in order to help meet these challenges. The project unfolded in three steps:

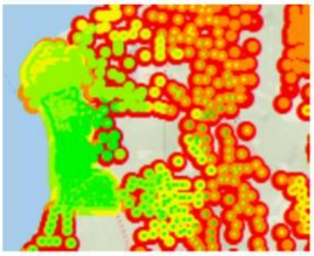
1. ***Identify/calculate meter density*** **-** The first part of this project can be viewed at caseyfinedell.weebly.com. This website explains the process and displays screenshots of the results of a Python script used to analyze an existing set of meters for proximity based upon limitation parameters of the communication system and capacity of transmittable meter information read packets. As can be seen in appendix A, this is a parameter based script, allowing modification of communication distances as technology improves. This script provides a view to help initially assess an existing meter system's communication density and identify geographic outliers that may present communication difficulties. Collector meters should be placed in areas of highest calculated meter density. Although environmental factors may interfere

with locations, higher meter densities provide better opportunities for central collection. Meter density is calculated by a simple series of distance selections. Looping through a meter dataset, all meter points within 1200 feet of each record are selected. This value is written to a field noted as first hop. Using the selected set, all meter points within 1200 feet are selected and written to a field as the second hop value. This process is repeated eight times. This process can be visualized as shown in figure 3. The basic symbology used to visualize the density of each hop can be seen in figure 4.

Proximity selection with Python Script

Select all meters within 1200 feet of given meter – write value of meters selected

Repeat with selected set writing values for each selection quantity



Symbolize data in ArcMap

Figure 3: Image helps to visualize the selection process that forms the base of the Python script in this methodology.

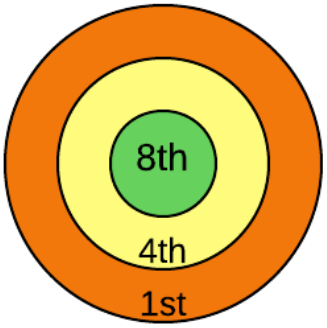


Figure 4: Sample symbology to show classification for quantity of meters meeting parameters at each hop. Feature class is symbolized three times; this specific symbol shows the lowest class at the first hop and highest at the eighth hop.

2. ***Establish communication path* -** A second layer is created to symbolize the meters within the area of interest by the collector meter each is reporting to. The collector meter ID is assigned to every meter within the metering database. Using nightly SQL queries, all meter records in the GIS database will be updated with an identification number of the collector meter they are reporting to. The map document is set up using this collector identifier to define symbology. An ArcMap document is created to symbolize the results using the symbology theme, shown in figure 6.
3. ***Usability, prototyping and user feedback:*** This project developed a methodology that requires minimal expertise in use and deployment, and therefore encourages maximum uptake and use in electrical system planning and operations. Currently this AMI siting methodology will not be able to be used without access to ESRI products. The entire basis of this project is built on the first line of the Python script that reads: Import ArcPy. Efforts have been made to simplify the interface so that the presence of a GIS specialist is not necessary. A key element of creating a useful script and methodology is repeatability and portability. Because site selection and communication standards are equivalent between AMI and AMR, all aspects of this methodology are currently being utilized at Jefferson PUD during the implementation of an AMR system. The only difference between AMI and AMR communication is that in AMI the signals travel in two directions. The difference between these two networks does not impact site selection.

Project Results and Outcomes:

Smaller utilities often contract specialized vendors for larger projects such as an AMI meter deployment. These contracts generally provide the basic framework and guidelines to implement the product. Often there is a support line available, but details are mostly left to the utility. This project builds upon the broad suitability studies that vendors offer and has developed an AMI siting methodology that can empower utility managers directly by helping to isolate local areas for possible collector meter and signal repeater installments.

Data are symbolized to only the eighth hop because this is greater than the average hop level utilized in a functioning AMI system. The mesh communications are capable of sixteen hops, but often reach the collector meter using far fewer meter nodes. Looking at the contrast between the first, fourth, and eighth hops can help visualize the behavior of the system. It is not uncommon when comparing two meter locations to find one with a lower first hop value and higher eighth hop value. Candidacy is mostly based on fourth or greater hop value. The ideal candidate may be located in a less dense area between two very dense areas allowing this location to process reads from both dense areas. This meter location may fall into the lowest quantile class in the first hop analysis, but the highest class on the eighth. A sample area is shown in figure 5.

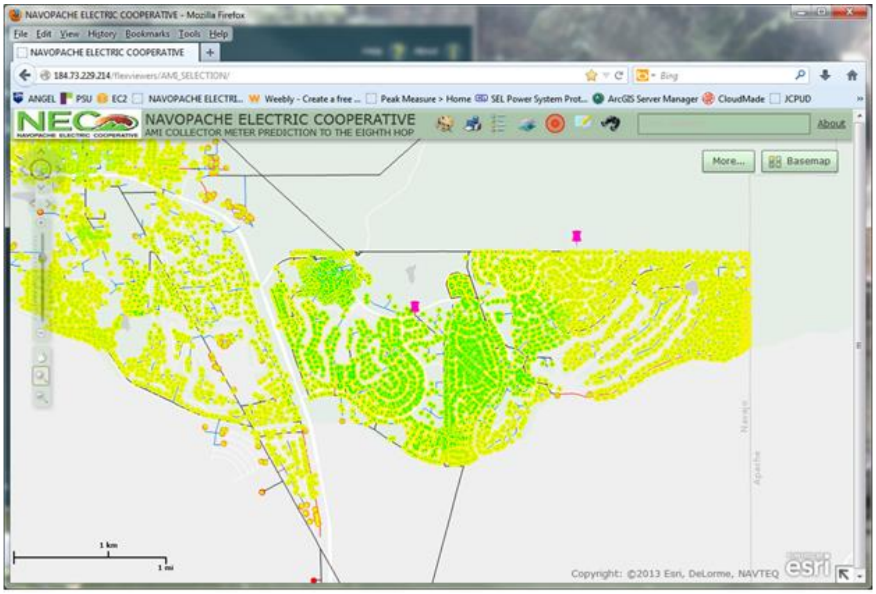


Figure 5: Results of Python script after calculating meter density. As described above, green shows greater density.

Setting up a GIS map document with symbology for each collector meter illustrates trends across the system, as shown in figure 6. Because this is a mesh communication network, it is inherently self-healing. End point meter signals may migrate among collector meters. Visualizing this process allows the metering manager to start the day with a snapshot visualization of the communication of meters on the AMI system. Having a daily snapshot of the each collector meter's reporting meters will keep the metering manager informed about changes and possible problems in a timely manner. AMI meter reads are received periodically throughout each day; this metering system pulls reads every four hours. If desired, the collector meter value could be updated upon receipt of each report providing more frequent or even live snapshots if the metering system streams meter data information. It is probably most sensible to schedule this as an overnight process due to the quantity of meter records in most utility systems. This aspect of the methodology helps present the existing data in a geographic context where trends and outliers may be more visible.

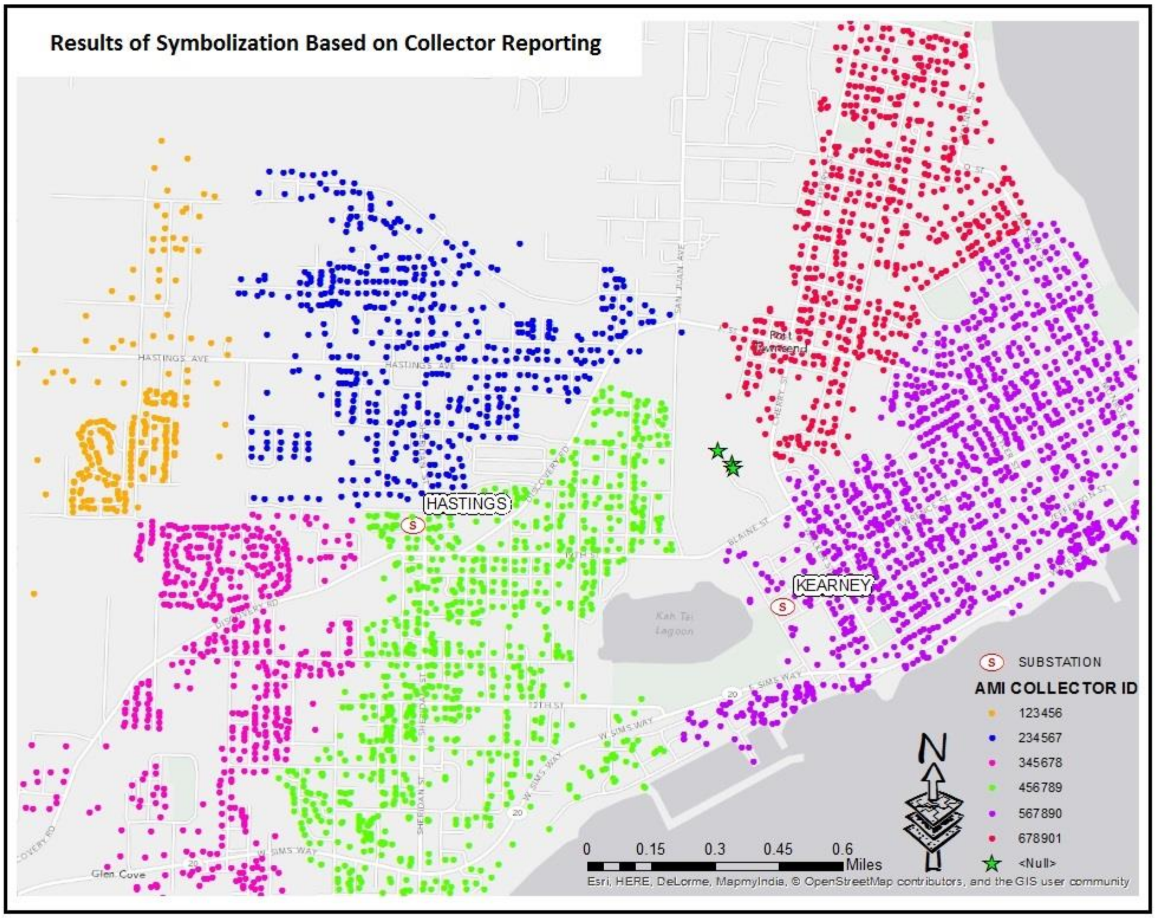


Figure 6: Results after nightly SQL queries to symbolize based on reporting collector meter number.

This methodology has proven to save the utility time and money. During the first five years of AMI installation at Navopache Electric Cooperative (Lakeside, AZ) AMI locations were selected by way of best assessment and trial and error. Collector meters and repeaters needed to be moved frequently, adding costs and reducing overall system efficiency. During the year that a version of this methodology has been used, the locations have been correct on first or second installment, thereby reducing operating costs and maximizing system efficiency.

The author has brought this methodology to Jefferson PUD in Washington State. The PUD is currently revamping their meter system and is looking to deploy an AMR system. This methodology will be utilized during the assessment, pilot, and installation phases of the project. Running the script on the new data was simple. Data was uploaded to an Amazon EC2 instance with Python installed and parameters were changed within the Python script to match the new data. Results of the methodology can be seen in figure 7. At this time the PUD is moving to ArcGIS for server and will soon have the ability to view the results in a webmap created using ArcGIS Online. This upgrade to a server based mapping system will also provide a more reliable framework for completing regular SQL updates of collector meter ID for symbolization in a separate layer or autonomous map document.

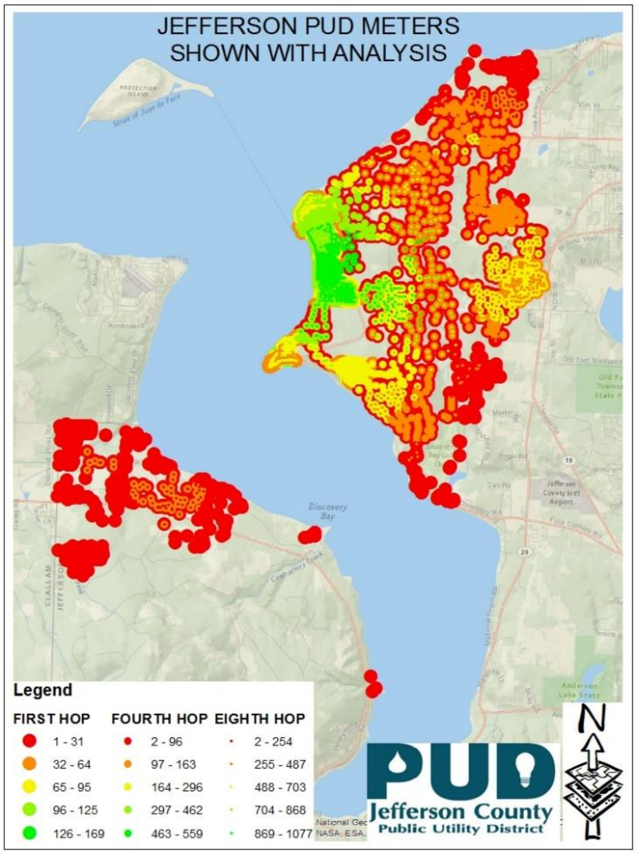


Figure 7: Results of Methodology when applied to Meter data at Jefferson PUD.

Conclusion:

Although AMI systems greatly improve the functionality of electricity grid systems, learning their spatial relationships for siting collector meters and to monitor daily operation is important in order to reduce cost of deployment and improve their operating efficiency. The methodology described above will help smoothly implement an AMI system to compliment other components including SCADA systems and database organization. This methodology is predicated on a parameter based Python script, which means that it is scalable throughout the electrical industry and could easily be applied to other utility industries that use automated meter reading systems, whether it be AMI or AMR. The spatial relationship is the focal point of the script, not necessarily the functionality of an AMI system. Analysis of spatial relationships is necessary in aspects of many industries from real estate and retail to radio communications and emergency response.

More importantly, this methodology empowers metering managers who are challenged in AMI deployment during both planning and operational phases of an AMI implementation project. The first aspect of the methodology is specifically suited to select candidate sites for master collector meters by measuring meter density across space. The second aspect can be used to monitor and troubleshoot an existing operational system, from the day of installation until decommissioning by providing daily snapshots of AMI system operation. Together, these two parts are the primary goal of the project. Outputs from this methodology would be prepared by an employee with basic experience in GIS and communicated in a local viewing format. A web based mapping solution tied to a physical or cloud server for automated processes would be optimal. Allowing the user to drop notes on a basemap will help this process greatly. On-the-fly geoprocessing may prove to be less valuable because this information is best conveyed in an overview format, but providing the ability to select the area of interest would arm the user with immediate feedback and allow modification of selection area and parameters. Once the site selection is narrowed to a small geographic area this site specific visualization may prove more useful. Completion of a project of this nature will give control to the individual with the specialized knowledge and interest in the project.

Appendix A:

```
# This script will loop through the input service points, create a buffer for each,
#    and count the total service points that fall within the buffered area

import arcpy
arcpy.env.overwriteOutput = True

# Define data locations
servicePointClass = "C:\WCGIS\FINAL\METERS.shp"
##servicePointSelect = "C:\\WCGIS\\Geog586\\Term Project\\servicepointtestCopy.shp"


# Define variables for fields to be used throughout script
countField1 = "COUNT_1"
countField2 = "COUNT_2"
countField3 = "COUNT_3"
countField4 = "COUNT_4"
countField5 = "COUNT_5"
countField6 = "COUNT_6"
countField7 = "COUNT_7"
countField8 = "COUNT_8"
selectDistance = "1200 FEET"
idField = "arcpy"


# Extract field name to see if new fields exist
# Add fields for feature counts if they do not exist
fields = arcpy.ListFields(servicePointClass)
for field in fields:
   if field.name =="COUNT_1":
      print "COUNT_1 Field already exists"
##       arcpy.AddMessage("COUNT_1 Field already exists")
   if field.name =="COUNT_2":
      print "COUNT_2 Field already exists"
##       arcpy.AddMessage("COUNT_2 Field already exists")
   if field.name =="COUNT_3":
      print "COUNT_3 Field already exists"
##       arcpy.AddMessage("COUNT_3 Field already exists")
   if field.name =="COUNT_4":
      print "COUNT_4 Field already exists"
##       arcpy.AddMessage("COUNT_4 Field already exists")
   if field.name =="COUNT_5":
      print "COUNT_5 Field already exists"
####       arcpy.AddMessage("COUNT_5 Field already exists")
   if field.name =="COUNT_6":
```

```
        print "COUNT_6 Field already exists"
####        arcpy.AddMessage("COUNT_6 Field already exists")
    if field.name =="COUNT_7":
        print "COUNT_7 Field already exists"
####        arcpy.AddMessage("COUNT_7 Field already exists")
    if field.name =="COUNT_8":
        print "COUNT_8 Field already exists"
####        arcpy.AddMessage("COUNT_8 Field already exists")


    else:
        # Create a field for service point counts
        arcpy.AddField_management(servicePointClass, countField1, "long", "", "", 8, "", "NULLABLE", "", "")
        arcpy.AddField_management(servicePointClass, countField2, "long", "", "", 8, "", "NULLABLE", "", "")
        arcpy.AddField_management(servicePointClass, countField3, "long", "", "", 8, "", "NULLABLE", "", "")
        arcpy.AddField_management(servicePointClass, countField4, "long", "", "", 8, "", "NULLABLE", "", "")
        arcpy.AddField_management(servicePointClass, countField5, "long", "", "", 8, "", "NULLABLE", "", "")
        arcpy.AddField_management(servicePointClass, countField6, "long", "", "", 8, "", "NULLABLE", "", "")
        arcpy.AddField_management(servicePointClass, countField7, "long", "", "", 8, "", "NULLABLE", "", "")
        arcpy.AddField_management(servicePointClass, countField8, "long", "", "", 8, "", "NULLABLE", "", "")

# Make a layer for all Service Points
arcpy.MakeFeatureLayer_management(servicePointClass, "ServicePointLayer")
arcpy.MakeFeatureLayer_management(servicePointClass, "ServicePointLayer2")
arcpy.MakeFeatureLayer_management(servicePointClass, "ServicePointLayer3")
arcpy.MakeFeatureLayer_management(servicePointClass, "ServicePointLayer4")
arcpy.MakeFeatureLayer_management(servicePointClass, "ServicePointLayer5")
arcpy.MakeFeatureLayer_management(servicePointClass, "ServicePointLayer6")
arcpy.MakeFeatureLayer_management(servicePointClass, "ServicePointLayer7")
arcpy.MakeFeatureLayer_management(servicePointClass, "ServicePointLayer8")


# Start looping through each service point
servicePointRows = arcpy.UpdateCursor(servicePointClass)
servicePoint = servicePointRows.next()

try:

    while servicePoint:
        # Create query for current Service Point
        currentServicePoint = servicePoint.getValue(idField)
        queryString = '"' + idField + '" = ' + "'" + currentServicePoint + "'"

        # Make feature layer of selected Service Point
        arcpy.MakeFeatureLayer_management(servicePointClass, "CurrentServicePoint", queryString)

        # Select service points within parameterized distance of current point
```

```
    arcpy.SelectLayerByLocation_management("ServicePointLayer", "WITHIN_A_DISTANCE",
"CurrentServicePoint", selectDistance, "NEW_SELECTION")

    # Get count of features within distance of current service point
    meterCount = arcpy.GetCount_management("ServicePointLayer")
    meters = int(meterCount.getOutput(0))-1

    # Update row with feature count in appropriate field
    servicePoint.setValue(countField1, meters)
    servicePointRows.updateRow(servicePoint)


    # Select meter point that fall within distance of selected points
    arcpy.SelectLayerByLocation_management("ServicePointLayer2", "WITHIN_A_DISTANCE",
"ServicePointLayer", selectDistance, "NEW_SELECTION")

    # Get count of features within distance of current service point
    meterCount = arcpy.GetCount_management("ServicePointLayer2")
    meters = int(meterCount.getOutput(0))-1

    # Update row with feature count in appropriate field
    servicePoint.setValue(countField2, meters)
    servicePointRows.updateRow(servicePoint)

    # Select meter point that fall within distance of selected points
    arcpy.SelectLayerByLocation_management("ServicePointLayer3", "WITHIN_A_DISTANCE",
"ServicePointLayer2", selectDistance, "NEW_SELECTION")

    # Get count of features within distance of current service point
    meterCount = arcpy.GetCount_management("ServicePointLayer3")
    meters = int(meterCount.getOutput(0))-1

    # Update row with feature count in appropriate field
    servicePoint.setValue(countField3, meters)
    servicePointRows.updateRow(servicePoint)

    # Select meter point that fall within distance of selected points
    arcpy.SelectLayerByLocation_management("ServicePointLayer4", "WITHIN_A_DISTANCE",
"ServicePointLayer3", selectDistance, "NEW_SELECTION")

    # Get count of features within distance of current service point
    meterCount = arcpy.GetCount_management("ServicePointLayer4")
    meters = int(meterCount.getOutput(0))-1

    # Update row with feature count in appropriate field
    servicePoint.setValue(countField4, meters)
    servicePointRows.updateRow(servicePoint)
```

```
    # Select meter point that fall within distance of selected points
    arcpy.SelectLayerByLocation_management("ServicePointLayer5", "WITHIN_A_DISTANCE",
"ServicePointLayer4", selectDistance, "NEW_SELECTION")

    # Get count of features within distance of current service point
    meterCount = arcpy.GetCount_management("ServicePointLayer5")
    meters = int(meterCount.getOutput(0))-1

    # Update row with feature count in appropriate field
    servicePoint.setValue(countField5, meters)
    servicePointRows.updateRow(servicePoint)

    # Select meter point that fall within distance of selected points
    arcpy.SelectLayerByLocation_management("ServicePointLayer6", "WITHIN_A_DISTANCE",
"ServicePointLayer5", selectDistance, "NEW_SELECTION")

    # Get count of features within distance of current service point
    meterCount = arcpy.GetCount_management("ServicePointLayer6")
    meters = int(meterCount.getOutput(0))-1

    # Update row with feature count in appropriate field
    servicePoint.setValue(countField6, meters)
    servicePointRows.updateRow(servicePoint)

    # Select meter point that fall within distance of selected points
    arcpy.SelectLayerByLocation_management("ServicePointLayer7", "WITHIN_A_DISTANCE",
"ServicePointLayer6", selectDistance, "NEW_SELECTION")

    # Get count of features within distance of current service point
    meterCount = arcpy.GetCount_management("ServicePointLayer7")
    meters = int(meterCount.getOutput(0))-1

    # Update row with feature count in appropriate field
    servicePoint.setValue(countField7, meters)
    servicePointRows.updateRow(servicePoint)

    # Select meter point that fall within distance of selected points
    arcpy.SelectLayerByLocation_management("ServicePointLayer8", "WITHIN_A_DISTANCE",
"ServicePointLayer7", selectDistance, "NEW_SELECTION")

    # Get count of features within distance of current service point
    meterCount = arcpy.GetCount_management("ServicePointLayer8")
    meters = int(meterCount.getOutput(0))-1

    # Update row with feature count in appropriate field
    servicePoint.setValue(countField8, meters)
    servicePointRows.updateRow(servicePoint)
```

```
        # Delete current service point layer to prepare for next run through loop
        arcpy.Delete_management("CurrentServicePoint")

        # Proceed to next row
        servicePoint = servicePointRows.next()

except:
    print arcpy.GetMessages(2)


# Delete feature layers
arcpy.Delete_management("ServicePointLayer")

print arcpy.GetMessages()
print "Script was sucessful!"
```

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