Duke Energy: Developing the communications platform to enable a more intelligent electric grid

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Certain statements in this paper regarding our business strategy, plans and objectives reflect Duke Energy's aspirations with respect to developing, assessing and implementing an end-to-end digital grid system. Some aspects of the digital grid approach and architecture described herein may not be presently available as part of Duke Energy's current digital grid deployment, but these aspects, together with the other items discussed herein, represent Duke Energy's overall vision of the digital grid that we hope to realize in the near future.

Contents

State of the industry

The energy industry is poised for a dramatic transformation as climate change, the rising costs of energy, increasing regulation and energy independence are all addressed. The singular approach of building new, centrally-located power plants to meet energy and capacity requirements can no longer be the sole solution. Renewable generation and energy efficiency must play a larger role. That is why we need a smarter power grid that will help us increase our use of renewable capacity, embrace the emergence of electric vehicles and distributed generation, and enable customers with the tools and technology needed to help manage through this type of environment. Striking the right balance to deliver energy that is affordable, reliable and clean will require the optimization and proactive management of the nation's grid infrastructure.

Duke Energy's corporate vision

Duke Energy's vision for a connected, end-to-end digital grid that gives customers choices and control will create a sustainable energy future while working to reduce our carbon footprint. Efforts include our aspiration to cut our carbon emissions in half by 2030, by building more efficient power plants, developing robust energy efficiency programs, and supporting a balanced state and federal energy policy approach that encourages market-based controls of greenhouse gas emissions and the development of new, cleaner technologies. Together, these initiatives will allow Duke Energy to continue to meet our customers' energy needs in an environmentally sound manner, while keeping our product – energy – reliable and affordable.

To accomplish our vision, we are implementing technologies that will modernize our power grid infrastructure making it more receptive to the wide-scale adoption of renewable energy and supportive of new energy efficiency technologies and programs. We are investing $1 billion in digital grid technologies that are already beginning to transform today's century-old power delivery system into an advanced energy network that will allow for timely energy usage information and remote grid monitoring, automation and control. By deploying advanced energy technologies and modernizing our power grid, Duke Energy will give our customers more choice and control over how and when they use energy. This can help delay the need for new power plants and create a cleaner, lower carbon, energy-efficient world making it easier for Duke Energy and its customers to utilize new technologies in the energy market as they come available.

Duke Energy's digital grid vision

Definition

Duke Energy defines the digital grid as an end-to-end energy Internet powered by two-way digital technology. It is comprised of an Internet Protocol (IP) based, open standards communication network that allows for automation and the exchange of near real-time information as well as enabling the adoption of new technologies as they become available. Duke Energy's digital grid will have more efficient and reliable transmission and distribution systems; it will leverage energy efficiency programs to reduce wasted energy; it will integrate more distributed energy resources into our grid and decrease carbon emissions.

The functionality will be enabled by:

The implementation of a digital communications network.
Intelligent distribution grid devices (i.e. digital meters, sensors and self-healing technologies).
Dynamic pricing programs that include residential and commercial pricing options.
IT systems implementation and enhancements.
Customer options that include Home Area Network (HAN) capabilities and support for integration with plug-in electric vehicle (PEV) charging stations.

Digital grid technologies create a virtual "handshake" between Duke Energy and our customers – a powerful commitment to work together to use energy more efficiently, save money and create a cleaner, lower-carbon world.

Duke Energy's digital grid architecture

Managing the distribution grid in the 21st century necessitates monitoring electricity and the equipment that provides and supports its delivery as it passes millions of discrete points. Moreover, the need for distribution grid management is greatly increased by the potential for widespread adoption of residential and commercial solar systems, PEVs and other distributed energy resources.

This required digital grid network must have the bandwidth, embedded sensing, control and software, both distributed and centralized, to collect, organize, and analyze an immense volume of information. This requires the two-way bandwidth necessary to link the real-time events detected (such as load and congestion, system stability and equipment health or outages) with the appropriate grid devices that will respond to address those events both grid-wide and locally, to maximize and improve efficiency and reliability. This will require an integrated implementation strategy that adheres to a common infrastructure model since an incremental and disconnected approach proves too costly and ineffective. The communications network must make it easier to adopt new technologies and solutions, allowing us to take advantage of advancements in storage, micro-grids and distributed generation as well as adapting to other energy transformations in the future. This network will need to support local intelligence that provides autonomous, decision making controls as well as centralized notifications, overrides and inputs with situational awareness from multiple sources. The autonomous operations of the devices will need to take in to consideration factors that include: a customer's preferences and actions, equipment operating parameters, weather, equipment failures, local and more wide-spread grid activities such as actions in other homes, neighborhoods, cities and states.

Approach

Duke Energy is leading the industry's digital grid transformation by assessing, developing and implementing an end-to-end digital grid system that lays the groundwork for an energy evolution where information and automation will enable customers and companies to work together to keep energy affordable, reliable and clean. Without the digital technology and local intelligence, sustainable energy efficiency is difficult to achieve.

Duke Energy expects the amount of energy data available to grow exponentially as we continue to deploy the digital technology. This increased volume of data means that a completely centralized approach to data collection is not practical. Where practical, the digital grid will aggregate and analyze data locally in order to convert the raw data into meaningful, actionable intelligence that other systems and applications can use efficiently. This one common communications infrastructure with distributed local intelligence is more flexible, cost effective and more capable than today's multiple, disparate, legacy networks.

What drove our approach?

In a world increasingly focused on improving efficiency and reliability while reducing the environmental impact of electricity use there has been a convergence of many internal and external factors that have influenced our multifaceted approach. Some of the key drivers and challenges are:

Drivers

- Meet our customers growing energy needs in a cost effective and sustainable way.
- Utilize technology advancements to change the way we do business in the future.
- Make it easier and faster to adopt new technologies as they become available.
- Incorporate proven technologies currently being used in other businesses or industries.
- Implement systems that afford Duke Energy the flexibility to grow and adapt without requiring a complete technology replacement.

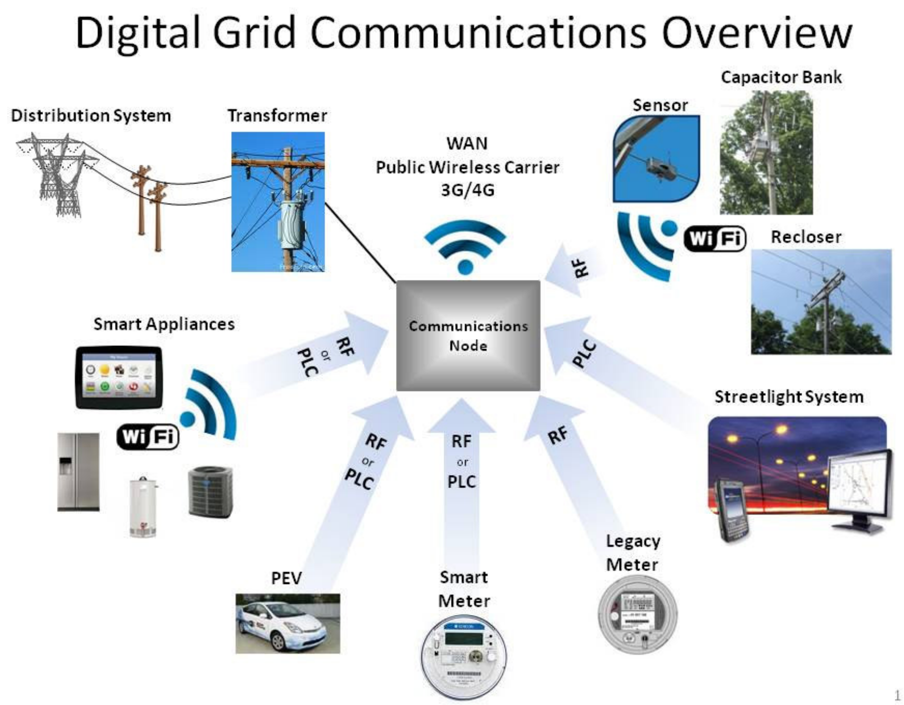
Challenges

- With the life of most utility assets being long and the evolution of the communications technology being rapid, embedding the communications technology into the utility assets makes it difficult to take advantage of new technology as it becomes available.
- Vendors and manufacturers are accustomed to building single-use solutions for a utility based upon a specific organizational requirement.
- Vendors and manufacturers new to the utility industry lack a broad understanding of utility operations and functions.
- A utility does not normally behave as an early adopter or developer of new technologies.

After evaluating systems deployed by other utilities and industries, we determined that the solutions currently being offered would not fulfill our key drivers or meet our requirements. Most proposed systems are based primarily on an automated metering solution that leverages proprietary radio technologies or protocols, limiting bandwidth and the capability to fulfill the vision for 2-way digital communications beyond metering.

Achieving the approach

Duke Energy's communication architecture vision is based on utilizing a communications node to transmit, locally aggregate and manage the deluge of data that results from implementing a digital grid. The digital grid communications overview diagram below illustrates the role the communications node plays and the relationship it has with other components on the distribution grid.



The communications node will manage the data of various applications (including, but not limited to: distribution automation, distribution management, mobile workforce, PEVs, smart metering and customer energy management) locally or will route data back to a centralized location or to other nodes on the distribution grid that may be in a key location for further analysis and action. All three options enable Duke Energy to apply and manage various energy management applications individually or in concert with others, providing the capability for optimization and management based upon a particular situation in any given area. Duke Energy has a unique architecture in that we are connecting public carrier WAN access to each distribution transformer while simultaneously having the communications node serve as a communications gateway to communicate, manage and operate various smart home, smart meter, and distribution devices.

This local aggregation affords Duke Energy the flexibility and management capabilities as it prioritizes data traffic, analyzes data and enables device operation. Additionally, Duke Energy is able to apply a single set of rules to data management as opposed to creating several sets for individual or vendor specific data while providing true situational awareness based on the local geography, and condition of the overall grid. This is especially important from a security standpoint where development and application of a single schema to secure data from multiple devices greatly strengthens the overall security approach. This approach also supports a similar security approach for legacy equipment that does not support some of the newer security requirements. Local aggregation provides the capability to operate in a micro-grid situation or as dynamic switching becomes more prevalent, understanding what impact those switching changes will have on the network. Finally, by having local access to data from the various devices that will be utilized on the grid, the capability to operate in times of limited WAN communications or heavy data loads are greatly increased. The use of local aggregation and analytics also provides the capability to manage the WAN and data storage cost by utilizing exception based reporting in place of bringing ***all*** data back to the data center to analyze and report on.

Think of the communications node as an iPhone® for the modern grid. It is a device with the future communications capability for multiple networks, with capability to route the data between multiple devices and with enough storage and processing power to enable an extensible ecosystem of data applications which are anticipated to be built over a number of years. One of the largest challenges most vendors face in the digital grid space is finding the adequate infrastructure for their solution. Since the node architecture is based on an open hardware and software development environment, the node will play a crucial role in creating that secure infrastructure for vendors developing compatible applications. Through this integration and aggregation of applications, Duke Energy gains a better view of where our assets are, of the relational environment our various grid components have to each other and how they are working together to optimize energy for our customers.

Communications

A key philosophy behind the communications solution is that no single technology is capable of meeting the needs of or providing the coverage necessary for Duke Energy's service territory. Therefore, the communications node is designed to have the options of utilizing wireless and wired connectivity for the three types of communications it supports:

- Wide Area Networking (WAN) – The WAN is the network connecting the communications nodes to the enterprise data center and back office.
- Local Area Networking (LAN) –The LAN is the network serving end points such as sensors, capacitor banks, homes, etc. - in the same general area as the communications node. Local connections to communications nodes are considered part of the LAN network (example: a serial connection to a capacitor bank)
- Node-to-Node Communications (N2N) – N2N is a peer-to-peer form of communications that can be utilized in lieu of, or in conjunction with a WAN connection to a communication node. The N2N feature allows communications nodes to interface with each other and utilize a single WAN connection in one of the communications nodes for connectivity to the data center. Additionally, the N2N capability can also be utilized for diagnostics and to support other envisioned utility support functions. As optimization becomes more prevalent the ability to communicate and understand what is happening at other nodes will become a requirement.

The communications node will be capable of supporting multiple wireless and wired communications technologies in order to address unique situational requirements or a very specific application. The table below shows the representative forms of communications and the association to the types of communications:

WAN	LAN	N2N
Ethernet/Serial/USB	Ethernet/Serial/USB	Ethernet/Serial/USB
2G/ 3G/4G wireless	IEEE 802.11 (Wi-Fi)	IEEE 802.11 (Wi-Fi)
	LonWorks® Powerline Carrier (PLC)	Mid-voltage PLC
	900 MHz ERT Receiver	

The communications node will have access to both internal and external Ethernet, serial and USB interfaces that can be utilized to connect to devices or modems. This open hardware/software architecture along with the capability to utilize other manufacturers' modems as well as end devices (fiber optic equipment, satellite equipment, capacitor banks, reclosers, and sensors) enables flexibility and capability.

Wide Area Network (WAN)

Duke Energy's current plan is to utilize public wireless carriers to support the WAN components of a digital grid platform. Use of a public wireless carrier within the utility is not new. Meters at some of our largest customers, capacitor banks and other devices currently utilize public wireless carriers. Utilities in other countries are currently utilizing public wireless carriers for their entire metering infrastructure.

Why Duke Energy has incorporated the use of public wireless carrier networks

- Cellular technologies are based on existing standards and have been used extensively and securely in the communications sector with more than 5 billion active connections.
- Duke Energy benefits from the economic and technical economies of scale that have been unlocked by the public wireless carrier ecosystem.
- Public wireless carriers use Internet-based protocols (where available) as the transport layer standard, allowing the use of IP based WAN connectivity from the data center to the nodes.
- Utilizing the 3G networks available today provides for backwards compatibility to the cellular 2G networks, providing access to a redundant network.
- The public wireless carrier industry will continue to invest billions in its hardware, software and facilities.
- The technological advances stemming from investments to serve the retail voice and data customers directly benefit the utility and its customers.
- Utilities will have a greater influence on technology and price as a customer of the larger carriers than if we are developing private communications equipment for ourselves only.
- Duke Energy has no desire to be in the communications business. We need to harness already-existing expertise and capabilities that the cellular networks provide in designing, building, and maintaining the communications.

As we started evaluating the various options for communications utilizing public carriers several things become apparent. First, embedding the WAN connectivity into end devices such as meters had several challenges, i.e. development time, cost, certification testing, power supplies and heat dissipation. Utilizing the 3G modules in a meter would presently be cost prohibitive. While utilizing 2G modules would be more price-competitive, employing those 2G networks with a high number of devices in a small area could create problems. These issues, combined with other challenges like the disparity in life cycle of assets and the product evolutions, moved us into a LAN/WAN communications node environment that allow us to take advantage of the new capabilities without changing everything.

Up until recently, there was little digital grid activity utilizing cellular networks. The incorporation of a holistic digital grid communication infrastructure significantly changes and increases this activity. Consequently, Duke Energy spent a significant amount of time with its cellular partner developing technical and functional specifications for the WAN. For example, unlike the "typical" cellular customer, a unique aspect with the utility digital grid infrastructure is that hundreds or thousands of devices may go off and come on at the same moment. If not managed properly, this activity could overload a cellular station and cause problems to other cellular customers. The cellular companies advances in allowing companies to establish private, not internet routable IP networks has also been instrumental in providing the capabilities for security that will be required as we move forward.

As a result of our approach, Duke Energy established a collaborative effort with one of the cellular carriers and, together, has developed innovative pricing and operations and maintenance (O&M) model that supports the requirements and reduces the overall costs of digital grid communications This effort has also enabled the cellular company to better understand the utilities operations and needs thus making the present and next evolutions more capable of supporting machine-to-machine (M2M) environments for the utilities in a more robust fashion.

Why Duke chose to use 3G technology instead of 2G?

- Reduced latency.
- Increased throughput.
- Enhanced security capability.
- Fallback to 2G provides a measure of redundancy.
- Network access time faster.
- Capable of supporting the number of cellular devices with less impact.

Coverage by the public carriers continues to increase, mitigating the expense and complexity of providing a private network capable of supporting the digital grid. While all areas today are not covered by a single carrier, utilizing multiple carriers and the possibilities of micro-cells, satellite and repeater technologies will ensure that Duke Energy's service territory is covered. Duke Energy's core competencies and focus is on generating and delivering energy.

Utilizing the public carriers that have a nationwide footprint affords Duke Energy the ability to rapidly expand its digital grid infrastructure is its service territory expands.

Local Area Network (LAN)

The LAN connection provides connectivity to all of the end devices that can operate in a local environment utilizing point to multi-point communications such as meters, sensors, distribution automation equipment, in-home/business gateways, etc. Much like the WAN, the LAN connectivity in the node provides the capability to utilize both internal and optional external Ethernet, serial, and USB interfaces that can connect to 3rd party devices or modems. This capability along with the open hardware/software development environment will provide the capability to connect to and communicate to legacy devices as well as new devices as they become available. The node has the capability to support connectivity to devices or head-ends utilizing the DNP protocol as a master or slave allowing this to become a protocol converter if needed. Existing devices have been integrated into the node and connected to an internal Ethernet port. By doing this, we have been able to utilize, for example, the 900 MHz capability of an ERT-enabled gas meters with very little integration effort. The node also utilizes a wireless 802.11 option and a wired power line communication option utilizing LonWorks®. The use of the 802.11 Wi-Fi provides a radio and protocol that has been widely adopted and is manufactured by a large number of device manufactures. Wi-Fi should be considered as a joint use device in that its capability is utilized not only in the LAN environment but also in the N2N environment. The LAN will provide a connection to metering, sensors, capacitor banks, in-home devices or gateways, on the same Wi-Fi or PLC connection depending on the functions needed at a particular location.

Node-to-Node (N2N)

The primary driver for N2N functionality was the need to supply communications that provides details for a geographical area based upon the electric grid design versus the communications network design. As envisioned today, the N2N network would leverage a Wi-Fi with mesh capability (802.11s) to reach more nodes within a fairly small geographic region thereby creating a Neighborhood Area Network (NAN). This capability also allows the use of the N2N network to gain access to another node's WAN connection as a means to fill in for spotty cellular coverage or redundancy of the WAN. When utilizing the N2N network as means for outage detection, nodes that are located at strategic points on the grid would poll other nodes, reporting only exceptions or upon communications failures. This polling would occur on the N2N network only and would not, therefore, incur any data usage on the cellular network.

Also under evaluation is a low frequency, lower bandwidth power line communication solution providing circuit level capabilities. This form of PLC has the capability to travel long dist ances on the mid-voltage network and pass through the low voltage transformer where it could then communicate with the various nodes. This level of connectivity would allow for phase detection of the transformers and enhances outage detection capability.

The N2N capability would allow the nodes to gather and analyze the data for all of the devices within its LAN and pass on the relevant data, alerts or required information to other nodes without having to traverse the WAN or head-end systems within the data center. Additionally, this capability also allows the use of the N2N network to gain access to another nodes' WAN connection as a method of compensating for spotty cellular coverage and provide redundancy for the WAN. The N2N network would be utilized as means for supporting outage detection so that nodes could be polled without the need to incur cellular usage charges.

Technology decisions

Why Duke Energy is utilizing LonWorks® PLC

Utilizing PLC as a method of communicating to utility devices has been done in many different forms for many years. With the combination of the communications node, utilizing a cellular WAN and the LonWorks® PLC, the vision of utilizing a communication method that leverages the existing electric infrastructure is now achievable.

LonWorks® PLC Drivers

- Standards-based.
- Multiple manufacturers of both chips and devices.
- Primarily designed as a controls mechanism.
- Utilizes the power company's existing wires for the communications media.
- Allows for accurate asset association.
- Provides added benefits by proactively aiding in determining low voltage cable and connections degradation or failures prior to an actual failure.
- Provides an alternative to wireless for communicating to end devices, in home, in building or on the low voltage network of a utility.

LonWorks® PLC had been largely utilized for deployment and connectivity to meters in Europe and was also the predominant method used in commercial buildings for control applications and automation. LonWorks® is a networking platform specifically created to address the needs of control applications and networking devices over media such as power lines, among others. Approximately 90 million devices have been installed with LonWorks® technology. Manufacturers in a variety of industries including building, home, street lighting, transportation, utility, and industrial automation have adopted the platform as the basis for their product and service offerings. The LonWorks® protocol has been approved by several standards bodies and the chipsets and devices that utilize this capability are manufactured by multiple manufactures. Utilizing this solution in our trials and present deployments has also provided the capability to explore and validate some of the aforementioned drivers. Utilizing the PLC signal level, error rate and signal-to-noise information between the node and the meters allows for an accurate determination of the relationship of meter to transformer. Understanding which transformer is serving which meter will become more important as applications evolve to institute programs for optimization, cold load pick-up, balancing the PEV charging at a transformer level, etc. Utilizing the improved accuracy will enhance operations capability by more accurately identifying the relationship of the various grid devices. Also utilizing this same signal, we have been able to identify degradation in the low-voltage network allowing for a proactive approach to fixing potential problems prior to an actual outage. By monitoring the signal over time and alerting as the signal reaches various thresholds, instances of splices going bad, underground cable breakdown, or fraying due to trees on wires can be exposed. These items are only available because we are on the wire. The node will have the capability of utilizing both the A and C band communications utilizing LonWorks® PLC. This will allow a separation of data types from the utility (meters) and commercial devices (street lighting, in-building, etc…) providing another level of security and capability.

Why Duke Energy is utilizing 802.11 Wi-Fi

- Since Wi-Fi is already the dominant home networking standard, easy adoption / leveraging for HAN use is more likely.
- Many mature 802.11 products that implement large outdoor networks exist today. These networks have been deployed successfully for years and broad expertise exists for deploying, maintaining and securing these networks.
- Supports all IP-based applications (both IPv4 and v6) including Smart Energy Profile 2.0
- Security protections: Link-, network-, and application-level security based on international standards which meet FIPS 140-2 certification. Rogue device and intrusion detection tools.
- 802.11s: amendment for mesh networking, defining how wireless devices can interconnect to create a WLAN mesh network (for N2N, etc).

- Longevity of the standard – The 802.11 standard was introduced in 1997.
- The number of endpoints, device types, manufacturers – adoption – proves scale.
- The chips cost effective.
- Decreased chance for interference with other unlicensed products since Wi-Fi is designed to co-exist.
- Dual operating frequency ranges are available.

The first IEEE 802.11 (Wi-Fi) standard was released in 1997. Since then, three major modulation changes (a, b and g) have been released along with several additional and relatively minor amendments. These revisions have collectively produced a single standard that allows for the implementation of several interoperable performance profiles and data rates that can range from 1 Mbps (802.11b) to 600 Mbps (802.11n). This flexibility has allowed the standard to be widely accepted and deployed making it the dominant home wireless standard today (roughly 100 million households worldwide leverage Wi-Fi in some capacity).

The demand has been met with a wide array of products from a broad swath of manufacturers. More than 1 billion end points have been deployed and chipset shipments now exceed 1 million units per day. All of this has served to provide multiple chipset and product choices to the consumer meaning that costs, due to scale and market demand, have consistently dropped.

Communications node

The communications node that Duke Energy is deploying to support its vision of the 21st century grid is a combination of hardware and software that enables two way exchange of data between Duke Energy organizations, assets on the power delivery system and equipment at and within the premises providing the tools and information that the customer and Duke Energy will need to fulfill the vision. The intent is to have the communications node perform a variety of functions:

- Serve as a data aggregator for end points
- Perform remote analytics and appropriate control
- Provide short term storage for end point and local analytics data
- Provide integrated I/O options
- Provides embedded intelligence into the grid itself at key locations
- Serve as a router that forwards data between end devices, nodes and servers
- Serve as a gateway and perform protocol conversion as needed

The communications node has an operating system and open software framework. This operating system and open software framework will enable the communications node to manage multiple digital grid applications, interfaces and ports. More importantly, the open software framework will allow for new applications development and integration.

At a technical level, the communications node provides a physical and logical link between wide area networks, distribution assets and end points, as well as consumers' in-building networks and energy components (e.g. smart meters). It provides a single point of access for multiple organizations and systems to gather information and data from a variety of distribution and customer premise equipment.

Functional vision

The communications node provides several inherent advantages over today's more conventional technology deployments:

- Data from diverse endpoints can be aggregated and analyzed locally, allowing for less data traffic and providing a more holistic and robust characterization of the local environment.
- Control applications can leverage data and act in near real-time to both reduce overall traffic on the WAN, centralized server loads, and be more responsive in addressing grid events that directly impact the consumer.
- Monitors the state of the distribution transformer and low-voltage grid.
- Applications can be installed in the communications node, and/or software pushed to end points that are able to be remotely upgraded. This will enhance the ways the communications node collects and analyzes data.

Duke Energy expects the amount of data available about the grid itself to grow exponentially as new, intelligent end points are installed on the power delivery system. The digital grid will need to aggregate and analyze data locally in order to convert the bulk data into meaningful information that other systems and applications can use. The ability to aggregate data from different types of end points also reduces the need to support multiple, disparate communications networks to support line monitors, distribution automation, smart metering, etc. All these functions can benefit from integrated communications cost savings. Finally, the ability to modify what data aggregation and analysis occurs in a distributed fashion will allow the communications node to exploit new analytical capabilities as they become available along with the ability to modify the communications node's functionality to improve interaction with other enterprise and/or distributed applications that are implemented.

An end point is a physical entity that resides on either the power delivery system or at the customer premise and has the ability to communicate with the communications node utilizing at least one or more of the listed means of communications capabilities. The communications node is intended to support a growing number of end points that will be interfaced with the communications node throughout its effective lifetime. End points that Duke Energy envisions using with the communications node include, but are not limited to those in the table below:

End point devices that will communicate with the communications node	Connectivity via the communications node
• Electric / Gas / Water Meters • Transformers • Distribution line sensors • Capacitor banks • Reclosers • Streetlights • Distributed Generation Assets • PEVs • PEV Charging Stations • In-Premise Devices such as gateways, thermostats, load switches and displays	• Cellular • LonWorks® PLC • IEEE 802.11 2.4GHz Wi-Fi • IEEE 802.11 5.0GHz Wi-Fi • 900 MHz (ERT enabled receiver) • Ethernet • Serial • USB

Local Data Access (LDA)

There are many different end points that will be supported by the communications node. Moreover, these end points will produce data that require management both locally and centrally. Local data access (LDA) will be a key attribute of the communications node. LDA will enable third-party applications to access this data for local analysis and control when suitable without disrupting the flow of data to Duke Energy's back office operations. Examples of these applications include transformer overload alerts and voltage monitoring.

Applications enabled

There are a variety of applications that are envisioned to utilize the communications node. Due to the unique properties of the node, these applications can either be centrally managed, or the applications themselves can reside on the node. The following are some examples of applications that could be developed:

Application	**Description**
Voltage Monitoring	Utilizes voltage sensing at the transformer and meter to generate exception reports which indicate voltage regulation problems
Transformer Overload Monitoring	Monitors loading on transformers and provides real-time alerts when transformer is overloaded
Remote Fault Detection	3-phase line devices that measure current (amps) and identify the fault current and location of a fault
Outage and Restoration Notification	Remote and automated notification of power outages
Integrated Volt/Var Management -	Ability to remotely configure and control capacitor banks and regulators to achieve specific power factor and voltage objectives on the grid
Demand Response Event Management -	Remote control of customer equipment to manage peak capacity and grid operation issues
Streetlight Monitoring	Monitoring of streetlights to ensure they are operating appropriately
PEV Monitoring	Remotely identify in real time where PEV vehicles may be located and charging

Partner Ecosystem

Given Duke Energy's mission to reduce carbon emissions, enable energy efficiency programs and modernize its electric infrastructure to keep our product affordable, reliable and increasingly clean, we anticipate partnering with vendors and forming strategic alliances over time to develop those systems and solutions.

The digital grid has the capability to impact every aspect of a utility's business. Therefore, various initiatives within the company to support a uniform and integrated digital grid approach should be coordinated to encompass regulatory policy, generation, transmission and distribution, energy efficiency, technology research and development to optimize the benefits from these efforts.

Duke Energy is currently teamed with a number of partners, all of whom have industry expertise with a proven track record of delivery, and the ability to develop an innovative and integrated approach to digital grid solutions.

Standards activities

Duke Energy is an active participant in the National Institute of Standards and Technology (NIST) standards development process and contributes thought leadership on national standards. Duke Energy actively works with several standards bodies and trade organizations to insure that we can obtain the proper alignment with the standards as they are adopted   This alignment effort allows us to leverage economies of scale passed on by the vendors of systems and equipment, resulting from a much larger opportunity for our vendors. This alignment ultimately benefits customers by allowing competition from a greater pool of vendors, systems and equipment in terms of features, functionality and cost , as well as reducing the risk of stranded assets as future enhancements are developed and deployed, as these should be compatible with standards based systems deployed today.

Besides NIST, Duke Energy participates in many of the digital grid standards development groups. Standards are still emerging and it is important for Duke Energy to continue to play a key role in standards bodies, to help shape standards that reflect its digital grid aspirations.

Some of Duke Energy's involvement includes:

- SGIP - Smart Grid Interoperability Panel.
- UCA - UCA International Users Group.
- IETF – Internet Engineering Task Force.
- IPSO – Internet Protocol Smart Object.
- OpenSG IUG- Open Smart Grid International Users Group.
- HomePlug.
- IEEE.
- EEI – Edison Electric Institute.
- EPRI – Electric Power Research Institute.
- UTC – United Telecom Council.
- GridWise Alliance.
- NERC - North American Reliability Council.
- NAESB – North American Energy Standards Board.

Summary

Duke Energy has been instrumental in the development of the node and architecture depicted in this paper. We have multiple vendors building products that align with this architecture utilizing the capabilities described within this document. Cellular companies have recognized the potential and multiple carriers are stepping up to the plate to provide expertise and networks. In conjunction with our partners we have substantially driven cost down while increasing capability. Vendors are producing equipment that utilize these standards and capabilities and are introducing the innovations that will be required to make our vision a reality. This effort was not to develop something fundamentally new but more about utilizing existing knowledge and capabilities of other industries to obtain the needed capabilities.

Duke Energy has installed hundreds of thousands of communications nodes, meters, sensors and distribution automation equipment in aggregate, utilizing the very equipment and networks discussed. Today the communication nodes interface with electric and gas meters, line sensors, transformers and other end points. Duke Energy will continue to innovate and collaborate with its ecosystem of partners to identify, develop, and incorporate new applications and technologies that best leverage this platform for the digital grid.