An Approach for Open and Interoperable AMI Integration Solution

Gerald R. Gray, Consumers Energy

Mark A. Ortiz, Consumers Energy

Shawn Hu, Xtensible Solutions

Joe Zhou, Xtensible Solutions

Consumers Energy

1 Energy Plaza, EP4-275,

Jackson, MI 49201

Xtensible Solutions

6312 S. Fiddler's Green Circle, Suite 210E,

Greenwood Village, CO 80111

grgray@cmsenergy.com, maortiz@cmsenergy.com, shu@xtensible.net, jzhou@xtensible.net

Key Words: Advanced Metering Infrastructure (AMI), IEC CIM, IEC 61968-9, MultiSpeak, Service-Oriented Architecture (SOA), Integration Architecture, Technical Interoperability, Semantic Interoperability, Enterprise Information Management (EIM).

Abstract

Utilities across North America are investing tens of millions of dollars in implementing the Advanced Metering Infrastructure (AMI) and the Smart Grid technology and solutions. Key concerns remain about the stability and maturity of solutions being offered in the market today. As utilities solidify their visions on Smart Grid and as technologies advance to address the market needs, AMI solutions will continue to evolve and consolidate at a rapid pace. As a result, utilities need to be confident about moving forward with Smart Grid investments and not be stranded by costly and proprietary technologies as they choose to implement the core of an AMI solution.

This paper addresses the need for an open and interoperable AMI integration solution that is based on industry best practice integration architecture frameworks and standards. Such a solution would enable a utility to implement AMI incrementally and in alignment with business priorities and available industry solutions, within an interoperable framework. While standards such as IEC 61968-9 and MultiSpeak provide necessary components for open AMI integration solution, not all the pieces are available from a single standard. A detailed approach has been developed to address both the technical and semantic interoperability needs of an open AMI integration solution. This approach includes key architectural designs such as integration requirements analysis for service identification, service patterns, semantic models, integration schema design patterns, and mapping to standards for compliance and openness.

Authors will share Consumers Energy’s endeavor to develop and implement such an approach, with the goal of collaborating with key vendors and utilities to drive de facto implementation of desired standards. Ultimately, this approach will enable utilities to reduce both risk of implementation and cost of ownership, and increase their flexibility in building out the Smart Grid capability as technologies evolve.

1. MARKET NEEDS

1.1. Utility Business Drivers

Consumers Energy has several high level goals that drive the enterprise, and the AMI investment supports these goals in a number of ways. Consumers Energy believes that an AMI system provides the foundation for the smart grid; so while the smart grid is not being built yet, it is anticipated that the communication infrastructure that is deployed to support AMI will be leveraged as smart grid technologies are deployed, see Figure One. The high level business strategies are:

- Leverage business environment knowledge
- Ensure efficient and effective operations
- Develop a safe and skilled workforce
- Deliver what customers and regulators value
- Manage risk and capitalize on change
- Consistently achieve financial results

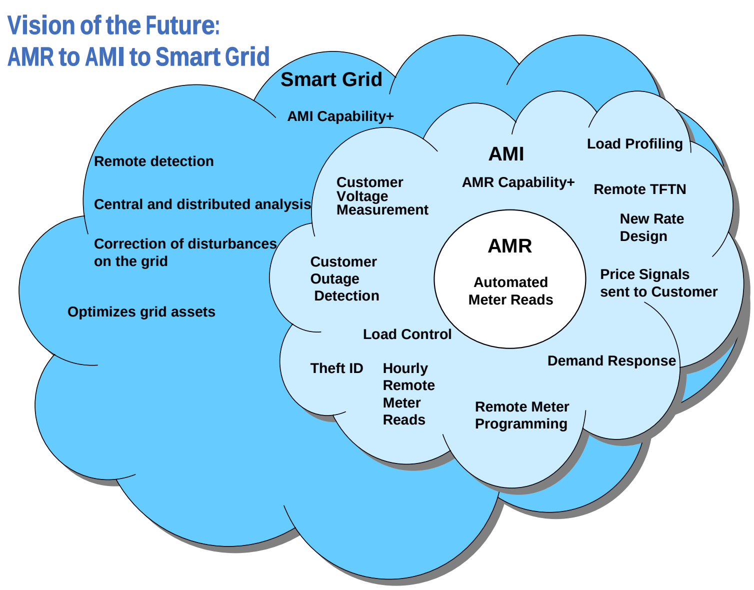

Figure One: AMI, a Foundation for Smart Grid

Leverage business environment knowledge

Any significant technology advance has both competence-enhancing and competence-destroying components. AMI includes competence-destroying aspects such as the knowledge associated with manually reading a meter. Competence-enhancing components include leveraging the meter and grid performance expertise of engineers, the ability of the company to analyze where outages are occurring, and the ability of the company to leverage its investment in updated information systems to enable new business processes.

Ensure efficient and effective operations

The AMI system will facilitate efficient and effective operations in several ways; eliminating the O&M expenses related to meter reading by automating this function, reducing the number of visits to a premise associated with a meter by automating the turn-on/turn-off function, reducing theft by indicating when someone is tampering with a meter, and automatically reporting consumption for all meters connected to the network, thereby reducing the number of "lost" meters. Smart meters will allow the capture of distribution information that may enable analysis to help prevent distribution failures before they occur. The AMI system will also facilitate quick localization where outages have occurred.

Develop a safe and skilled workforce

While the meter-reading workforce is being eliminated, there will be an opportunity for these workers to re-skill into higher value positions. The AMI system deployment will reduce or eliminate the "foot-miles" traveled, reducing the company's exposure to safety issues related to meter reading, such as slips-trips-falls and dogs bites. The ability to do a remote disconnect of an electric meter will also eliminate the need for an employee to visit a potentially hostile premise.

Deliver what customers and regulators value

Michigan's 21st Century Energy Plan and the Energy Policy Act of 2005 have called for utilities to enable greater energy efficiency and demand-response systems. AMI is an enabler of demand-response by communicating time of use (TOU) rates to the meter, facilitating the ability of consumers to make informed decisions about their usage. TOU will also allow easy customization service offerings for all classes of customers. Reducing the turnaround time associated with turn-on/turn-off by performing this task remotely, arming the consumers with information, along with the ability of the utility to improve reliability and responding more quickly to outages, will increase customer satisfaction.

Manage risk and capitalize on change

AMI incorporates several leading edge technologies. Utilities must be careful when making technology choices, especially considering a smart meter may be deployed for more than fifteen years. Consumers Energy has been working with industry thought leaders and leading vendors, and "borrowing the brains" of other utilities that are in similar places within the AMI implementation life cycle to manage the risk with its AMI deployment. Consumers Energy is being very thoughtful in the assessment phase to carefully consider each technology component. Because

AMI will fundamentally change how Consumers Energy does its business, consideration is being given on ways to capitalize on this change and best manage the relationship with our customers and regulators.

Consistently achieve financial results

There are no guarantees with AMI, especially when one considers the risk involved, but the idea is that an investment in AMI uses capital to reduce O&M expenses. Some of these O&M reductions were noted previously. The capital investment used to fund AMI is expected to be recovered through a rate case. Rate recovery will contribute to the utility's ability to realize its authorized return on equity.

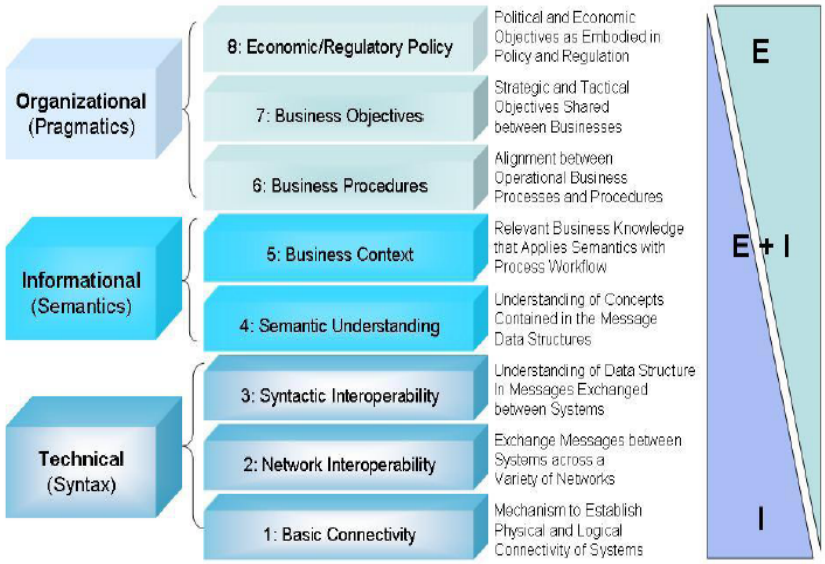

Figure Two: GriWise Interoperability Framework

1.2. Information Technology Trends

While the utility industry is going through tremendous changes due to increasing demand and higher energy prices, the information technology industry continues to mature with regard to technologies for systems integration and information management. Most notable are the technology solutions that deliver Service-Oriented Architecture (SOA) and Enterprise Information Management (EIM) capabilities, allowing enterprises to improve systems interoperability and manage and leverage information more consistently and intelligently. The evolution of the web technologies from yesterday's hyperlinks to tomorrow's Semantic Web has brought us semantic integration technologies that are aimed for semantic interoperability. The technologies that deliver SOA, EIM, and Semantic Integration are advancing and maturing rapidly, and are ready for the utility AMI and Smart Grid initiatives to take advantage of.

1.3. GridWise Interoperability Framework

The GridWise Architecture Council recognized the importance and need for developing and promoting an interoperability framework that will facilitate the development of open and interoperable AMI and Smart Grid solutions. As the result, it published an Interoperability Context-Setting Framework, see Figure Two.

This framework calls for addressing interoperability at three levels—Technical, Informational, and Organizational—as well as cross-cutting issues such as "Share of Meaning of Content," etc. Such a comprehensive framework is both necessary and useful as vendors and utilities work together to move forward with the vision of intelligent utility of future.

The approach developed as part of the Consumers Energy AMI project addresses the Informational level of the interoperability framework and how the consistent semantics can be used to drive the Syntactic Interoperability using Service-Oriented Architecture technologies.

2. AN OPEN AND INTEROPERABLE AMI INTEGRATION SOLUTION

2.1. Main Objectives

Before considering the objective of an open, interoperable integration standard, an environment needed to exist that fostered this desired end state. Several factors contributed to this environment. Some of the impetus for the move to AMI was the Energy Policy Act of 2005 and, in Michigan, the 21st Century Energy Plan that outlined the need to reduce peak energy demand requirements. These actions created a favorable legislative environment that encouraged the type of capital investment that would be required to develop an AMI system. A favorable technology environment at the utility needed to exist as well. As part of significant investment in its business systems, Consumers Energy migrated numerous legacy systems into a single comprehensive enterprise application. The result of this migration was the removal of many point-to-point interfaces that would have made integration to an AMI system more complicated and costly. Finally, the metering technology that was available to support AMI systems matured to the point that AMI systems were now practical. These three forces created the perfect storm of events that led to a decision to invest in an AMI system.

Once a decision had been made to make the AMI investment, thoughts could then be turned to the nature of that investment. An examination of the offerings in the AMI market revealed a mix of communication technologies, some vendors with proprietary interfaces or vendors that had replicated back-office systems in their metering databases. Having recently migrated legacy systems into a comprehensive enterprise application, there was no desire to create another application silo. One of the lessons learned from that legacy migration was that open, interoperable interfaces reduce the implementation costs and facilitate an environment that is more agile compared to point-to-point or proprietary systems.

2.2. The Approach Overview

Introduction

Utilities have realized the need to invest in communication networks infrastructure and IT technology infrastructure for integration and data management. Without a shared understanding of how different systems' data is structured and expressed, however, the technology infrastructure will crumble to its knees due to massive amounts of point-to-point data translations. The only way to scale the integration platforms to meet the future demand for process integration and business intelligence needs is to ensure that the data flowing through the various integration platforms have the same business semantics. They make the same sense for all systems and people that consume them without duplicating effort for translation and interpretation; as such effort at individual levels will inevitably increase cost and opportunity for errors.

In order to help utilities understand where they are and where they want to go, a simple Intelligent Utility Information Management Maturity Model, see Figure Three, is developed to guide the decision making process as to where to invest utilities' valued IT and OT dollars.

Level One: Ability to integrate and allow access of data from applications, but still confined within business units and domains. No enterprise view and consistency.

- Point-to-point integration
- Application-driven data marts and business intelligence
- Duplicate and overlapping data, information, infrastructure, etc.

Level Two: Ability to manage both data and information (meaning of data) with common governance and infrastructure for consistent, accurate, and on-demand needs of information to drive improved operations.

- Enterprise strategy and governance for managing data as assets
- Business semantic and metadata management
- Consistent integration and information management platforms
- Ability to obtain data and information when it is needed with trust

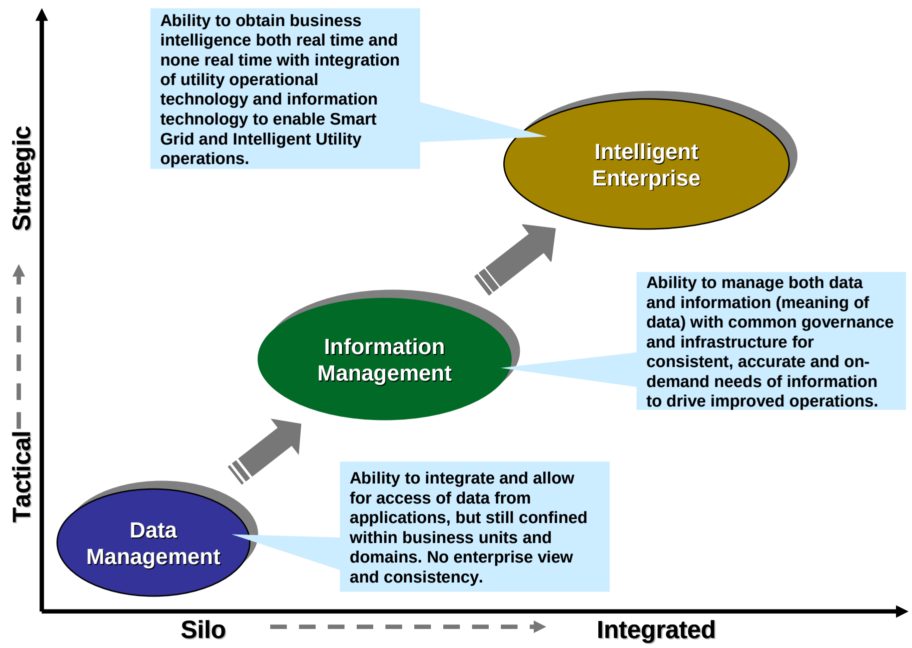

Figure Three: Intelligent Utility EIM Maturity Model

Level Three: Ability to obtain business intelligence in both real time and non-real time with integration of utility operational technology and information technology to enable Smart Grid and Intelligent Utility operations.

- Ability to derive intelligence from many sources of data and information to drive and optimize operations

- Ability to adapt to new business requirements and operational needs with different data/information

While some utilities are still trying to get from Level One to Level Two, others are poised to take on the challenges of establishing the strong foundation of EIM and leveraging their SOA investments to move toward an Intelligent Enterprise. SOA and EIM have been adopted by the CMS AMI program to achieve an interoperable AMI solution that combines industry standards and common practices. As one of the best practices in enterprise integration, SOA provides consistent, reusable, scalable, and extensible business integration solutions. EIM provides necessary governance, methodology, and technologies to develop common informational models, i.e. integration canonical models used to develop services that achieve both technical and semantic interoperability. Another key consideration for developing the approach to deliver an open and interoperable AMI integration solution is the GridWise Interoperability Context-Setting Framework. The project focuses on addressing the Informational level of the interoperability framework and determining how the consistent semantics can be used to drive the syntactic interoperability using Service-Oriented Architecture technologies.

The approach to developing an open and interoperable AMI solution development includes the following key components:

- A structured approach for analysis and design using model-driven methodology for consistent business semantics and leveraging industry standards such as IEC CIM and MultiSpeak, which drive toward semantic interoperability
- A set of service-oriented integration patterns and web services standards to drive technical interoperability

Model-Driven Services Analysis and Design

There are two main steps involved in CMS AMI solution development: high level analysis and detail level analysis and design, see Figure Four.

In high level analysis, a top-down approach is followed with the major steps listed below and illustrated in the diagram.

- Develop To-Be business process models for AMI
- Review To-Be business processes and conduct gap analysis by utilizing industry standards
- Identify integration requirements (services and information objects) in a context of business process
- Normalize services and information objects for detail design

Business processes provide a collection of activities across multiple systems and applications. They are essential for identifying integration requirements (services and information objects) from business perspective. Data flows captured in a business process often indicate integration lines.

Multiple industry standards such as IEC CIM and MultiSpeak are used as a basis for developing interoperable AMI solutions. Logical mapping from business processes to the standards is conducted to align CMS business needs with existing industry common practices.

The outcomes of the High Level Analysis provide the Business Context (see the GridWise Interoperability Framework) within which integration services function. This is critical for an open and interoperable AMI solution to be adopted by multiple utilities and vendors.

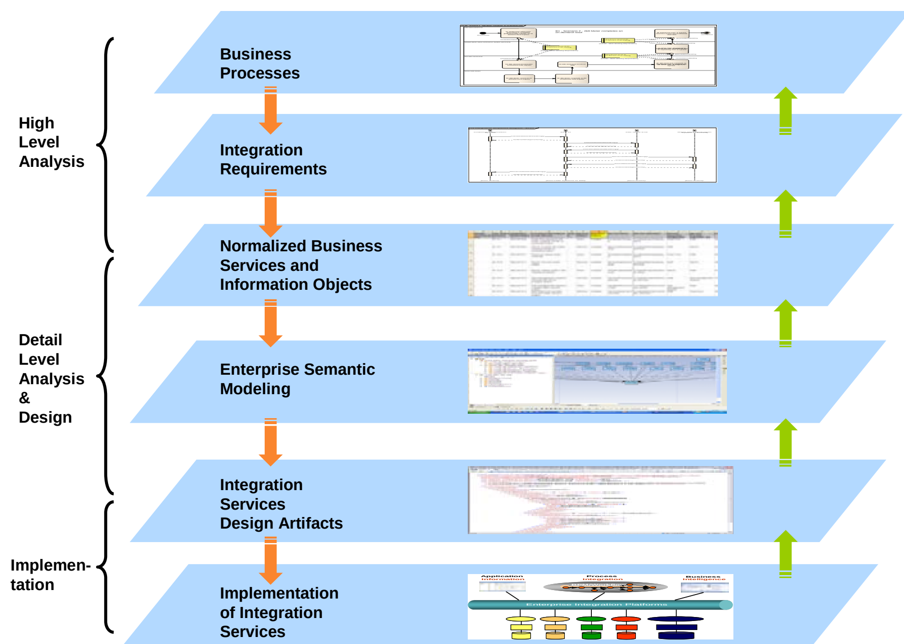

Figure Four: Model-Driven Services Analysis and Design

Based on data flows between systems and applications, information objects can be identified with a collection of entities and properties unique to a business context. With multiple business processes, it is possible that an information object is identified in another business process or overlapped with other information objects. Therefore, it is critical to have a normalization process that defines objects at a certain level of granularity based on business needs.

The normalization process can help define a relatively accurate scope of the detail design phase with a list of common services and information objects that need to be constructed.

In the detail design phase, a combination of top-down and bottom-up approaches is employed. The steps involved are as follows:

- Review identified data requirements (services and information objects)
- Develop CMS Enterprise Semantic Model (ESM) for AMI with business context for each integration scenarios.
- Deliverable in XML schemas and WSDLs (Web Service Definition Language)

The outcomes of the Detail Level Analysis provide the Semantic Understanding (see the GridWise Interoperability Framework) upon which all integration services design artifacts will be based. This is also critical for an open and interoperable AMI solution to be adopted by multiple utilities and vendors.

The goal of the detail design is to provide sustainable implementation artifacts in terms of performance, reliability, reusability, interoperability, and so on. For this reason, the identified services and information objects from high level gap analysis need to be examined carefully to avoid unnecessary rework in the future as much as possible. Implementation artifacts are delivered in the form of XML schema (XSD) for information objects and WSDL for endpoint service definition.

Model-driven methodology is adopted for the detail design process. Information objects are modeled in UML. The objects modeled in UML come from the logical information objects identified from high-level analysis (top-down), data requirements from each systems/applications, and industry standards (bottom-up). After a data model is constructed, generating design artifacts using Xtensible Solutions' MD3i Framework is an automated process.

The inputs to the CMS ESM are the IEC CIM and MultiSpeak standards, which will ensure that integration services and payload designed are going to be compatible with the standards and can be promoted back to the standard bodies for wide adoption. This also ensures the openness of the solution from business process to services identified and designed.

The success of the AMI solution development largely depends on proper analysis, design, integration, and testing. The cycle of the high-level analysis and detail design approach is not just one-way traffic. There can be many project lifecycle iterations to get a sustainable AMI solution and achieve best ROI for CMS.

Service-Oriented Integration Patterns

Strategic initiatives, such as the AMI program, are moving Consumers Energy in a direction toward adopting Service Oriented Architecture in the enterprise. Consumers Energy wants to ensure that it maximizes its return on investment by using this integration philosophy wisely.

Technologies, requirements, and priorities impose constraints on the system integration delivery process. Quick solutions are often developed to address these problems, resulting in point-to-point interfaces and duplication of data and business logic, which create a lack of consistency across the enterprise. This integration becomes costly to maintain and difficult to grow with the business. Part of Consumers Energy's SOA strategy includes leveraging service design patterns to ensure that service design principles are applied consistently across the enterprise, minimizing the need for quick solutions during the system integration delivery process.

The service design patterns created for the AMI project provide a documented solution in a generic template to insure consistency in service design, compliance to industry standards, and technological independence. The service design patterns incorporate industry standards, such as WS-I and IEC TC57 WG14 verbs, and provide a consistent environment to discover and consume services across the enterprise by enforcing common service semantics. As a result, the AMI project adhering to the service design patterns will enable the reuse of decoupled services by other enterprise projects.

In Summary, the service design patterns collections consist of:

- Message Exchange Patterns
- Service and Operation Patterns
- Service Interaction Patterns

Below is an example of three patterns from each of the Service Design Patterns. The integration scenario is between two applications, where application A sends work order data to application B via a service broker.

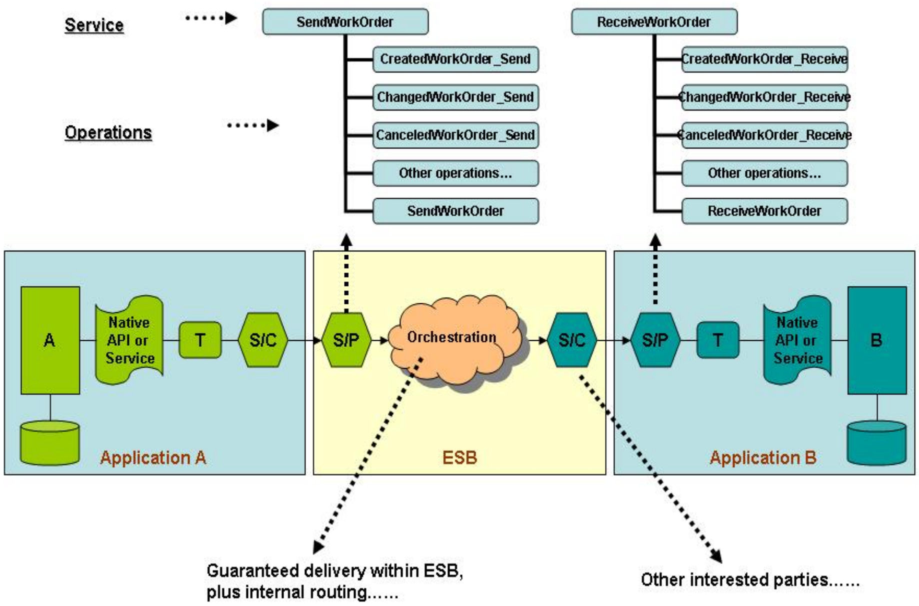

Figure Five: Send-Receive Service Interaction Pattern

Figure Five shows Application A sends work order data through a "Send" service at the integration layer, acting as a service broker. Application B provides a "Receive" service in order to receive the work order data. This is an indirect interaction process, as Application A does not send its data directly to B, but through the Enterprise Service Bus (ESB). It is an asynchronous process because multiple invocation threads are involved.

The Message Exchange Pattern used in this scenario is:

- A two-way pattern is a synchronous process that typically involves two messages, one for request and one for response.

The Service Naming Patterns below are used in these scenarios:

- **Send** - to provide (send) information (information object) for public (enterprise) consumption. To be invoked by the system of record for the business object and only when the state of the business objects has changed.
- **Receive** – to consume (receive) information (information object) from an external source.

The Operation Naming Patterns (IEC 61989 verbs) below are used in these scenarios:

- **Created** - operation: used in Send, Receive, Reply services.
- **Changed** - operation: used in Send, Receive, Reply services.
- **Closed** - operation: used in Send, Receive, Reply services.
- **Canceled** -operation: used in Send, Receive, Reply services.
- **Deleted** - operation: used in Send, Receive, Reply services.

The Service Interaction Pattern below is used in this scenario:

- Send-Receive Services Interaction Pattern (Indirect & Asynchronous).

2.3. Benefits

This approach brings benefits to the industry for utilities, vendors, and customers. For utilities, having vendors support a common set of services on a common information model reduces the cost of integrating vendor offerings into the IT and OT landscape at the utility. This also drives down the base price for utilities if vendors support standard services and information models. This is because if the services and information exchanged are the same, then vendors have to differentiate themselves on price, product performance, and execution within the market.

There are opportunities for vendors that perform well. Those that adopt common services and information models will find a welcome market. Vendors that have attempted to tie customers to proprietary products and interfaces will increasingly find this approach a difficult sell. Vendors that take the proprietary approach will have to show that their products are demonstrably better than products based on open standards and will need to justify what will likely be a higher total cost of ownership.

All AMI systems promise to arm customers with more information, allowing them to reduce their usage in thoughtful ways, and reduce their direct costs by shifting their use to off-peak hours. However, the huge amounts of investments for technologies and systems required to enable such capabilities require the entire industry to drive toward more open and interoperable solutions to reduce the risks of implementation and total cost of ownership. Although there continually will be market and regulatory pressures to move toward Smart Grid and Intelligent utilities, the market will not bare costly and proprietary solutions.

3. CHALLENGES

While the goals and benefits of open and interoperable AMI integration solution are clear, challenges remain that prevent making the solution a reality for the market as a whole. Chief challenges are listed as follows:

- Market positioning: As demand for AMI and Smart Grid solution increases rapidly, competition is heating up in the market. Inevitably, there will be parties who want to "lock" the market into their proprietary technologies, while others believe that open and interoperable solution creates a win-win situation. The rapid evolution of the technologies in this space requires a very prudent approach for adoption and implementation. While it may seem less costly to buy into the market hype and go with a "turn-key" solution, the risk of "stuck" with unproven and proprietary technologies remains extremely high in today's market condition.

- Utilities and vendors community cooperation: Achieving an open and interoperable solution for the market requires tremendous support and cooperation from the utilities and vendors community. While OpenAMI, OpenHAN, and AMI-ENT, etc. under UCA OpenSG are making significant progresses toward knowledge sharing and creating open specifications for AMI, much still needs to be done to reach defacto implementation standards for the market as a whole.

- Industry standards evolution and harmonization: Significant progress has been made within IEC TC57, Multispeak, and other organizations to provide standards that will be supported by vendors, yet the internal processes to individual standards bodies and inter-standards competition make their adoption by utilities and vendors more complicated. It was encouraging to see IEC TC57 WG14 and MultiSpeak agree to collaborate and move both standards in the same direction. The user community needs to work together to drive these standards into something that is both implementable and maintainable.

Acknowledgement

The authors wish to thank Consumers Energy for sponsoring and supporting activities described in this paper, which provide benefit for utilities and vendors alike.

Gerald R. Gray

Mr. Gray is an enterprise architect with Consumers Energy, a combination electric and gas utility serving over two million customers in the lower peninsula of Michigan. Mr. Gray has over 25 years of IT experience in a variety of roles, and now as an enterprise architect is leading the application integration effort for Consumers Energy's AMI program. Mr. Gray participates in and has contributed to the Open HAN and AMI–Enterprise working groups.

Mark A. Ortiz

Mr. Ortiz is an Enterprise Architect with Consumers Energy. He has extensive experience in integration architecture, leveraging SAP NetWeaver technologies and Service-Oriented Architecture. He played a key role in architecting the integration between Consumers Energy's SAP environment, Outage Management System, and Mobile Workforce Management System. He is a graduate of Michigan Technological University and is a Certified SAP Exchange Infrastructure Consultant.

Shawn Hu

Mr. Hu is a Solution Architect with Xtensible Solutions. His expertise includes AMI integration, utilizing SOA Web service technology, enterprise information management, and detail XSD/WSDL designs. He has worked on a variety of system integration projects that focused on interface design and data flow. He holds a Ph.D. from University of Western Ontario in Canada.

M. Joe Zhou

Mr. Zhou is CTO of Xtensible Solutions, which provides enterprise information management and integration solution and services to the energy and utility industry. With about 20 years of industry experience, and having provided services for more than two dozen utilities worldwide, Mr. Zhou works with his clients to build sustainable information management and integration solutions that leverage industry standards and best practices in order to enable and improve business and systems interoperability. Mr. Zhou played key roles in and contributed regularly to standards groups, including IEC TC57 WG14, OAGi, and UN/CEFACT TMG, which defines standards for systems interoperability.