Smart Grid Enterprise Application Interoperability Needs Assessment and the MultiSpeak® Specification

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Abstract

This paper identifies and characterizes in detail the enterprise software application interfaces that will be required to facilitate the eventual smart grid functionality. Each interface is defined in terms of the framework for smart grid standards developed by the National Institute of Standards and Technology (NIST).

Many of these interfaces will be demonstrated as part of the National Rural Electric Cooperative Association (NRECA)'s smart grid demonstration project. The paper evaluates the adequacy of the current MultiSpeak specification and delineates the needed extensions to that specification that will be required in order to fulfill the needs of end-to-end demand response and advanced distribution grid management. Furthermore, the paper summarizes the results of a survey of existing standards, specifications, and protocols including those in progress, and lays out how developments in those standards will impact future MultiSpeak efforts. The paper outlines a plan for including the output of other standards setting organizations (SSOs). This plan provides an approach to harmonization that could be used as a model for other smart grid SSOs attempting to adapt to an evolving standards landscape.

1. INTRODUCTION

NRECA and member cooperatives have been chosen as one of the demonstration projects for a Department of Energy Smart Grid Demonstration Grant [1]. As part of the completed Phase I of that project an Interoperability and Cyber Security Plan (ICSP) was prepared [2]. This article briefly discusses key results for the enterprise applications interoperability portion of the ICSP. Key objectives of the work were: (i) to develop an appreciation for the constituent parts of key smart grid domains and their interactions, (ii) to provide an organizing methodology and reference numbering system for key actors (applications), (iii) to determine the details of all required interfaces between enterprise software applications for the smart grid, (iv) to determine the current state of each interface between actors and what interface capabilities will need to be developed to achieve the objectives of the smart grid, and (v) to establish how to support compatibility with NIST's emerging Smart Grid framework for standards and protocols.

The starting point for our analysis was the MultiSpeak Specification (MultiSpeak) [3]. MultiSpeak is a standard that has offered guidance on enterprise application integration since 2000. MultiSpeak is stable and mature in its support of 30 enterprise application integration profiles. It is in operation at over 500 utilities in at least 11 different countries. However, the eventual smart grid will entail significant extensions to the existing interfaces and the addition of many new interfaces. Our Phase I project work was aimed at full definition of these needs.

MultiSpeak consists of (i) a data model documented in Unified Modeling Language (UML) class model and Extensible Markup Language (XML) schema formats and (ii) service definitions defined in Web Services Description Language (WSDL) contracts.

The MultiSpeak Initiative has a strong commitment to the use of well understood and widely-adopted standards and protocols as is evidenced by the fact that MultiSpeak web services make use of (i) XML Schemas, (ii) Simple Object

Access Protocol V1.1 (SOAP) [4], (iii) Web Services Description Language V1.1 [5], (iv) Hypertext Transfer Protocol (HTTP) V1.1 [6] and (v) Extensible Markup Language (XML) [7]. Further, within the standard itself, MultiSpeak already incorporates content from such standards as: ANSI C12.19/MC19 [8] for revenue metering end device tables and the Open Geospatial Consortium GML [9] for exchange of location-based information addressing geographic data requirements. The MultiSpeak reference architecture is based on the Basic Profile 1.1 (Profile), which was developed by the Web Services Interoperability Organization (WS-I) [10]. MultiSpeak expects to continue to push toward standardized interface definitions with other SSOs as the smart grid evolution continues.

2. USING AND EXTENDING THE NIST SMART GRID CONCEPTUAL REFERENCE MODEL

We began our needs assessment by placing it within the context of the Smart Grid Conceptual Reference Model which has been developed by (NIST) [11]. Figure 1 shows the detailed conceptual model.

The first step in our detailed assessment was to develop the specific logical architecture for the enterprise applications needed for the smart grid. The result is shown in Figure 2 which indicates that the smart grid will extensively involve four of the domains as defined in the NIST Conceptual Model: Markets, Operations, Service Providers/Aggregators, and Customer, as well as the distributed storage and the distributed generation portions of the Distribution domain. The Operations domain is divided in Figure 2 into three sub-domains: Distribution Operations, Generation and Transmission Operations and RTO/ISO Operations to accommodate vertically-integrated utilities as well as those for which there is a division between the distribution utility operator and the generation and transmission utility operator such is more typical of U.S. electric cooperatives. Thus the diagram shown in Figure 2 applies to markets, operations, service providers and customers for all utilities.

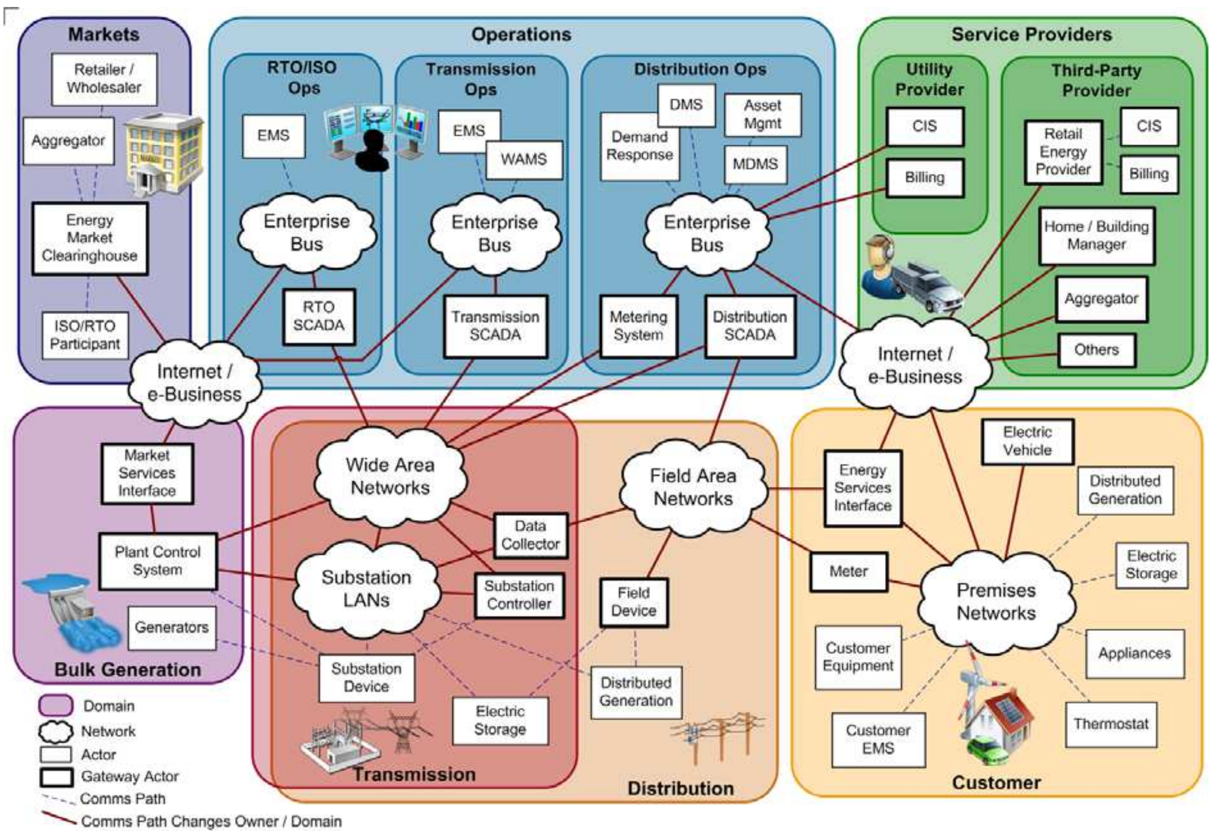

Figure 1. NIST Conceptual Model: Detailed View.

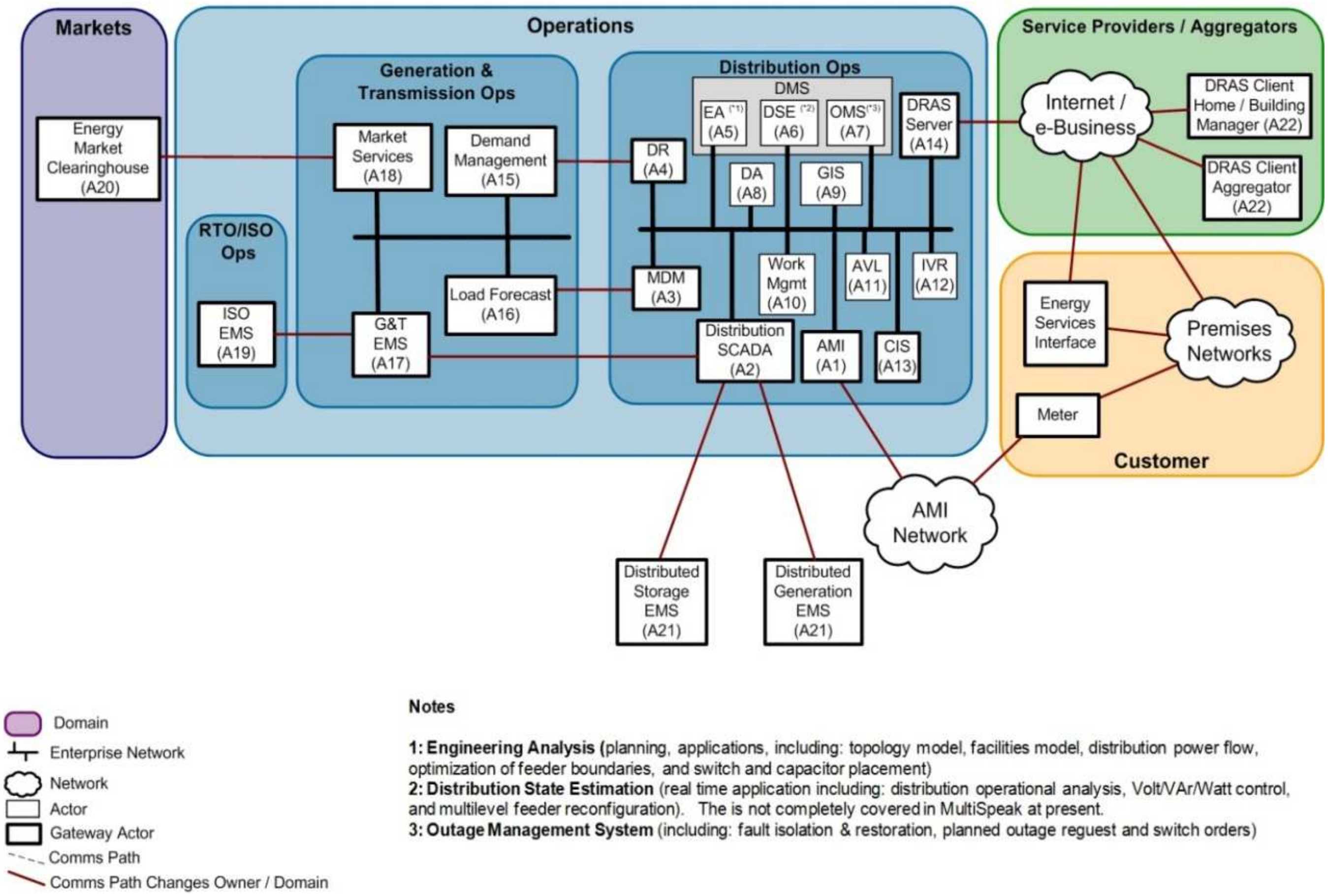

Figure 2. Logical Architecture for Enterprise Applications. Bracketed numbers A1 through A22 refer to specific Actors (Software Applications).

Each box in Figure 2 is an actor. Boxes with lightweight bounding lines are actors that are contained within one domain or sub-domain; boxes with heavy weight lines are gateway actors – those that bridge two domains or sub-domains. As far as the discussion of logical architecture is concerned, actors are software applications, with the exception of the meter in the Customer domain that acts as the gateway actor between the distribution utility operator and the customer. Software applications that potentially exchange data *within* an enterprise network are shown as being connected with heavyweight black lines. Such an exchange of data occurs across *interfaces*. Enterprise networks may be local area networks (LANs) or wide area networks (WANs) or any combination of the two. When software applications are connected together in such a manner that the data flows span NIST conceptual model domains (or sub-domains) then the communications path between the linked gateway actors is shown as a lightweight line. Table 1 describes each enterprise software application shown in Figure 2.

Table 1
Description of Enterprise Software Applications

Application	Description
(A1) AMI	Advanced Metering Infrastructure (AMI). This system manages communications with meters, typically at customer locations. The AMI system also often acts to manage customer loads or to connect/disconnect/reconnect customer services.
(A2) Distribution SCADA	Distribution domain Supervisory Control and Data Acquisition (SCADA). Distribution SCADA systems control and obtain data about (typically) distribution substation equipment.
(A3) Meter Data Management	Meter data management (MDM) systems typically act as a centralized data management system to store meter readings and meter-related event data, such as customer outages, meter change-outs, or meter demand resets. MDM systems often are used to validate meter data, including estimating missing data. MDM systems may also include supplemental modules to filter, accumulate, or analyze meter data before it is sent to other systems. In the context of this project, the MDM system may be either (i) a shared system located on the generation and transmission operator network or (ii) a system on the network of a single distribution operator.
(A4) Demand Response	Demand response (DR) systems accept demand targets or market price signals from other systems, such as the Demand Management system (see A15, below), and send control or price signals to other systems, such as the AMI (see A1, above) or the Demand Response Automation Server (see A14, below) so that those systems can pass such control or price signals to other systems or to end devices.
(A5) Engineering Analysis	Engineering analysis (EA) accepts facility data and/or power system models from a geographic information system (see A9, below) and operational data such as metered data from AMI (A1, above) or system operations data from distribution SCADA or distribution automation systems (A2, above or A8, below) and performs off-line analyses of the data. EA systems are often used for system planning purposes. EA systems are sometimes deployed as a module of a distribution management system (DMS).
(A6) Distribution State Estimation	Distribution state estimation (DSE) systems are an emerging variety of engineering analysis system that are designed to perform real-time or near-real time analyses of power system models based on actual metered data and system operations data. DSE systems are often deployed as a module of a distribution management system (DMS).
(A7) Outage Management System	Outage management system (OMS). The OMS accepts detected outage information from customer telephone calls, as well as from automated outage detection systems such as the AMI system (A1, above) or the interactive voice response system (A12, below). The OMS system then analyzes the pattern of detected outages based on a power system model and assists a dispatcher to manage crews to restore the affected facilities.
(A8) Distribution Automation	Distribution automation systems are similar to distribution SCADA systems (see A2, above) except that DA systems typically control or obtain data from devices down line of the distribution substation.
(A9) GIS	Geographic Information System (GIS). The GIS stores and displays information about customers, facilities and work in a geographic context. The GIS is often used as the central repository for the power system model that is subsequently provided to the EA (A5, above), DSE (A6, above), or OMS (A7, above).
(A10) Work Management	Work management (WM). The work management system generates and tracks work-related activities. The work management system is often integrated with (i) the AMI (A1, above) or MDM (A3, above) for managing work related to setting, replacing and retiring meters, (ii) the customer information system (A13, below) for managing service or construction work, and (iii) the OMS (A7, above) for managing outage restoration.
(A11) Automated Vehicle Location	Automatic Vehicle Location (AVL). The AVL system uses global positioning system (GPS) technology to locate utility-owned vehicles and display them in geographic context. AVL system output is often used in the GIS (A9, above), the OMS (A7, above) and the WM (A10, above).

Table 1 (continued)
Description of Enterprise Software Applications

Application	Description
(A12) Interactive Voice Response	Interactive Voice Response (IVR). The IVR system automatically answers customer calls and routes them to the appropriate department or system for further action. In this context, the IVR is integrated with the OMS (A7, above) to manage customer outages.
(A13) Customer Information System	Customer Information System (CIS). The CIS typically consists of several software modules that include a customer database, a bill calculation mechanism, plant inventory, and accounting systems. The CIS must be integrated with many of the systems listed here to provide customer information and to accept meter readings from the AMI (A1, above) or MDM (A3, above).
(A14) Demand Response Automation System (DRAS) Server	Demand Response Automation System (DRAS) Server. The DRAS Server is a system that accepts demand response targets or market price signals from the DR (A4, above) and implements the Open Automated Demand Response (OpenADR) protocol. OpenADR is used to coordinate demand response actions with DRAS Client systems (A22, below) at customer facilities or third-party service aggregators.
(A15) Demand Management	Demand Management (DM). The DM system accepts demand response targets or market price signals from the Load Forecast system (A16, below) and manages appropriate demand response actions with the Demand Response (DR) system (A4, above) at each of the distribution utilities.
(A16) Load Forecast	Load Forecast (LF). The LF system accepts market signals from the Market Services application (A18, below), calculates the relative value of the output of generation assets and demand response resources, and sends demand response management targets to the DM system (A15, above).
(A17) G&T EMS	Generation and Transmission (G&T) Energy Management System (EMS). The G&T EMS is a system that collects data from and controls generation and transmission assets, acting in a manner similar to a SCADA system.
(A18) Market Services	Market Services (MS). The MS coordinates market signals with the Energy Market Clearinghouse (A20, below) and sends market information to the Load Forecast application (A16, above).
(A19) RTO/ISO EMS	Regional Transmission Operator (RTO) /Independent System Operator (ISO) Energy Management System (EMS). The RTO/ISO EMS collects information on regional transmission assets and operational conditions and acts to control those transmission assets.
(A20) Energy Market Clearinghouse	Energy Market Clearinghouse. The energy market clearinghouse is the market system that coordinates with market participants to exchange either price signals or bid and offer information. The energy market clearinghouse system in the market domain communicates with the market services application(s) (A18, above) in the generation and transmission system operator domain.
(A21) Distributed Energy Resources EMS	The distributed energy resources (DER) energy management system (EMS). This system acts to collect information about the operation of and to control the assets of a DER facility. In the context of this demonstration project, the DER may be either a distributed generation (DG) or distributed storage (DS) facility. In the context of this demonstration project, it is assumed that the DER EMS will coordinate with the distribution SCADA application (A2, above) in operation at the distribution operator.
(A22) Demand Response Automation (DRAS) Client	Demand Response Automation System (DRAS) Client. The DRAS Client implements the client portion of the Open Automated Demand Response (OpenADR) protocol, which is used to coordinate demand response actions with DRAS Server system (A14, above).

III. Analysis of Standards Other Than MultiSpeak

NIST SP 1108 identifies 75 existing standards that are applicable or likely to be applicable to the ongoing development of the smart grid. A significant subset of those will directly impact the work on MultiSpeak. A considerable completed effort during Phase I of this project has been to investigate existing standards and interfaces that might play a role during the development of the project interface designs. Sources of information have included: (i) discussions with representatives of other SSOs, (ii) participation on various Priority Action Plan (PAP) committees, (iii) participation in the Transmission and Distribution Domain Expert Working Group (DEWG), (iv)

attendance at technical meetings such as the NIST Smart Grid Interoperability Panel, and (v) discussions with affected
vendors. As a result of those efforts, it has been possible to identify the key standards, protocols and interfaces which will need to be incorporated into the enterprise application interoperability portion of this project. Their specific impacts are discussed in the next section.

New interfaces will need to be developed, and existing MultiSpeak interfaces will need to be enhanced, in order to achieve the goals of the project. The first step was to characterize all of the interfaces that would be required and establish interface identification numbers. The result is shown in Figure 3.

IV. Interface Needs Assessment

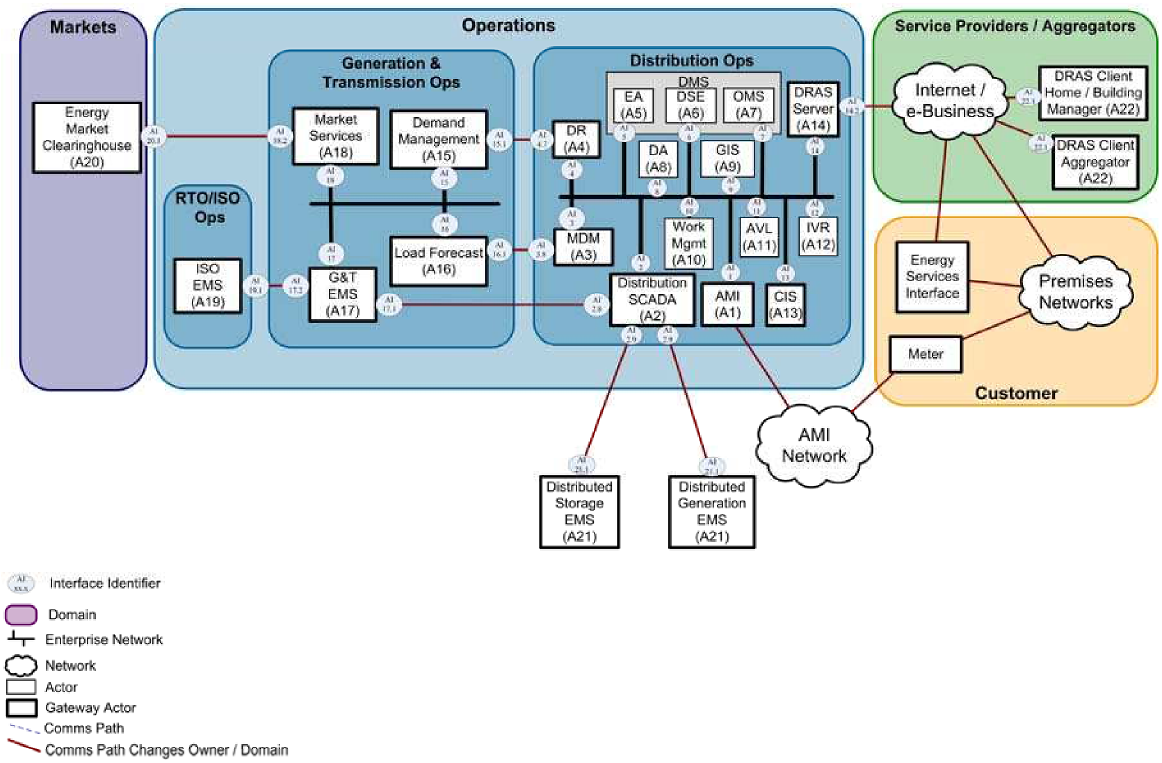

Figure 3. Integration Development Requirements for Enterprise Applications.

Table 2 gives detailed information on all of the interfaces anticipated to be needed for the smart grid for enterprise application interoperability. Column 1 lists each application that is shown in Figure 3 along with its corresponding application number. Column 2 shows the detailed interfaces that each application has with other applications; Column 3 identifies each of those detailed interfaces using the numbering scheme developed and used in Figure 3. Note that some of the numbers in Column 3 are shaded and others are unshaded. ***Shaded boxes are those for which MultiSpeak standards currently exist.*** Those which are unshaded show interfaces that will need to be developed for eventual use in meeting the needs of the smart grid. All interfaces, existing or to be developed, will also need to be iteratively updated to reflect needed refinements or to harmonize with complementary standards.

Column 4 lists those standards which were identified as impacting a given interface. It should be noted that many of these interfaces potentially could be impacted by several outside standards. In many cases, a single interface might potentially be impacted by standards that are being developed by as many as five different standards development organizations.

Table 2
Enterprise Application Interfaces

Application	Interfaces With	Interface Number	External Standards
A1) AMI	A3) Meter Data Management	AI 1.1	ZigBee SEP (1.0, 2.0), IEC 61968, Part 9, C12.19
	A4) Demand Response	AI 1.2	ZigBee SEP (1.0, 2.0), IEC 61968, Part 9, C12.19
	A5) Engineering Analysis	AI 1.3	IEC 61968, Part 9, C12.19
	A6) Distribution State Estimation	AI 1.4	IEC 61968, Part 9, C12.19
	A7) Outage Management System	AI 1.5	IEC 61968, Part 9, C12.19
	A13) CIS	AI 1.6	ZigBee SEP (1.0, 2.0), IEC 61968, Part 9, C12.19
A2) Distribution SCADA	A3) Meter Data Management	AI2.1	
	A4) Demand Response	AI 2.2	
	A5) Engineering Analysis	AI 2.3	
	A6) Distribution State Estimation	AI 2.4	
	A7) Outage Management System	AI 2.5	
	A8) Distribution Automation	AI 2.6	ICCP (TASE.2)
	A9) GIS	AI 2.7	
	A17) G & T EMS	AI 2.8	ICCP (TASE.2)
	A21) DER EMS	AI 2.9	ICCP (TASE.2), DNP3
A3) MDM	A1) AMI	AI 3.1	ZigBee SEP (1.0, 2.0), IEC 61968, Part 9, C12.19
	A2) Distribution SCADA	AI 3.2	
	A4) Demand Response	AI 3.3	ZigBee SEP (1.0, 2.0), IEC 61968, Part 9, C12.19
	A5) Engineering Analysis	AI 3.4	IEC 61968, Part 9, C12.19
	A6) Distribution State Estimation	AI 3.5	IEC 61968, Part 9, C12.19
	A7) Outage Management System	AI 3.6	IEC 61968, Part 9, C12.19
	A13) CIS	AI 3.7	ZigBee SEP (1.0, 2.0), IEC 61968, Part 9, C12.19
	A16) Load Forecast	AI 3.8	NAESB and OASIS (Price and Schedule)
A4) Demand Response	A1) AMI	AI 4.1	ZigBee SEP (1.0, 2.0), IEC 61968, Part 9, C12.19
	A2) Distribution SCADA	AI 4.2	
	A3) MDM	AI 4.3	ZigBee SEP (1.0, 2.0), IEC 61968, Part 9, C12.19
	A9) GIS	AI 4.4	
	A13) CIS	AI 4.5	ZigBee SEP (1.0, 2.0), IEC 61968, Part 9, C12.19, NAESB and OASIS (Price and Schedule)
	A14) Demand Response Automation Server (DRAS)	AI 4.6	NAESB and OASIS (Price and Schedule), OpenADR
	A15) Demand Management	AI 4.7	NAESB and OASIS (Price and Schedule)
A5) Engineering Analysis	A1) AMI	AI 5.1	IEC 61968, Part 9, C12.19
	A2) Distribution SCADA	AI 5.2	
	A3) Meter Data Management	AI 5.3	IEC 61968, Part 9, C12.19
	A7) Outage Management System	AI 5.4	
	A9) GIS	AI 5.5	
	A13) CIS	AI 5.6	
A6) DSE	A1) AMI	AI 6.1	IEC 61968, Part 9, C12.19
	A2) Distribution SCADA	AI 6.2	ICCP, TASE.2
	A3) Meter Data Management	AI 6.3	IEC 61968, Part 9, C12.19
	A7) Outage Management System	AI 6.4	
	A8) Distribution Automation	AI 6.5	
A7) OMS	A1) AMI	AI 7.1	IEC 61968, Part 9, C12.19
	A2) Distribution SCADA	AI 7.2	
	A3) Meter Data Management	AI 7.3	IEC 61968, Part 9, C12.19
	A5) Engineering Analysis	AI 7.4	
	A6) Distribution State Estimation	AI 7.5	
	A8) Distribution Automation	AI 7.6	
	A9) GIS	AI 7.7	
	A10) Work Management	AI 7.8	
	A11) Automatic Vehicle Location	AI 7.9	
	A12) Interactive Voice Response	AI 7.10	
	A13) CIS	AI 7.11	

Table 2 (continued)
Enterprise Application Interfaces

Application	Interfaces With	Interface Number	External Standards
A8) Distribution Automation	A2) Distribution SCADA	AI 8.1	ICCP (TASE.2)
	A6) Distribution State Estimation	AI 8.2	
	A7) Outage Management System	AI 8.3	
A9) GIS	A2) Distribution SCADA	AI 9.1	
	A4) Demand Response	AI 9.2	
	A5) Engineering Analysis	AI 9.3	
	A7) Outage Management System	AI 9.4	
	A13) CIS	AI 9.5	
A10) Work Management	A7) Outage Management System	AI 10.1	
	A11) Automatic Vehicle Location	AI 10.2	
	A13) CIS	AI 10.3	
A11) AVL	A7) Outage Management System	AI 11.1	
	A10) Work Management	AI11.2	
A12) IVR	A7) Outage Management System	AI 12.1	
	A13) CIS	AI 12.2	
A13) CIS	A1) AMI	AI 13.1	ZigBee SEP (1.0, 2.0), IEC 61968, Part 9, C12.19
	A3) Meter Data Management	AI 13.2	ZigBee SEP (1.0, 2.0), IEC 61968, Part 9, C12.19
	A4) Demand Response	AI 13.3	ZigBee SEP (1.0, 2.0), IEC 61968, Part 9, C12.19, NAESB and OASIS (Price and Schedule)
	A5) Engineering Analysis	AI 13.4	
	A7) Outage Management System	AI 13.5	
	A9) GIS	AI 13.6	
	A10) Work Management	AI 13.7	
	A12) Interactive Voice Response	AI 13.8	
A14) DRAS Server	A4) Demand Response	AI 14.1	NAESB and OASIS (Price and Schedule), OpenADR
	A22) DRAS Client	AI 14.2	OpenADR
A15) Demand Management	A4) Demand Response	AI 15.1	NAESB and OASIS (Price and Schedule)
	A16) Load Forecast	AI 15.2	NAESB and OASIS (Price and Schedule)
A16) Load Forecast	A3) Meter Data Management	AI 16.1	NAESB and OASIS (Price and Schedule)
	A15) Demand Management	AI 16.2	NAESB and OASIS (Price and Schedule)
	A18) Market Services	AI 16.3	NAESB and OASIS (Price and Schedule)
A17) G&T EMS	A2) Distribution SCADA	AI 17.1	ICCP (TASE.2)
	A19) ISO EMS	AI 17.2	ICCP (TASE.2)
A18) Market Services	A16) Load Forecast	AI 18.1	NAESB and OASIS (Price and Schedule)
	A20) Energy Market Clearinghouse	AI 18.2	NAESB and OASIS (Price and Schedule)
A19) ISO EMS	A17) G&T EMS	AI 19.1	ICCP (TASE.2)
A20) Energy Market Clearinghouse	A18) Market Services	AI 20.1	NAESB and OASIS (Price and Schedule)
A21) Distributed Energy Resources EMS	A2) Distribution SCADA	AI 21.1	ICCP (TASE.2), DNP3
A22) DRAS Client	A14) DRAS Server	AI 22.1	OpenADR

In order to be able to carry out the ultimate objectives of the smart grid as currently visualized by the industry, all of the application interfaces shown in Figure 3 and described in Table 2 will eventually need to be developed and integrated at a particular utility.

A key challenge facing the MultiSpeak Initiative is how to continue to maintain and enhance the MultiSpeak specification in light of the significant dependencies on other SSOs noted in Table 2. The MultiSpeak Initiative Technical Committee has adopted a procedure of rolling into the development cycle any final outputs of the other applicable SSOs. Going forward, it is planned that the Technical Committee will issue a release of MultiSpeak roughly annually, near the first of each year, beginning with calendar year 2011. The committee will consider modifications necessary to support the work of other SSOs in each annual release ***provided the final output of that group has been made publically available during the first two quarters of the prior calendar year***. This procedure will enable the MultiSpeak Specification to move forward, while adequately considering the output of other SSOs.

V. Summary

Achieving the goals that have been established for the smart grid will require the development and standardization of many technologies. This paper discusses the portion of that work pertaining to enterprise application interoperability. The NIST conceptual reference model has been expanded to provide specific detail about the enterprise applications that will be required and, more importantly a complete view of the interfaces between those applications that will be required. A reference numbering system has been developed. The total list of needs has been compared to the list of interfaces contained within the MultiSpeak specification for interoperability and as a result of that comparison, a list of needed developments to extend the MultiSpeak specification has been completed. The outside standards, protocols and specifications that may influence the required MultiSpeak developments have been compiled and are associated with the specific interfaces needing development. It is anticipated that much of the required work will be completed under Phase II of the NRECA-CRN DOE Smart Grid Demonstration Project.

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Biography

Gary A. McNaughton is the Vice President and Principal Engineer for Cornice Engineering, Inc. He received a B.S.E.E. degree from Kansas State University in 1976 and an M.S.E.E. degree from the University of Colorado in 1980. Prior to joining Cornice in 1995 he worked as a Plant Electrical Engineer for Union Carbide, at the Oak Ridge Gaseous Diffusion Plant, at Oak Ridge, TN, as a Transmission Planning and Protection Engineer for Colorado-Ute Electric Association, a generation and transmission cooperative, located in Montrose, CO, and as Staff Engineer, Manager of Engineering, and Assistant General Manager for Engineering and Operations for La Plata Electric Association, in Durango, CO. Mr. McNaughton currently serves as the Project Technical Coordinator for NRECA's MultiSpeak® Initiative. Mr. McNaughton is a registered professional engineer in the State of Colorado.

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Robert Saint is a Principal Distribution Engineer in the Energy & Environmental Policy Department at the National Rural Electric Cooperative Association (NRECA). At NRECA his primary role is technical advisor for the T & D Engineering Committee. The subcommittees he works with are System Planning and Smart Grid. He is also the Program Manager for the MultiSpeak® software integration initiative. Mr. Saint graduated from Wichita State University, in Wichita, Kansas, with a BS degree in Electrical Engineering. Since graduation he has worked for electric utilities in Texas (2½ years) and Colorado (22 years). He worked for Tri-State G & T for over 5 years primarily performing substation design and 17 years with distribution cooperatives in Colorado. He is a registered Professional Engineer in Texas and Virginia.