Service Oriented Architecture (SOA) for electric utilities in electrical distribution

Student: Lazaro Adolf Luhusa

Supervisors: Prof. Dr. Marco Aiello,
Drs. Giuliano Andrea Pagani

University of Groningen

Acknowledgement

I wish to express my appreciation to those people who supported me to the completion of my Msc studies. I would like to thank my supervisor prof. dr. Marco Aiello, prof. dr. Michael Biehl and Drs. Giuliano Andrea Pagani. They invested their time, ability and talent to guide me, challenge me and provided me with the constructive ideas to pursue this research.

My appreciations go to my colleagues at the department of computing science. We shared knowledge and experience which encouraged me to the success of my studies.

I want to thank my good friends, M.D. Kwayu, E. Kihanga, Z. Talib, L.Ishemoi, J. Nguridada, M. Venaely, A.Mbinga, V. Kidole, A. Silungwe and M. A. Mrema. Being with them made me feeling at home by socializing through internet chatting, jogging, traveling, football playing and partying. Many thanks should also go to my African friends in Groningen for unforgettable social life.

Appreciations will also go to NFP program which provided me with the scholarship opportunity to pursue my masters program in the Netherlands.

Appreciations will also go to Sokoine University of Agriculture management who accepted my absence for two years.

I want to thank my wife Regina for her love, commitment, encouragement and tolerance which gave me strength to study. And, of course, thank you to my daughter Clara who managed to remain close, though far away, and nourish my spirit. I love them greatly.

I want to thank my parents for their encouragement and support. They always called me through the mobile phone and provided me with the lovely spirit and a feeling of home. Thank you all.

Lazaro Adolf Luhusa

Groningen, August, 2010

Abstract

Electrical utilities require optimum information sharing for achieving electrical distribution goals. Utilities have various heterogeneous software applications which provide information. The heterogeneity nature and network infrastructure bring three main problems, redundancy of similar software components, lack of interoperability and difficulties in attaining software evolution.

We investigate Service Oriented Architecture (SOA) and significant electrical standards to study the interplay between them to address the mentioned information problems of electricity utilities. SOA provide loosely coupled, standards based and protocol independent distributed computing solutions. SOA is realised through the middleware (Utility Integration Bus (UIB)) which contains all the necessary protocols. Electrical standards such as CIM/ XML, IEC 61968, IEC 61970, IEC 62325, IEC 61850, IEC 61870 and IEC 62056 contribute to the integration of power applications.

We evaluated the SOA infrastructure in terms of quality attributes such as availability, performance, scalability, modifiability and security. We focused in the challenges and solutions which faces SOA. Moreover, we proposed researches which can be done to upgrade existing middleware. The conclusion part kept attention on the challenges and solutions which faces the electrical standards.

Contents

Figures

Table

1 Introduction

1.1 Background

The Service Oriented Architecture (SOA) approach [3] provides a set of design principles that address the requirements of loosely coupled, standards based and protocol independent distributed computing for the purpose of connecting heterogeneous components and systems. The hardware and software work independently as building blocks providing the complete services to solve the required problems. Electricity distribution is the delivery of electricity from the transmission systems and some generators that are connected to the distribution network to the industrial, commercial and domestic users. The distribution network include equipments such as medium-voltage power lines, pole mounted transformers, electrical sub stations, low-voltage power lines and electricity meters. Electric utilities use these equipments to deliver electricity.

Different heterogeneous applications have been connected to the electrical equipments. These applications use the network infrastructure which is either standalone machines or point to point connected machines to support processes relating to electricity distribution. Some of the main processes of these applications are: real time information processing from electrical objects, metering information processing, customer information processing, etc. These processes are required for monitoring, planning, control, trading, management and data archiving.

The heterogeneity nature and the network infrastructure of these applications have caused three main problems such as: redundancy of similar software components, lack of interoperability and software evolution attainment.

Redundancy of similar software components has caused electrical utilities to invest money improperly. Moreover, it has caused redundancy of the same data into multiple sources [4, 5].

The lack of interoperability between processes has hindered information sharing. Processes such as the delivery of planning reports, electricity invoices and electricity operations had been practiced inefficiently due to the lack of information sharing.

Software evolution attainment is process of changing the software due to the changing environment. The power industry is in significant stage of evolution in many of the countries [2]; deregulation and competitive market have been introduced causing electric utilities to compete for electricity business. The evolution has raised the emergence of new business functions [2] such as contracts management, electricity trading, market data analysis, meter information and statistics. Consider an electrical utility which is responsible for electrical distribution grid would like to analyze the power voltage in several medium power lines for the purpose of power lines expansion. The existing solution is to analyze the data from each stand alone machine which is connected to the required power lines. Such a solution takes time and money. Electric utilities applications must evolve to solve such type of business functions. The evolution of software should be independent of one another, at low cost, and high customer satisfaction.

SOA is the solution for electric utilities at a reasonable cost to accommodate old and new requirements. It supports integration architecture which provides a loose coupled, flexible and extensible integration pattern which is a key issue in a decoupled electric market. It consists of three roles named service provider, service broker and service requester which are linked to each other by the operations of publish, discover and binding. The service is the main issue connected to those operations. Services have neutral interfaces causing them to be consumed or requested independent of hardware, platforms, operating systems and programming languages. Web services are the key issue for the realization of service oriented architecture. The series of standards such as IEC 61970, IEC 61968, IEC 61850, IEC 60870 and IEC 62325 provide interfaces for the electrical systems to interact. The open standard such as common information model (CIM) was developed to represent electrical equipments as common set of objects and their relationship.

1.2 Research question

How can the business processes of the electrical utilities get integrated to achieve the optimum electrical distribution as mentioned above?

To answer this question requires investigation on the following issues:

1. How do current electrical utilities negotiate electricity?
2. How can the electrical utilities move to SOA?
3. What are the current standards?

1.3 Thesis Organization

This thesis is divided in eight chapters: The first chapter contains the introduction which constitutes the main definitions, background, problem statement, proposed solution (SOA) and research question. The second chapter discusses the significant information which relates to electricity distribution. Electricity market, major business process and major IT systems are discussed. The interchanged service is also discussed. The third chapter is concerned with the details of the proposed solution. SOA is discussed in details. The forth chapter discusses the information about significant standards. The fifth chapter discusses about integration. The sixth chapter discusses about evaluation in which SOA is investigated in terms of quality attributes. The seventh chapter is concerned with the future work (vision). The last chapter contains the conclusion and bibliography.

2 Electricity Distribution

Electrical utilities constitute network operators, traders, generators and retail suppliers. They have the function to transmit, generate, distribute and trade electricity. Electricity negotiation is an agreement between electrical utilities to exchange a bulk of power. Also electricity negotiation is an agreement between electrical utilities and customers to deliver power to the customers. Currently, Electricity negotiation is influenced by the forces of electricity market.

In this chapter, we discuss the electricity market, supporting processes for electricity distribution, major IT support systems and information exchange.

2.1 Electricity Market

The electricity market is characterized by three main issues [2]: Open access network which separates the functions provided by the participants in the market; Competition in the functions provided by generators and traders; a free market which gives flexibility in the price of electricity. Figure 1, describes the flow of energy from the generators to the network operators. It also shows the flow of energy contracts from the suppliers and customers to the transmission system operator. An energy market is a commodity market that specifically deals with the electricity market under the regulation of government policies.

2.1.1 Open access network

The main suppliers of electricity are generators, traders and retail suppliers. The generators create electricity after they have received a demand in advance from the customers and traders. The traders are the potential electricity buyers and after that they sell their electricity directly to the retail suppliers and certain types of customers. Retail suppliers sell electricity to individuals. The suppliers sign energy contracts with the customers and inform the network operators about their energy programs. The customers are free to switch their suppliers when they are not satisfied with the service. There are many suppliers in the energy market and each of them is trying to provide the service in the excellent format in terms of electricity price and quality of support.

The distribution network operators are responsible to deliver the following electricity services: Transfer electricity to the customers from the pool of electricity under special transfer tariffs, they have to maintain the security of electricity supply in terms of reliability of supply, transfer losses minimization, quality of voltage and frequency and overall effectiveness. The national grid company is the main supervisor and controller of the transfer services.

2.1.2 Competition in power generation and trading

The power generators and traders have to make sure that they remain successfully in the business as they know customers are free to switch their contracts. The efficiency of their operation is the key issue to make them surviving in the competition market

2.1.3 A free market place

The customers, traders and generators establish the price of electricity at the market.

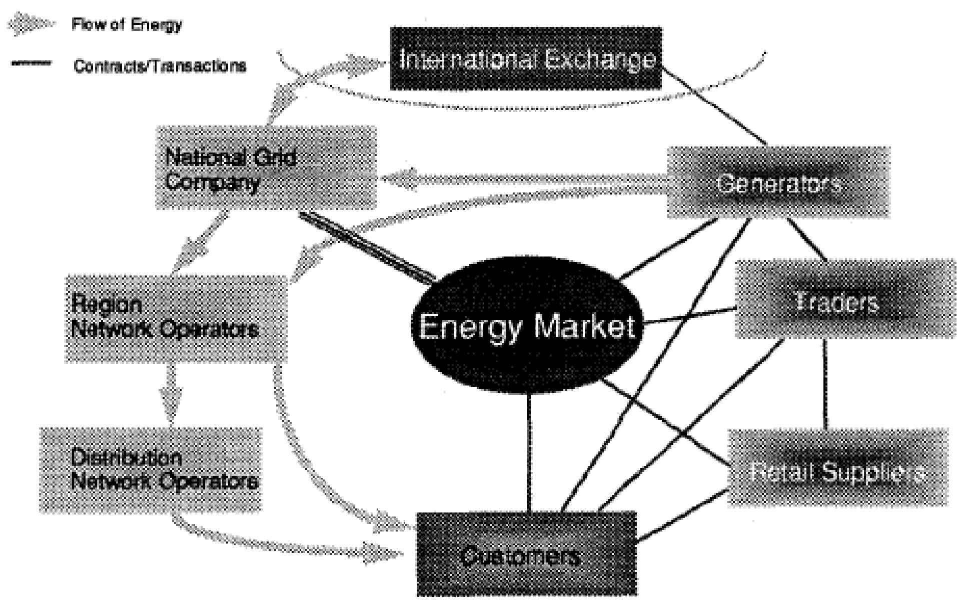

Figure 1 Electricity Negotiation [2]

2.2 Processes for electricity distribution support systems

The electricity market described in section 2.1 has led to the new demands of processes for the support systems in the electricity distribution. The electric utilities (suppliers, traders, network operators) require systems [2] that can support all business processes. The traditional energy management systems must be set to the demands of new requirements to deliver optimum operation. Below are few significant requirements for the electricity distribution.

2.2.1 Business Support

These are the types of processes which covers all the interfaces with the market oriented systems. The support for business process consists of customer information, contracts management, energy trading, retails sales, market data analysis, energy accounting and billing.

Customer information- This is a process that covers customer information from various databases of electrical utilities. Customer analysis such as potential customers can be reported by using this database.

Contracts management- This is a process that covers contracts management. Contract analysis such as the amount of electricity purchased from a specific generator can be reported by using this function.

Energy trading- This is a process to support energy trading between generators and suppliers, both in the market and bilateral contracts. It must support the marketing and bidding electronically through posting and negotiations.

Retail sales- The retail package must offer functions for retailing activities such as support energy agreement with the households.

Market data analysis- This is the process that takes market information as input, analyze the market contents and the output shall be various reports into various formats. The format such as graphical presentations will be required.

Energy accounting- The package must support measuring and analyzing energy consumption to improve energy efficiency. The users of the system can know how much energy is needed at each connected point. The system keeps track of energy in and energy out.

Billing- The package brings revenues to the company. It supports customer invoices, payment tracking, etc. The system uses energy contacts and customer information to deliver the billing.

2.2.2 Operation support

The operation support covers all processes to keep the network up and running providing a high quality supply of energy to the customers. The operations such as network control, planning and supervision are significant in determining the most cost efficient power generation both long term and short term. Below are a few examples in which the traditional energy management systems can fit into the new electricity distribution.

Load forecast- The system must support load forecasts to help discover potential customers for any supplier. The load forecasts are related to the market analysis and in this way utilities can use the information to make significant decision.

Power transfer capability evaluation- This function is required to calculate the maximum transfer capability of power between areas. This is important so that the power transfer does not exceed the transfer capability for power system planning.

Wheeling transaction evaluation- The wheeling transactions are the act of transporting power between areas or the provision of transmission services over transmission lines.

Utility need to know the amount of power transferred or congested within the transmission lines for cost analysis.

Fuel Allocation and optimization- This function is to support the operational planning of activities to reach decision making regarding fuels, emissions, thermal and hydro generation transactions.

2.2.3 Metering support

Metering information is a vital issue for companies since it is the source for generating energy invoices. Faster and reliable metering is required for connected electricity points. Analysis of the metering information can led to price setting. A common standard for metering, meter data collection, communication and reporting are required as the base for electric utilities performance. Below are the few key points regarding metering functionalities

Energy counters and tariffs data- Energy counters and tariffs data are collected per a connected point and stored in the identified database. This can be done according to the existing policy, let say hourly etc.

Meter data- This is the management of meter data. The function provides handling of data to deliver various analysis reports including the billing. The energy counters are stored over certain period of time and then they are used for the purpose of analysis and billing.

Information reporting- Energy and accounting information are handled by this function to provide analysis of reports for electronic media, hard copy depending on the standards of the agreement of each electricity market.

Meter information and statistics- This is the handling regarding information of the metering communication system. It is important to know the status of the meters.

Customer two way communications- This function is required to achieve the objectives of remote metering in a competitive market. In a two way communication data are transferred to the central data management station and in return data can be transmitted back to the meter devices. The return data can be messages, power off the electricity, remote software upgrade etc.

2.3 Major IT systems

There are various types of systems which support the activities of electricity distribution. The systems cover the processes explained in section 2.2. Efforts have been made to update the traditional systems to meet the demands of new electricity distribution. Considering an example of the supervisory control and data acquisition (SCADA) has evolved [7] from first generation “Monolithic”, second generation: "Distributed" and now third generation: "Networked". The third generation of SCADA systems utilizes open standards and protocols to make the systems exposed to the Wide Area Network. Below is a discussion of few major IT support systems in the electrical distribution [6]. The interrelation between the processes is also explained.

2.3.1 SCADA/DMS (Supervisory Control and Data Acquisition/ Distribution Management System)

It is the process of physical devices management. SCADA is also known as process of collecting data from physical devices in the substation region for the purpose of monitoring and archiving in computers and applying commands from computers to control the devices [8]. SCADA systems consists of four potential components/subsystems

The human interface- This is the place in which information can be presented to the human operator. Control, monitoring and archive are usually done at this place.

A supervisory (computer) system- This is a machine which acquire data from physical devices and send commands to the physical devices.

Remote Terminal Units (RTUs) - These are components which capture data from the sensors and convert sensor signals to digital data and sending digital data to the supervisory system.

Programmable Logic Controller (PLCs)- These are the components which have the same functions as RTU except that they are more advanced in terms of economical, versatile, flexible, and configurable than special-purpose RTUs.

Communication infrastructure- This is the connection between the supervisory system and the Remote Terminal Units.

The main functions of the SCADA systems are explained in [6]. The system is able to achieve Monitoring, planning and control operations of electricity distribution devices in real time. This is facilitated by data acquisitions such as meter reading and sensors, which are communicated at regular intervals depending on the system. The human operator through an interface is able to override settings or make changes in the devices when necessary.

2.3.2 Network information systems (NIS)

The NIS is the information systems which stores the information about all objects in the electrical network topology. The objects are equipments like transformers, electrical switches and other related equipments for electricity distribution. The attributes like location of the objects and names are required for network management to provide optimum electricity distribution. Normally the NIS contains the Geographical information systems (GIS) functionality. There are other functions which the NIS can do as expressed in [6]. The functions like load flow studies, protection coordination engineering, reliability estimates, engineering and budgeting tools are possible in the NIS systems.

2.3.3 Customer information systems

These are systems which provide information about the customers. Information like names, addresses, meter number and energy usage information is required by other systems. The information about a customer is obtained when a customer is registered for the service of electricity.

2.3.4 Computerized Maintenance management systems

This is a system which provides a detailed register of all utility assets. It also provides transactional data such as work order management, project management and purchasing.

2.4 Information interchanges

These are services offered by the systems to the external people or to other applications for the purpose of delivering the intended objectives. The case list of services required by other systems [6] is described in figure 2.

The SCADA/DMS requests for up to date information about the networked objects for the purpose of fault isolation or other purposes as in [6]. The bulk and incremental exports from the NIS to the SCADA as indicated by number 1 contains regular updates of the networked objects.

The NIS requires meter readings and other customer information from the CIS to provide the network analysis such as load flow analyses. Load flow analyses is the study of various forms of AC power (i.e. Reactive, real and apparent) rather than focusing on voltage and current. The study is important for the planning of the future expansion of power systems and is important for improving the existing systems. The customer classes and annual energy consumption as indicated by number 3 contains meter readings and other customer information which is significant for load flow analyses in combination with other information in the network information system.

The CIS/CRM exchanges information with the SCADA/DMS as indicated by number 2. Customer information regarding the queries of the service is needed in the SCADA, outage management part for fault analysis and solving. The DMS will update the CRM on the estimated restoration time. The CRM will submit customer trouble reports to the

DMS system for notification and evaluation. The DMS will use the reports to trouble shoot and supply restoration.

The ERP/CMMS exchanges information with the SCADA/ DMS as indicated by a number 4. The CMMS require reports for planning and preventive maintenance of power system components located in the electrical network. The reports will be received from the SCADA/ DMS and they will contain information about equipment faults which is required for corrective maintenance and equipment usage history which is required for estimating reliability.

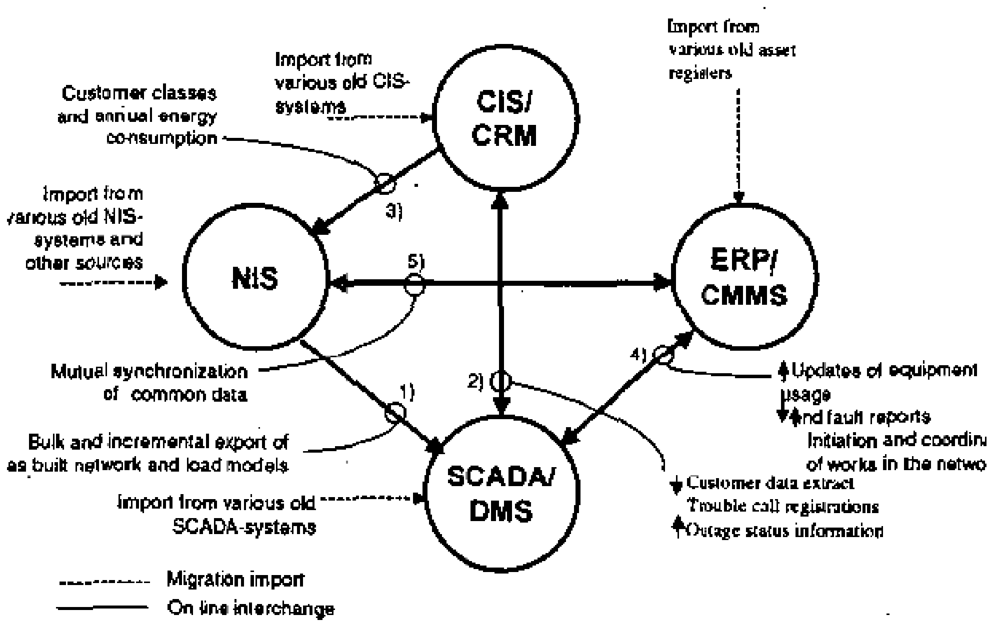

Figure 2: Information exchange [6]

3 SOA

Service-Oriented Architecture (SOA) is the computing paradigm that utilizes services as fundamental elements for developing applications/solutions [11]. A service is a business function that is provided by any computer application and is a main element which is communicated between computer applications to achieve the desired end results. The business functions of computer applications are wrapped with web service interface to provide services over the internet, local network or intranet. This is possible because the interfaces are defined in neutral manner, and are independent of hardware platforms, operating systems and programming languages. The generic semantics of interfaces between computer applications have reduced dependencies to a minimal resulting loose coupling. The descriptive of the exchanged services follow the *structure, format and vocabulary* in which all the participating entities will understand and hence allowing interoperability while realizing sharing of information.

The standards such as Common Information Model (CIM) and Generic Interface Definition (GID) developed by International Electrotechnical Commission (IEC) have been significant to provide capabilities to operations, planning, design and client services department [4].

Through SOA, Electrical utilities can match and mix significant functions of electrical distribution with minimal programming to provide complex transactions.

3.1 Web services

A web service is a software resource that can be accessed by a uniform resource identifier (URI) whose service description and transportation utilize open internet standards [1]. The adaptation of a web service into a computer application leads an application to be renamed as a web service provider or web service consumer due to the technologies the web service implements. The two fundamental technologies which are implemented by the web service are Extensible Markup Language (XML) and Simple Object Access Protocol (SOAP). XML is a set of rules which is used for standardizing data formats to help data exchange among different platforms. XML has become a global tool for exchanging business data and has been adopted by World Wide Web consortium (W3C). XML, similar to HTML has a capability to provide a designer with the ability to create self describing messages. This capability is platform neutral to transport mechanisms (HTTP, FTP and SMTP), calling conventions (the order in which parameters are passed or how data is returned) and data formats. SOAP is a protocol to provide the exchanging of structured information (XML messages) in the domain of web service implementation.

A web service provider is a new kind of a software service that is modular, platform independent, self-describing, and self contained applications that can be published, located and dynamically invoked across the web [5]. The properties of web services make software services discover each other, connect dynamically and execute transactions in real time with minimal human interaction. Web services have led computer applications of different utilities to be integrated and benefit from the core principles of SOA. Computer applications can message to each other by using Extensible markup language (XML) under the umbrella of SOA enabling frameworks (e.g. Oracle Fusion, Microsoft BizTalk and IBM WebSphere).

There are three fundamental components for a web service: service providers, service consumers and service registry [1] [5] [9]. See figure 3

Service providers are computer applications which expose their services through their interface by using Web Services Description Language (WSDL). WSDL is an XML based language which is used to describe and locate the contents of a web service. WSDL is an entry to the address book.

Service consumers are computer applications which require invoking services from other applications. Invoking of a web service is done by using the Universal Description, Discovery, and Integration (UDDI). UDDI supports the service consumer to find, locate and point to a service and there after the exchange of message is done by using the SOAP. SOAP is an XML service protocol that is responsible for transporting messages between network applications over the same hyper text transport protocol (HTTP).

Service registry is a service directory which stores the services of all connected computer applications. The standard name for it is Universal Description, Discovery, and Integration (UDDI). It is an online directory through which registered web services advertise their business services.

The use of standard XML protocols makes web services platform, language and vendor independent. Service oriented architecture (SOA) utilizes the web services to integrate the business services within electrical utilities and across electrical utilities over the internet by using open standards and XML encoding.

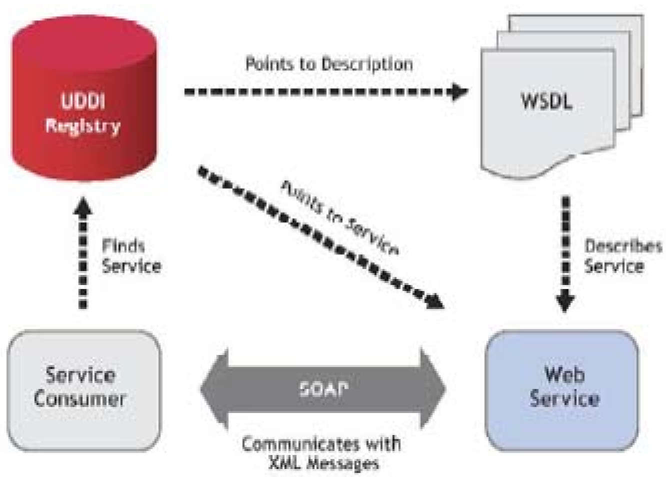

Figure 3: Web service architecture [9]

3.2 Service Management

Once a computer application has been configured with a web service that means it can act as a service provider or a service consumer. We have already described in section 3.1 how service provider and service consumer share information. Actually the service provider has to publish its services to the online directory (UDDI) and through the directory the service consumer has to find a service. The service consumer will then point to the service following by the exchange of messages between the service consumer and the service provider. Such a design system is possible in the small systems infrastructure. This will lead to the multitude of dependencies for a large system and hence causing problems such as system troubleshooting and difficulties in integration logic changing. Figure 4 describes the way business services communicate without the central control.

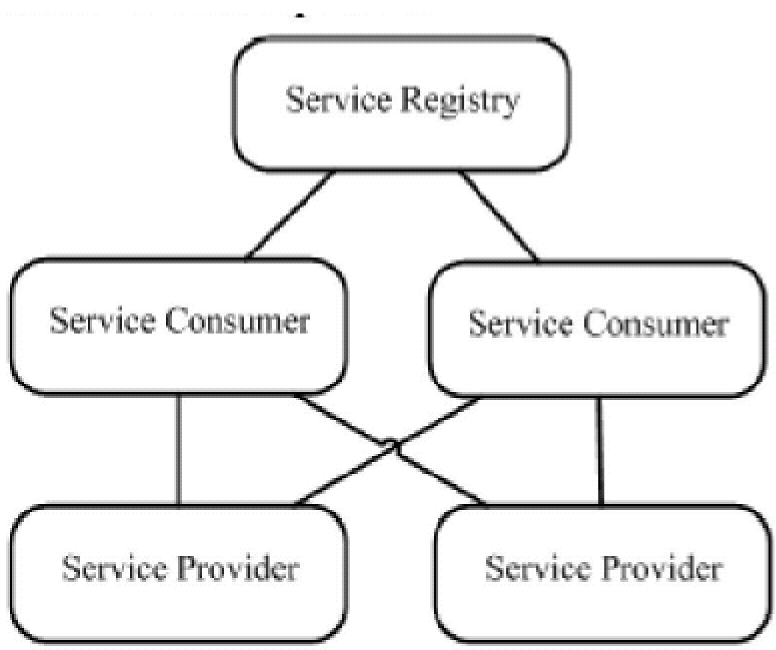

Figure 4: Interaction of service consumer and service provider [35]

The solution to such types of problems is to use an orchestration engine. Orchestration engine is an engine which is used to manage the composed business services. The manageability and maintainability occurs centrally and in this way there is no need for business services to interact in the form of point to point. Figure 5 shows the orchestration engine managing the services 1, 2 to "n" services.

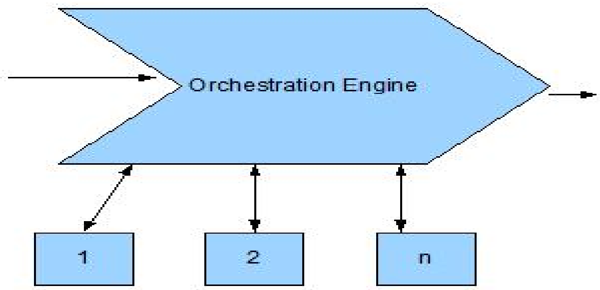

Figure 5: Orchestration of services

3.3 The layers of a SOA

There are seven layers of SOA. Figure 7 represents the seven layers of SOA

Layer 1: Operational layer

Electrical utilities have various computer applications which support business functions. The operation layer is a lowest layer which is built up with the portfolio of existing computer applications which provides significant functionalities. These applications include: Legacy applications and systems, which are applications which are still useful to the electrical utility but they are not supported by the vendors. Existing transaction processing systems (such as SCADA), which are current useful to the electrical utility and still get supported by the vendors. Existing databases are broad database which store information regarding the operations of the electrical utilities. Information like asset management will get extracted from the similar databases. Existing packaged applications and solutions, including enterprise resource planning (ERP). The integration techniques in the composite layer of SOA can leverage existing systems and integrate them.

Layer 2: Enterprise Component layer

This layer is built up with software components which contain the implementation details for the functionality realization of the utilities computer applications. Figure 6 describes the software component which satisfies three factors. First, the component act as a single enforcement point to ensure the quality of service obtained from packages x and package y. The quality of service is achieved by adhering to the service level agreements (SLA). Second, a software component assures business flexibility since it supports functional implementation of different flexible services. Third, a software component assures information technology flexibility. Package x may be removed without the awareness of the consumer application B. A package can be replaced with another improved package without any impact to the consumer.

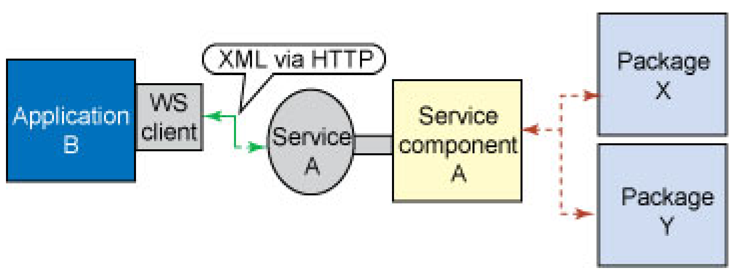

Figure 6: service component architecture [14]

Layer 3: Services layer

This layer is the residing base of services. The service layer is a layer which is built up with abstract specification of a collection of (one or more) business-aligned functions of computer applications. A service is a realization of a business function and can be accessed over a network. The specification is the sufficient contents which describe the platform independent invocation techniques such that the service consumer can bind the services of the service provider. Standards (such as WSDL) can be used to describe the invocation techniques. Services at this layer can be choreographed to form other composite services.

Layer 4: Orchestration layer

The composed services in layer 3 are orchestrated in this layer. The orchestration of services means that services are impacted by automated arrangement, coordination and management. Business process execution language is a language to enable the impacts described. This layer utilizes web services to be discovered by other orchestration layers

Layer 5: Presentation layer

This is the layer in which the business services are consumed by the end users. The consumption of services includes providing business functions and data to meet specific objectives of the end users. This layer interfaces the orchestration engine through specific mechanisms such as channels, portals, rich clients. Various standards such as Web Services for Remote Portlets (WSRP) Version 2.0, portlets, and Web Services for Remote Portlets (WSRP) support the mechanisms for interfacing between the end users and the components. Utilities can have a web portal to interface with the integrated business functions.

Layer 6: Integration Layer

In this layer, key activities for SOA are found, making a layer a key enabler. The layer has capabilities to messaging, intelligent routing, data transformation and web services to reliably connect and coordinate the interaction of significant numbers of diverse applications across the extended enterprises with transactional integrity [13]. The integration that occurs here is primarily the integration of layers 2 thru 4. This is the layer that provides communications, invocation, and quality of service between adjacent layers in an SOA [14]. For example, this layer is where binding of services occurs for process execution, allowing a service to be exposed consistently across multiple customer-facing channels such as Web, Seibel client, and the like [14].

Layer 7: Quality of Service.

In this layer, non functional requirements (such as reliability, availability, manageability, scalability, and security) are fulfilled. The layer acts as an observer for each layer and is able to emit signals when non compliances have been detected. It insures the required non functional requirements for each layer complies with the supposed requirements.

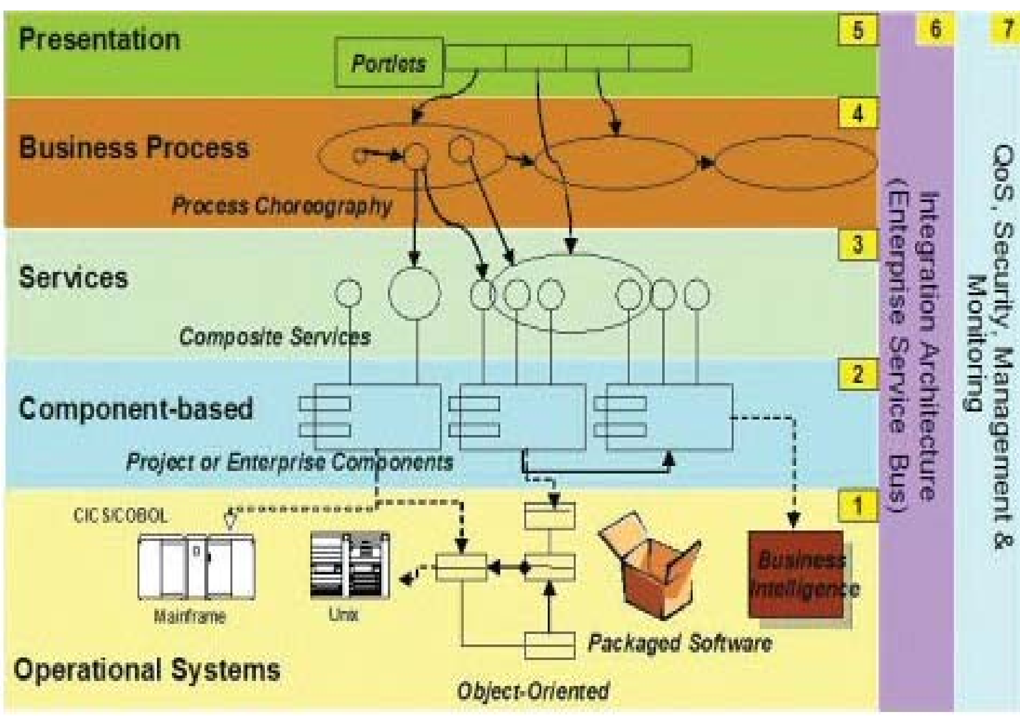

Figure 7: The layers of SOA [10]

4 Standards and Integration Technologies

Efforts have been made since the early of 1990 by the Electric Power Research Institute (EPRI) to create standards for data communication. EPRI initiated aggregated projects to push the wheel towards electrical standards for utility operations. The Control Center Application Programming Interface (CCAPI) developed the Common Information Model (CIM) which is important to describe what data is exchanged between applications. The International Electrotechnical Commission (IEC) focuses on developing the interfaces which describes how the data is exchanged between applications.

4.1 Common Information Model (CIM) - SOA

A CIM [15] is an open standard that provides applications with the common meaning to allow them to exchange information about configuration and status of an electrical network between many different applications. CIM supports what data to exchange and reduces number of data transformations from N*(N-1) to N. The primary purpose of CIM was to adopt the standard only in the Energy Management Systems (EMS). The purpose which was later extended to allow interoperation of systems and applications used for production, transmission, distribution, marketing and retailing functions of electric, water and gas utilities.

CIM- SOA [34] uses a Resource Description Language (RDF) to create the abstraction of objects. RDF is a language which is used to represent resources in terms of XML schema. CIM uses RDF to describe real world objects in terms of classes, properties and relationships.

The idea of using CIM/ RDF is evolving from CIM/ Unified Modeling Language (UML). UML is a standardized modeling language which can be used to specify, visualize, modify, construct and document the abstract view of an object-oriented software intensive system under development. CIM uses UML to describe real world objects in terms of classes, attributes and relationships.

The limitation of UML is in the interoperability between different geographical distributed vendors. XML is only a language which can describe the exchanged messages without limitation.

Figure 8, describes the simplified CIM/ UML which is mapped to the CIM/ RDF. The breaker is a sub class of a switch and contains the property ampRating. A switch is a sub class of the conducting equipment and contains the property normalOpen. The ConductingEquipment contains the property terminal.
In CIM/ RDF, a class is named as rdfs:Class, a subclass is named rdfs:subClassOf, a property is named rdf: Property

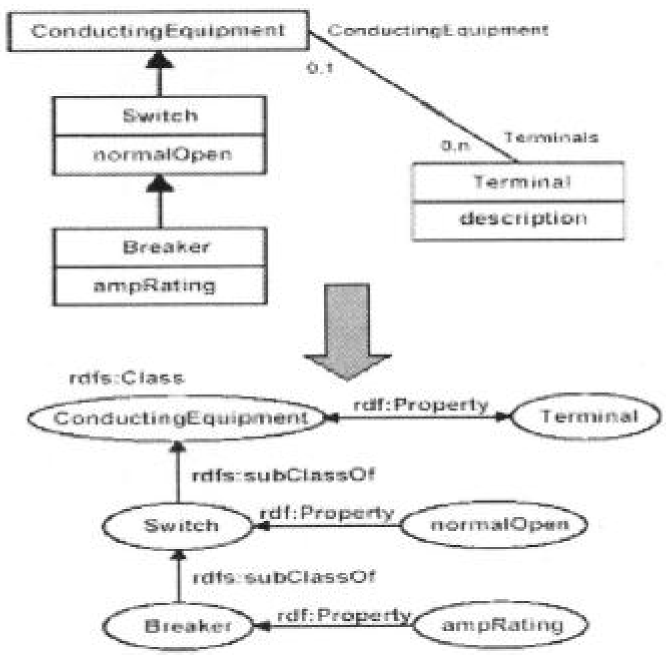

Figure 8: The mapping of CIM/ UML to CIM/ RDF [34]

The mapping to CIM/ RDF generates an XML document which can be interpreted by any application regardless of the location, language, operating system and hardware. Figure 9 describes a resource Breaker which has two property values ampRating and InTransitTime. The Breaker contains two terminals which are described the

ConductingEquipment. Each terminal is described by two property values, name and description.


```xml
<cim:Breaker rdf:ID="BRE00001">
<cim:Naming.name>BRE1</cim:Naming.name>
<cim:Breaker.ampRating>1000</cim:Breaker.ampRa
ting>
<cim:Breaker.inTransitTime>0.2</cim:Breaker.inTra
nsitTime>
</cim:Breaker>

<cim:Terminal rdf:ID="TER00001">
<cim:Naming.name>BRE1_T1</cim:Naming.name>
<cim:Terminal.description>Terminal_ofBRE1</cim:
Terminal.description>
<cim:Terminal.ConductingEquipment
rdf:resource="#BRE00001"/>
</cim:Terminal>

<cim:Terminal rdf:ID="TER00001">
<cim:Naming.name>BRE1_T1</cim:Naming.name>
<cim:Terminal.description>Terminal_ofBRE1</cim:
Terminal.description>
<cim:Terminal.ConductingEquipment
rdf:resource="#BRE00001"/>
</cim:Terminal>
```


Figure 9: The Breaker Data in the CIM XML using RDF schema [34]

4.2 IEC Standards

The International Electrotechnical Commission (IEC) technical committee 57(TC57) working groups 13 and 14 (WG13 and WG 14) have developed a set of standards that enable middleware to achieve the integration of real time and non real time power system applications in electrical utilities. Middleware is a software entity built with standards that connects software components regardless of their hardware platforms, operating systems and programming languages and in this way allows interoperability between systems. Middleware includes web servers, application servers which utilize fundamental information technology such as XML, SOAP, CIM, Web services, and SOA. The TC 57 has split the work of developing the standards into various parts [9]. WG 13 is developing IEC 61970 standard for transmission power systems and WG 14 is developing IEC 61968 standard for distribution power systems. WG 10 is developing IEC 61850 for substation automation. WG 7 is developing IEC 60870 for Wide Area Network

4.2.1 IEC 61968 Standard

The objective of the IEC 61968 [12] [20] series is to enable information exchange between electrical distribution systems. Utilities collect data from different distributed systems that are legacy or new systems and each has a different interface and run time environment. The purpose is to support inter distributed systems integration which are loosely coupled applications and heterogeneous in nature. This standard supports high speed of data transfer between systems and is intended to be built in the enterprise service bus.

The IEC 61968 defines various interfaces and CIM for its operations. The interfaces provide the capability to integrate with the intended mentioned system. CIM provides the capability to describe what data is intended to be exchanged within the electrical distributed power systems.

The IEC 61968-1 for Interface architecture and general requirements, in which the general picture of the way the systems can interact to one another is provided. This standard provides a framework which includes the CIM and interfaces for the systems to integrate.

IEC 61968-2 for Glossary, in which definitions, terms and abbreviations are explained in a manner which focuses in the distribution management.

IEC 61968-3 for Network Operations, in which the network operation systems are able exchange the messages with other systems. The core message is the operation documents which include operation restrictions, outage, safety and switching schedule.

IEC 61968-4 for Records and Asset management, in which records and asset management systems are capable to exchange messages with other systems. The core message includes information for network data sets, assets and asset catalogue.

IEC 61968-5 for Operational planning & optimization, in which systems related to planning are able to exchange messages with other systems.

IEC 61968-6 for Maintenance & Construction, in which distributed systems related to maintenance and construction are capable to exchange messages with other distributed systems.

IEC 61968-7 for Network Extension Planning, in which distributed systems related to Network Extension Planning are able to exchange messages with other distributed systems

IEC 61968-8 for Customer Support, in which a customer is able to be supported because of the message exchange relating to customer queries with other systems.

IEC 61968-9 for Meter Reading & Control, in which Meter Reading and Control systems are able to exchange messages with other systems. The message include meter reading, meter control, meter events, customer data synchronization and customer switching.

IEC 61968-10 for business functions external to distribution management which includes Energy management & trading (EMS), Retail (RET), Supply Chain & Logistics (SC), Customer Account Management (ACT), Financial (FIN), Premises (PRM) and Human Resources (HR).

IEC 61968-11, IEC 61968-12 and IEC 61968-13 define the Common Information Model (CIM) Extensions for Distribution, Use Cases and RDF Model exchange format for distribution respectively.

IEC 61968-14-xx, IEC Standards to Map IEC 61968 and MultiSpeak Standards. Implementation of MultiSpeak functions. MultiSpeak is a standard based in the US which defines the data to be exchanged. It is similar to IEC 61968/ CIM in the sense that they both use XML schema for data message formatting. MultiSpeak has unique properties to make it different from IEC 61968/ CIM. MultiSpeak focuses in the distribution only and it is transport specific.

Figure 10, clarifies the IEC 61968-1 for Interface architecture and general requirements. The interfaces of power distributed systems are built with this standard to enable connections with other systems. The network operation system scans information from distributed substation and share the information with other systems such as utility business systems

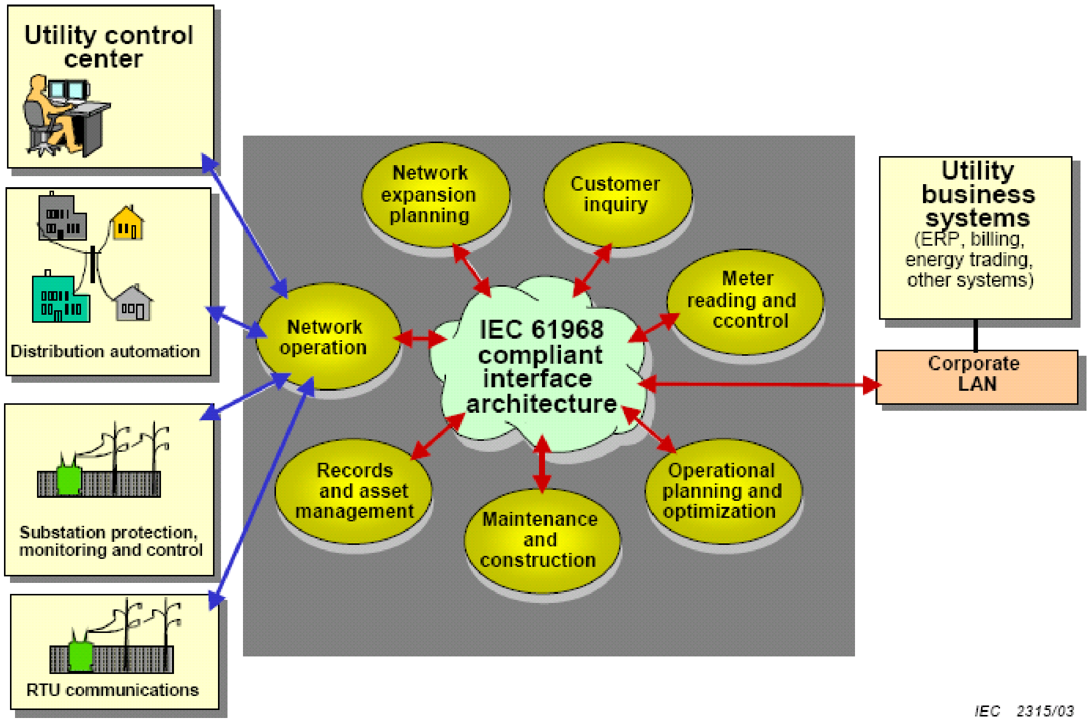

Figure 10: Distribution management system with IEC 61968 compliant interface architecture [20]

4.2.2 IEC 61970 standard

The objective of the IEC 61970 [9] series is to enable information exchange between electrical transmission systems within the control centers of the electrical utility. The focus of this standard is: to enable the integration of applications developed by different vendors in the control center, to enable the exchange of information to the systems external to the control center, to provide suitable interfaces for data exchange across legacy and new systems. IEC 61970-3XX is the core part of the CIM and is defined by the wires model. The wires model is the description of the electric components which transport electricity. IEC 61970-5XX and IEC 61970-4XX are parts which define the interfaces using XML for the purpose of data exchange. RDF is the model which is used to define the XML. IEC 61970-4XX is also called generic interface definition (GID).

Generic Interface Definition (GID)

The GID is the standard interface which falls into four types of interfaces. Each interface shall be utilized depending on the required demands when applications connect directly or through an integration framework such as enterprise message bus or data warehouse. The major functionality of the GID is to provide a mechanism on how data is exchanged between applications.

Generic Data Access (GDA)

This is a standard interface, request and reply oriented service that supports accessing and querying randomly structured *generic data* from a specific application [9] [15] [16]. This request and reply–oriented service is intended for synchronous, non-real time access of complex generic data structure. The interface does not need to know the logical data schema of the application it accesses; only a common information model is sufficient for accessibility and querying. The interface is also a platform independent therefore it can be used by different vendors.

The GDA is an extension of Data Access Facility (DAF) of the Object Management Group (OMG).

High Speed Data Access (HSDA)

This is a standard [9] [15] [16] interface which provide request/ reply and publish/ subscribe oriented service intended to allow the exchange of *real time data* at a high speed. The interface has a capability to support namespace defined in TC57 and hence the task of data exchange is done in a user friendly way.

The HSDA is a platform neutral and is derived from two groups: first, OPC data access (OPC DA and DA XML) which was a window product. Second, Data Access from Industrial Systems (DAIS) which comes from CORBA, java and c languages

Figure 11, describes the exchange of data between the SCADA system and SCADA client at a high speed exceeding the rate 5,000 points per second through HSDA interface.

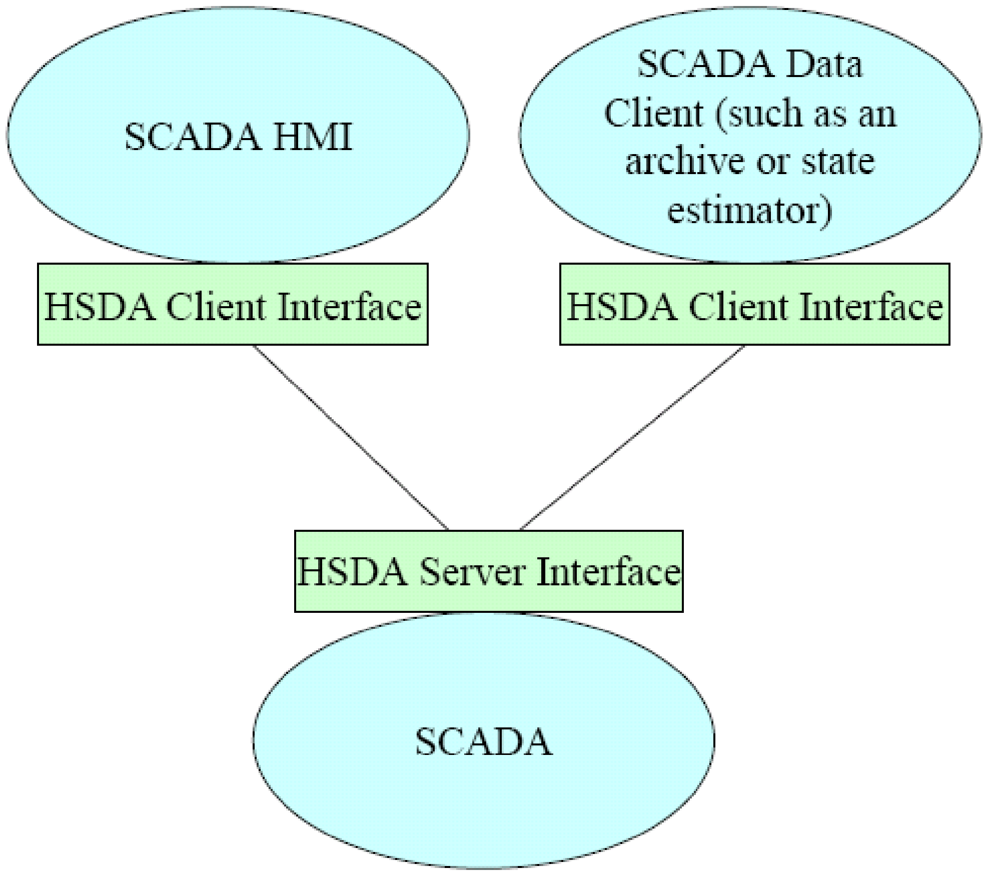

Figure 11: HSDA and SCADA system [15]

Time Series Data Access (TSDA)

This interface [9] [15] [16] was designed to provide the exchange of *historical data series* through request/reply and publish/subscribe oriented services. The interface has a capability to support namespace defined in TC57 and hence the task of historical data exchange is done in a user friendly way.

The TSDA is a platform neutral and has evolved from two groups: first, historical data access from industrial systems (HDAIS) which was specific for major software vendors such as CORBA, java and c programming languages. Second, OPC historical data access which was windows specific.

Figure 12, describes the exchange of data between the archive server and archive client through a TSDA interface. An archive server contains a series of data based on time. An archive client can access the data by customizing the request based on the dates it prefers.

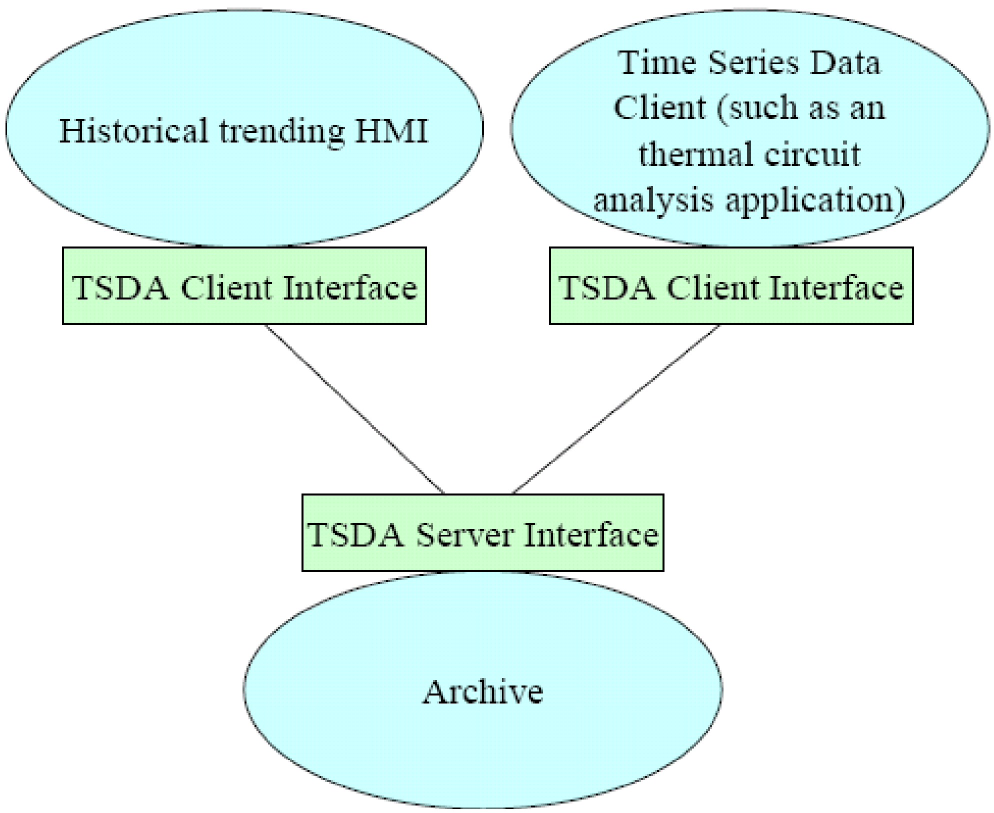

Figure 12: TSDA client and server exchanging an archive of data [15]

Generic Eventing and Subscription (GES)

This is a kind of standard interface [9] [15] [16] which provides applications with the capability to exchange XML data messages related to *alarms and events* through the operation of publish/subscribe. These publish and subscribe operations are achieved through the use of naming space derived from the Common Information Model (CIM). GES uses XML as its formatting language to describe the contents of the data and send it as an XML messages. The word generic, just as in GDA is due to the fact that the exchanged information does not define its operation, differently from TSDA and HSDA, real time and historical data defines the operation of the interface. GES is a platform neutral and has evolved from OPC Alarms and Events (OPC A &E and A & E XML) which was a window specific product.

4.2.3 IEC 61850 standard

This is the communication standard [17, 18] [36] which was developed for substation automation and integration. WG 10 TC 57 is the responsible working group for this communication standard. This standard was developed to enable the exchange of information between intelligent electronic devices (IEDs), IEDs and control centers, station control and IEDs. The abstract data model of this standard has been built with future vision in such a way that it can be mapped to the Ethernet technology such as Manufacturing Message Specification (MMS), GOOSE and soon to web services which run over TCP/IP.

The major features in this protocol are: *object oriented data model*, which provides the functionality of the IEDs in terms of the Logical Nodes (LN). These LNs consists of data and data attributes which represent information related to processes and configurations. Through the LN it is possible to configure, control, protect, and measurement/status exchanges. Figure 13, describes a physical device containing multiple LN. Protection and metering are the substation functions which also contain the type of information derived from the data with standardized units.

The configuration language (SCL) is an XML language which can be used to describe what has to be exchanged between the IEDs, part 6 of this standard describes an SCL. *Communication technology*, the communication services and models are designed with future forecast. The Abstact Communication Service Interface (ACSI) has been implemented into the communication technology so as the mapping to emerging Ethernet technology like MMS is possible. Part 7-2 of this standard is explaining about communication technology.

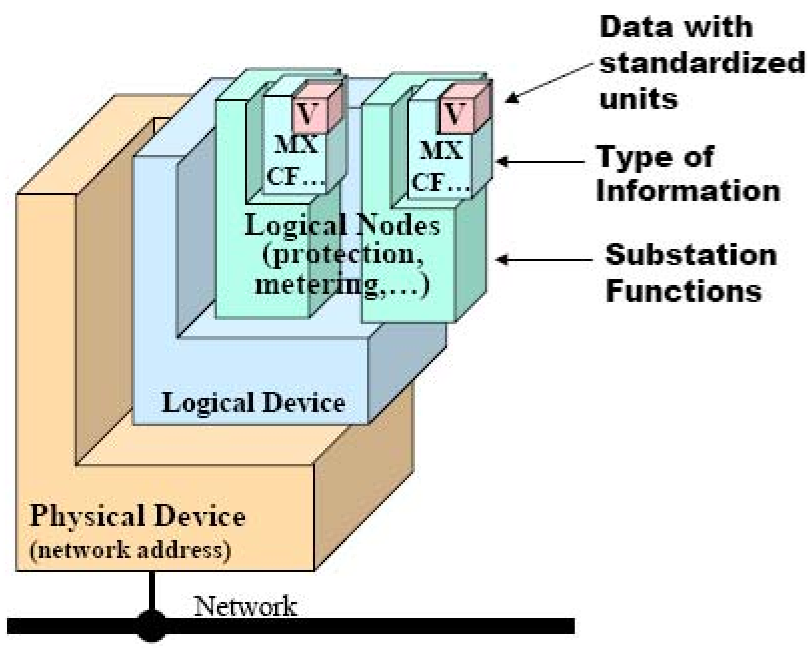

Figure 13: IED containing the logical nodes [18]

4.2.4 IEC 60870-6 standard

Section 4.2 and 4.4 explain the standards for data exchange within control centers and distribution substation respectively. The real time and non real time data need to be exchanged over Wide Area Network (WAN) between utility control center and other utility control centers, transmission system operator, generators, substation and market participants. IEC working group 7 has a responsibility to develop this standard to achieve the WAN data exchange. The data exchange includes the exchange of status and control data, measured values, scheduling data, energy accounting data and operator messages.

IEC 60870-6 is also known as Inter Control Center Communications Protocol (ICCP). It resides in the layer number 7 of the Open System Interconnection Model (OSI Model) and uses Manufacturing Message Specification (MMS) for transferring real time data and supervisory control information between networked devices or computer applications [19]. The mechanism of operation of the ICCP is either International Organization for Standardization (ISO) compliant transport layer or TCP/IP transport layer. TCP/IP over Ethernet (802.3) provides the common rules to make communications between networked devices. In this way it is the most common applicable.

The protocol architecture of the ICCP is a client/ server model [19]. The client and server can reside from the same or different control center. The data transfer requests are initiated by the client and the server provides the authorization for the access. Point to point or Wide area network are the two linking mechanisms for the client server model. Multiple associations may be created to support the client server model. It is allowed for a client to initiate multiple requests to the same server (control center) or multiple requests to different servers. The server owns the bilateral tables to provide the *access control* of the data. The access control holds the rules such as execute, read/write, read only and no access to the data.

ICCP consists of two types of object models [19]; data objects and server objects. Data objects are defined in the protocol part IEC 60870-6-802. These are the objects which do not implement the ICCP protocol and are recognized as external objects. These are the elements which are exchanged between control centers. The objects have the data attributes and methods and tend to be simple to complex data objects. Server objects are defined in the protocol part IEC 60870-6-503. These are the objects which implement the protocol and services. The objects consist of the methods termed as operations and actions. Operations are the methods which receive client initiated requests and send response to the client. Actions are initiated by the server to execute the required services for the requested services and respond back to the client with a report.

4.2.5 IEC 62325 standard

This is the standard which was built for market participants to ensure energy market communications. It replaces the previous standard which was called IEC 62195. The standard has been built with advanced modern technologies that make it use XML and replaces traditional Electronic Data Interchanges (EDI) with EDIFACT and X12

4.2.6 IEC 62056 standard

This is a protocol which was developed with the main goal of electricity metering. Originally, a protocol was developed as a Device Language Message Specification (DLMS) by the DLMS User Association. The protocol was later extended with the specification that defines the transport and application layers by the Companion Specification for Energy Metering (COSEM). The protocol was later adopted by the TC 57(WG 13 & 14) as electricity metering protocol to provide data exchange for meter reading tariffs, consumer information and load control. The protocol has various parts which lead to its achievements.

IEC 62056-42- This part [28] resides within the COSEM to provide physical services and procedures for connection-oriented asynchronous data exchange.

IEC 62056-46- This part [29] is based on the HDLC protocol to support the data link layer. The COSEM requests and responses are transported through this layer. There are other services accompanied with the data transportation such as data framing, data integrity checks, flow control, segmentation and re-assembly.

IEC 62056-47- This part [30] defines the transportation layer of the COSEM. This is an alternative transport layer for COSEM requests and responses over User Datagram Protocol (UDP) and Transport Control Protocol (TCP).

IEC 62056-53- This part [31] defines the application layer of the COSEM in terms of structure, services and protocols for COSEM clients and servers. It allows the exchange of metering information as modeled by objects and names [27]

IEC 62056-61- This part [32] defines the Object Identification System (OBIS) which is used to provide identification codes which are used to identify the most common used data items in the metering device. These identification codes uniquely identify all data items such as: all logical names of interface classes or objects as named in part 62, data transported in the transportation lines and data displayed on the metering equipment.

IEC 62056-62- This part [33] defines the interfaces classes which can be used to model the functionality of the meter. The interface classes insist different functions of the logical equipments which can communicate regardless of the product manufactures. For example, instantaneous quantities like the billing period counter could be modeled by a data class.

5 Integration

The standards and web services mentioned in the previous sections provide the solution to integrate the electrical distribution systems. The standards will be used to develop generic web services which will drive the integration and sharing of information regardless of the developer, application function, middleware and user. GID part of IEC 61970, interface parts of IEC 61968, interface parts of IEC 61850, interface parts of IEC 62056, interface parts of 62325 and the data model CIM/XML can be used to develop those generic web services. The generic web services will enable applications to benefit from the Enterprise Service Bus (ESB) advantages. The utility data model and interfaces can be incorporated into the ESB to develop an infrastructure which is SOA.

5.1 Enterprise Service Bus (ESB)

ESB is the software product which incorporates the principles of SOA discussed in section 3.3 to realize the SOA infrastructure which will allow applications in control centers, distribution substation, national grid operator and traders to exchange information. The software product acts as broker to permit communications between participants in the business of electricity.

The Utility Data Model (UDM) must be developed and used by the ESB. UDM is another name for CIM. UDM explains what message has to be sent or received. Applications subscribe for the message and in this way the ESB has the capability to send the message to the appropriate applications. The ESB encapsulates the functionality provided by its components through the use of UDM. The interfaces developed from relating standards must be supported in the ESB. Adapters can be used to transform non XML messages to XML messages in which case allowing the legacy applications to be used in this infrastructure.

There are various functions which are provided by the ESB such as: *routing*, in which messages are routed to the destination while providing quality of services. Routing can be done through XML- based content routing in which a message is routed based on the contents of the message. The message is opened and rules are applied to determine the destination of the message. The sending application program does not need to know the destination of the message. Content based routing contributes to the high degree of adaptability and flexibility; *Message transformation* into a common format, is done intelligently by the ESB to enable effective communications between disparate applications, components and services. This is possible through adapters and protocol transformation. XML transformation language like Extensible Stylesheet Language Transformations (XSLT) can be used for transformation. In this way the end points receive the contents which are understood; *invocation*, in which asynchronous and synchronous messaging is enabled. Service mapping (location and binding) is achieved; *process choreography*, in which business processes are implemented to form complete business processes; *process orchestration*, in which processes are coordinated in meaningful manner; *transaction management and security.*

5.2 Utility Integration Bus for the Control center

The ESB infrastructure can be extended to accommodate the utility data models and electrical standards to realize the SOA. The extension changes the name from ESB to Utility Integration Bus (UIB). The standards and utility data models have influenced to have the UIB in the control centers.

The UIB for control centers is the platform which supports IEC 61970 CIM, IEC 61970 GID, IEC 61968 CIM and IEC 61968 interfaces. UIB is based on web services standards which we discussed in section 3.1. Additional protocols upon web service standards can be categorized into three groups: Metadata related protocols, Messaging related protocols and security related protocols.

5.2.1 Messaging related protocol [1]

SOAP is a messaging relating protocol. It is used for transporting messages between networked applications. SOAP over UDP is used for reducing the network over load. There are other protocols which have been built upon SOAP such as *WS-addressing, WS-Enumeration and WS-Eventing.*

WS-addressing is the addition of routing information on the header of SOAP to enable web services to communicate. The routing information is transport- neutral. Normally, the routing is done through the network level transport. In this case, the network level transport will only deliver the message to the processing node that is able to read the WS-addressing metadata.

WS-Enumeration is the capability that has enabled SOAP to transfer large amount of data sets. The capability is due to the fact that a simple single-request/ single-reply metaphor is insufficient for transferring large data sets over SOAP. The transferring of data may involve streaming, traversal, query and enumeration.

WS- Eventing is the standard that enables interoperability between web services. It works under the pattern publish/ subscribe in which the consumer has to register for events in the event source/server to receive an event. This standard can be used to push status messages to the equipments in the substation region and vice versa.

5.2.2 Metadata-related protocols [1]

WS-policy is the capability for a web service to share its policy by using XML messages. The policy may base on characteristics like security and quality of service. Security issues like authentication will be detailed in the policy. The usage of a service will be accompanied by the policy.

WS- Metadata Exchange is intended to provide the mechanism in which a web service is able to describe its metadata which enable it to have interaction with other web service.

5.2.3 Security related protocols [1]

WS- security is intended to provide security in the web service. It ensures integrity and confidentiality of the XML messages through digital sign, encryption and security tokens. There are security tokens which have been applied to assist enough security such as SAML, Kerberos and X.509

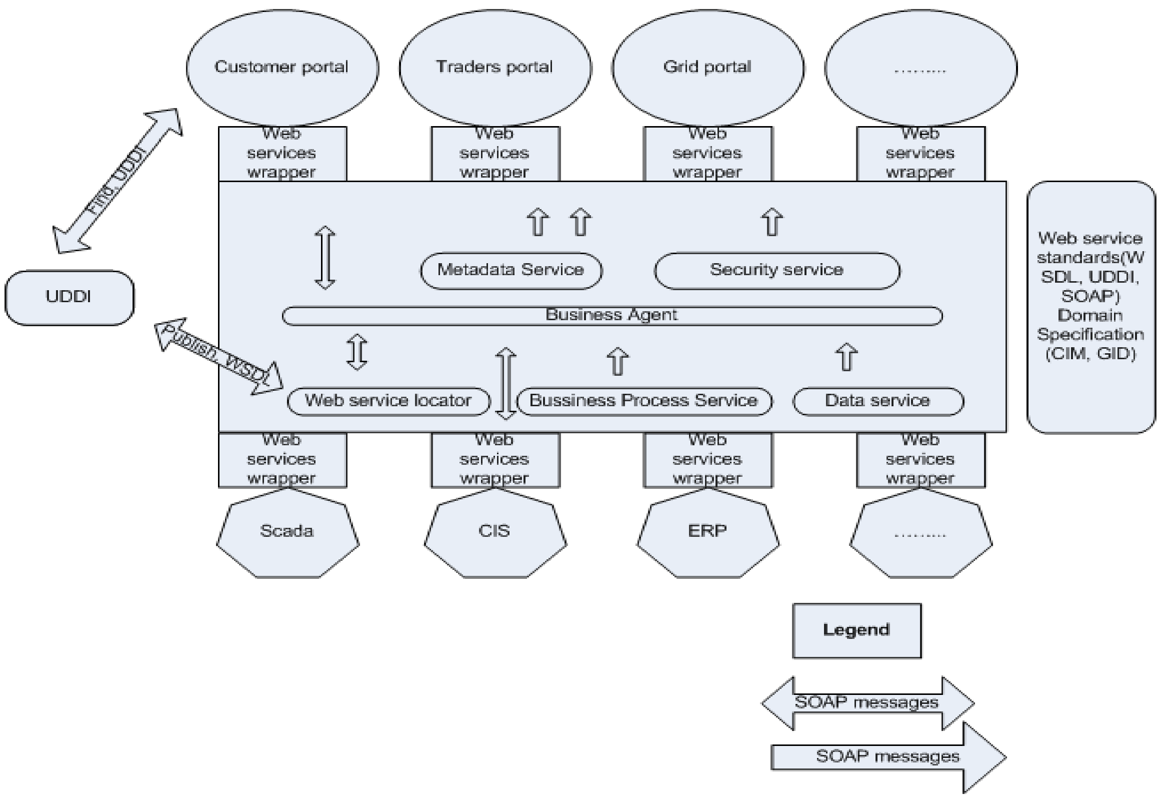

Figure 14: SOA infrastructure for plug and play integration

The support of these web service standards, IEC standards and data models have provided the capabilities to the electrical distributed systems, metering systems, market systems and energy management systems to share information under the utilization of SOA infrastructure.

Figure 14 describes the SOA platform. The platform carries significant functions for integration. Functions such as messaging, transformation, content based routing, orchestration and business activity monitoring are performed by this platform.

The web services wrapper transforms the contents of information into SOAP messages. A SOAP message contains the destination address and hence the web service wrapper is able to forward a message to the destination. A metadata service provided by the metadata related protocols shall provide transmission rules and processing order of the messages. The SOAP message is then received by the business agent. The business agent transforms a message into a local format using a data service. The business agent uses the web service locator to bind a required service and later calling a remote web service. A remote web service contains a required service and hence it processes the request and returns the results.

5.3 Utility Integration Bus for the substation

Energy Management Systems acquire and update information in the sub station region. A representation of any device is through the IED, which is an electronic device accommodating logical nodes. Section 4.3 explains the logical nodes in terms of their functionalities. In order for the devices and EMS to communicate in the manner of exchanging information web services standards and IEC standard must be enhanced to ensure that the task is accomplished. IEC 61850 standard discussed in section 4.3 is for devices within the substation.

Web services standard protocols for sub station devices are similar as those in the control centers. WS- Discovery is the added protocol for devices in the sub station.

WS- Discovery is intended for devices in the substation region to help them locate their services. The logical Nodes represent the services offered by the intelligent physical devices. The Logical Node advertises its services when it joins a Local Area Network (LAN). Normally, this is done through the multicast of the word “hello”. Similarly the logical node quits the network by advertising the word “bye”.

The support of these web services standards, IEC standards and data models have reinforced the devices in the substation to be plug and play.

6 Evaluation of SOA

There are challenges which face a SOA across the heterogeneous systems. The challenges have to be considered in the design time otherwise they will cost at the later time. The challenges such as intermediate layers, large XML payloads and scalability have to be considered by the practitioners.

6.1 High availability

Availability [26] is defined as the ability of the system to be in the operation at a certain acceptable percentages of time. During this operation the system is able to deliver the required services to the intended customers.

Electrical distributed systems have to be operable to ensure the objectives of the utilities are delivered. This requires advance configurations of the systems. Traditionally, this was done through duplicating a primary server with the backup server. The duplication requires specific software or hardware to ensure the data updates in the primary server are propagated to the backup server. The backup server will be operable when the primary server goes down. It takes some seconds to shift operations from one server to the other server. In this way availability was able to be maintained.

In the SOA, the procedures are slightly different from the traditional way. The web service servers are kept in the redundant format. Communications are enabled between the server to ensure that the data and status is exchanged between primary servers and backup servers. One way of doing this communication is through the active/ active failover fashion in which the primary server and the backup server synchronize themselves with the data and status updates. In order for the backup server to be discovered by the UIB, it needs to register as a hibernate service. During outage, the backup server will automatically be discovered and services will continue as usual.

6.2 Performance

Performance [26] is defined as the amount of useful work that the system can do in terms of response time (the amount of time a user should wait for a request to be processed), throughput (the amount of requests that can be processed per time) and timelines (deadline achievements as intended to process real time information).

There are various issues in the SOA infrastructure which can hinder performance. The issues such as data transformation, traffics on the internet, content based routing and filtering.

The web service wrappers as shown in section 5.2 have the task to transform the non-XML data to XML data so as to ensure the transportation of the messages. These transformations can create overheads to the infrastructure.

Content based routing is a technique in the UIB which involves the opening of the message contents and inserting new rules so as the message can be utilized by the service consumers who are in need of the messages. Such a process can be complicated and bring overheads in the busy SOA infrastructure. The size or number of the XML messages can cause the SOA infrastructure to become busy, in which case the process of content based routing service becomes inefficient.

The amount of traffics in the internet is larger than in the local area network (LAN), that means data can travel at higher speed in the LAN. SOA involves internet traffics which create overheads in terms of delay to deliver the messages.

Filtering is a technique to sort the messages based on specific filtering rules. The technique can be complicated when the number of messages is large and in this way has negative impact on the performance.

There are various techniques which can be applied to overcome performance overheads. Caching is one of the techniques to increase performance of SOA. The method intends to cache frequent accessed changing data and metadata such as integration rules, service WSDL description and data transform style sheets. Caching will remove a need to route traffics to the internet and instead it introduces a mechanism to re-use the services which have been used frequently by other consumers.

There are other performance methods which can be applied to increase the performance of the SOA such as threading, asychronization (none blocking) and SOAP attachment.

6.3 Scalability

Scalability [26] is defined as the ability of the system to continue handling the work well while the work has increased. SOA scalability can occur when the number of users utilizing a service has exceeded the capacity of the service providers. In such a scenario a user may experience problems such as a delay in response time.

The are various issues which may contribute to the SOA scalability such as low capacity of the server (memory, hard disk) and service design. Low capacity of the server is the tendency in which a server does not perform well due to the low power of the resources it contains. Service design must be accomplished to reach a standard where a service is independent from other services.

There are various techniques which can be applied to overcome SOA scalability such as horizontal scaling, vertical scaling and stateless services. Horizontal scaling is the addition of the load balanced server which has work to distribute the processing and communications unevenly to other servers such that no service servers is utilized 100%. Vertical scaling is the increase of the capacity of a server. It may happen that a server is required to be upgraded with more memory, hard drive and processor to accommodate the service requests. Service design is the design of the service to make it a self described, self contained and independent from other services. A service must not depend on the state of the other service and in this way session management and propagation issues are avoided to control scalability.

6.4 Modifiability

Modifiability is the ability of the system to adapt quickly to new requirements under the cost effectively [26]. SOA modifiability involves changes in the services themselves or service interfaces. SOA properties such as loosely coupling and service discovery favor changes in the service entities themselves without causing any problems to the whole system. Changes like upgrading or replacing an existing function can be done successfully. Service interfaces can be changed as well, in which case the impacts will propagate the broad part of the system.

6.5 Security

Security [26] is defined in terms of three principles: *confidentiality*, in which information is accessed to granted users; *authenticity*, in which the sender is the responsible of the sent information; *integrity*, in which information is protected from corruption.

There are various issues which can contribute to SOA security. Issues like message interception, third party system and service providers. Message interception is an interruption of the message normally done by the hackers for the purpose of stealing intended information. Third party systems can happen with the existing infrastructure for the purpose of exchanging important information. Service providers provided information to those who are in need of the information.

Efforts have been made to create the SOA security. Security model for web services was developed by the collaboration of companies like IBM, Microsoft and VeriSign. WS-security policy and specifications (WS-Authorization, WS-privacy, WS-Trust, WS-federation, WS-policy and WS-secure conversation) was made for message protection. Message protection was possible through extension of SOAP protocol. Message protection includes activities like content integrity and confidentiality.

There are other security standards for web services such as Security Assertions Markup Language (SAML) and eXtensible Access Control Markup Language (XACML). SAML has XML format which contributes to the exchange of security information by the security agents. XACML has XML format to interpret the policies in the declarative access control policy language.

7 Vision

We have seen efforts to develop standards and data models which can be used to develop an UIB as a direction to create a SOA. These efforts are ongoing processes. CCAPI task force has the work to develop this communication bus (UIB) which will keep the applications loosely coupled. Different authors have researched the development of UIB in terms of specific standards such as IEC 61970 and IEC 61968 and the data model (CIM). CISCO Company has already developed the Utility Integration Bus which incorporates IEC 61970 and IEC 61968 and the data model (CIM /XML).

We firstly propose the development of the communication bus which shall constitute all the required standards (IEC 61968, CIM/ XML, IEC 61970, and IEC 62325) to integrate all the applications from distributed systems, energy management systems and market participants. There are projects underway to update the communication bus that will ensure information sharing between all significant participants.

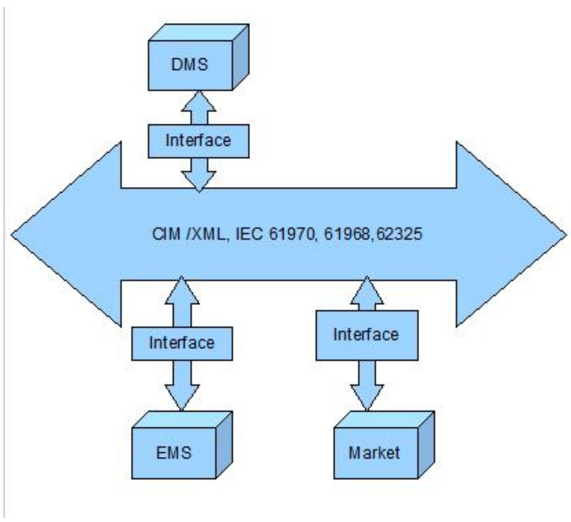

Figure 15: Communication bus which will accommodate more standards

Figure 15 describes the proposed communication bus which will support significant standards and hence causing energy management systems, distributed management systems and market participants to exchange XML messages.

We have also seen that IEC 62056 standard protocol is for metering data exchange. The data exchange in the protocol is through High-Level Data Link Control (HDLC) which is a bit oriented protocol. The mechanism of data exchange in this protocol hinders it to meet the requirements of SOA. The protocols continue to support data transfer based on the agreed manufactures of the metering devices. We secondly propose a research in the metering standards which will make the metering standards transmit the data in the format which will make it benefit from SOA

We thirdly propose a research which will study the interoperability between intelligent software agent technology and web services. An intelligent agent is a self-contained, autonomous software package with enough smartness to act as your personal assistant and to accomplish tasks on your behalf autonomously [24, 25]. An agent can move from one computer to another searching for required significant information, filter and manage.

There is a gap between software agents and web services. This gap obstructs the interoperability. Efforts have been made to bridge this gap through the special middleware. We expect the software agents to accomplish the tasks within the web services. Other agents can work in the UIB to exchanges information with those agents in the web services. In this way, enhancement of effective use and managing of available information online shall be successfully.

8 Conclusion

Our first research question, *how do current utilities negotiate electricity?* This question is answered in chapter 2 as follows.

Electricity distribution is driven by the forces of the main participants who sell, buy, transmit and distribute electricity. The main participants in the electrical distribution are network operators, traders, retailers, generators, customers and transmission system operator. These participants have to share specific information to achieve their goals. The sharing is driven by the collection of energy information from various heterogeneous distributed applications within the utilities. The distributed management systems such as distributed SCADA, network information system, customer information system and computer maintenance management systems are examples of the systems which provide information to the participants. These systems interchange specific information to perform electrical functions. The traditional way of interchanging information was point to point interaction. SOA is a current chosen method of integration to share information among participants.

Our second research question was "how *can electrical utilities move to SOA?"*

Applications must meet the requirements explained in chapter 3, 4 and 5. The interface of applications must be designed with Web services to make them adopt the properties SOA. The standards for the common meaning of information must be carefully designed to allow all the applications exchange information. The properties of UIB, interface design of applications and standards are the road to develop the SOA infrastructure.

Our third research question was "*what are the standards?"*

The success of SOA is influenced by the web services standards and electrical standards. In chapter 3 and 5, we discussed the web services standards. Web services standards such as WSDL, SOAP, UDDI and HTTP work jointly to ensure that messaging is done between a consumer and supplier applications regardless of the platform, programming language or hardware of the intended applications. The innovation of XML language together with the web service standards formed the basis for SOA.

The innovation of electrical standards such as CIM/ XML, IEC 61968, IEC 61970, IEC 62325, IEC 61850, IEC 61870 and IEC 62056 have contributed to develop the common meaning of information and interfaces for the applications to communicate. The table below summaries the challenges and the proposed solution for the electrical standards

Table 1: Challenges and Solutions for the electrical standards

Protocol	Challenge	Solution	Limitation
CIM/ XML	· CIM extension · Complexity of the model increases when the number of software applications increase	· Carefully design of the CIM since at the beginning of the project. Analysis of the requirements with picking appropriate architecture	Applying to energy management systems, distributed systems, market participants
IEC 61968 **IEC 61970** **IEC 62325** **IEC 61850**	· Data transformation from non XML to XML format will introduce performance overhead. · More utilization of system resources	· Improve the performance of resources (e.g. Random Access Memory, Processor speed). · Load balancing	Applying to distributed systems, energy management systems, substations and market participants

IEC 61870 **IEC 62056**	· Traffic load over wide Area Network (WAN) which causes large bandwidth consumption. · Theft of information. · Internet vulnerabilities	· Caching of frequent information · Compression · Traffic management · Firewalling · Encryption	Applying at control centers, metering devices

The main research question: *How can the business processes of the electrical utilities get integrated to achieve the optimum electrical distribution as mentioned above?*

SOA is the solution for the electrical utilities to integrate their business processes to overcome software components redundancy, lack of interoperability and difficulties in software evolution attainment. The properties of SOA discussed in chapter 3, provides the applications with the capability to achieve software evolution without affecting other applications. Moreover, the properties allow electrical utilities to specify only the services they want from the vendors.

The layers of SOA provides the vendors with the capability to develop the SOA middleware which has a capability of Routing, Message transformation, protocol transformation, service mapping, service choreographing, service orchestration, transaction management and Security. We have elaborated the usage of the middleware (UIB) to realize SOA in chapter 5. The routing capability of UIB realizes the interoperability and hence the sharing of information is possible to all the participants in the business of electricity.

References

[1] Qizhi Chen, Ghenniwa, H. and Weiming Shen. "Web-services infrastructure for information integration in power systems." *IEEE Power Engineering Society General Meeting*, 2006.

[2] Dahlfors, F. and Pilling, J. “Integrated information systems in a privatized and deregulated electricity market.” *Energy Management and Power Delivery in Proc. EMPD*, vol 1, pp 249-254, 1995.

[3] Mike P. Papazoglou and Willem-Jan Heuvel. "Service oriented architectures: approaches, technologies and research issues." *The VLDB Journal — The International Journal on Very Large Data Bases*, Vol 16 , pp. 389 - 415, 2007.

[4] Huang Xiaoqing and Jiang Hao."SOA-based integration of electric utility in open electric market." *Electric Utility Deregulation and Restructuring and Power Technologies, DRP* , pp. 2245 – 2250, 2008.

[5] Jun Zhu. “Web services provide the power to integrate.” *Power and Energy Magazine, IEEE*,Vol. 1 , pp. 40-49, 2003.

[6] Lundqvist, C and Jacobsson, J. “Enhancing customer services by efficient integration of modern IT-systems for asset management and network operation” *Power System Technology in proc PowerCon 2002*, vol. 3, pp. 1739 – 1743, 2002.

[7] McClanahan, R.H. "The benefits of networked SCADA systems utilizing IP-enabled networks." *IEEE Rural Electric Power Conference*, pp. C5 - C5_7, 2002.

[8] Phan Duy Anh and Truong Dinh Chau. “Component-Oriented Architecture for SCADA System” *Computing, Engineering and Information*, pp. 310 – 314, 2009.

[9] Mackiewicz, R.E. “The Benefits of Standardized Web Services Based on the IEC 61970 Generic Interface Definition for Electric Utility Control Center Application Integration” *IEEE Power Systems Conference and Exposition*, pp. 491 – 494, 2006.

[10] Bernhard Borges, Kerrie Holley and Ali Arsanjani. "Delving into Service-Oriented Architecture."Internet:http://www.developer.com/java/data/article.php/10932_3409221_2 /Delving-into-Service-Oriented-Architecture.htm, 17 September 2004[27 May 2010]

[11] Papazoglou, M.P. "Service-oriented computing: concepts, characteristics and directions." *Web Information Systems Engineering*, pp. 3 – 12, 2003.

[12] IEC - International Electrotechnical Commission. “Application integration at electric utilities – System interfaces for distribution management” Internet: http://webstore.iec.ch/preview/info_iec61968 1%7Bed1.0%7Den.pdf, [3 June 2010].

[13] Mulik, S. "Using Enterprise Service Bus (ESB) for connecting corporate functions and shared services with business divisions in a large enterprise." *IEEE Services Computing*, pp. 430 – 434, 2009.

[14] Ali Arsanjani and Liang-Jie Zhang. “Design an SOA solution using reference architecture” Internet: http://www.ibm.com/developerworks/library/ar-archtemp/, 28 March 2007 [10 June 2010].

[15] CISCO. "Standards For Transmission and Distribution System Integration: Towards, “plug and play” of Utility Applications" Internet: www.sisconet.com/downloads/Utility_PnP_08.pdf, [13 June 2010].

[16] IntelliGrid. “IEC 61970 Part 4 - Generic Interface Definition (GID).” Internet: http://intelligrid.ipower.com/IntelliGrid_Architecture/New_Technologies/Tech_IEC_61970_Part_4_-_Generic_Interface_Definition_%28GID%29.htm, [16 June 2010].

[17] Kostic, T, Preiss, O and Frei, C, “Towards the formal integration of two upcoming standards: IEC 61970 and IEC 61850.” *IEEE Power Engineering, Large Engineering Systems*, pp. 24 – 29, 2003.

[18] John Gillerman, Herb Falk and Ralph Mackiewicz. "FOCUS ON THE IEC TC 57 STANDARDS"Internet:http://www.ieee.org/portal/cms_docs_pes/pes/subpages/publications-folder/TC_57_Column.pdf, [18 June 2010].

[19] Mohagheghi, S., Stoupis, J. and Wang, Z. "Communication protocols and networks for power systems-current status and future trends." *IEEE Power Systems Conference and Exposition*, pp. 1 – 9, 2009.

[20] IEC. “Application integration at electric utilities –System interfaces for distribution management” Internet: http://webstore.iec.ch, [18 June 2010].

[21] JBOSS.”Content based routing”, Internet:http://docs.jboss.org/jbossesb/docs/4.3.GA/manuals/html/services/ContentBasedRouting.html, [20 June 2010].

[22] David Chappell and David Berry ‘The Next-Generation, Grid-Enabled Service-Oriented Architecture’, Internet: http://www.soamag.com/I10/0907-1.php, 3 September 2007 [19 June 2010].

[23] Gravic. “Continuous Availability with Shadowbase and Active/Active Systems.” Internet: http://www.gravic.com/shadowbase/uses/continuousavailability.html, [21 June 2010].

[24] M. Omair Shafiq, Ying Ding and Dieter Fensel, “Bridging Multi Agent Systems and Web Services: towards interoperability between Software Agents and Semantic Web Services.”*10th IEEE -Enterprise Distributed Object Computing Conference*, pp. 85 - 96, 2006.

[25] Murugesan, S."Intelligent software agents on the Internet and Web." *IEEE-Speech and Image Technologies for Computing and Telecommunications*, Vol 1, 1997.

[26] O'Brien Lero, L., Merson, P and Bass, L. "Quality Attributes for Service-Oriented Architectures", *Systems Development in SOA Environments*, pp. 3 – 3, 1997.

[27] Vinoo S Warrier and Kalkitech. "Implementing DLMS Client and Server Protocols in Meters, IED's, MRI's and Meter Reading Applications." Internet: http://knol.google.com/k/implementing-dlms-client-and-server-protocols-in-meters-ied-s-mri-s-and-meter#, [16 July, 2010].

[28] IEC 62056-42. "Physical layer services and procedures for connection-oriented asynchronous data exchange." Internet: www.dlms.com/documents/iec62056-42header.pdf, [16 July, 2010].

[29]IEC 62056-46."Data link layer using HDLC protocol."Internet: www.dlms.com/documents/iec62056-46header.pdf, [16 July 2010].

[30] IEC 62056-47. "COSEM transport layers for IPv4 networks." Internet: www.dlms.com/documents/iec62056-47header.pdf, [16 July 2010].

[31] IEC 62056-53. "COSEM application layer." Internet: www.dlms.com/documents/iec62056-53header.pdf, [16 July, 2010].

[32] IEC 62056-61. "Object identification system (OBIS)." Internet: www.dlms.com/documents/iec62056-61header.pdf, [16 July 2010].

[33] IEC 62056-62. "Interface classes." Internet: www.dlms.com/documents/iec62056-62header.pdf, [16 July 2010].

[34] Jian Wu and Schulz, N.N. “Overview of CIM-oriented database design and data exchanging in power system applications.”*Power Symposium, Proceedings of the 37th Annual North American*, pp. 16 – 20, 2005.

[35] Jiang Ji-chen and Gao Ming. "Enterprise Service Bus and an Open Source Implementation." *IEEE Management Science and Engineering*, pp. 926 – 930, 2006

[36] Brunner, C., “IEC 61850 for power system communication.” *IEEE, Transmission and Distribution Conference and Exposition*, pp. 1-6, 2008