Architecturally Significant Interfaces for the Smart Grid

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Abstract

Collaboration is of the essence of smart grids. Smart grids enable participants to collaborate to align energy supply and demand. The architecturally significant interfaces of smart grids are those that are at boundaries between the collaborating entities. These interfaces minimally constrain the parties on either side while providing effective conduits for actionable information between the entities. Each collaborator will maintain its own privacy while interacting through these interfaces. We apply these criteria to the roadmap for standardization.

While the two entities that interact at an architecturally significant interface can generally be called supplier and consumer, these roles are not fixed. The consumer may be a supplier to entities on its side of the interface. A consumer can also be a supplier of energy. The architecturally significant interfaces of the grid must honor the principles of symmetry and minimal knowledge, and interact with each other through carefully defined general services.

1. INTRODUCTION

The smart grid must be a platform for innovation [1], able to incorporate existing technologies as it spurs the development of new technologies. Process oriented integration uses deep knowledge of sub-systems to wring out every drop of performance from well-understood systems. Such integrations are expensive in time and in people; the expense of integration grows much faster than the diversity of technologies supported using such integration. This growing expense increases the cost of introducing new technologies into any system, and becomes a barrier to innovation.

Smart grids support diverse interests and motives. The North American Power Grid supports end nodes of every interest, purpose, and lifestyle. Such diversity of purpose can never be supported by unitary control strategies. If the end nodes are forced to accept direct control from the outside, they will accept only the smallest interference they can negotiate. Greater response from the end nodes must come from engagement rather than control.

The evolution of policy and technology are increasing the volatility of the energy supply for the smart grid. Increased volatility leads to greater needs for response and interaction. At the same time, the safety margins of the distribution infrastructure are being reduced. Today's grid has less room for error.

Distributed energy resources are changing the roles played at each interface on the grid. Electric vehicles and their batteries and generators are being used and considered for grid-scale distributed energy resources.[1] Site-based generation further blurs the formerly distinct roles of producer and consumer. Creative applications of information technology to consortia of buildings are being bid as fast response voltage regulation resources. Microgrids [2] are creatively managing their internal use and generation. The relations between the end nodes and power grids are becoming more varied.

The interactions between the end nodes and the grid are the most rapidly evolving. Flexibility in these interfaces will enable faster change and more innovation. For smart grids, the interfaces between supplier and consumer, between owners with different interests, are the ones that reduce friction and enable innovation.

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[1] Some hybrid buses and trucks can be used as emergency generators

In any system, there are articulation points, the places where something can bend, something can flex, and something can change. If the North American Power Grid is the world's largest robot, then the articulation points are the elbows and the knees where decisions, operations, and directions change. The inter-domain interfaces are the most architecturally significant to the development of smart grids.

2. COLLABORATIVE ENERGY

Collaboration has been defined as "a mutually beneficial and well-defined relationship entered into by two or more organizations to achieve common goals [3]." It is also defined as a process that "...occurs when a group of autonomous stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures, to act or decide on issues related to that domain [4]." The International Telecommunications Union further specifies that a "formal agreement, such as a Service Level Agreement (SLA), puts contract type language around the collaboration [5]".

We define Collaborative energy [6] [7] as two or more organizations working together to balance energy supply and demand. Either side may have energy to buy or sell. Either side may be able to mediate energy consumption. Either or both sides may have resources for energy generation or storage. Even storage itself is energy consumption or supply depending upon collaboration signals and direction of energy flow.

Collaboration relies on clear signals to share information between autonomous entities. These information elements are cross-cutting elements in smart grid standards [8]. The entities exchange mutually understandable price and product definitions. They must communicate interval and schedule, for energy is volatile and evanescent. They must communicate current market conditions and risks, and how these are anticipated to change.[2] They must share a common understanding of current energy use.

Because collaboration is between independent entities, and involves financial transactions, the interfaces of collaborative energy must work at arm's length, between organizations that may be hostile to each other. Privacy and security are critical to acceptance of any collaborative interfaces.

Collaboration enables partners on each side of an interface to apply their own creativity, to balance risk and innovation, at their own pace, to contribute to shared energy supply and reliability.

[2] Some might recognize these as the OASIS Technical Committees WS-Calendar, Energy Market Information Exchange (EMIX) and Energy Interoperation

3. ARCHITECTURALLY SIGNIFICANT INTERFACES

For the smart grid, the architecturally significant interfaces are those between domains. Intra-domain interfaces can benefit from similar discipline of approach, but the Smart Grid requires interoperation where collaboration exists now and will in the future.

3.1. Architectural principles for generative systems

The Smart Grid is a system of systems, just as the Internet is a system of systems. Deep and specific knowledge of how each of those systems is designed, implemented, and has evolved is not needed to use the Internet. The Internet design approach has proven astoundingly generative, that is, it is able to support the development and integration of new technologies and new business models without redesign or invalidation of its core behaviors.

Internet system architectures are based on four principles [5]:

- Separation between network technology and services
- End-to-End architecture, and extension of intelligence from the core to the edge of a network
- Scalability
- Distributed design and decentralized control

The architectures for smart grids are evaluated based upon the principles laid out by the Gridwise Architecture Council (GWAC). These are illustrated in a diagram referred to as the GWAC Stack. [9] (See Figure 1).

The GWAC Stack provides a context for evaluating architecturally significant interfaces. Collaborative interfaces are noteworthy in that they address layers 5-7, i.e., work at the upper end of the stack.

Figure 1 GWAC Stack [9]

The principles laid out by NIST to guide development of the interfaces of the smart grid [1] offer compatible advice. The interfaces should support:

- *Symmetry* – facilitates bi-directional flows of energy and information.
- *Transparency* – supports a transparent and auditable chain of transactions.
- *Composition* – facilitates building of complex interfaces from simpler ones.
- *Extensibility* – enables adding new functions or modifying existing ones.
- *Loose coupling* – helps to create a flexible platform that can support valid bilateral and multilateral transactions without elaborate pre-arrangement. *
- *Layered systems* – separates functions, with each layer providing services to the layer above and receiving services from the layer below.
- *Shallow integration* – does not require detailed mutual information to interact with other managed or configured components.

For the architecturally significant and long-lasting interfaces, these principles and the related guidelines are especially important. The principles all align with the goals of collaborative energy.

3.2. Consistency of Interfaces

Consistency of interface is important to the evolution and economic success of the Smart Grid. Without consistent interfaces, each system installation requires custom integration and configuration. This process, expensive and time consuming, itself becomes a barrier to participation.

For example, consistent communication of price and product definition will enable equipment manufacturers to build equipment that will work in each of the more than 3,000 utility service areas in the United States, and thousands more across the world. Standard interfaces drive that consistency, and increase market sizes and incentives for smarter devices.

Customization adds significant barriers to smart building agents today. Avoiding the requirement for customization would reduce design, integration, and installation costs.

Total uniformity, of course, is impossible. The equipment purchased today to meet new standards will be used with equipment purchased yesterday that does not; similarly, today’s purchases are tomorrow’s legacy systems.

3.3. Articulation Points

Each architecturally significant interface is a limited connection or articulation point between domains that exposes a selection of defined energy services. We use the approach of Service Oriented Architecture because a process view implies deep understanding of the managed process; while a service view implies understanding of the limited nature and content of communication between systems. [10]

In anatomy, articulation is defined as uniting by forming a joint or joints. In building architecture, articulation is to give visible or concrete expression to (the composition of structural elements). We use articulation to refer to both concepts as they appear in software architecture, as an interface that joins two domains or services, and as the location wherein the underlying processes and functions within a system become visible expressed as services.

The systems on either side of architecturally significant interfaces typically are owned by different enterprises, under different control, and serve differing purposes and functions.

3.4. Selecting Interfaces

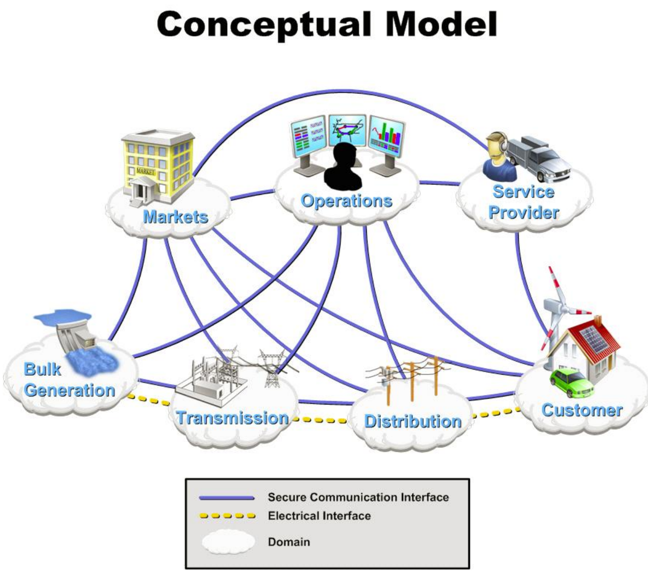

Figure 2 Smart Grid Conceptual Model [8]

The Smart Grid Conceptual Model [8] (see Figure 2) catalogues the domains of the Smart Grid. We use the interactions between the domains to determine the architecturally significant interfaces.

The interaction or interface points between the domains of the Smart Grid meet the criteria for articulation points. Consider the overall Conceptual Model in Figure 2.

Even at this high level of abstraction we see that the domains are typically under separate ownership and under separate control. Markets are used in all domains, and price (along with the characteristics and quantity of energy or service) is how value is communicated.

This reasoning leads quickly to the conclusion that energy price and characteristics communication is important to interoperability and is already in universal use. Since the details of price communication vary considerably, a common form of communicating price and characteristics is important information for interoperation. [11]

A similar argument leads to the decision that consistent communication of schedule is also important for interoperation.

3.5. A Matter of Balance

As with the design benefits of use cases, where a proposed design is evaluated in part by the use cases it supports, the determination of architecturally significant interfaces is one of balance (and often of iterative evolution)

Beyond proper layering, one important aspect of interface definition is the level of complexity—too complex, with too much information passed will make the interface brittle and hard to evolve; too simple and the power of the interface is compromised.

The level of abstraction, or how much function is in a service and the choice of interfaces, is another important aspect. Experience in Service Oriented Architecture-based development suggests that relatively large services allow for more effective reuse and repurposing. [12] [13]

4. INTEGRATION, INTERFACES, AND REUSE

In enterprise software, the term *integration* refers to the act of assembling diverse components and making them work together as part of a larger application.

4.1.1. Repurpose and Reuse

Determining the services needed, and keeping them at a relatively high level, intuitively should help reduce the number of components for a specific application. By making the connections (the interfaces) simple, clean, and flexible enough we can separately evolve the different components.

Independent innovation behind flexible (i.e., not brittle) interfaces allows the implementations and approaches to operate on a timeframe and scale that works for each component, and thus evolve the application more effectively. Flexible interfaces do not convey deep knowledge or characteristics of implementations, but tend to focus on minimal information exchanges and consistent data models.

Designing to repurpose and reuse relies on building composable services that can be reassembled and repurposed easily. See for example [14] and [8] Section 3.

4.1.2. Privacy

Many parties are expressing growing concern about privacy and smart energy. NIST has highlighted that the collection of energy-related information about the operation of systems in homes raises privacy concerns [1]. These concerns are developed in some detail by the Future of Privacy Forum [15].

Clearly detailed usage information poses privacy issues. Further work is needed in defining and managing the operation of privacy standards, i.e., practices and policies to protect privacy but to allow specific and revocable delegation to third parties.

5. ADOPT DON’T INVENT

In parallel with the dictum to repurpose, one should not (re) invent when one can adopt. Reinvention is seldom productive until it’s time to rethink an interface or engineered object. Since the broad world of enterprise and personal software has already evolved, re-engineered, and hardened most of the contents of this section it is likely that the requirements for energy are already met or can be met with minor adaptation or profiles.

Adoption also enhances interoperation, as it encourages re-use of components already known across domains. An intermediate service or system may not need to understand an entire message to know whether to ignore it or act, to relay it or discard it. Components make this easier.

6. SMART GRID INFORMATION EXCHANGE

Alex Levinson [16] has called the set of specification we discuss the Smart Grid Information Exchange standards (and standards to be). Inspired by his term, we use the prefix *SG* in our discussion of these specifications.

Many of the standards and interfaces already exist, at varying levels of maturity.

We start first with the existing specifications in our toolkit—since they already exist, we need only adapt some of them in minor ways; others may require more work.

6.1. Information Standards to Adopt

The standards (and should-be-standards) in this section are primarily for information communicated, rather than protocols for information exchange. We think of these as components of messages; some may include protocols, but our focus is primarily on the information exchange.

For example, an interchange of usage information may be carried by a web services protocol but the same usage information can be exchanged by other protocols or mechanisms.

6.1.1. Schedule and Interval

For human interactions and scheduling the well-know *iCalendar* [17] format is nearly universally used. While there are other standards for time (e.g. ISO 8601[18]) there are few others that integrate time and other scheduling information in an easily repurposed manner. Coordination of services to, from, and within homes, commercial buildings, and industrial facilities is easier with this near-universal format.

The iCalendar format is being updated for use as a component of web services messages in cross-domain communications. This work is being begun by the Calendar and Scheduling Consortium (CalConnect.org) working through the processes of the Internet Engineering Task Force (IETF). It will be completed within the OASIS WS-Calendar Technical Committee. This is the subject of NIST Priority Action Plan 4, *Common Scheduling Mechanism*. [19]

Coordination of services to, from, and within homes, commercial buildings, and industrial facilities will be easier with this near-universal format.

6.1.2. Weather

Knowledge of the future is important to all markets; knowledge of future weather is important to energy markets. All weather is local. Local weather awareness includes not only weather predictions, but also knowledge about the actual weather at my location following previous predictions.

DWML is an existing specification developed by the National Oceanic and Atmospheric Administration (NOAA). NOAA offers access to their National Digital Forecast Database (NDFD) [20] using DWML. DWML is somewhat quirky and hard to use. Smart energy would benefit from its further development. Further work would include defining a DWML profile for reporting as well as forecasting, to enable the exchange of actual conditions as well as forecasts. Such a profile would be used when querying local weather stations and even personal weather systems, and for dynamically determining ratings for transmission lines.

6.1.3. Geospatial Communication Standards

The Open Geospatial Consortium [21] develops standards for communication of geospatial information. Readers may be familiar with the OGC geolocation specification KML, used to pin information in Google Earth. [22]

Specialized standards from OGC such as SensorML can describe the location, geometry, dynamic, and observational characteristics of sensors and sensor systems. Other applications of OGC specifications include defining geographic polygons, e.g., the area served by a substation, which could in turn support either congestion pricing or be sent directly to emergency responders (via standards such as the OASIS Common Alerting Protocol [23]) to describe where traffic and street lighting may be out and facilities may be at risk.

6.1.4. Device Discovery and Profiles

Web Services Device Discovery (WS-DD) and Device Profile (WS-DP) are two web services OASIS standards for locating and configuring devices.

Two major manufacturers of electrical equipment have announced that they will include WS-DD and WS DP for all the equipment they sell.[3] There are open source implementations for small devices. [24]

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[3] Schneider and Kohler.

The authors expect that these standards will have a big role in the future world of dynamically configured and distributed generation, consumption, and Net Zero Energy facilities.

6.2. Structural Approaches

Three approaches to software and enterprise interoperation have proven valuable for wide-scale integration of software systems developed, owned, and maintained by disparate organizations.

6.2.1. Service Orientation

We have discussed the value of Service Orientation earlier. Toby Considine described *service oriented energy* [10] at Grid-Interop 2008.

Service-Oriented Architecture (SOA) [25] [26] provides a way to describe the loose, flexible integration required for the architecturally significant interfaces. By defining services supplied and consumed, SOA approaches hide the implementation details that create problems for independent evolution and long-term effectiveness.

Capabilities can be used without needing to know the details of the service implementation, those very details that create deep integration problems for independent evolution and long-term effectiveness—only the service interface and information meaning are shared. Moreover, coarse-grained services provide greater opportunity for repurposing. [13]

Service orientation, decomposition, and assembly are the state of the art in enterprise software. [27]

6.2.2. Fine Grained Security

There are many fine-grained security standards in wide use. We will not catalog these but refer the reader to Cox's high-level survey. [28] The typical approach in enterprise software is to compose the information and protocol standards with standards that implement appropriate security models.

6.2.3. Policy

Inheritable (and modifiable) policy standards such as WS-SecurityPolicy [29] have made management of large systems much easier. In addition, defining and enforcing consistent security policies can produce a higher level of assurance.

6.3. New Interfaces to Enable the Smart Grid

Finally we describe new architecturally significant interfaces. These interfaces enable the smart grid by allowing exchange of information where it is needed, while allowing flexibility and extensibility for requirements not yet known. These satisfy the generative nature requirement for the smart grid, and as implemented will allow the respective industries to simplify deployment and interoperation.

This is an evolution and refinement of work done throughout 2009 [30] [31] Many requirements for the work in progress are summarized in the NIST Framework [1] and in the respective NIST Priority Action Plans. [19] [32] [33] [34]

The guiding vision we have described has driven the work below and the work defining these standards has begun.

6.3.1. SG-Energy Interoperation

Lawrence Berkeley National Laboratory in collaboration with the California Energy Commission developed OpenADR, the widely deployed technology for automated demand response. This work was contributed to the OASIS Energy Interoperation Technical Committee [35] and others.

Collaborative energy embraces enterprise interactions as well as building systems. By recognizing the authority of the building occupant, whether be in a commercial building, factory, or home, we expect to be able to induce a larger response (energy reduction) and wider participation. The committee will also draw upon European work on cooperative energy use, and will include security and privacy requirements.

Utilities and other energy market participants are working within the North American Energy Standards Board (NAESB [36]) to define business use cases and requirements for Demand Response (DR) and Distributed Energy Resources (DER). This work will be contributed to the Energy Interoperation TC as well as to parallel efforts developing managed energy.

This is the work of NIST Priority Action Plan 9 [33].

6.3.2. SG-Market Information

We describe the motivation and details of interoperable price and characteristics communication in another paper in this conference. [11]

The OASIS Energy Market Information Exchange (EMIX) TC [37] began meeting in October 2009. EMIX is defining an XML vocabulary for exchanging price and energy characteristics (e.g., hydro, hard coal, nuclear, wind, etc, with a place for carbon information). EMIX will facilitate energy markets and device understanding of price and characteristics to enable consistently communicated dynamic pricing of energy.

EMIX will interact easily with financial and commodity market mechanisms. It will adopt and adapt market definitions and interactions from financial transaction standards such as ISO 20022 [38] and FIX [39]. EMIX also anticipates the development of new energy products that allow energy choice based on environmental issues as well as price.

6.3.3. SG-Energy Usage

Energy use has traditionally been summed over a month and then received by the consumer weeks later, far too late to affect behavior. Recent high profile efforts by Google PowerMeter [40] and Microsoft Hohm [41] have demonstrated the power of granting consumers access to near real time dynamic data about energy usage. Makers of industrial and of building automation systems (BAS), particularly makers of heating and cooling systems, have long wanted direct access to current meter information, and energy management systems need a standard format for devices reporting consumption.

Work in progress in this area is addressed in part in NIST Priority Action Plan 10. [34]

6.3.4. WS-Calendar

WS-Calendar [42] will build on the work we described related to *iCalendar* [17] to define light loose schedule components for use in web services and other eCommerce transactions. These components will be used in Collaborative Energy, and their semantics will be re-used in Managed Energy.

Because the work of the Calendaring and Scheduling Consortium (CalConnect.org) is used near-universally for enterprise and personal scheduling, and in the near future will be adopted by building systems and possibly finance, WS-Calendar will provide a common understanding of schedule and interval across many domains and for more purposes than energy.

Work in progress in this area is address by NIST Priority Action Plan 4. [19]

6.3.5. SG-Managed Energy

We use this term to encompass the entire range of direct load management and control technologies used to manage small devices without requiring a premises-based system for consumer input. Work in this area includes ZigBee Smart Energy Profiles [43] and Open Home Area Network Requirements (OpenHAN). [44]

Managed Energy is deployed widely if sparsely today, as it is an extension of the direct load control methods and tariffs developed following the oil-shock of 1973. Because Managed Energy includes detailed registration and management of in-home devices, it has raised growing concerns about electronic privacy and the potential to expose detailed personally identifiable information. [1] [15]

7. CONCLUSIONS

7.1. Challenges of Smart Grids

The greatest challenges of smart grids are to coordinate energy supply and consumption, a task that is growing in complexity. Energy supply will become more volatile as we add unpredictable renewable energy sources to the grid. Grid safety margins will continue to be reduced. Energy sources will distributed across the grid, including inside the traditional one-way end nodes, commercial buildings and homes.

This coordination occurs most significantly between domains, whether domains are defined operationally or by ownership. The natural mode of interaction between business entities an economic mode, in which scarcity and value are negotiated by economic transactions involving clearly defined products.

Limiting interactions to economic transactions minimally constrains solutions on either side of the interface. We need the fewest constraints consistent with grid coordination to enable rapid innovation on either side of each interface. Economic interfaces allow the introduction of new intermediation services that may add new value or better engage consumers. Economic interfaces are also likely to offer the least personally identifiable information and thereby improve privacy on smart grids.

7.2. Benefits of Smart Grids

The biggest benefits from smart grids will come from engaging the end nodes to assist in balancing energy supply and demand. This requires clear communications of energy scarcity and abundance, of the value each assigns to that energy, and of responsibility for outcomes. These signals are all in the realms traditionally assigned to economics and markets. The significant interfaces of smart grids are economic and market interfaces.

Current best practices in large system architecture define services, and assign responsibility for providing those services to systems n either side of an interface. To allow innovation and competition, services are agnostic of process, and focus exclusively on quality and timeliness of performance. Any system, including ones provided through innovative new technologies, can compete on quality and timeliness of service delivery without re-development of systems architectures or of interfaces. We require approaches that present minimal barriers to innovation to achieve smart grid goals.

The architecturally significant interfaces of smart grids are economic communications using service oriented architectures. These architecturally significant interfaces of smart grids are at boundaries between the collaborating entities. These interfaces minimally constrain the parties on either side while providing effective conduits for actionable information between the entities. These interfaces honor the principles of symmetry and minimal knowledge, and interact with each other through carefully defined general services.

References

[1] NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0 (Draft), September, 2009, http://www.nist.gov/public_affairs/releases/smartgrid_interoperability.pdf .

[2] Galvin Electricity Initiative, http://www.galvinpower.org/

[3] Mattessich, P., Murray-Close, M., and Monsey, B. (2001), *Collaboration: What Makes It Work*, 2nd edition, Wilder Research Center. (p 39)

[4] Toward a Comprehensive Theory of Collaboration, Donna J. Wood, Barbara Gray, The Journal of Applied Behavioral Science, Vol. 27, No. 2, 139-162 (1991) (p. 146)

[5] International Telecommunication Union and InfoDev, "ICT Regulation Toolkit," http://www.ictregulationtoolkit.org/en/index.html

[6] Cox, William, "Buildings, Industry, Automation, and Smart Grids," B2G Summit, Chicago, January, 2009, http://www.pointview.com/data/2009/01/29/pdf/William-Cox-3808.pdf

[7] Cox, William, "Achieving the Smart Grid Vision," NIST Smart Grid Workshop Keynote, April 28, 2009. http://www.coxsoftwarearchitects.com/Resources/SmartGridWorkshops/Achieving_the_Smart_Grid_Vision_Cox_20090428.pdf

[8] Electric Power Research Institute, "Report to NIST on the Smart Grid Interoperability Standards Roadmap" (Contract No. SB1341-09-CN-0031—Deliverable 7), August 10, 2009, http://www.nist.gov/smartgrid/Report%20to%20NISTlAugust10%20(2).pdf

[9] GridWise Architecture Council Interoperability Framework, http://www.gridwiseac.org/pdfs/interopframework_v1_1.pdf

[10] Considine, Toby, "Ontological requirements of the Service Oriented Grid," Grid-Interop 2008, Atlanta, November, 2008, http://www.pointview.com/data/files/2/1338/1134.pdf

[11] Cox, William, and Considine, Toby, "Price Communication, Product Definition, and Service-Oriented Energy," Grid-Interop 2009, Denver, November, 2009.

[12] Eisenstein, Jon, "Lifecycle Management of SOA: GE Money's Strategic Approach to Ensuring SOA Delivers," InfoWorld SOA Executive Forum, New York, November, 2007, http://akamai.infoworld.com/event/soa/07/november/docs/Lifecycle_Management.pdf

[13] Brodbeck, Martin, "Building a Connected Enterprise," InfoWorld SOA Executive Forum, New York, November, 2007, http://akamai.infoworld.com/event/soa/07/november/docs/Keynote-Laying_Foundation.pdf

[14] Cox, William, "Repurpose, Reuse, Profit--SOA Next Generation Infrastructure," OASIS Open Standards Symposium 2008, http://events.oasis-open.org/home/sites/events.oasis-open.org.home/files/Cox%2020080430.ppt

[15] Information & Privacy Commissioner, Ontario, Canada, Future of Privacy Forum, *Privacy for the Smart Grid: Embedding Privacy into the Design of Electricity Conservation*, November 2009 http://www.futureofprivacy.org/wp-content/uploads/2009/11/smartprivacy-for-the-smart-grid.pdf

[16] Alexander Levinson, Personal communication.

[17] Internet Engineering Task Force iCalendar specification, RFC 5545, http://tools.ietf.org/html/rfc5545

[18]] International Standards Organization, ISO 8601:2004, http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=40874

[19] NIST Smart Grid Priority Action Plan 4: Common Scheduling Mechanism, http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP04Schedules

[20] National Oceanic and Atmospheric Administration (NOAA), http://www.nws.noaa.gov/xml/

[21] Open Geospatial Consortium (OGC), http://www.opengeospatial.org

[22] Google Earth, http://earth.google.com/ , and Google Earth User Guide: About KML, http://earth.google.com/userguide/v4/ug_kml.html

[23] Common Alerting Protocol (CAP) 1.0, OASIS Standard, October, 2005, http://www.oasis-open.org/specs/#capv1.1

[24] Service-Oriented Architecture for Devices, https://forge.soa4d.org/

[25] Reference Model for Service Oriented Architecture 1.0, OASIS Standard, October, 2006, http://www.oasis-open.org/specs/#soa-rmv1.0

[26] OASIS SOA Reference Model Technical Committee, http://www.oasis-open.org/committees/soa-rm/

[27] OASIS Open Composite Services Architecture Member Section, http://www.oasis-opencsa.org/

[28] Cox, William, "From Physical to Fine-Grained Security," GridWeek 2008, Washington, September, 2008, http://www.pointview.com/data/2008/09/24/pdf/William-Cox-3613.pdf

[29] WS-Security Policy 1.3, OASIS Standard, February, 2009, http://www.oasis-open.org/specs/#wssecpolv1.3

[30] Considine, Toby, "Standards Roadmap for the Smart Grid (SGIX) (v2), March 2009, http://www.newdaedalus.com/articles/2009/3/10/standards-roadmap-for-the-smart-grid-sgix-v2.html

[31] Considine, Toby, and Cox, William, "SGIX — Smart Grid Information Exchange," Handout, http://coxsoftwarearchitects.com/Resources/SmartGridWorkshops/SGIX%20Handout%2020090503.pdf

[32] NIST Smart Grid Priority Action Plan 3: Common Specification for Price and Product Definition, http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP03PriceProduct

[33] NIST Smart Grid Priority Action Plan 9: Standard DR and DER Signals, http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP09DRDER

[34] NIST Smart Grid Priority Action Plan 10: Standard Energy Usage Information, http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP10EnergyUsagetoEMS

[35] OASIS Energy Interoperation Technical Committee, http://www.oasis-open.org/committees/energyinterop/

[36] North American Energy Standards Board (NAESB), http://www.naesb.org/smart_grid_standards_strategies_development.asp

[37] OASIS Energy Market Information Exchange Technical Committee (EMIX), http://www.oasis-open.org/committees/energyinterop/

[38] ISO 20022 Financial Services – Universal Financial Industry Message Scheme, http://www.iso20022.org/UNIFI_ISO20022_standard.page

[39] The FIX Protocol Organization, http://www.fixprotocol.org/

[40] Google PowerMeter, http://www.google.org/powermeter/

[41] Microsoft Hohm, http://www.microsoft-hohm.com/ and http://www.microsoft.com/environment/hohm.aspx

[42] OASIS WS-Calendar charter (in process). Draft charter at http://lists.oasis-open.org/archives/smartgrid-interest/200912/msg00000.html

[43] ZigBee Smart Energy Profile 2.0, Work In Progress, http://zigbee.org/

[44] UCA International Users Group (UCAIug), Open Home Area Network Requirements (OpenHAN), http://osgug.ucaiug.org/sgsystems/openhan/

Biography

William Cox is a leader in commercial and open source software definition, specification, design, and development.

He is active in the NIST Smart Grid interoperability efforts, including the Domain Expert Working Groups. He contributed to the NIST conceptual model, architectural guidelines, and the interim roadmap and framework documents.

Bill is co-chair of the OASIS Energy Interoperation and Energy Market Information Exchange Technical Committees, and an elected member of the OASIS Technical Advisory Board, where he advises the Board and membership of the leading XML and Web services standards organization in the world.

Bill has developed enterprise product architectures for Bell Labs, Unix System Labs, Novell, and BEA, and has done related standards work in OASIS, ebXML, the Java Community Process, Object Management Group, and the IEEE, typically working the boundaries between technology and business requirements.

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Toby Considine is a recognized thought leader in applying IT to energy, physical security, and emergency response. He is a frequent conference speaker and provides advice to companies and consortia on new business models and integration strategies.

Toby has been integrating building systems and business processes for longer than he cares to confess. He has supported and managed interfaces to and between buildings, cogeneration plants, substations, chilled water plants, and steam and electrical distribution. This work led to Toby's focus on standards-based enterprise interaction with the engineered systems in buildings.

Toby has been chair of the OASIS oBIX Technical Committee. oBIX is an unencumbered web services standard designed to interface between building systems and e-business. He is an elected member of the OASIS Technical Advisory Board. He is active on the NIST Smart Grid Domain Experts Groups and works to promote applying information technology to buildings with groups such as buildingSmart and FIATECH.

Before coming to the university, Mr. Considine developed enterprise systems for technology companies, apparel companies, manufacturing plants, architectural firms, and media companies old and new. Before that, Toby worked in pharmaceutical research following undergraduate work in developmental neuropharmacology at UNC.