The Key Starting Point for a Business Level Roadmap to Achieve Interoperable Networks, Systems, Devices in the Smart Grid

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Introduction

A utility smart grid consists of sensors, actuators, and controllers interconnected via communication networks that are interoperable across the entire utility network. This scope spans the traditional utility sectors involved in generation, transmission, distribution, and metering. Recent applications depend on utility communications of data and control that reach customer premises interfaces. These interfaces link to premises networks that support demand response programs, the integration of local generation sources (wind, solar, etc.), and the proliferation of electric vehicles.

Each segment of the electric network uses different communications methods and application models. It is not feasible to specify a uniform communications protocol for all aspects of utility operations because they have different requirements. However, for seamless operation of a smart grid, these differences must not impede the flow of data and control. Therefore, the various protocols need to interoperate, possibly via gateways that translate between protocols. This paper defines interoperability and explains how to achieve it with in the smart grid..

A number of industries in the past have attempted to achieve interoperability among providers of software systems necessary for exchanging information between endpoints within the industry chain. Some have been very successful, and their hard won efforts are proudly trumpeted. Yet, many others have either not succeeded or have made slow progress in their efforts to achieve interoperability. This paper explores what is required to conceive and execute a successful interoperability testing methodology, and what are some problem areas to avoid. It will provide the reader with the high-level principals and guidelines (not the excruciating detail by any means) for creating a business and technical plan to build a successful interoperability testing program, regardless of the specific standards or profiles under test. Both positive and negative case studies of other interoperability programs will be provided as informative illustrations. Every industry has different adoption drivers and subtle adjustments must be made to generic testing regimes and methodologies to reflect these differences. This position paper will not discuss these adjustments, and it is assumed the reader sufficiently understands his or her industry and is capable of making these adjustments.

Also, it must be noted that while the energy industry and electric grid utilize many hardware components that are generally best tested through standalone conformance test programs, the electric grid evolution will utilize more aspects of information networks. Information networks, like those found with Internet communications, benefit from an interoperability testing methodology that is distinctly separate from conformance-only testing programs.

This paper focuses on installation roll-out with interoperability (IOP) verification**.** This is the single key perspective necessary for a successful testing program. This paper does not address the follow-on business plan and procedural details in order not to obscure IOP verification as critical for success. This perspective for success is independent of any particular communication standards and interface technology.

Network, software & Device development/deployment life cycle

Before we can describe the keys to a successful interoperability program, we must step back for a moment to see why industries are successful or unsuccessful in their strategies to achieve interoperability. To do this we have to first look at the sequence of how a standards-based software network, system, device, application or component progresses from concept to production and finally to deployment in some marketplace:

1. Standards development begins
2. Early adopters roll-out their 1.0 versions
3. Standards work is completed
4. Late adopters roll-out their 1.0 versions
5. Early adopters roll-out their 2.0 versions
6. Life-cycle maintenance continues for systems and devices in networks

The list above is quite simple, but accurately depicts the realistic roll-out of standards-based devices into network deployments. Earlier vendor adopters often work on implementations of the standard before it is fully ratified or completed. Late adopters join after seeing the market place develop and grow, with the early adopters rolling out new versions that offer improvements and enhancements. Patches and new versions for the systems or device applications are issued continually for products in the field.. One aspect missing from this list that is typically associated with standards development is the testing of implementations to verify conformance or interoperability. Here is the same list, but with some form of a basic conformance testing program inserted:

1. Standards development begins
2. Early adopters roll-out their 1.0 versions
    a) Conformance test profile is introduced by industry normally; early adopters are conformant
3. Standards work is completed
    1. Key to successful standards is inclusion of conformance criteria in the specification
4. Late adopters roll-out their 1.0 versions
5. Early adopters roll-out their 2.0 versions
    a) Conformance test suite is improved/expanded; early and late adopters are conformant
6. Life cycle maintenance continues for systems and devices in networks

The conformance test suite could be as complex as a test harness administered by a third party testing authority or a simpler case of using publicly available testing scripts. From the perspective of the standards community and the implementing vendors, the standards development and roll-out of the system and devices for deployments are complete.

However, the perspective of the users is different:

1. Standards development begins
2. Early adopters roll-out their 1.0 versions
    a) Conformance test suite introduced; early adopters are conformant
3. Field installation of early adopters 1.0 version
4. Installation roll-out with interoperability (IOP) verification
5. Resolve IOP problems among partners over a few 1.0 version devices and systems
6. Standards work is completed
7. Late adopters roll-out their 1.0 versions
8. Early adopters roll-out their 2.0 versions
9. Conformance test suite is improved/expanded; early and late adopters are conformant
10. Field installation of late adopters 1.0 version and early adopters 2.0 version
11. **Installation roll-out with IOP verification**
12. Resolve IOP problems among partners over many version 1.0 and version 2.0 devices and systems
13. New network devices and systems and updated versions constantly enter the marketplace; installation roll-out with IOP verification effort grows exponentially

For end-users, several key facts are observed when standards-based software is involved:

1. Vendors start developing commercial off the shelf (COTS) devices or systems for the market place based on the standard.
2. Vendors market them as conformant to the standard.
3. The industry end-users often understand conformant to mean interoperable.

These three facts may result in high risk to the end-user in the purchase of these COTS units. Depending on how the industry controls the “standard deployment life cycle sequence,” the end-user may purchase systems and devices that are not really “conformant and interoperable” with respect to the standard, but the users may believe that they are in fact both. As a result, this end-user's experience is likely this:

*"The device I purchased does not intercommunicate out-of-the-box with other COTS units claiming to be conformant and/or interoperable to the specification in the marketplace. I have just wasted a lot of effort installing and attempting to make my installed product intercommunicate with my partner's installed unit (i.e. the '**installation roll-out IOP verification**' step did not work well or not at all)."*

As word travels within an end-user community about this unexpected additional time in the "***installation roll-out IOP verification***" step, the introduction and adoption of the standard within the industry may be greatly slowed. How can this be prevented from happening? Negative feedback from a significant number of end-users slows adoption. Positive feedback speeds adoption. Negative feedback happens because software installation is too complex, not interoperable, or not conformant. Positive feedback happens because software is conformant and interoperable as demonstrated by the "***installation roll-out IOP verification***" step.

Of course, not all software used in industry is COTS. Some systems, devices and even networks are developed in-house because of special requirements or needs. However, the same issues apply to these implementations that apply to the COTS units. The implementers followed the standard and expected their systems to be conformant and interoperable with other implementations that follow the same standard. Their experience is similar:

*"Our high-level objective for success is that we need positive end-users who deploy the software and interface to other systems quickly and easily, and the final intercommunication check – '**installation roll-out IOP verification**' – works. Instead, most of our time is spent tweaking and debugging"*

This disconnect in expectations between the end-users, the authors of the standard, and the software/hardware vendors implementing standards-based systems, devices and networks occur in two areas.

Life-cycle Maintenance for IOP among Systems, Networks and Devices

An often important and overlooked component necessary for the industry adoption of a standard is the process and methodology for maintaining interoperability among tested systems, networks and/or devices as they evolve over time via the release of new versions. It has many of the attributes of the "***installation roll-out IOP verification***" step from the end-user perspective, as they install or upgrade to new versions. However from the perspective of the testing regime, backward and forward interoperability compatibility issues must be addressed and resolved so that previous, current and future versions of the standards-based software/hardware systems will intercommunicate properly.

This means there may be significant interaction between the facilitators of the testing regime and the authors of the standards (step 1) to ensure that:

- Previous, current and future versions of the standards are compatible.
- Any ambiguities or contradictions in the standards that lead to interoperability issues are clarified in the standards.

Interoperability and Conformance

Before we look more into detail at how to accomplish the high-level objective stated above, some basic information on interoperability and conformance must be explained. There are many definitions of interoperability and conformance with respect to standards-based software/hardware systems[1]. Two such definitions are listed below. Often a specific standard will have a detailed description of what conformance means to that standard. Hence this detailed description defines conformance for an "interoperable standard."

Definition of Interoperability

"The capability of two or more networks, systems, devices, applications, or components to exchange information between them and to use the information so exchanged."[2]

In general, interoperability testing verifies that two or more implementations adhere to the standard (i.e., are conformant to) *as* they intercommunicate. An important point to note is that saying a single system or device is interoperable has no meaning unless one defines with what it interoperates.. Interoperability denotes a relationship with other implementations; conformance only relates the standard the system, device or network implements but being conformant to the specification is a pre-requisite to interoperability.

Definition of Conformance

International standard ISO/IEC 10641 defines conformance testing as a "test to evaluate the adherence or non-adherence of a candidate implementation to a standard."

In general, conformance testing validates that a single implementation adheres to the requirements of the specification. This type of testing is normally accomplished by executing an implementation against a conformance test engine.

Note: Most standards define sets of functionality that may be implemented from the standard with the resulting software designated as conformant. However, if two implementations that are certified as conformant include different subsets of functionality, achieving interoperability between these two implementations will be problematic depending on how well the standard

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1 Note: Not all standards are interoperable and are not meant to be. Conformance and interoperability are often tightly intertwined when referring to "interoperable standards." We also have in general two classes of standards designed to be interoperable: 1) technical standards and 2) semantic standards. The first deals with the means to exchange information in a reliable, secure and coordinated manner between the software/hardware endpoints. The semantic standards deal with how to interpret the data which has been exchanged. They often differ in how well conformance or interoperability testing uncovers errors. For technical standards we see two classes that differ in how well conformance and/or interoperability testing uncover errors – simple devices and more complex software. Further discussion of these subtle issues is beyond the scope of this position paper and is less important at this point.

2 "EICTA Interoperability White Paper," European Industry Association, Information Systems Communication Technologies Consumer Electronics, 21 June 2004.

specification handles such situations. Thus, it is usually necessary in interoperability and conformance testing to define a “profile”: a subset of the specification that all implementations must include if they wish to be interoperable.

These two concepts, while distinct in definition, are highly interrelated as an industry attempts to facilitate interoperable and conformant software/hardware use among endpoints that exchange information.

The important points to consider from a high level are:

- Conformance testing, while a pre-requisite to interoperability, does not by itself generally produce interoperability among tested units, especially in complex software systems, devices or networks.
- Interoperability is a relationship among systems, devices and networks, and
- Interoperability may be compromised as these systems evolve through the deployment of new versions without a rigorous process for updating the specification, test suites and validation process.

Creating Interoperability and Conformance Testing Programs

In order to facilitate complex systems and networks that are both conformant and interoperable, it is important that standards experts, vendors, end-users and testing methodology experts work closely together to design the test-cases and run the actual testing of the systems, networks or the devices. There are detailed processes and procedures developed to administer this area. A lack of knowledge or cooperation from either group may result in the deployment of non-interoperable or non-conformant systems, networks or devices to the end-user.

> *It is also essential to have executive-level government and industry buy-in to these programs from the start. Ideally, government or industry groups will require testing certification to provide incentives for all vendors to participate. The use of non conformant and/or interoperable products on a standard in the network by some end-users will cause serious problems for all other end-users.*

Some industries may strongly prefer to rely primarily on conformance testing to prepare systems and devices for network rollout. If this is the path chosen, performing a short interoperability test event is still beneficial to verify that system-to-system and device-to-device interoperability was achieved through conformance testing prior to installation roll-out.

The most efficient and effective way to verify that interoperability between systems, devices or networks is in place is to have them intercommunicate via an interoperability test. Not to do so leaves it to the “Install IOP verification” step in the field. We should think of this as a trust the conformance test, but verify it accomplished interoperability – a *Trust but Verify* step. If the implementations are interoperable leaving the conformance testing then this will be a short interoperability test of one or two weeks. Over time interoperability testing may not be required as implementations mature. This all depends on how active the marketplace for these product remains.

Case Studies

Several case studies are listed below. The first shows a sub-optimized adoption of a standard, and the second illustrates that conformance testing through reference systems does not automatically engender interoperability across all devices. The remaining studies are short descriptions of standard tested and certified by Drummond Group and show like finds of these two below. (One of these is mostly semantic interoperability the other is technical interoperability.)

Case Study One – Sub-optimal Adoption

The Drummond Group (DGI) worked with a standards organization serving the electronics supply-chain industry. This standard allows trading partners of all sizes to exchange electronic transactions and move information across their extended supply chains. They came to DGI when faced with growing implementation costs, adoption problems, and unhappy end-users asking about interoperability testing as a means to solve their adoption issues. DGI produced a plan for them because many of their software vendors were involved in a highly successful interoperability program with another standard and were recommending DGI as an entity to help facilitate adoption. Those vendors presented the standards group with an interoperability plan, yet despite many meetings and conversations, it was decided to spend millions of dollars on the development of a conformance engine. The conformance engine took about a year to develop, and with growing outcries from their user community, a certification program around the conformance engine was put into place.

Within two years, the standards group was having financial issues because their projected revenues for this conformance engine did not meet their costs. Why? Interoperability issues persisted and unhappy users did not view the certification as important because it was not resolving their deployment problems in the field. They did not find the certification program worthwhile, and were no longer requiring it of software vendors. The implementation costs spiraled and adoption of the standard slowed to a crawl.

A year later, this organization was purchased by another group who contracted DGI to run their conformance test engine certification program. As a result, DGI could see from the inside the interoperability challenges this organization faced and never addressed. The standard continues today but the implementation costs are significant and only large scale implementations can afford the costs. (This is largely semantic interoperability with some technical interoperability (protocols))

Case Study Two – Conformance Testing Failing to Lead to Interoperability
Drummond Group began sponsoring and administering AS2 interoperability test events. AS2 is a secure business-to-business (B2B) transport standard (RFC 4130) providing data encryption, authentication signatures, receipt acknowledgment and other defined requirements to enable non-proprietary interoperability. The test events defined by DGI were full-matrix, where each

participant executed all test cases with the other participants. This simulated product-deployment permutations they would encounter within the end-user community.

Within a few years, AS2 adoption in retail and other vertical industries grew, and the number of interested vendors grew as well. To improve the test process, DGI created a pre-test conformance prerequisite for new applications. These new participants were required to test successfully against three reference products that had completed the previous AS2 interoperability test event before the new product was allowed to join the next interoperability test event. The same test cases required in the interoperability test event were used in this preceding conformance test.

It was clearly observed that reference product conformance testing did not engender interoperability across all other similarly conformant products. Even though the new participants would meet the pre-test requirement and demonstrate AS2 conformance, they still experienced numerous interoperability problems with some of the other products participating within the full-matrix interoperability test event.

The important take away from this AS2 conformance test program was that while it did better prepare products for interoperability through conformance checking, only simulated end-user deployment interoperability testing fully prepared them for successful and interoperable deployment to production environments. (This is technical interoperability (protocols) and no semantic interoperability involved)

DGI Experience in Interoperability Testing

Other standards DGI has tested over the last ten years of interoperability/conformance testing show much the same findings as the above two case studies. The developers of the implementations and the deployments in the marketplace span the global market including North America, Europe, Asia, and the Pacific Rim and include Fortune 500 and Fortune 100 companies. A list of the standards that regular undergo interoperability include:

AS1 - AS1 (Applicability Statement 1) is the RFC standard (RFC3335) by which vendor applications communicate EDI or other business-to-business data (such as XML) securely over the Internet using SMTP, the same standard used for email. AS1 interoperability certification testing has been preformed for over 10 years, certifying over 70 different product-versions. (Technical interoperability)

AS2 - AS2 (Applicability Statement 2) is the RFC standard (RFC 4130) by which vendor applications communicate EDI or other business-to-business data (such as XML) over the Internet using HTTP, a standard used by the World Wide Web. The AS2 standard continues to be one of the most widely adopted messaging standards in the world. With retailers, consumer products goods, hard-lines, insurance, financial services, petroleum and government industries adopting AS2, the critical financial information that flows over AS2 messaging represents billions of dollars each year. To ensure that important transactional information is received securely, full matrix interoperability certification is mission critical for these industries. There are typically some 20-30 products from around the globe participating in each round of testing with an estimated 40,000 test cases exchanged in each test round. There are a number of additional optional profiles that are also tested which include Certificate Exchange Messaging, Multiple Attachments, Filename Preservation, Reliable Messaging, and Chunked Transfer. (Technical interoperability)

AS3 - (Applicability Statement 3) is the draft specification standard by which vendor applications communicate EDI (or other data such as XML), similar to AS2 and AS1, but over the Internet using File Transfer Protocol (FTP). Nearly 50 versions of AS3 systems have been certified by DGI in the last 6 years. (Technical interoperability)

ebXML Messaging - ebXML-MS does not define the business processes or the content of the messages being sent. ebXML-MS only concerns itself with the secure and reliable transmission of the payload. ebXML-MS Message Service Handler (MSH) sits between the network protocol (SMTP, FTP, HTTP, etc.) and the Business Process at each end. In this way, the MSH is independent of both the transport protocol and the higher level business processes. ebXML-MS can be used to transmit any payload over any network connection. ebXML-MS adoption has been widespread in the auto industry, healthcare and technology verticals industries as well as through out Europe and Asia. DGI has sponsored yearly certification tests since 2001 with over 60 products-with-version certified. (Technical interoperability)

SAML – SAML is a standard for exchanging and consuming identity assertion among parties of a trusted federation. Heavily deployed in governments, like the US, France and Denmark, it has broad acceptance in the identity management world. Nearly a dozen product versions have participated in the DGI interoperability SAML test events over the last two years. (Technical interoperability)

GDSN – GDSN is from the GS1 organization, and this standard enables the exchanging and synchronization of item data information. It is a worldwide initiative, with companies from US, China, Germany, UK and over twenty other countries employing GDSN for retail, hardline and other industries. DGI has certified all GDSN data pools since its inception in 2004. (Semantic and technical interoperability)

Conclusions and Recommendations

Regardless of the standard or the industry, a successful interoperability testing methodology must take a complete view of the entire network and standard life-cycle, especially at the "***installation roll-out IOP verification***" step where end-users experience the greatest difficulty. We must not start our planning for interoperable conformant networks, systems or devices with a focus on the actual technical testing. We must start our planning with a much wider view that focuses on facilitating adoption in the industry. A critical key in this plan is starting at the point of facilitating the "***installation roll-out IOP verification***" step and working backwards into the actual testing and test plans**.** Since this step requires early adopter end-users to be part of the testing process along with the standard body and early adopter vendors. The administration will organize all parties to create an interoperability testing program that delivers successful end-user deployment and wide industry adoption.

It is critical to remember that you never know if conformance produces software that is conformant and interoperable as seen in the "***installation and roll-out IOP verification***" step until either:

1. Feedback is received from the installer that it worked or did not work.
2. IOP test event is executed on all the implementations before they are released to field.

Relying solely on a conformance test to provide end-user installers the interoperability they need is short sighted. If an IOP event is not scheduled, expectations must be clearly set with the industry users that interoperability problems may occur, and with the vendors that the standards body may need to make wide scale changes quickly based on the feedback they receive. Given the challenge of doing so, IOP events are more efficient means of achieving the desired interoperability even though they often take weeks to perform.

Finally, when used to describe systems, device and networks that distribute and consume information, the term "*interoperability*" must be understood as a relational term. A single device or system can not be interoperable by itself but only in relation to another device or system. Without repeated interoperability verification with new devices and systems, an individual version of a particular devices and system "ages" in the network life-cycle and loses value. In information networks, interoperability has a shelf-life of 12-18 months. Only by repeated testing through out the life-cycle can a version of a device or system extend interoperability within a deployed network.

In the end all of the above means that the industry must administer a "life cycle testing program" for each standard, not just a "technical test." This "life cycle testing program" for each of the appropriate standards will be needed for many years or in the utility industry possibly for decades. Depending on the demand by the market-place for implementations of any given standard, some tests are repeat twice annually, some annually and some every few years.