Smart Grid Testing & Certification Committee (SGTCC)

Interoperability Process Reference Manual (IPRM)

Version 1.0

November 18, 2010

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Contents

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1.0 Introduction

One of the major issues facing the Smart Grid community to-date is unacceptable levels of product interoperability with products claiming to be certified to common standards-based communication technologies. This poor level of product interoperability formed the basis in which the Smart Grid Testing and Certification Committee (SGTCC) was tasked by the Smart Grid Interoperability Panel (SGIP) to create "the necessary documentation and organizational framework for compliance, interoperability and cyber security testing and certification". The SGTCC determined that an Interoperability Process Reference Manual (IPRM) was a critical part of this framework.

The IPRM outlines the conformance, interoperability and cyber-security testing and certification requirements for SGIP-recommended Smart Grid standards. This document has been designed to capture testing and certification processes and best practices needed to verify product interoperability amongst two or more products using the same standards-based communications technology. These processes and best practices are intended for use by an Interoperability Testing and Certification Authority (ITCA) in the design and management of a testing and certification program.

This IPRM focuses on describing the functions and responsibilities of the ITCA, but does not propose an organizational structure since it will vary based on the standard and standard's marketplace.

2.0 Purpose

The IPRM outlines the role of an ITCA and specifies the testing and certification processes associated with achieving interoperability for a specific smart grid standard. The IPRM is intended for adoption by any ITCA that is responsible for coordinating testing and certification of a Smart Grid technology standard. Mandatory requirements are denoted by the keyword "shall", and other recommended best practices are denoted with keywords "should, must or may".

In the context of interoperability, product certification is intended to provide high confidence that a product, when integrated and operated within the Smart Grid, will function as stated under specific business conditions and / or criteria. The IPRM defines criteria, recommendations and guidelines for product interoperability and conformance certification. It is important to understand "Interoperability" has no meaning for a single product but for a relationship among two or more products. Alternatively, conformance does have meaning for one product as it applies to its meeting the requirements of the standard or test profile. Conformance testing alone does not guarantee interoperable products and interoperability testing does not necessarily mean that products are conformant to the standard. Conformance testing increases the likelihood that products will be interoperable and is typically a pre-cursor to interoperability testing. The IPRM requires that a certified interoperable product shall conform to a standard or profile of the standard.

3.0 Intended Audience

The IPRM is to be used by the ITCA in its role in managing the interoperability testing and certification processes of smart grid standards based products. While standards-based products can reach the market-place and eventually be interoperable, many standards require organizations whose sole function is to drive and coordinate adoption from a business and marketing point of view. The function of the ITCA is to increase the adoption rate by bringing together end-users, vendors, test labs and certification bodies with the goal of reducing lead times associated with standards development and the subsequent provision of interoperable products in the market-place.

While the IPRM's audience is the ITCA, it recognizes that many parties will actively participate in the generic product interoperability certification processes. In particular, the following major actors are involved with the evolution of interoperable standards based technologies:

- Product and System Integrators
- Product Developers and Vendors
- SSOs - developing interoperability standards
- Interoperability Testing and Certification Authority
- Testing Laboratories
- Certification Bodies
- Customers/users of the products

4.0 Scope

The IPRM assumes an ITCA is established for a given standard and addresses responsibilities of that ITCA. Some activities associated with ITCA include:

- Designing, developing and managing a testing and certification program
- Monitoring and enforcing testing and certification policies and procedures
- Managing relationships between various actors and stakeholders
- Managing conformance and interoperability assessments in the course of standard creation

It should be noted that ITCAs do not currently exist for all Smart Grid interoperability standards. As a result, new ones will need to be organized to coordinate and help drive adoption of specific standards. While the IPRM can help new ITCAs in establishing their policies and best practices, it does not address the process by which an ITCA is formed.

5.0 Overview

The overview provided in this section will assist in clarifying the goals and requirements of the Interoperability Process Reference Manual (IPRM).

5.1 IPRM Model for Product Testing and Certification

The testing of products involves the transformation of use-case scenarios into an appropriate set of testing scenarios. Figure 1 depicts the process of transforming product use cases into a set of test scenarios which will be used to define an application test profile group[1]. A product vendor instantiates the application test profile group by building a particular hardware or software solution. As a rule, product vendors attest to the supported feature set by way of the proforma (e.g. protocol and / or profile) implementation conformance statement (PICS)[2]. PICS documents, together with the test specification and the most up-to-date applicable tests as maintained on the Test Case Reference List (TCRL)[2], produce a Test Plan for a particular testing campaign[2].

[1] Application test profile group is the set of test profile categories (the folders in the picture) that form the totality of a series of tests that correspond to verification of the application profile feature set.

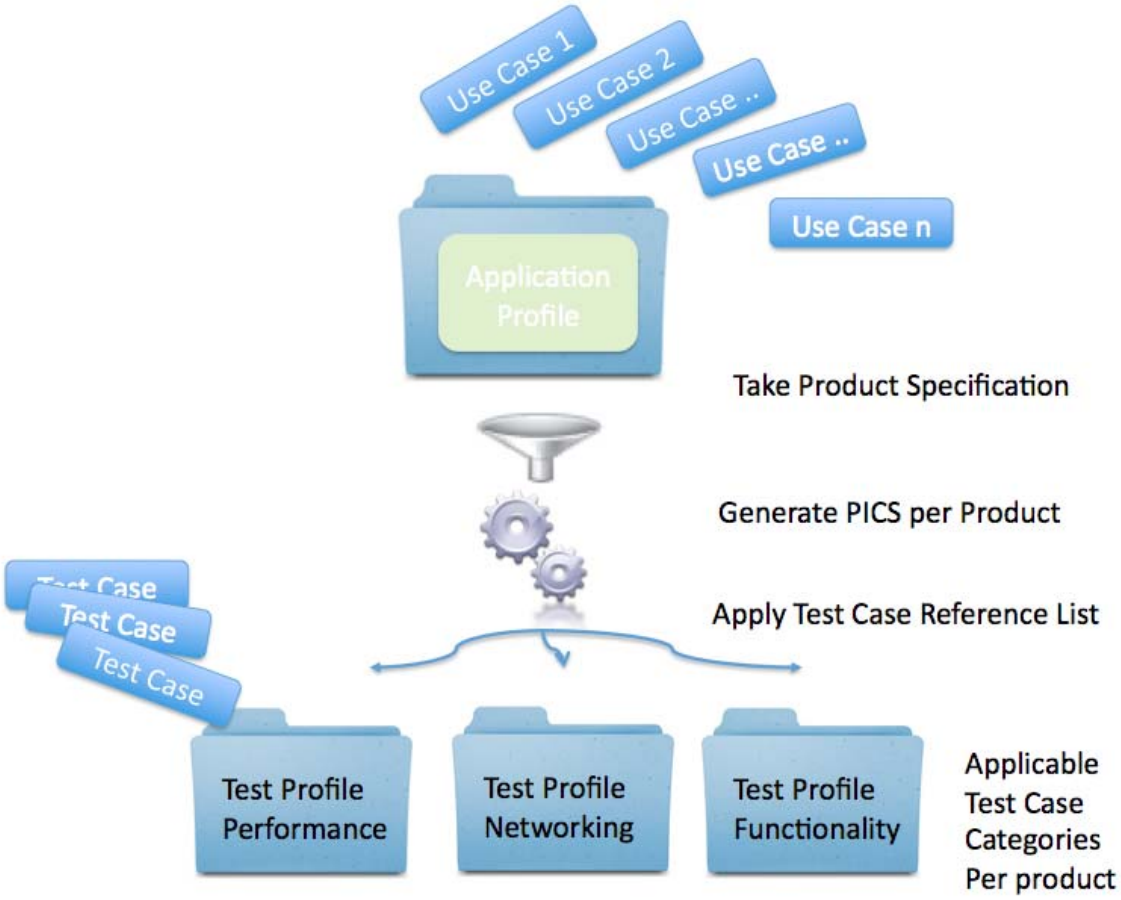


Figure 1 – Use Case to Test Case Transformation

The application test profile group is used to develop test plans with the intent of directing a test laboratory in executing the appropriate product tests within each of the test profile categories. A set of conformance tests is generally required during the testing process, and applies to different layers of a product.

In Figure 2, the 7-layer Open Systems Interconnection (OSI) model illustrates the communication network environment for a product. Generally, both hardware and software products fit into this communication application architecture model and their specific test profiles

relate directly to a respective layer of the OSI model. Each specific test profile will generally use a test setup or "test harness[2]". It is the role of the ITCA to determine the technical viability of using test harnesses for the product interoperability testing processes.

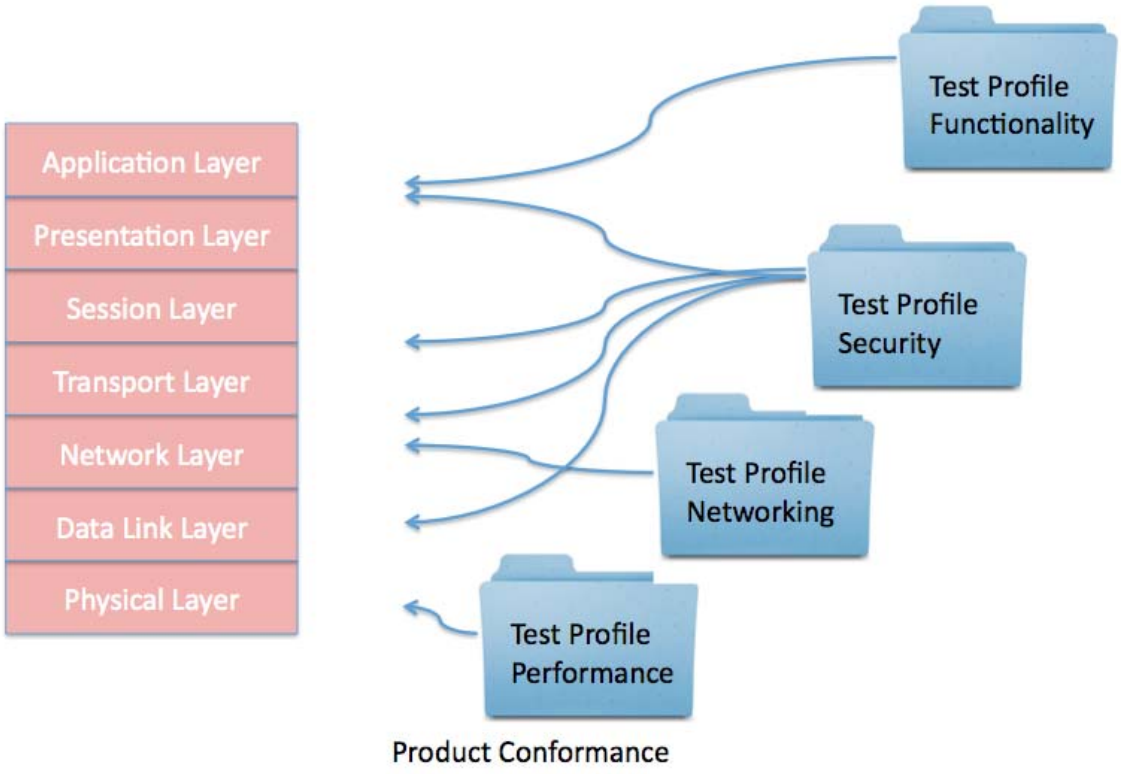


Figure 2 – 7 Layer OSI Model Mapped To Product Testing Profiles

Prior to interoperability testing, a product is tested for conformance to the specification at each relevant OSI layer.

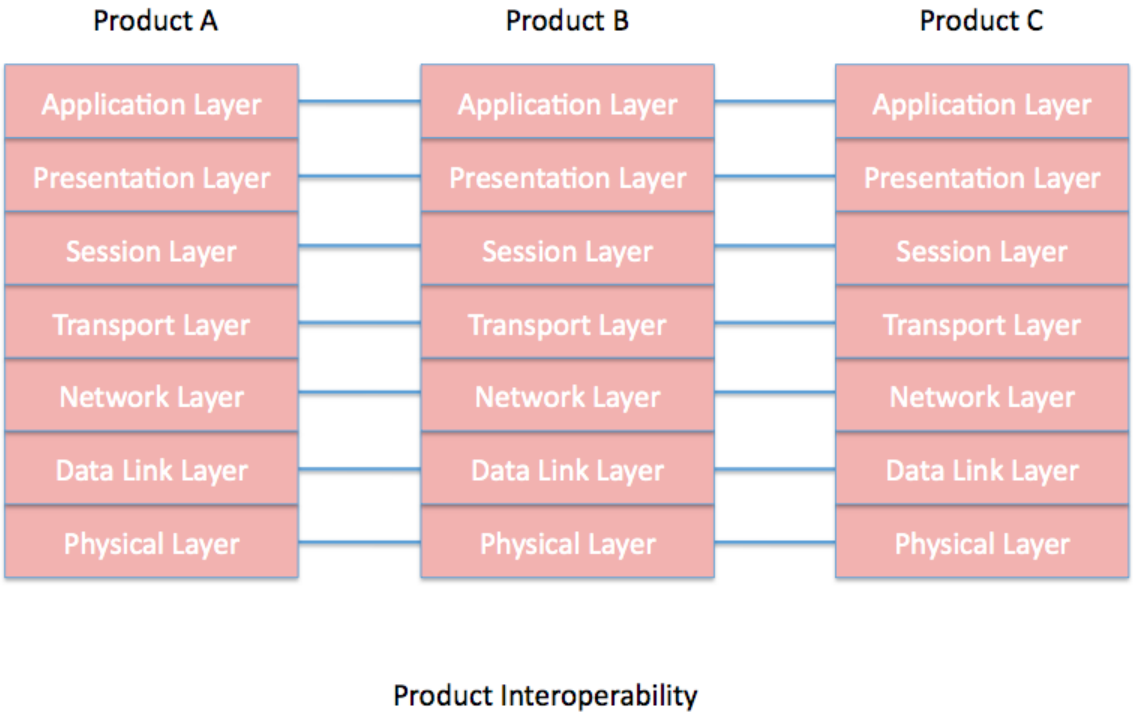


Figure 3 – Product Interoperability Correlations At Each Relevant OSI Layer

As depicted in Figure 3, product interoperability testing involves hardware and / or software products (e.g. product A, B and C) intercommunicating at each relevant OSI layer. With this depiction, product A may be part of a validated test harness and therefore treated as a "golden unit". The introduction of golden units (i.e. actual production market devices) in a testing program is made at the discretion of the ITCA. In general, product conformance testing assures product level interoperability.

The set of conformance and product interoperability tests help define a testing program for smart grid solutions, and is applicable to both hardware and software products. A typical set-up in the communication industry is the alignment of a testing program with the specific test profiles. As noted previously conformance testing is in general "orthogonal", or sepa-

rate from interoperability testing. Nevertheless, conformance and interoperability testing are interrelated in a matrix relationship.

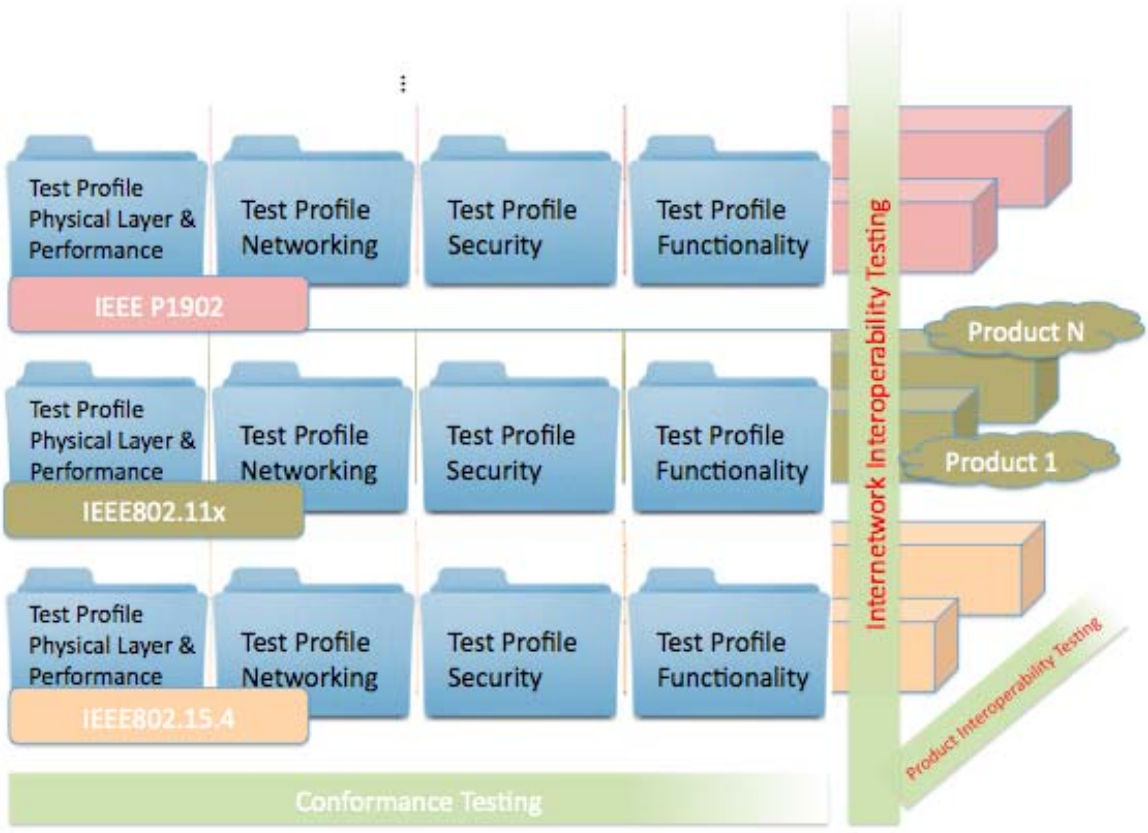


Figure 4 – Product Conformance And Interoperability Testing Matrix

As shown in Figure 4, the Y-axis represents internetwork interoperability (i.e. transactions between different physical layer implementations via routing systems) while the Z-axis represents inter-product interoperability related to interaction between different instances of a particular set of physical networks.

Finally, the end-to-end network interoperability testing example in Figure 5 illustrates the requirements of a smart grid utility when implementing a communications standard from the meter head-end system to the edge realm.

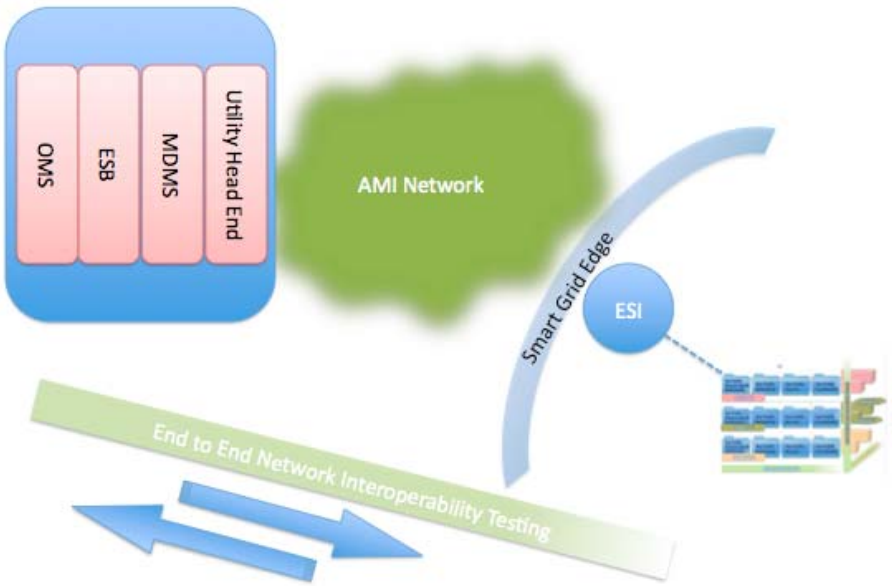


Figure 5 – End-to-End Network Interoperability Testing

In summary, interoperability testing is not only relevant for product-to-product interoperability but also for inter-network and end-to-end network interoperability.

Figure 6 shows the relationship between conformance and interoperability testing.

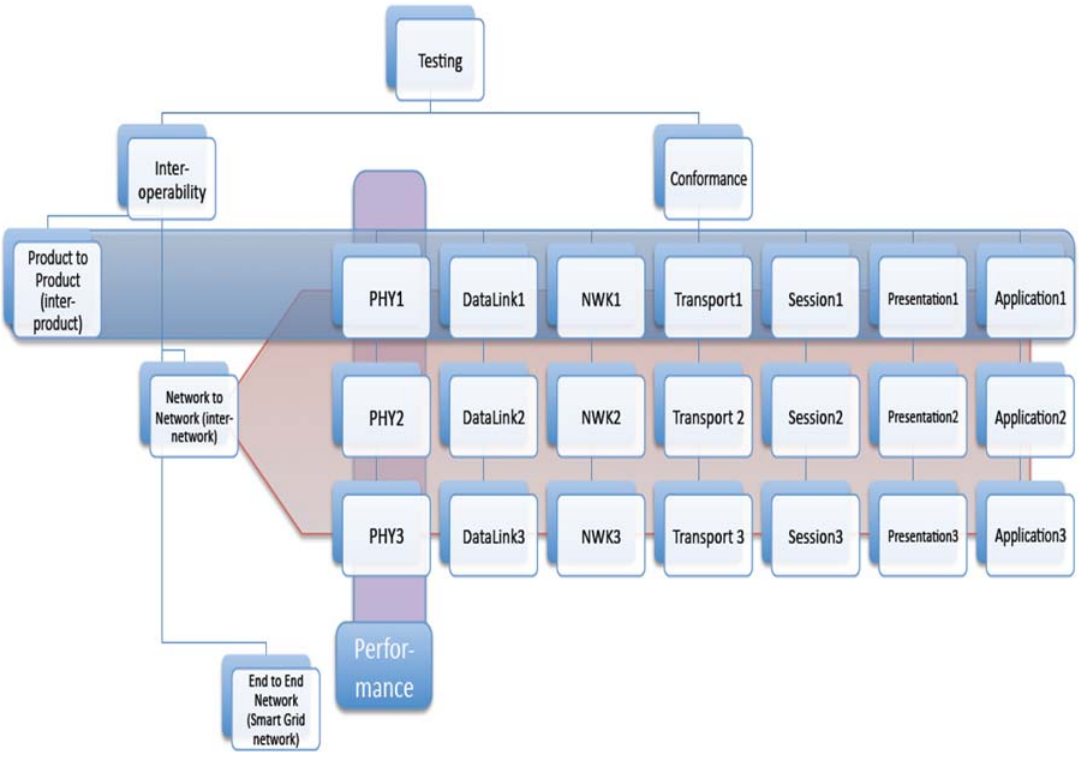


Figure 6 – Conformance and Interoperability Testing Relationship

A full coverage of all use cases and resultant test cases, and verification against all instances of products is the only way to ensure full deterministic interoperability. Generally, practical considerations make a full coverage impractical. Hence this document assumes statistical coverage of use cases and test cases, and therefore by default, the product interoperability discussed here is generally statistical in nature.

5.2 Scope of ITCA Categories

Communications technologies have typically followed certain methods to verify interoperability, and these methods are reviewed in this section based on their category. Each ITCA

category addresses different scopes of communication, networking, or business layers and logic.

5.2.1 Category I ITCA:

Manages testing and certification programs for communication technologies involving one or more layers from layers 3-7 of the OSI stack. Typically it involves verifying the application level pair-wise communication between two product implementations of a standard.

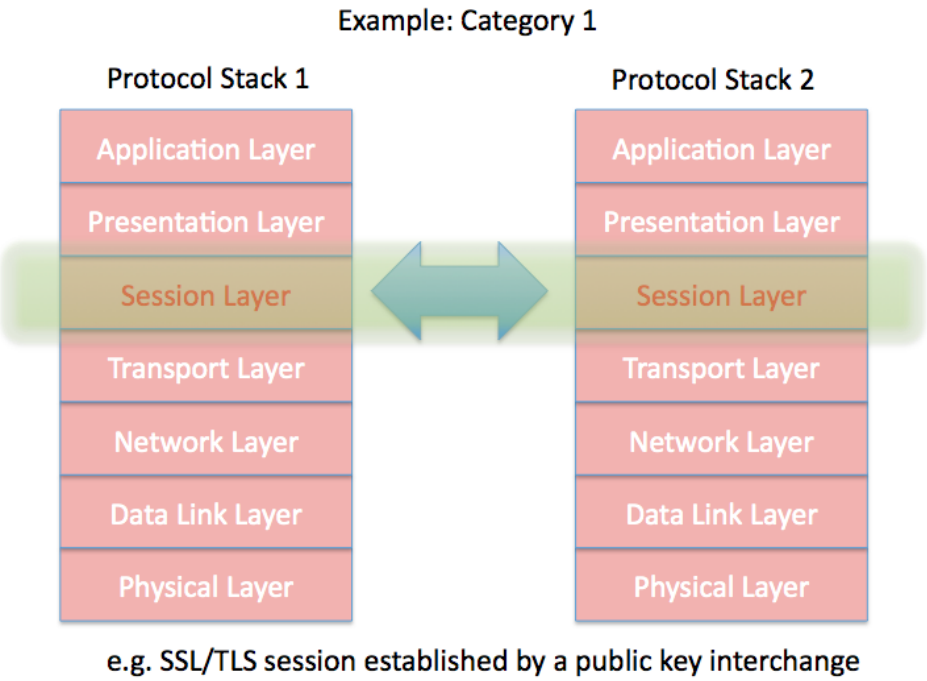


Figure 7 – Example of Category I ITCA

5.2.2 Category II ITCA:

The Category II ITCA manages testing and certification programs for platform[2] level communication protocols. This includes Physical and Data Link Layer conformance testing, interoperability testing, and performance testing.

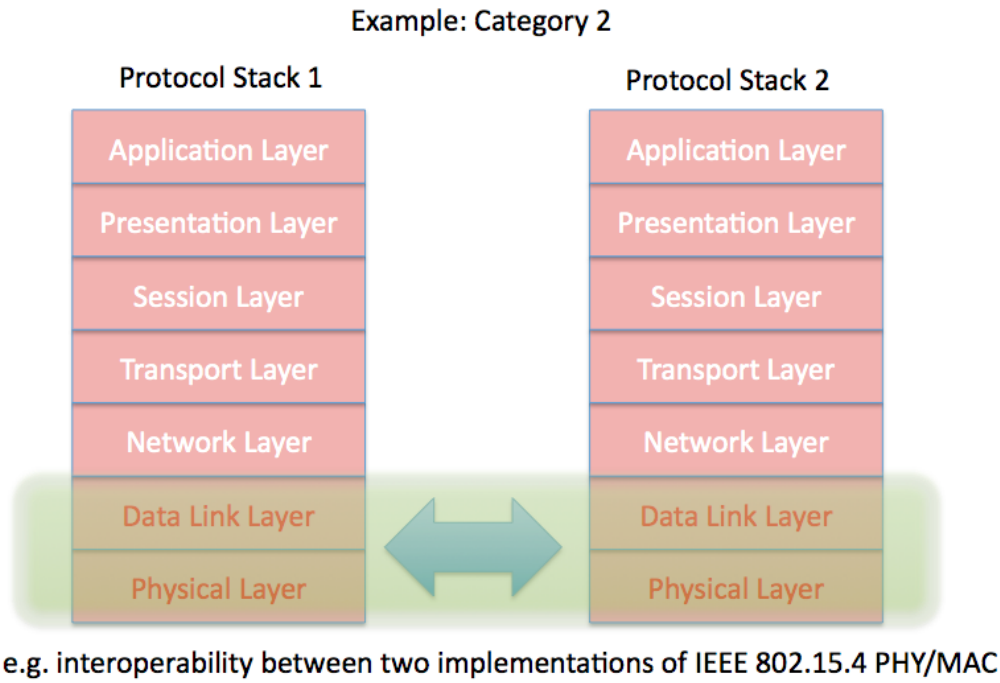


Figure 8 – Example of Category II ITCA

5.2.3 Category III ITCA:

The Category III ITCA manages testing and certification programs for communication technologies corresponding to Physical and Data Link Layer and one or more of the higher layers. The Category III ITCA includes Category II ITCA, protocol conformance testing above PHY / MAC layers and device level or product level interoperability testing. The Category III ITCA may also rely on Category II ITCA certificates when sufficient inheritance rules are defined and agreed upon.

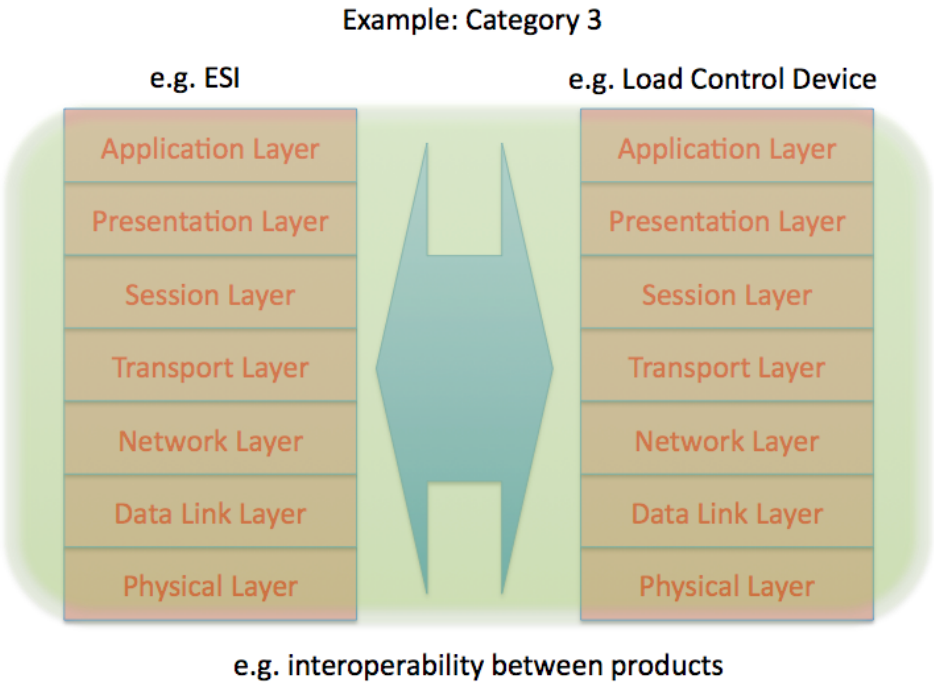


Figure 9 – Example of Category III ITCA

5.2.4 Category IV ITCA:

The Category IV ITCA manages testing and certification programs for communication technologies based on standards requiring interoperability between dissimilar physical networks. The Category IV ITCA includes Category II ITCA and Category III ITCA certification results, as well as the certification of interoperability for other relevant layers.

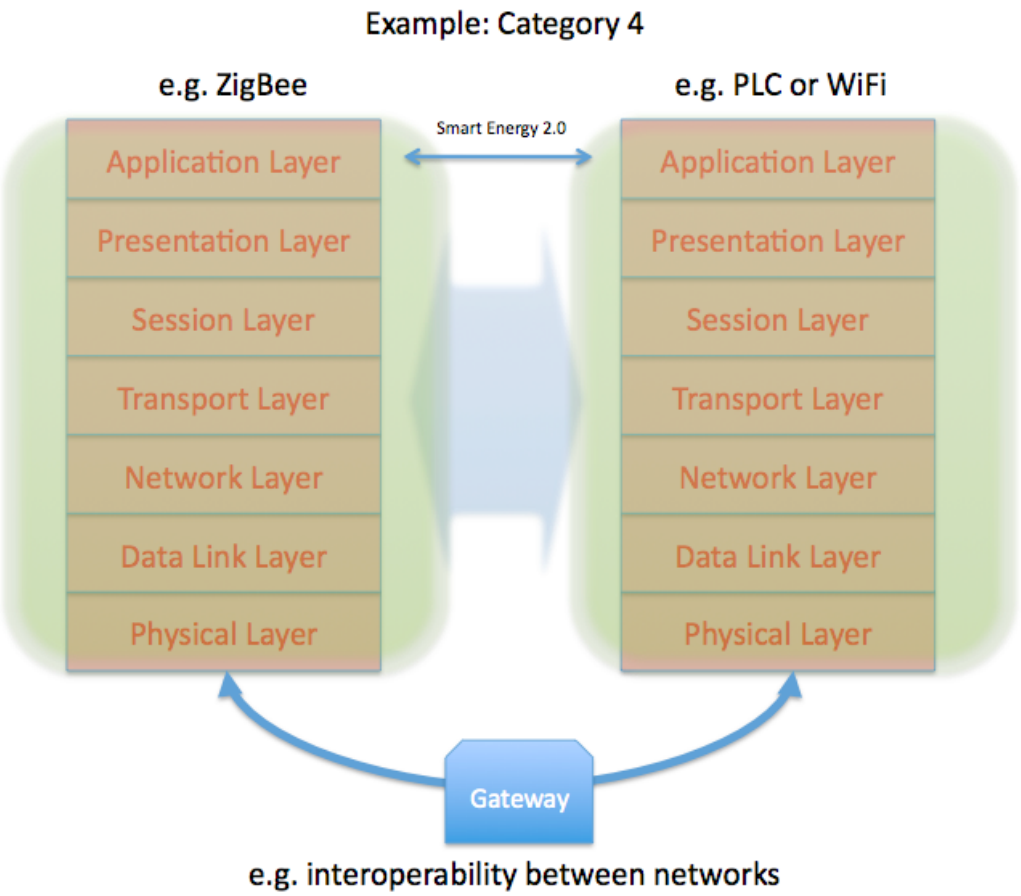


Figure 10 – Example of Category IV ITCA

5.2.5 Category V ITCA:

The Category IV ITCA manages testing and certification programs for communication inter-networking technologies, and incorporates Category I, II, III or IV ITCA testing results depending on the standard and system level interoperability required by a deployment. End-to-End network interoperability testing (e.g. simulating a back office network) is typically involved as part of the Category V ITCA.

Any category standard can require a Category V ITCA if the standard also specifies behavior associated with communicating with a third party (e.g., utility back office

system). In this case, the Category V ITCA shall specify test cases that capture the desired behavior (e.g. simulate a utility back-office system).

Other than the above requirement, a Category V ITCA shall follow the requirements stated elsewhere in this document depending on the type of standard it specifies (i.e. Category I, II, III, or IV ITCA). Smart Energy Profile 2.0 is an example of a Category V ITCA standard since the standard describes registration to a service provider network.

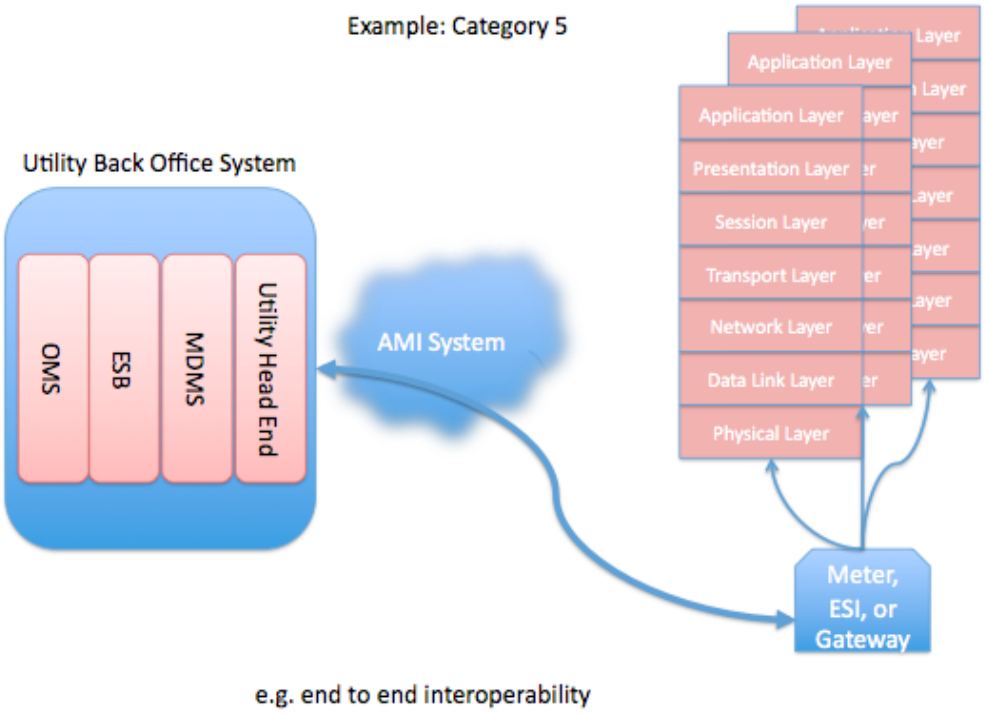


Figure 11 – Example of Category V ITCA

5.2.6 Business Reference Authority:

Depending on the standard, there might be a need for an additional layer of authority testing to enforce additional specific requirements for a standards-based technology. This document recognizes the importance of such entities, but does not specify requirements for such entities since their scope varies greatly based on the business requirements.

As an example, the development and integration of the Smart Meter Texas portal to support energy management programs using Smart Energy Profile 1.0 was based on business processes defined within the State of Texas. The business processes further defines the operational aspects of the integrated solution which ultimately affects the product interoperability test cases.

6.0 Product Testing

6.1 Testing Scope and Administration

Testing for conformance and interoperability requires considerations for the overall test coverage as illustrated in Figure 12. A test suite generally represents a set of test cases in each of the categories (e.g., network test suite) represented in the diagram. A test profile can be defined for an element of that category, along with various test suites and test resources[2] such as test harnesses. A test campaign can represent a test profile implementation or specific test suites; in either case, the campaign defines the scope of testing and the administration related to management of the process.

ITCA is expected to dependably manage a testing program. The details of the actual process control are described as part of the Testing Program outlined in section 6.2.

For each test suite, basic administrative controls are required and formalized using testing resources such as PICS, test case reference lists, version control, test ;aboratories, and validated test harnesses. The record of administrative control is outlined in the test plan, test report and product compliance folder[2]. It should be noted that a test harness[2] and test interfaces[2] shall follow the architecture according to ITU X.291.

[2] See Glossary of Terms.

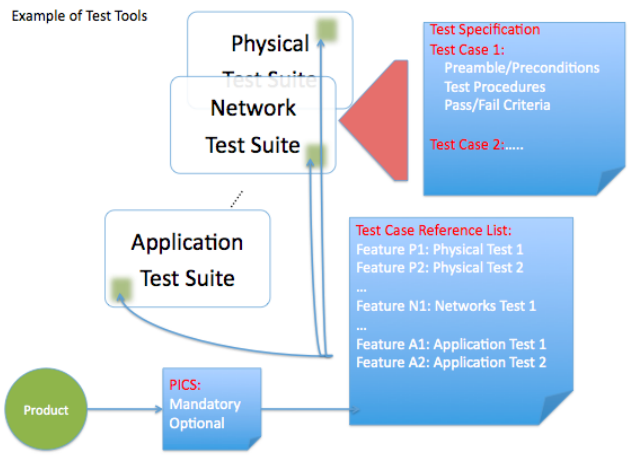


Figure 12 – Product Test Planning

Figure 12 also illustrates a process in which the product, with its mandatory and optional features per declared PICS, is processed for test planning using the Test Case Reference List and a subsequent test implemented according to the test specifications.

7.0 Testing Program

7.1 Testing Process Management

Testing processes are often developed separately from the product development process. This provides for a level of technical independence that makes good testing rigorous and objective. At the same time, it creates a conflict with certain realities of product development, both in the hardware and software realm. Figure 13 depicts a typical product life cycle process which is used in delivering a product to market. Previous sections in this document provide a context in which these processes are applied in a particular test campaign.

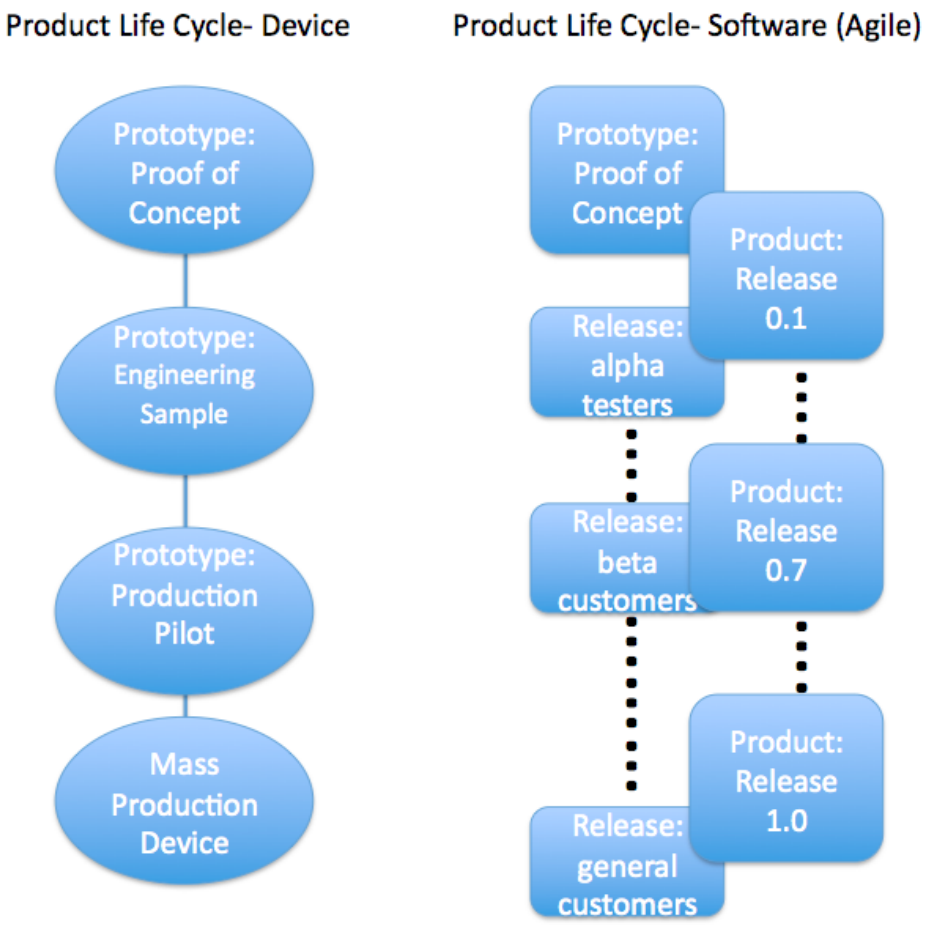


Figure 13 – Product Life Cycle

Product certification through testing ostensibly needs to happen at the end of the process depicted in the diagram. With respect to hardware, product certification lies somewhere between the production pilot and mass production processes. As for software, product certification is performed before the general release of the software (i.e. version 1.0) to customers. However, economic reality dictates that changes resulting from test evidence should happen as early in the process as possible. This requires that during each and every step of the product development process, it is in the best interest of both the manufacturers and the ITCA to provide frequent certification program-related testing resources[2] throughout the process. Frequent testing reduces the total cost of the product and increases market acceptance, since problems are detected early and folded into the design of the product.

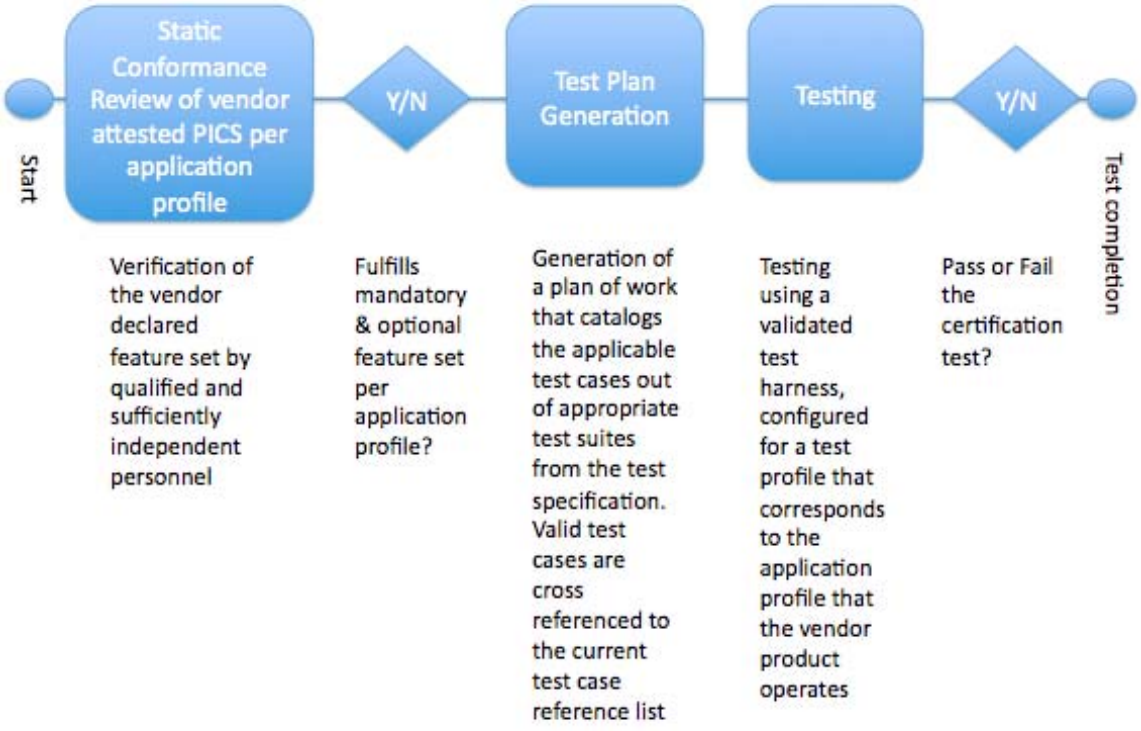
To address the need for frequent testing, third-party test laboratories are used for pre-testing. ITCA-sponsored testing events are organized to facilitate the introduction of a fully conforming and interoperable product into the market

Figure 14 – Transition From Pre-Testing / Engineering Testing To Certification Testing

The transition from ITCA-sponsored pre-testing / engineering testing to certification testing, as noted in Figure 14, may not always be as clear-cut when the service is rendered by an ITCA-validated third-party test laboratory. Rigor is injected into the process by third-party laboratories by their having a test service management system adhering to ISO Guide 17025..

7.2 Certification Testing for Conformance and Interoperability

Once testing moves to the Conformance and Interoperability Certification Testing phase with the test laboratories, the following steps are generally expected. Note that this may happen at any point in the product development process, and that when it is prior to the end of the development cycle, it is the responsibility of the vendor together with the test laboratory, per their test service management system, to fulfill the canonical steps described in Figures 15 and 16 for certification related testing.



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381 Figure 15 - Conformance and Interoperability Certification Testing – Part 1

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Figure 16 – Conformance and Interoperability Certification Testing – Part 2

The process denoted in Figures 15 and 16 is implemented by a test laboratory for certification testing of conformance and interoperability. The roles and responsibility of individual experts may differ with each ITCA. One key point to recognize is the independence of the product vendor, tester, qualifier, and certifier processes.

7.3 Products and Product Systems

The testing and certification process will be applied to products being implemented as smart grid technology. In certain instances, products are composed of components which are used to build a total product system. In such cases, components or "subsystems" may be subject to separate and inheritable certification processes by the ITCA.

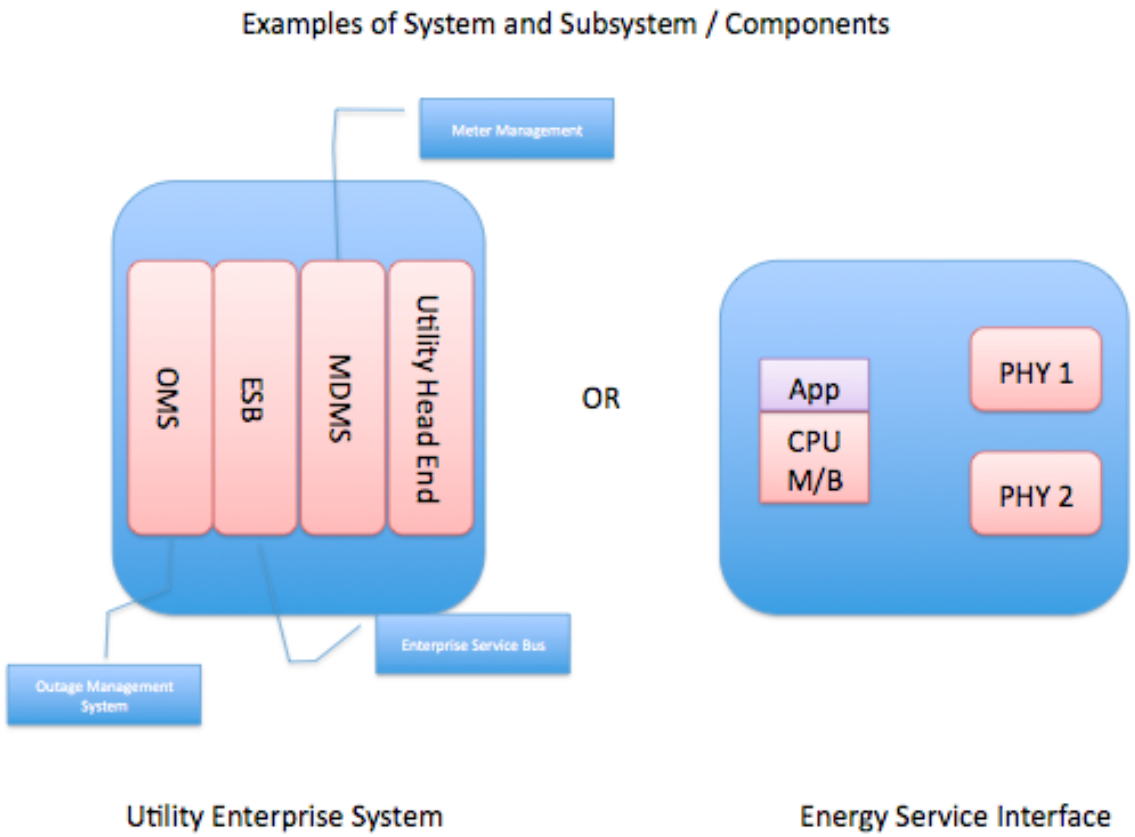

Figure 17 – Examples of System and Subsystem / Components

In figure 17, a large enterprise utility software system and an edge in-premise energy service interface device are given as examples of a system and subsystem / components. Any one of the components of the respective integrated product may be subjected to testing under the ITCA requirements, and its results may or may not be inheritable by the integrated system. The successful inheritance by an integrated system depends on the test coverage and the version of the testing applied to the subsystem, and the version of the subsystem itself.

The record of work of the subsystem component, or the system test, is stored in the compliance folder of the product. The compliance folder will include the detail of the Compliant Portion Description (CPD)[3] of the subsystem, if it is to be inheriting the certified test status of that subsystem and integrating it into the whole system. In such a case, the system certification is additive of the CPDs of constituent components, but may still need additional tests based on test coverage as defined by relevant applicable test for the application profile for the product in question, and as defined by the test plan derived from the PICS, Test Case Reference List, and Test Specification.

[3] See Glossary of Terms for definition and explanation of CPD

8.0 Interoperability Testing And Certification Authority Role And Requirements

The ITCA shall provide governance and coordination for the maintenance and administration of Interoperability Testing Laboratories and Certification Bodies in cooperation with the relevant SSOs and user groups. An ITCA shall manage the end-to-end processes associated with interoperability testing and certification. It is assumed that the ITCA has the appropriate infrastructure in place to support this function. Although beyond the scope of the IPRM, if a new ITCA is being launched, establishment of the following is recommended:

- Business plan
- Clear governance structure and IPR policy
- Testing lab(s)
- Certification body / bodies
- Security certificate authority
- Technical Lead(s)

The following information shall be used as a guide by the ITCA to improve the interoperability and quality of a Smart Grid standards based product.

8.1 Interoperability Requirements For Use By The ITCA

The interoperability requirements are comprised of five major categories which will be used by the ITCA to effectively manage the testing and certification organization processes. The five major categories are:

- Governance
- Lab Qualification
- Technical Design
- Improvement
- Security

The IPRM requirements are written with the key word "shall". However, depending on the standard under consideration, only a subset of those requirements are relevant. The following conventions are being used for classification:

- Basic (B) – Minimum requirement. The requirements shall be considered mandatory and included to ensure interoperability.
- Optional (O) – Requirement identified as a use case for the business application, but shall not be considered mandatory as part of the interoperability testing.
- Not Applicable (N/A) – Requirement identified as a use case for the business application, but does not apply to the specified standard under consideration.

As mentioned in section 5.2.5 above Category V ITCAs are required to adhere to the requirements of Category I, II, III and IV ITCAs depending on the standard under consideration. However, in addition they shall satisfy requirements Tech 36 and Tech 37 below.

8.2 Governance

Governance defines the structures, policies, rules and regulations associated with the ITCA certification program. A governance process example would require the ITCA to establish and maintain an independent and vendor neutral testing and certification oversight authority. The following list of Interoperability Governance Process Requirements provided in Table 1 shall be considered governance process requirements for managing the interoperability testing and certification programs.

Govern-x	Interoperability Governance Process	ITCA Category			
	Requirement Description	I	II	III	IV
Gov-1	An interoperable standard shall have an entity identified as the ITCA. This entity shall be responsible for	B	B	B	B

	ensuring that implementations are in fact interoperable.[4]				
Gov-2	An ITCA shall be considered valid as long as its users' community considers it valid, and when there exists three or more distinct implementations of the specification for which the three distinct implementations are from three different entities. These three or more distinct implementations must be available or declared available. Note: If the three distinct entities declare intent to implement the specification, this requirement is satisfied.	B	B	B	B
Gov-3	The ITCA certifying the highest layer of technology under test shall not declare an implementation as interoperable if it discovers interoperability problems at a lower layer (e.g. the ITCA responsible for application layer testing returns the product to lower layer ITCAs for further investigation of non-interoperable features).	B	N / A	B	B
Gov-4	The ITCA shall clearly define the circumstances in which it supports first party testing.	B	B	B	B
Gov-5	The ITCA shall clearly identify the circumstances in which third-party testing is required.	B	B	B	B
Gov-6	The ITCA shall define a corrective process for resolving interoperability problems (e.g. in the field or as part of the test).[5] Further, it shall implement preven-	B	B	B	B

[4] Situations where a clear ITCA does not exist are out of scope of this document. The SGTCC will tackle issues where clear ITCAs do not exist in a separate effort.

[5] The ITCA should use best efforts in contacting a standards body with respect to a specification; however, it not their responsibility to resolve issues with the specification.

	tative processes to avoid recurrence of such problems. A problem may be associated with the specification, the test processes and procedures or the test data.				
Gov-7	The ITCA shall define roles, responsibilities, and resource elements of the interoperability program in a concise document.	B	B	B	B
Gov-8	The ITCA shall support a mechanism to raise issues up to steering bodies and liaison organizations for business, regulatory and standards interoperability considerations.	B	B	B	B
Gov-9	The ITCA shall maintain a certified product and systems list. This list shall be publicly available.	B	B	B	B
Gov-10	The ITCA shall maintain a test case reference and modification history list.[6]	B	B	B	B
Gov-11	Test Suite Specifications (TSS)[7] used for interoperability or conformance testing shall be managed in a well-defined, open and formal manner with change control.	B	B	B	B
Gov-12	A common TSS shall be established when multiple test labs are deployed to test the same standard and / or profile. If common unique test procedures are required to support this test suite, then they shall also	B	B	B	B

[6] See Glossary of Terms for definition and explanation of the test case reference list.
[7] See Glossary of Terms for definition and explanation of the TSS.

	be defined. The TSS should be test tool agnostic.				
Gov-13	All certification bodies and ITCAs acting as certification bodies shall adhere to ISO / IEC Guide 65 principles, and requires auditing by outside third-parties.[8]	B	B	B	B
Gov-14	The ITCA shall minimize divergence of interoperability requirements interpretations.[9]	B	B	B	B
Gov-15	If an ITCA has multiple testing laboratories and certifying bodies, processes shall be in place to avoid quality differences and assure repeatable testing between the laboratories.	B	B	B	B
Gov-16	The ITCA shall periodically re-examine their internal processes, best practices and tools based on corresponding specifications, and obtain a qualified third-party review per ISO guide 65.	B	B	B	B
Gov-17	The ITCA shall ensure that the test labs and certification bodies maintain their accreditation for the specific standard under consideration. If a standard is not yet available for listing by an accreditation body, it shall be assured that the test facility overall maintains an accreditation and is being reviewed by the ITCA as technically able to test the standard.	B	B	B	B

[8] Some interpretations of ISO Guide 65 consider certification body membership requirements as non-conforming to the intent of ISO Guide 65 Section 4.1. The SGTCC recognizes that many of the certification authorities supporting Smart Grid standards are member based organizations providing useful services. It is the view of the SGTCC that membership based programs are acceptable in meeting the intent of its criteria and recommendations. As long as membership requirements are offered to any interested participants in a fair and unbiased process, meeting the other non-discriminatory criteria of ISO 65, this form of certification authority is acceptable to the SGTCC.

[9] One way to minimize divergence of interpretations is to limit the number of labs to only one. Another option for minimizing divergence are to have a technical lead (also known as a lead lab) responsible for properly interpreting conformance and interoperability issues.

463 Table 1 – Interoperability Process Governance Requirements

464

465 8.3 Lab Qualification

466 Lab qualification defines the requirements in Table 2 that shall be applied by ITCAs when
467 recognizing testing laboratories. It should be noted that additional requirements are further
468 detailed in ISO 17025.

469

Lab-x	Interoperability Lab Qualification Process	ITCA Category			
	Requirement Description	I	II	III	IV
Lab-1	In selecting test organizations, the ITCA shall have uniform and transparent procedures for evaluating test labs.	B	B	B	B
Lab-2	The ITCA shall define requirements to qualify the personnel involved in the certification and testing processes per ISO 17025.	B	B	B	B
Lab-3	The ITCA shall require that its test labs adhere to ISO 17025.	B	B	B	B
Lab-4	Where applicable, the ITCA shall use existing laboratory qualification standards and schemes for evaluating test labs.	B	B	B	B

470 Table 2 – Interoperability Lab Qualification Process Requirements

471

472 8.4 Technical Design for Interoperability and Conformance Program Design

473

474 The Technical Design for Interoperability and Conformance Program Design defines the
475 requirements needed to effectively manage the procedures and processes associated with
476 interoperability and conformance testing.

477

478

Tech-x	Interoperability Technical Design Process		ITCA Category			
	Category	Requirements Description	I	II	III	IV
Tech-1	Technical	The ITCA shall specify in the test program requirements features that are mandatory, and those features that are optional.	B	B	B	B
Tech-2	Technical	The ITCA shall require and enforce that vendors declare the optional features implemented in a product.	B	B	B	B
Tech-3	Technical	If more than one vendor implements the same optional feature in a product, the ITCA shall require that future implementations of that optional feature be tested and certified for conformance and interoperability. Furthermore, the ITCA shall define common test cases for that optional feature to be used by all test labs when testing for that optional feature.	B	B	B	B
Tech-4	Technical	Where market clarity is required, separate certificates[10] shall be associated with products implementing optional requirements.	B	B	B	B
Tech-5	Technical	An ITCA shall have procedures and processes in place to retain a record of work	B	B	B	B

[10] See Glossary of Terms for definition of certificate.

		of the testing and certification process to be called a Compliance Folder or record of work. For example, a compliance folder per certified product could include test reports, revision control documents, description of the implementation, etc.				
Tech-6	Inheri-tance	The ITCA shall allow for sub-component (e.g., previously certified hardware modules used in developing final products, previously certified software components with well defined interfaces and dependencies etc.) inheritance in development of final products. However, it is the ITCAs responsibility to ensure that interoperability is maintained.	B	B	B	B
Tech-7	Inheri-tance	The ITCA shall maintain a controlled list of compatible sub-components that can be inherited to build final products. This might include specifying compatible feature-sets.	B	B	B	B
Tech-8	Inheri-tance	When supporting products composed of sub-components, the ITCA shall define the set of additional tests necessary to ensure interoperability (e.g. integration testing, final performance testing, etc.)	B	B	B	B

Tech-9	Inheri-tance	The ITCA shall implement a Compliant Portion Description (CPD)[11] to be used as a guide for assembling a product based on compatible sub-components.	B	B	B	B
Tech-10	Version Control	The ITCA shall have an explicit process in place to assess necessity of re-certification against subsequent release versions of a specification, including security.	B	B	B	B
Tech-11	Version Control	The ITCA shall define the level of re-certification required for subsequent release versions of a specification.	B	B	B	B
Tech-14	Version Control	The ITCA shall define a mechanism to identify the latest version of a previously certified product or system implementation. This is important in cases where a previously certified product or system has been upgraded to a different version.	B	B	B	B
Tech-15	Version Control	The ITCA shall have a mechanism to enforce version control rules to ensure compliance (e.g. standards usually have to go back to the accreditation body if they are changing the version).	B	B	B	B
Tech-16	Testing - General	The testing and certification program shall have common well-defined standardized test cases. These test cases	B	B	B	B

[11] See Glossary of Terms for definition and further explanation of CPD

		should be defined in an open, consensus-driven fashion, following ANSI-type processes. These test cases will be used by all test labs approved by the ITCA.				
Tech-17	Testing – General	There shall be a defined correlation between implementations and required testing, commonly called a Proforma Implementation Conformance Statement (PICS).[12]	B	B	B	B
Tech-18	Testing - General	The testing and certification program shall maintain a current and upcoming list of applicable test cases to be called a Test Case Reference List.	B	B	B	B
Tech-19	Testing – General	There shall be a Test Plan derived from the Test Case Reference List and used by all authorized test labs. Tests shall be identified using the test plan.	B	B	B	B
Tech-20	Testing – General	The testing and certification program shall require that a static conformance review[13] take place prior to testing a product.	B	B	B	B
Tech-21	Testing – General	The testing and certification program shall first validate the tests, and implement them utilizing validated test tools. Golden reference test equipment may be	B	B	B	B

[12] PICS can be referred as both Protocol Implementation Conformance Statement and Profile Implementation Conformance Statement. Proforma is being used in this requirement to reference both concepts.
[13] See Glossary of Terms for the definition and explanation of a static conformance review.

		utilized where appropriate.				
Tech-22	Testing – General	The TSS shall be subject to revision control, including revision history, revision numbering, and a defect and expansion management process. The TSS should clearly identify the test purpose, references, resource requirements, test setup, procedures, observable results and possible problems / lessons learned with the test approach. Observables should clearly identify pass / fail / indeterminate requirements and informational elements.	B	B	B	B
Tech-23	Testing - Conformance	The testing and certification program shall assure that defined product test cases cover application profiles for specific feature sets and functions defined by the specific application profile, and implement interoperability evaluation within that application profile.	B	B	B	B
Tech-24	Testing – Conformance	Where practicable, the testing and certification program shall assure that defined product test cases cover all feature sets and functions.	B	B	B	B
Tech-25	Testing – Conformance	The testing and certification program shall define and evaluate based on concise pass / fail criteria, yet allowing for inconclusive outcomes. Note: An in-	B	B	B	B

		conclusive test run cannot result in certified products. Inconclusive test results shall be investigated to clearly identify what is required to move out of the inconclusive state.				
Tech-26	Testing – Conformance	The testing and certification program shall define conformance testing per OSI 7-layer, and end-to-end testing from the physical to the application layer as relevant and necessary.	B	B	B	B
Tech-27	Testing – Product Interoperability	The testing and certification program shall assure that defined product use cases are covered in application profiles. Interoperability testing and evaluation shall be implemented within those application profiles.	B [14]	N / A	B	B [15]
Tech-28	Testing – Product Interoperability	The testing and certification program shall classify common or major market products according to their application profiles, and include them as part of an interoperability evaluation for those specific profiles. The evaluation shall make use of test profiles correlated to those specific applications.[16]	B [17]	B	B	B [17]

[14] Only basic for category I ITCAs that tackle the application layer.
[15] Can be N/A for category IV ITCAs that correlate to Category II standards.
[16] Interoperability testing is tied to market realities. Hence the testing and certification program needs to have a mechanism to adopt representative market products as an integral part of interoperability testing.
[17] Only a basic requirement for those ITCAs that correlated with application layer standards.

Tech-29	Testing – Product Interop-erability	The testing and certification program shall ensure that venues are provided for multi-vendor and multi-product communi-cation and interchange evaluations (i.e. "plug fests"). This program may be op-tional for ITCAs correlated to standards resulting in application interfaces and not a physical product (e.g. OpenADE)".	O	B	B	B [18]
Tech-30		Prototyping of draft standards or major revisions shall be supported via multi-vendor / multi-product testing. The ITCA shall solicit for the prototyping of draft standards or major revisions, and organ-ize multi-vendor / multi-product testing. It is recommended that the prototyping take place in the late stages of standards de-velopment in order to verify the correct-ness of the standard, verify the test suites and verify that the anticipated interopera-bility or conformance testing is debugged.	O	B	B	B [18]
Tech-31	Testing – Product Interop-erability	The ITCA shall have a process to select a minimum of two distinct reference imple-mentations as golden implementations or golden units. The selection is usually based on the results of the interoperabil-ity testing. All other implementations	O	B	B	B [18]

[18] Can be optional for Category IV ITCAs that correlate to Category I standards.

		shall be tested against these golden implementations.[19]				
Tech-32	Testing – Product Interoperability	The ITCA shall make appropriate provisions for the use of golden implementations in the testing and certification program to strengthen consistent and standard implementation and interoperability testing and certification processes.	O	B	B	B[18]
Tech-33	Testing – Product Interoperability	The golden implementations or golden units shall be clearly associated with each version of the standard. Each golden unit is a snap shot (instantiation) of each version of the standard.	O	B	B	B[18]
Tech-34	Testing – Product Interoperability	The testing and certification program shall ensure that critical vendor implementations be made available to the labs as golden implementations.	O	B	B	B[18]
Tech-35	Testing – Product Interoperability	The testing and certification program shall define interoperability testing per OSI – 7 layer or per collection of layers, and end-to-end testing from the physical to the application layer as relevant and necessary.	O	B	B	B[18]
Tech-36	Testing –	If a Smart Grid standard impacts and / or	B	B	B	B

[19] The industry prefers three golden units for product testing, but the minimum number of golden units shall be no less than two golden units.

	System Interop-erability	crosses multiple Smart Grid systems, then the responsible ITCA[20] shall ensure that venues are provided that support end-to-end testing of Smart Grid systems involving multiple vendors.				
Tech-37	Testing – System Interop-erability	A category V ITCA shall involve all relevant parties to define various business logic models for the end-to-end system testing, and make scenarios and test harness systems available for testing.	N / A[21]	N / A[21]	N / A[21]	N / A[21]
Tech-38	Testing - Perform-ance	The testing and certification program shall ensure that when functional performance requirements are defined in an application profile, the performance test profile(s) shall be designed to implement test cases for evaluating these requirements.	B[17]	N / A	B[17]	B[17]
Tech-39	Testing – Perform-ance	The testing and certification program shall define test performance per OSI – 7 layer, and end-to-end testing from the physical to the application layers as relevant and necessary.[22]	B	B	B	B
Tech-40	Tools	The ITCA shall validate test cases, intro-	B	B	B	B

[20] This is a category V ITCA as described in section 5.2.5. This can remain a Basic requirement for all ITCAs since it is a conditional statement.
[21] This is only N/A for Category I, II, III, IV ITCAs who are not also category V ITCAs.
[22] This is a different requirement than requirement Tech-26 and Tech-35. Tech-26 specifies conformance testing, tech-35 specifies interoperability testing, and this requirement specifies performance testing requirements.

		duce standardized test tools and reference implementations as validated tool sets where appropriate.				
Tech-41	Tools	The ITCA shall ensure that test tools have a complete mandatory feature-set coverage of a standard. In cases where two or more implementations of optional features are available, the ITCA shall incorporate those feature-sets in the test tool.[23]	B	B	B	B
Tech-42	Tools	The ITCA shall define procedures and processes to validate the use of test tools and reference implementations.	B	B	B	B
Tech-43	Technical Lead	The ITCAs shall identify an entity (e.g. lab, person, committee etc.) as the technical lead. This technical lead is the responsible authority for ITCAs technical conformance and interoperability matters. Note: The ITCA is the administrative organization, whereas the technical lead has the technical expertise to resolve technical testing and certification issues.	B	B	B	B
Tech-44	Technical Lead	A technical lead(s) shall be responsible for verification of new test cases, valida-	B	B	B	B

[23] Effective test tools need to be able to test all features and functions of a standard. Some features of a standard may never be supported by certain products; however when a standard is published, the industry is free to implement optional feature set in addition to the mandatory set; lack of testing capability of optional feature sets hinders interoperable feature set introduction. Normally, validated test tools have implementations of all features, including optional ones as a condition for the tool validation.

		tion of test tools, resolution of interoperability problems, and other issues of technical discrepancies where the testing laboratories and certification bodies require guidance.				
Tech-45	Technical Lead	A technical lead shall not commercially compete with testing laboratories and certification bodies	B	B	B	B
Tech-46	Technical Lead	The ITCA and the technical lead shall remain neutral to testing laboratories and certification bodies.	B	B	B	B

Table 3 – Interoperability Technical Design Process Requirements

8.5 Improvements

The Improvements section outlines the controls that will need to be in place to support the interoperability testing processes.

Improv-x	Interoperability Improvements Process	ITCA Category			
	Requirements Description	I	II	III	IV
Improv-1	The ITCA shall implement monitoring and auditing programs to ensure adherence to its policies..	B	B	B	B
Improv-2	The ITCA shall establish a checklist for the auditing of the appointed evaluation laboratories.	B	B	B	B
Improv-3	The ITCA shall periodically audit the laboratories at appropriate intervals to ensure laboratories uphold necessary capabilities.	B	B	B	B

Improv-4	The ITCA shall establish an auditing procedure and implement audits to verify that product inter-operability is maintained after the product passes the testing and certification programs and enters the market.	B	B	B	B
Improv-5	The ITCA shall have processes in place, including corrective and preventative actions, which results in continual improvement of their testing and certification programs.	B	B	B	B
Improv-6	The ITCA shall be in constant communication with the standards writing committees to create a feedback loop. For example, the ITCA should define a process to communicate the TSS test results back to the SSOs and stakeholders.	B	B	B	B
Improv-7	The ITCA shall provide a forum for feedback to be received from a stakeholder, interested business party and use case in order to improve its interoperability best practices.	B	B	B	B
Improv-8	It is preferred that ITCAs have a method for actively soliciting interoperability feedback on implementations of the standard in order to achieve some level of customer and user-community satisfaction on that feedback.	B	B	B	B

Table 4 – Interoperability Improvements Process Requirements

8.6 Cyber Security

488 The Cyber Security section outlines the requirements which shall be used by the ITCA to
489 validate the security-related components of the interoperability testing program.
490

Sec-x	Cyber Security Improvements Process	ITCA Category			
	Requirements Description	I	II	III	IV
Sec-1	The ITCA shall define the procedures and processes which will be used to validate interoperability cyber security requirements.	B	B	B	B
Sec-2	The testing and certification program shall ensure that cyber security functional performance requirements are defined, and test cases designed to evaluate the requirements.	B	B	B	B
Sec-3	Where applicable, the ITCA shall have a process in place to select and implement a Digital Certificate Issuance mechanism that may include the election of a Certificate Authority. The energy service providers can use this certificate for authentication that a given product has actually been certified.[24]	O	B	B	B[24]
Sec-4	The ITCA shall be responsible for certificate management including issuance, maintenance and policing. The ITCA can choose to outsource this responsibility as long as they remain responsible for the interoperable outcome.[24]	O	B	B	B[24]
Sec-5	The ITCA shall implement a process to qualify testing personnel at an appropriate level for their cyber security test training and experience.	B	B	B	B

[24] Optional for ITCAs that result in interfaces and not result a physical product.

Sec-6	The ITCA shall specifically require a test methodology that includes widely-accepted stress testing processes including static analysis and penetration testing.	B	B	B	B
Sec-7	The ITCA shall assure that cyber security models are policy driven, and testing shall also be based on policy settings.	B	B	B	B
Sec-8	The ITCA shall ensure that processes are in place for vendors to submit threat analysis as part of the certification process.	B	B	B	B
Sec-9	The ITCA shall leverage and align with existing security test programs.	B	B	B	B
Sec-10	The ITCA shall ensure that processes are in place to incorporate component-based cyber security concepts in the testing program.	B	B	B	B
Sec-11	The ITCA shall ensure that all business, system, and technical interests are represented in the testing program.	B	B	B	B

491 Table 5 – Interoperability Cyber Security Process Requirements

492

9.0 Best Practices For Interoperability and Conformance Test Construction

This section provides best practices and guidelines for ITCAs in their development and operation of interoperability and conformance testing programs. The recommendations provided in this section were generated based on input from experienced testing organizations that have evolved interoperability and conformance programs through lessons-learned in executing tests for both software and hardware applications.

This section addresses general testing policies, test suite specifications (TSS) and test profile attributes. The recommendations may not apply directly to all testing applications; however, they should be considered for interoperability and conformance test programs as these practices have proven to be valuable in executing a broad cross-section of program types. Each ITCA should evaluate how these recommendations, observations and practices apply to their specific programs, and incorporate the recommendations into their programs where applicable.

9.1 General Test Policies

- Product vendors need to know if their products are eligible for testing and certification, and how to prepare for certification. In many cases, product vendors may be required to prepare specific test environments (i.e. GUI applications to access low-level APIs, test scripts, supported browsers, dedicated test hardware, samples, etc.) in order to conduct testing of the standard and all underlying software. Advanced knowledge of certification processes helps set expectations of vendors to prepare a product for certification.
- Final Test Reports should include at a minimum:
  - Test completion dates
  - Test expiration dates as defined by the Certification Body
  - Product name / version / release tested

- Type of tests (i.e. interoperability or conformance)
- Test script version information
- Standards version information
- Technique(s) used for a test including standards and procedures followed
- Test profile used or a list of test cases if a complete test profile is not used
- Test equipment used, and all equipment traceability statements.

- Some Certification Bodies have perishable Interoperability Certifications as a best practice. Criteria may include expiry dates, and may be dependent on release of new standards or products.
- A certified interoperable product shall be conformant to the standard.
- The level of Interoperability and Conformance testing is always a trade-off between cost and test coverage. It is highly recommended that the ITCA perform a cost-benefit analysis on the degree of coverage associated with the test for both conformance and interoperability against the cost to test. In determining the test coverage, the security and safety concerns along with appropriate NERC / similar requirements should be considered paramount in determining the coverage assessment.
- Proper test tools produce reliable, repeatable and traceable test results. Such tools require validation processes, test suites, tool documentation, test reports, calibration certificates and other relevant artifacts. The validation of the test tools must be performed against a defined sample of software and / or hardware implementations under test. Refer to ISO / IEC 17025 for more detail on the use of qualified and calibrated test tools.

9.2 Test Suite Specification (TSS)[2]

- A common TSS should be established when one or multiple test labs are deployed to test the same standard and / or profile. If unique test procedures are required to support a test suite, then they should also be defined.
- The TSS should be test tool agnostic.
- The TSS should be subject to revision control including revision history, revision numbering, and a defect / expansion management process. The TSS should clearly identify the test purpose, references, resource requirements, test setup, procedures, observable results and possible problems / lessons learned with the test approach. Observables should clearly identify pass / fail / indeterminate requirements and informational elements.
- The TSS should clearly define any conventions that will be required to achieve interoperability.
- The TSS should restrict cardinality and define the exact attributes and associations required for interoperability.
- The TSS should remove or clarify all ambiguities and any areas of the standard that may be interpreted differently between two or more interoperable systems.
- The TSS should be a standard and managed as such by an SSO. The documentation should include scope, date of issue, revision, change control, and methods to feedback implementer's results.
- The TSS should have accompanying tools to validate data and data structures contained in, or produced by, the test.
- Test cases should have clear mappings to feature-sets, use-cases, and requirements.
- The TSS should have a way to feedback the results of the testing back to the profile.
- The TSS should ensure all areas of the interoperability and conformance testing are sufficiently defined and documented such that the test can be repeated.

- The TSS should define the test data required to execute the test cases. The TSS should define any test stub required to execute messages that will generate negative responses.
- The TSS should identify interoperability issues arising from ambiguities in the standard, and establish requirements sufficient to prevent those interoperability issues.

9.3 Attributes of a Test Profile in lieu of complete TSS

- Must be a subset of the TSS
- Specifies mandatory and optional elements
- Specifies all restrictions
- Cannot add to the standard, but can only restrict the standard
- Define the type of profile (i.e. message, model or implementation) and provide a name for the profile that clearly defines the objective / scope of the profile and the use-cases it is designed to test
- Is a companion standard or is submitted to the SSO for progression as a companion standard

10.0 References

NIST Framework and Roadmap for Smart Grid Interoperability Standards

ISO 17000 - Conformity Assessment -- Vocabulary and general principles

ISO 17011 - Conformity Assessment -- General requirements for accreditation bodies accrediting conformity assessment bodies

ISO 17025 - General requirements for the competence of testing and calibration laboratories

ISO Guide 65 - General requirements for bodies operating product certification systems

ISO Guide 67 - Conformity assessment — Fundamentals of product certification

ITU X.291

11.0 Glossary of Terms

Accrediting Body – Organization that formally evaluates processes of test laboratories or certification bodies with respect to specific standard(s) or specification(s).

Application Profile - A selected subset of the product and / or standard which can be used to implement a particular feature set or use case scenario.

Attestation - Issuance of a statement that fulfillment of specified requirements has been demonstrated.

Certificate – Unique identifier of a particular product. It applies to both software and hardware products. The certificate can be a physical or digital artifact (e.g., X.509 PKI schemes require digital certificates).

Certification – Third-party attestation related to products, processes, systems or persons.

Certification Bodies (CBs) – The entity responsible for certifying that products have fulfilled the requirements of a standard or specification.

Compliance Folder - The set of test evidence, usually including test data, test report, product information, and review records. The folder serves as the record of an implementation fulfilling all requirements of a certification test program.

Compliant Portion Description (CPD) – A CPD is a definitive manifest of all mandatory and optional features implemented in a certified product. The CPD is generally used by product designers to judge:

- Conformance of an implementation,
- Completeness of a system composed of pre-certified sub-components by comparing each of the CPDs of those sub-components.
- Interoperability of two products based on matching feature sets as described by their respective CPDs.

For example, a designer can compare the CPD with the test requirements to determine the level of conformance of a product to a specification. When designing a product composed of pre-certified

sub-components, the respective CPDs will serve as selection criteria to design the complete product. The CPD also helps to judge the level of interoperability that can be expected from interactions between two independent implementations. A client service and a server function can be reviewed for their expected level of interoperability solely based on their respective CPDs.

Conformance Certification – A third-party attestation that a product conforms to a standard or specification.

Conformance Testing – Determines whether an implementation conforms to the standard as written. This is done by evaluating the implementation with a test tool such as an emulator, test harness, golden unit, etc.

Feature set – A feature set is a particular characteristic of a product based on a particular use case scenario. For example: signaling price is a feature set.

First Party Testing – is when an implementer self-tests their own product. This is usually permitted after a technology has matured to where sufficient tools and specifications enabling first party testing are available to all vendors.

Inheritance – Those actions required to evaluate the compatibility of a proposed inherited design including products, subsystem functions and design requirements.

Interoperability – Ability of a product or system to work with or integrate with another product or system based on defined business requirements.

Interoperability Testing – Connects two or more implementations together and determines whether they can successfully communicate. Significantly different from conformance testing, it is often possible for two systems that conform to the standard to be unable to communicate. If they can communicate, it is possible that they cannot perform any useful functions. These situations arise because the implementations have conflicting interpretations of the specification, or because they have chosen conflicting options within the standard. A particular form of interoperability testing is application testing, in which there is a specification for the particular use of standard that can be tested.

Implementation Under Test (IUT) – The implementation subject to testing. Covers System Under Test (SUT) and Device Under Test (DUT)

Multi-vendor and Multi-product Testing Event – An interoperability test of products with other peer products. The outcome of the testing is used to improve both products and the specification.

Performance / Protocol / Proforma Implementation Conformance Statement (PICS) – Defines all mandatory and optional feature sets of a specification that can be used to implement a product.

Platform level communications protocol - In the IPRM, platform level communications protocols are integrated products based on standards only associated with layers 1 and 2 of the OSI layer. (e.g., WiFi platform)

Qualified Product Notification (QPN) – A certificate and accompanying explanatory document issued by the ITCA as a record when a product has fully satisfied the requirements of the testing and certification program. The QPN details all supported feature sets verified by the program.

Record of Work - The material evidence of any work or task, such as test data or test report.

Second Party Testing – Testing activities performed by buyers and users.

Security Testing – Analyzes whether the implementation correctly makes use of any security features from the standard or other security features available in the product. This is the most difficult type of testing program since it must evaluate whether the system has vulnerabilities, which are not always obvious.

Standards Setting Organizations (SSOs) - An association whose primary activities are developing, coordinating, promulgating, revising, amending, re-issuing, interpreting, or otherwise maintaining standards. A Standards Developing Organization is one form of a Standards Setting Organization. Example SSOs including International Organization for Standardization (ISO), International Electro technical Commission (IEC), Institute of Electrical and Electronics Engineers (IEEE), American National Standards Institute (ANSI), etc. An SSO can also be an industry trade association that develops industry standards such as the ZigBee Alliance.

Static Conformance Review – A review of designed feature sets versus the specified PICS to determine the extent to which the features are supported by the IUT. This is the first step when a

product enters a testing program. Generally the test lab requests that the implementer declare all supported feature sets in a product. This information is used to create the test plan for that product.

Testing and Test Control Notation (TTCN) - A formalized test scripting language used to describe communication protocol test cases per ISO / IEC 9646.

Test Campaign - A series of tests for a particular product out of the TSS, based on the running Test Profile group and the Test Plan, derived from the Test Case Reference List.

Test Cases – A set of tests to verify a particular feature set. There are many ways to test a feature set, with each of those representing a test case. Generally, a program defines all possible test cases in the test specification document.

Test Case Reference List – A current master list of all tests that are to be included into a product test plan. This list also indicates the time variable applicability of each test by reflecting those tests which are no longer valid, and those that are not currently valid but are scheduled to become active in the near future. This helps a product implementer in preparing fully conforming and interoperable products for an upcoming launch.

Test Harness - Collection of software, test data, and hardware configured to test a product by operating it under varying conditions and monitoring its behavior and output.

Test Interface - The programmatic application interface to enable communication between a test harness and system or device under test.

Test Plan – A Test Plan is a list of applicable tests for a specific product and is derived from the Test Case Reference List.

Test Procedure – A stepwise test method of a particular test case. An example of a test procedure can be the steps needed for an Energy Services Interface (ESI) to send price signals, which may include configuring the time information, updating price tables, etc.

Test Profile or Profile - A select subset of a product and / or standard to implement a particular test of a feature or a use-case test. Test Profiles evaluate a subset of a TSS and are used to target specific areas of product interoperability.

Test Resource - Any information, equipment, material, and support required to implement testing.

Testing – According to EN 45020, testing is defined as "the technical operation that consists of the determination of one or more characteristics of a given product, process or service according to a specified procedure".

Testing Laboratories (TLs) – Test service providers for a standard or specification.

Test Suite Specification (TSS) or Test Spec- Consists of a suite of tests, categorized into logical functional areas, such as use cases or well-defined features. Each test suite consists of many related test cases corresponding to a particular feature set or use case. Test cases would include both valid and invalid behavior tests. Each test case is further described step-by-step with test procedures and well defined pass / fail / indeterminate criteria, along with references.

Test Suite- A collection of related test cases. A test suite can be put together to test a feature set. A pricing test case would be in a "price test suite" but a messaging test case would be in a "messaging test suite".

Third Party Testing – Testing activities performed by organizations independent of first or second parties.

Use Case - A description of a system's behavior as it responds to a request that originates from outside of that system

Annex

12.0 17025 and ISO Guide 65 Overview

General laboratory and certification body criteria used for accreditation are described in two documents: ISO / IEC 17025, General Requirements for the Competence of Testing and Calibration Laboratories, and ISO Guide 65, General Requirements for Bodies Operating Product Certification Systems. These two documents are widely used across various industries and applicable for Smart Grid testing and certification programs. ISO 17025 is focused on test laboratories and contains requirements that labs need to demonstrate that they operate a management system, are technically competent, and are able to generate technically valid results. It incorporates all requirements of ISO 9001 that are relevant to testing services and facilitates acceptance of test results from accredited laboratories. Accreditation bodies apply these requirements in their laboratory assessments.

12.1 ISO – 17025

ISO 17025 can be applied to any testing lab operation, whether independent (i.e. third-party) laboratories or in-house laboratories operated by manufacturers for their own internal product testing. The advantage of applying ISO 17025 for Smart Grid testing operations is that many labs have already pursued and achieved compliance for selected aspects of the services they offer, and can simply expand their scope of accreditation to encompass new services necessary to support Smart Grid interoperability. This approach will build on common best practices used across the testing industry, speeding implementation and avoiding unnecessary creation of redundant processes.

ISO 17025 focuses on two major areas of laboratory operations: 1) management requirements and 2) technical requirements. The management requirements address issues such as a lab's documented practices (i.e. both administrative and technical), impartiality of the

lab in its operations, responsibilities for continuous improvement and issues resolution, and the active support and involvement of lab management in assuring commitment to complying with these criteria.

The technical requirements focus on areas such as ensuring that lab staff are competent in performing their testing duties, assuring that the lab environment is adequate for services performed, assuring that test plans and other necessary operating instructions are documented and available, and that necessary equipment and software used for testing is calibrated, maintained and appropriate for its intended usage.

The criteria described in ISO 17025 is extensive and the brief description above simply provides a high level view of some of the key elements that labs need to address in attaining accreditation.

The technical scope of accreditation is specific to the selected tests / services for which the lab applies for evaluation. Evaluations for compliance can be performed by a number of different accrediting bodies, and there are global and regional agreements in place that provide for broad acceptance of an accreditation once attained.

12.2 ISO Guide 65

ISO Guide 65 is focused on certification bodies but parallels many of the same concepts applied to test laboratories. There are general criteria that assure that the organization is non-exclusionary, open and without conflict of interest. Documented administrative policies and processes, as well as documented technical requirements and specifications for certification are among the required criteria. Criteria is also included to assure that procedures are in place to describe the granting of certifications, as well as ongoing maintenance, extensions and terminations of certifications once granted. Personnel qualifications are addressed for those involved in the evaluation and decision making process associ-

ated with the organization's certifications. As in the case for ISO 17025, this is only a brief description of highlights associated with the more extensive criteria described in the document.

12.3 Testing Programs

This section is informational only. The goal is to demonstrate how some of the requirements are being used by various ITCAs. This is not an endorsement of any of the following programs but rather examples to help provide context.

12.3.1 Bluetooth SIG

Bluetooth products are low-cost, low powered cable replacement products, primarily aimed at low-rate voice / data applications in portable telecommunication products. Popular application profiles include hands-free phones, headset, and stereo cable replacements. Bluetooth products are widely known for their interoperability, and billions of products have reached the market.

The Bluetooth SIG has been operating a testing and certification program for roughly ten years. The design of the program is described in the Program Requirements Document (PRD). Throughout the history of the testing and certification program, a well defined PRD version has been in effect.

The current Bluetooth SIG PRD calls for physical layer testing with a validated test system at the Bluetooth Qualified Test Facilities (BQTF), and upper layers and profile applications are tested by a test harness issued to members by the Bluetooth SIG. The Bluetooth SIG operates as an ITCA for this wireless technology, and has the Bluetooth Qualification Administrator, BQA, as the individual in charge of the PRD administration and interoperability assurance. The BQA and the PRD en-

sures that the Bluetooth Logo signifies a high-level of interoperability and rich user experience.

The PRD has defined a testing regime involving various levels of testing, including First, Second, and Third-party testing. The testing is defined in the Test Case Reference List (TCRL), and issued periodically to the industry to define the level of testing depending on the content. For example, the radio layer has been and still is a third-party test, requiring a fully validated test system running a Testing and Test Control Notation (TTCN) radio tester with full test control interface and automated testing. In the past, baseband, link manager and protocol conformance tests were designated as third-party testing, with a specialized protocol conformance tester. However, these tests have become implementable by a single common software test system issued by the Bluetooth SIG lead laboratory function since PRD 2.0.

The BQA chairs the Bluetooth Technical Advisory Board (BTAB), and issues arising in the market are handled by the BQA directly through the BTAB or other corrective feedback processes. The Bluetooth SIG maintains a Qualified Product Listing, and issues for each product a Qualified Product Notice (QPN) that defines exactly the conformance and interoperability feature set verified by a static conformance check of the PICS, and objectively verified with the test harnesses. The BQA oversees verification and auditing process of the BQTF organizations. The BQTF organizations are additionally required to maintain accreditation based on ISO Guide 17025.

Additional mechanisms include personnel qualifications of Bluetooth Qualification Experts (BQEs), formerly known as Bluetooth Qualification Body's (BQBs). Companies are required to maintain a Compliance Folder, detailing the conformance

and interoperability evaluation record. Products are comprised of smaller Bluetooth components tested separately, and integrated in a manner that maintains interoperability through a Compliant Portion inheritance. The Bluetooth SIG holds regular "UnPlug Fests", allowing various vendors to test interoperability in a development environment early in the product and specification lifecycle.

12.3.2 WiMAX Forum

WiMAX is a communication technology that enables high-speed wireless data communication backhaul over large distances between fixed base stations, and similar high-speed links from base stations to mobile products. It is also known as a "4G" network, and utilizes the IEEE 802.16e standard for the physical and medium access control (MAC) sub-layer. Some AMI networks utilize WiMAX links.

The WiMAX Forum is an ITCA for the WiMAX standard, and the IEEE 802.16e physical and MAC layer technologies. WiMAX maintains a testing and certification administrator to manage the logo program. A commercial lead lab is operated out of Malaga, Spain. The WiMAX Forum has gone through extensive accreditation processes to select a single testing laboratory in each country, and to provide an economically viable incentive for the labs to participate and facilitate in the growth of the interoperable technology.

The WiMAX Forum has structured its technology development in stages, and certified products in "waves" synchronized with the product stages. All products are rigorously tested for conformance, regulatory, and interoperability requirements with a validated test set supplied by the lead lab. The test labs participating in the WiMAX certification program are mandated to equip themselves with a validated test system, and manufacturers are encouraged to verify for pre-certification status

by testing with the same equipment either by themselves or at the accredited laboratories. All test cases are clearly defined in a test case reference list, and tests are categorized according to First, Second, and Third-party tests. Logo certification tests third-party accredited test houses. All accreditation of test houses are performed directly by a team of experts selected by the WiMAX Forum. The WiMAX Forum further implements personal qualifications in the form of a WiMAX Qualification Body, who "signs-off" on the test results from the test laboratories. This model provides flexibility to deal with complex interoperability issues. All test labs are required to obtain ISO Guide 17025 accreditation under their respective national auditing schemes defined by their country.

Manufacturers and test houses are required to maintain a compliance folder that serves as a Record of Work for the logo testing.

The WiMAX Forum has specified and operated its conformance and interoperability program as described by their Certification and Interoperability Reference Manual.

12.3.3 WiFi Alliance

The WiFi Alliance is an industry organization promoting interoperable products utilizing the IEEE 802.11 a / b / g / n physical and MAC layer standards. Initially defined as an Ethernet cable replacement technology, it has progressed to include embedded products and mesh networks. Some implementations of Advanced Metering Infrastructure (AMI) systems rely on a WiFi-based mesh transport layer for the communication link to the smart meter.

The WiFi Alliance maintains multiple competing laboratories to provide testing services around the globe. A single lead laboratory is maintained by the WiFi Alliance to develop test cases, evaluate test systems, and in general to be the center of technical competence for the industry regarding conformance and interoperability. An interoperability test harness is defined by and supplied by the Alliance. A certification administrator oversees the program.

WiFi Alliance laboratories are required to obtain ISO 17025 accreditation, and go through a rigorous auditing process before being selected by the Alliance as a certified laboratory. The WiFi Alliance holds regular test events to help facilitate standard development and interoperability between vendors.

A product manufacturer can obtain a WiFi logo only after undergoing rigorous testing at a WiFi Alliance-selected laboratory, and providing test report evidence to the WiFi Alliance certification administration.

The WiFi Alliance coordinates with the ZigBee Alliance in support of the Smart Energy Profile 2.0 standard for smart grid products in the home.

12.3.4 HomePlug Alliance

The HomePlug Alliance is an industry organization promoting interoperable products utilizing the IEEE P1901 power-line communication standard. The Alliance maintains several testing laboratories to perform conformance and interoperability testing of the physical / MAC layer based on well-defined test cases and test harnesses. Several different Phy / MAC layer platforms are supported by the Alliance but not necessarily meant to interoperate across platforms.

The HomePlug Alliance coordinates with the ZigBee Alliance in support of Smart Energy 2.0 standard for smart grid products in the home.

12.3.5 ZigBee Alliance

ZigBee Alliance oversees the development of a class of products utilizing Personal Area Network (PAN) technology. Similar to Bluetooth SIG, the ZigBee Alliance handles the interoperability of full application profiles leveraging the IEEE 802.15.4 physical / MAC layer standard. This is in contrast to WiMAX and WiFi programs, which are mostly concerned with interoperability of the physical and MAC layer. The ZigBee Alliance handles multiple application profiles, including Telecom Applications, Health Care, Home Automation, Commercial Business Automation, Retail Services, and Smart Energy. The Smart Energy application profile is widely adopted by smart meter vendors and electric utilities as the basis of two-way communication between the smart meter and home-area-network (HAN) products. The Smart Energy application profile is transitioning from 1.x to 2.0, where the salient feature is not only the support of a ZigBee IP layer, but also other IP-based technologies, such as WiFi, HomePlug and others.

The ZigBee Alliance maintains a few commercial laboratories around the globe, and requires ISO 17025 accreditation and rigorous evaluation of candidate laboratories. As with other Alliances, each test laboratory is qualified for a particular platform or application profile testing after undergoing a peer review process. A certification administrator oversees the logo certification program, and laboratories undergo periodic review of performance.

Test specifications are defined by the industry working groups and “ZigFests” held to verify the viability and interoperability of the technical and test specification with

participation of the test laboratories. Currently, only third-party testing is allowed in the ZigBee Alliance.

12.3.6 OPC

OPC Self-Testing

The OPC Foundation first-party testing program includes a test tool provided by the OPC Foundation which produces a signed and encrypted log file. This log file reports the system configuration, product version and results of the test. It also reports what optional features are supported by the product. This log file can be uploaded to the OPC Foundation website where the signature is verified before it is added to the product catalogue.

OPC Best Practices

OPC is a family of specifications that provide software interoperability in the industrial automation space. The OPC Foundation has been running a certification program for 10 years, and has evolved over time based on feedback provided by product vendors and end-users.

The current certification program has three aspects: 1) self-testing with a tool provided by the OPC Foundation, 2) interoperability workshops where multiple vendors gather and test their products with each other and 3) third-party lab testing. A vendor who completes the self-testing process or participates in an interoperability workshop is eligible to use a 'Self-Tested' logo offered by the OPC Foundation. A vendor that completes lab testing is eligible for a 'Certified' logo. Certifications expire after 2-3 years and vendors are expected to re-certify their products. The OPC Foundation maintains a product catalogue on its website that lists all products which have passed the certification process.

The process for developing the certification programs starts during specification development, where a completely functional reference implementation is completed before the specification is released. This process ensures the specification is implementable. When a specification is nearing completion, a separate compliance committee is formed. The compliance committee creates a test document for the specification, and is used to develop the self-testing tool and the lab test procedures. The compliance committee reports any issues that affect testing back to specification committee so the specification can be corrected.

12.3.7 USGv6 Test Program

Overview

In the White House Office of Management and Budget (OMB) Memorandum 05-22, NIST is tasked to develop a set of technical requirements for IPv6 for use in the Federal Government. In response, NIST published the USG v6 Profile. This document suggests that product testing services are likely needed to ensure the confidence and to protect the investment of early IPv6 adopters. After surveying the existing testing programs, it concludes that a distinct United States Government [USG] testing program is needed, but with the commitment to harmonization and convergence in a broad collaborative user / vendor testing initiative, in which the technical and profiling requirements of the USG can be accommodated.

NIST has established the USGv6 testing program as a way to document products' compliance with USGv6 requirements. The test program makes use of a set of abstract test specifications, each validated against the respective protocol specifications. To be documented as USGv6-compliant, products must be tested against tools validated to these tests, in accredited laboratories. Having implemented and tested their products, developers must make their claims of USGv6 compliance in a systematic and standardized way.

The Supplier's Declaration of Conformance (SDOC) is a tool that offers a flexible means of constructing these claims, and will be used to document compliance with USGv6 requirements.

USGv6 contains a wide range of elements, and the testing program includes components that are subject to enhancement and revision over time. Hence it is necessary to have in place a scheme to manage the evolution and maintenance of these components that includes collaboration with the stakeholders.

Stakeholders

"USG Agencies" have a primary interest in making sure that IT products with IPv6 capabilities are available to meet their acquisition requirements. However, they are typically more interested in the end product than the testing process.

"Testing Laboratories" are central to the USGv6 testing process. Each such laboratory seeks accreditation from an ISO 17011 compliant, ILAC signatory, accreditation body. Test laboratories may conduct any of the conformance, interoperability or network protection testing. First, second and third-party labs are recognized as follows: 1) a first-party lab is associated with the product developer, 2) a second-party lab is associated with a USG agency and 3) a third-party lab is independent.

"Test Method Developers" include open source suppliers (e.g. Tahi) and private sector developers, who develop IPv6 test methods for conformance and interoperability based on the abstract test specifications. In conjunction with test laboratories, test method developers take part in inter-laboratory comparisons to make sure that test results for the same test using different methods in different labs are equivalent.

"Accreditors" - The role of an accreditor is to assess test laboratories for their compliance with ISO / IEC 17025, which are the quality provisions for testing. They also assess the technical test methods and technical competence based on NIST SP 500-273.

"IPv6 Device Developers" develop hosts, routers and network protection devices which shall be tested according to the IPv6 criteria when offered for sale to the US government.

"NIST and the USG test program" - NIST is a technology agency of the US government charged with creating a standard for IPv6 devices, and a means of determining compliance to that standard. NIST SP 500-267 is that standard. NIST SP 500-273, together with NIST SP 500-281 and this testing program are the means of establishing compliance.

13.2.7.3 Processes

Processes associated with USGv6 compliance include testing processes and management processes. These processes regulate the development of tests, test methods and accredited laboratories. All processes are described below.

Conformance Testing

- is conducted between the device and / or protocol implementations under test, and a special purpose test system.
- uses tests described in the published abstract test specifications.
- must be performed in a first, second or third-party accredited laboratory.
- is the gate required before interoperability testing.

Interoperability Testing

- is conducted among several host or router devices under test.
- uses tests described in the published abstract test suites.

- must be performed in a second or third-party accredited laboratory.
- is the prerequisite for issuing SDOC for Host / Routers.

Network Protection Testing

- is conducted with special purpose test equipment
- uses tests generally described in published abstract test suites
- must be performed in a second or third-party accredited laboratory
- is the prerequisite for issuing SDOC for network protection devices

SDOC Protection

After testing their devices in an accredited laboratory, product vendors will develop a Suppliers Declaration of Conformance according to ISO / IEC 17050:2004 that serves as indication to purchasers that required testing has taken place. Whether a test laboratory wants to offer the service of SDOC creation after testing is a matter between the lab and its customer.

Test Methods and Specifications

Test Methods exist for Conformance, Interoperability, and Network Protection testing. For test specifications use the following link: http://www.antd.nist.gov/usgv6/test-specifications.html.

Conformance Test Methods

Any accredited test laboratory can offer the conformance test methods, including first, second or third-party test labs. Conformance test methods are located at http://www.antd.nist.gov/usgv6/test-meth-c.html.

Interoperability Test Methods

A seemingly intuitive way to do interoperability testing is on a device-by-device basis. However in practice, the range of configurable options in the USGv6 profile is so flexible that in the end it is better to construct interoperability test suites per Request-for-Comment (RFC) and run the required set of tests according to each device's configuration. For this reason, the interoperability test methods are structured identically with the conformance test methods. The test suites associated with these methods are uniquely applicable to interoperability testing. Interoperability test methods can be found at http://www.antd.nist.gov/usgv6/test-meth-c.html#interop.

Network Protection Test Methods

Network protection test methods cover firewall, application firewall and intrusion detection systems, and may be tested by a second or third-party test lab. Network Protection Test methods can be found at http://www.antd.nist.gov/usgv6/test-meth-c.html#npd.

Supplier's Declaration of Conformance

Suppliers test Host, Router or NPD products in accredited test laboratories. Testing of different capabilities can occur in different test labs. Each test event and its date are recorded in the Supplier's Declaration of Conformance (SDOC). Capabilities implemented and tested should be correlated with the test methods listed at this site. An SDOC template in Excel format is provided to allow for summarization of the testing done. The second sheet of this Excel file is the USGv6 version 1 capabilities checklist, indicating what functions must be supported.

References

- USG IPv6 Profile - http://www.antd.nist.gov/usgv6/usgv6-v1.pdf
- User's Guide - http://www.antd.nist.gov/usgv6/docs/NIST-SP-500-281-v1.3.pdf

- FAQ - http://www.antd.nist.gov/usgv6/faqs.html

IPv6 Forum - IPv6 Ready Logo Program

The IPv6 Forum (http://www.ipv6ready.com) IPv6 Ready Logo Program is a conformance and interoperability testing program intended to increase user confidence by demonstrating that IPv6 is available now and is ready to be used.

The IPv6 Ready Logo Committee mission is to define the test specifications for IPv6 conformance and interoperability testing, to provide access to self-test tools and to deliver the IPv6 Ready Logo. The Key objectives and benefits of the IPv6 Ready Logo Program are to:

- Verify protocol implementation and validate interoperability of IPv6 products.
- Provide access to free self-testing tools.
- Provide IPv6 Ready Logo testing laboratories across the globe dedicated to provide testing assistance or services.

Process

The process requires vendors to pass 100% for both conformance and interoperability test specifications. Interoperability requires testing with four different interoperable vendor devices.

Allows vendors to either use self-test tools or utilize test laboratory services. No accreditation is required.

Once the vendors have applied for the Logo, the IPv6 Ready Logo Committee has an administrative process to review and verify the test results. Once approved, the vendor will be added to the Approved List. https://www.ipv6ready.org/db/index.php/public/

12.3.8 System testing

System-wide, end-to-end interoperability testing is crucial to build an ecosystem of interoperating vendor products. As such, the following example has proven to be effective to ensure system wide testing.

Texas Go-To-Market ZigFest

The joint Texas T&D utilities and the ZigBee Alliance has sponsored multiple events to test an end-to-end provisioning and signaling system that connects Smart Meters to HAN products. This has allowed finer interpretation and business use case verification and interoperability with multiple vendor implementations of specified application profiles.

13.0 Working Group

Interoperability Process Reference Manual (IPRM) – Working Group #4	
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Weekly Calls	
Every Wednesday at 8:00 PT / 10:00 CT / 11:00 ET https://www2.gotomeeting.com/join/802811482 Conference Code: 646-558-2100 Access Code: 802-811-482	
Listserv Information	
To send an e-mail to the IPRM working group list: SGIP-SGTCC-IPRM@SMARTGRIDLISTSERV.ORG To subscribe to the IPRM working group, go to the following address: http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGridTestingAndCertificationCommittee select Join SGIP-SGCTCC-IPRM listserv.	

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14.0 Document History

Revision Number	Revision Date	Revision By	Summary of Changes
1	5/30/2010	Zahra Makoui	Initial template with some basic text based on the 5/24 face to face meeting
2,3	6/2/2010	Zahra Makoui	Initial base requirements based on editing team calls.
4	6/8/2010	Rik Drummond, Zahra Makoui	Rik Drummond comments and edits. Zahra Makoui edited the purpose section based on Rik's suggestions.
5	6/14/2010	Zahra Makoui	Edited based on editing team call
6	6/16/2010	Mark Ortiz	Section 2.1 input
7	6/16/2010	Zahra Makoui	Edits based on WG4 call
8	6/21/2010	Zahra Makoui	Edits based on editing team call
9	6/23/2010	Zahra Makoui	Edits based on WG4 call
10	6/23/2010	Zahra Makoui	Added Kent and Rik's suggested texts for scope.
11	6/24/2010	Zahra Makoui	Added "publicly available test cases" and "golden units" based on Dean Prochaska's recommendations
12	6/25/2010	Zahra Makoui	Edits based on 6/25 editing team call
13	6/28/2010	John Lin	Added pictures
14	6/28/2010	Zahra Makoui	Edits based on 6/28 editing team call
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18	7/21/2010	Zahra Makoui	Edits based on face to face meeting
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23	9/7/2010	Donny Helm, Rik Drummond	Edits based on 8/31 conference call

24	9/7/2010	Zahra Makoui	Further edits for consistency and prior to release of the document for WG4 comments
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24-5	9/27/2010	Rik D, Rudi	Added new text throughout the document.
24-8	9/28/2010	Zahra M and John Lin	Incorporating Larry's team's best practices for final release.
25	9/29/2010	Donny Helm	Formatting document for release version 25.
26	11/18/2010	Zahra M, John L, Rudi S, Donny H., Phil B., James M.	Updating document release version 26 based on received comments and release of IPRM Version 1.0.

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