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Standards-Based Interoperability for the Advanced Telecom Computing Architecture* (AdvancedTCA*)

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ABSTRACT

The adoption of Modular Communications Platforms (MCP) and Advanced Telecom Computing Architecture* (AdvancedTCA*) has significantly matured during the past two years and is now achieving broad market acceptance by major Telecom Equipment Manufacturers (TEMs) and Service Providers (SPs). While open standards such as PICMG3.x are firmly in place in the industry, a barrier to broad adoption is the lack of uniform implementations of these standards by vendors. To date, this has been kept manageable through periodic plug-fest events hosted by the PICMG organization, but to achieve truly uniform interoperability the AdvancedTCA ecosystem must coalesce around a set of procedural standards on how to interoperate. Intel is working with fellow travelers on this industry-wide effort to drive ease of integration by TEMs and System Integrators (SIs) while lowering their validation costs and overhead as well as reducing the development cycles experienced by building block suppliers. This ultimately increases the competitiveness of the AdvancedTCA architecture with SPs. It will be achieved through the creation of interoperability requirements driven and owned by the AdvancedTCA industry. In this paper we focus on driving a common understanding in the AdvancedTCA ecosystem around interoperability and the path to achieve it.

INTRODUCTION

Modular Communications Platforms (MCPs) based on standard AdvancedTCA are experiencing rapid adoption across the User Plane, Control Plane, and Application Plane of next-generation communications networks. Leading TEMs are specifically focusing on AdvancedTCA deployment in green field opportunities, such as the build-out of 3G networks and emerging IP Multimedia Subsystem (IMS) network elements. The industry's expectation is that these platforms will be rapidly integrated from best-of-breed modular ecosystem components that offer basic interoperability "out of the box." To help realize this promise, standards-based Commercial Off-The-Shelf (COTS) modular components must be specified, designed, and tested for the all-important attributes of interoperability.

Interoperability Defined

Generally, interoperability is the ability of the components of a system to communicate with each other using standard interfaces and protocols while operating in a common environment. The scope of the interoperability is at the system level, not just at the component level; it does not include the specific functionality of an AdvancedTCA component.

For the purposes of this paper, AdvancedTCA interoperability is meant to emphasize multi-vendor product interoperability. Subjects that represent interoperability points for mechanical, electrical, thermal and management follow:

- Mechanical–Connector alignment, dimensions, front panel characteristics.
- Electrical–Electronic signaling across backplane, clock presentation, fabric options .
- Thermal–Shelf airflow and thermal tolerances including volumetric airflow, board cooling.

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* Other names and brands may be claimed as the property of others.

- Management–Shelf management, power and cooling management, hot swap and E-keying.

Under the options allowed by PICMG, two boards might well conform to the specification, but not talk to each other. The first step to attaining interoperability is to specify the basic level of conformance to PICMG specifications. This involves defining a subset of the PICMG allowed options and submitting products to formal validation to this subset. The second step to attaining real interoperability amongst different vendors is to validate a product's interoperability with other vendors' products.

Today, there is growing evidence throughout the industry that integrating multi-vendor products to build AdvancedTCA platforms is oftentimes challenging, due to limitations in interoperability of the products involved. We will illustrate these challenges and conflicts using prominent examples and discuss the root causes. The industry lacks comprehensive set of requirements which can be incorporated into product designs. The current approach to interoperability testing is unstructured and it lacks test metrics that is necessary for benchmarking interoperability compliance. If left unchecked, the AdvancedTCA product ecosystem faces likely fragmentation under too many non-interoperable custom Stock Keeping Units (SKUs), possibly missing out on the true standard high-volume potential.

A disciplined, industry-wide approach is required to evolve toward better interoperability of AdvancedTCA products. Intel is driving such an interoperability initiative, aiming to ultimately ease the integration challenges for TEMs and System Integrators (SIs). In this paper we focus on the main pillars behind this initiative and the progress accomplished to date. The first step is collaboration on the interoperability requirements which would lay out a set of testable requirements essential to interoperability. Equally important is the creation of complementary test procedures and underlying tools, that will validate conformance to the interoperability requirements. This lays the foundation for industry-wide interoperability certification of AdvancedTCA products backed by independent test labs.

CURRENT STATE OF ADVANCEDTCA INTEROPERABILITY

The rapidly growing number of AdvancedTCA products from a multitude of suppliers offers an unprecedented choice to platform integrators. The challenge is to ensure that all standards-based AdvancedTCA products will interoperate with each other "out of the box."

Since the inception of PICMG3.0, Intel had spearheaded early efforts to promote interoperability of AdvancedTCA products. Out of industry collaboration came the first Design Guide (DG), a collection of Best Known Methods for designing AdvancedTCA building blocks. As such, the DG is helpful in guiding toward common designs, but falls short of the needed interoperability focus, and is not backed by either test specifications or a certification framework.

The journey toward creating a cohesive set of interoperability requirements starts with understanding the key interoperability challenges. Based on field experiences, the top interoperability issues can be found in the following areas:

- Thermal interoperability of shelf and boards.
- Manageability as demonstrated by shelf/system and shelf/boards interactions.
- Mechanical issues related to boards and shelf.
- Interconnect implementations of various PICMG3.x options.
- Advanced Mezzanine Card (AMC) interaction with AdvancedTCA carrier boards.
- Presenting a common interface paradigm for service personnel.

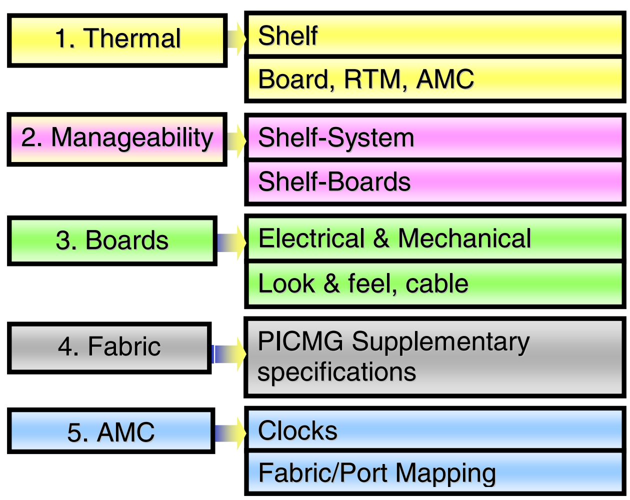

Figure 1: Top interoperability challenges

Challenges in Manageability Area

The AdvancedTCA shelf management system monitors, controls, and ensures proper operation of boards and other shelf components. The key element of this subsystem is the shelf manager that interacts with boards and other shelf resident Field Replaceable Units (FRUs) inside the shelf and also acts as an agent of the system manager, which in most common configurations is located outside of the shelf. From the shelf manager's perspective there are two communication interfaces–one directed internally towards the shelf resident FRUs (boards, etc.) and the other directed externally towards the system manager, as shown in Figure 2.

The PICMG 3.0 base specification defines in great detail, the interactions between the shelf manager and the management controllers located on the FRUs within a shelf. In an ideal world this would mean that an FRU manufactured by one vendor will interoperate with a shelf manager provided by another vendor, but to achieve this requires a significant integration effort because portions of the specification are interpreted differently resulting in incompatible implementations. A comprehensive compliance test suite that validates conformance to these specifications would go a long way to achieve interoperability.

There is also a need to define the interface between shelf manager and the system manager to achieve interoperability at that layer.

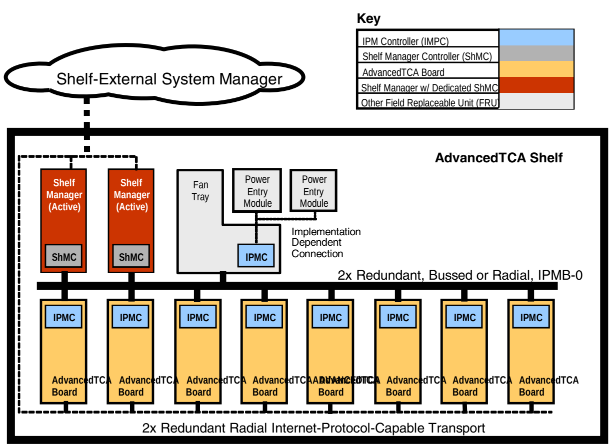

Figure 2: AdvancedTCA management architecture

Thermal Interoperability of Shelf and Boards

An AdvancedTCA integrator has to select a shelf that is capable of cooling a given configuration of boards under a broad range of operating conditions such as those defined in Network Equipment Building System (NEBS) deployment practice. The shelf suppliers rate the cooling capacity of their shelves, expressed in volumetric airflow through each slot. However, without an industry-wide benchmark, the underlying airflow tests and simulations are constructed differently from one vendor to another, and changing slightly just one parameter of the test, such as the slot thermal impedance, will significantly influence the reported ratings. This makes objective side-by-side comparison of shelves difficult, adding an element of risk to the interoperability of AdvancedTCA products in the ecosystem.

Adding to the challenge, the shelf airflow will be re-distributed under load (i.e., with boards installed) due to the fact that blade thermal impedance varies with the type of blade. Slots populated with low-impedance boards (e.g., switch blades) adjacent to high-density Single Board Computers (SBCs) will effectively starve the neighboring high-density slot of needed airflow, potentially exposing the SBC to thermal failures. Although PICMG3.0 mandates that board and shelf vendors publish pressure-airflow curves, it does not mandate impedance thresholds for boards.

Without a benchmark for consistent airflow rating of shelves, and without complementary guidelines mandating blade impedance thresholds, integrating a thermally sound platform remains an art of simulating and optimizing the P-Q curve of each slot to match the airflow requirements of its intended board. The industry desires a broader configuration-independent thermal interoperability model of shelves and boards.

THE INTEROPERABILITY FRAMEWORK

Interoperability Requirements –The Blueprint for Compliance

Interoperability requirements provide the link between options promoted by the PICMG specifications and interoperable products. The same holds true for the Service Availability Forum (SAF) and other specifications used to develop Modular Communications Platforms. The clear objective is to fill this gap so that vendors will deploy products that interoperate with each other, rather than customize SKUs for each design win. This linkage requires a narrowed view of the parent specifications to support a set of usage models. There are valid and important uses of the variety of options that PICMG promotes; however, some are applicable only to a small set of applications.

Interoperability of products relies foremost on conformance to standards. The interoperability requirements define the interface requirements from relevant standards organizations to set the stage for interoperability. As necessary, the performance levels required to support the target applications may also be defined. Beyond this level of specificity, interoperability requires one more step–conformance.

Conformance is assured when a product is validated to meet specific test criteria designed to ensure that the interoperability requirements are met. To reduce the overall cost of the compliance testing, it is important not to test beyond that which is required to demonstrate that the interoperability goals are met. To that end, test requirements can be classified into four categories, each level elevating the difficulty, hence cost, of the implementation.

1. *Inspection*–Requires physical examination of a Device Under Test (DUT) by a human operator to verify compliance.
2. *Connectivity*–External equipment is required to verify point-to-point connectivity of a DUT in a passive state.
3. *Functional*–Requires a DUT to be put into an operational state to verify compliance.
4. *Performance*–Higher degree of functional validation is required, such as signal integrity or stress.

These test objectives lead to a set of interrelated test procedures that ensure adequate validation to promote interoperability.

Interoperable Management

The PICMG 3.0 AdvancedTCA base specification defines the management infrastructure inside the AdvancedTCA Shelf in great detail. The PICMG AMC.0 Base specification further defines the infrastructure for managing the mezzanine modules. Ideally, the support of these requirements by respective components should produce interoperable systems, but that is not always the outcome. In some instances, the requirements are implemented differently leading to interoperability issues. In other cases, requirements do not exist. Therefore, a focused effort is necessary to achieve interoperability across components.

The first step is to list all the existing requirements in the PICMG specifications that are important for interoperability, and target them for compliance testing by a common test suite. A collaborative approach among component vendors drives consensus toward a common interpretation of the requirements, improving the likelihood that different vendors' implementations of the same requirement will conform, thereby improving interoperability.

Additionally, there are many areas which are of practical importance, but have not yet been addressed by the present specifications. To address these gaps identified by the system integrators and TEMs, new requirements have to be formulated.

One simple example is obtaining the revision number of various components on the boards such as hardware, firmware including the BIOS, FPGA etc. Currently there is no uniform way to query this information from the boards. Consequently, in some cases it may be necessary to reboot a board just to find its BIOS version information. To alleviate this situation, a new IPMI command can be defined for accessing the version and revision numbers of these components.

Another example is handling of telco alarms. Telco alarms are important for telecom systems. The current specification articulates the hardware-related requirements for support of telco alarms such as connector pin assignments and electrical specifications, but it does not provide a uniform way to control the generation and suppression of the alarms themselves. Here again, a new command and message structure needs to be defined to facilitate control of the telco alarms. This command can then be adopted by the system management entity to exercise control over the telco alarms.

There is a strong industry incentive to identify the problem areas for interoperability and agree on solutions to these challenges that translate into new requirements. Ultimately, these requirements will guide conformant implementations with enhanced interoperability.

The interface between shelf manager and system manager is also a major interoperability concern. The PICMG specification mandates the support of Remote Management Control Protocol (RMCP) at this interface. RMCP is Intelligent Platform Management Interface (IPMI) messaging over the User Datagram Protocol (UDP). However, a typical IPMI message is 32 bytes long, which is not adequate for the serious amount of communication required over this interface. Thus, one approach is to define another interface and leverage it to integrate the shelf manager with a system manager in an interoperable fashion. This scenario envisions expanding the current scope of PICMG and mandating a standard interface at this management layer, such as the Hardware Platform Interface (HPI) already defined by the Service Availability Forum (SAF). This brings about an interoperable interface architecture between the system manager and ATCA shelf manager, as represented in Figure 3.

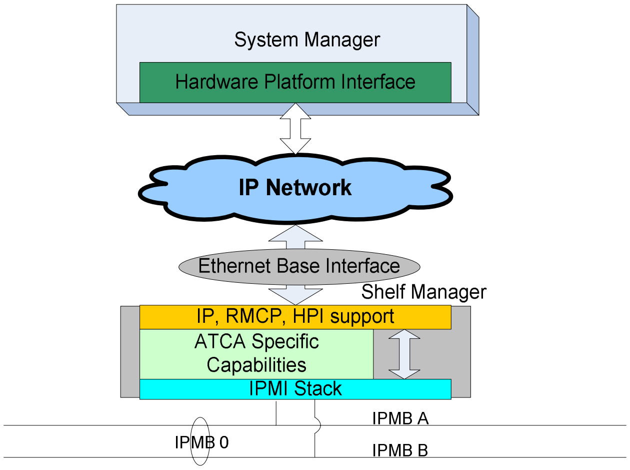

Figure 3: System manager and shelf manager interfaces

Thermals: Boards Meet Shelf

The PICMG3.0 specification recommends the upper thermal envelope as 200 Watts per slot. The laws of thermodynamics then dictate the minimum required volumetric flow rate sufficient to dissipate this thermal power, under given environmental conditions. Since board thermal impedance affects the air throughput within the slot, PICMG3.0 mandates that board and shelf vendors publish pressure-airflow curves, to aid in the shelf/board integration process. These P-Q curves are helpful in simulating the effects of low-pressure and high-pressure boards in various shelf slot configurations, allowing the shelf slot configuration to be customized for a particular set of boards in a given shelf. However, any board reconfigurations within the shelf will inevitably impact slot impedances, thus re-distributing the airflow across the slots. This falls short of enabling a generic reconfigurable shelf, without impacting the thermal integrity of the platform. The reason is simple–the boards are not required to use the available airflow judiciously, and shelves have no requirement to deliver an adequate airflow proportional to slot impedance.

To enable thermal interoperability across a broad cross-section of boards from different vendors, there is a need to mandate that boards present minimum impedance to airflow based on their power consumption. When implemented, this model allows for a far greater degree of thermal interoperability by providing balanced impedances across the shelf. This also facilitates moving disparate boards to different slots of the same shelf, to build targeted network applications, while preserving the thermal integrity of the system.

On the shelf side, the current PICMG3.0 recommendation of a 200 W/slot alone does not provide an adequate design requirement to guide the shelf vendor. Rather, the shelf's cooling capacity is determined by the amount of airflow delivered in each slot of the shelf. Therefore, there is a need to outline shelf thermal requirements explicitly in terms of the minimum airflow per slot that a shelf has to supply, pegged to a reference slot impedance. This philosophy could then be applied to measure slot airflow under the full range of environmental conditions as mandated by NEBS and the European Telecommunications Standards Institute (ETSI) specifications.

Laying out this interlocking framework for blades and shelves will enable a deterministic ecosystem of shelves and boards designed for thermal interoperability from the ground up.

INTEROPERABILITY FRAMEWORK

Test Specification & Tools

The identification of interoperability requirements is the first step towards achieving interoperability in the multi-vendor AdvancedTCA environment. The next step is compliance testing for these requirements. This is a significant task, keeping in mind the scope of AdvancedTCA architecture, which consists of mechanical, thermal, electrical and manageability components. Each of these areas requires its own kind of test environment.

The compliance test requires very precise, verifiable, and repeatable test procedures. These procedures need to be developed in a collaborative environment where different stakeholders such as component manufacturers, system integrators and TEMs bring their own insight to the problem. The requirements specified in the first step will lead to the test procedures that will be organized into a test manual. The test manual defines the environment, tools, and detailed steps to validate these requirements.

Automated Test Suite

Manageability requirements describe software interaction and as such can be validated via automated software test suites. The AdvancedTCA manageability framework is based upon IPMI infrastructure. All the intelligent FRUs are linked to the shelf manager by IPMB links and the shelf manager exchanges IPMI messages with these FRUs. The software test suite exchanges IPMI messages with the shelf manager as well as management controllers on the intelligent FRUs to exercise this interface. A conceptual view of IPMI test architecture is provided in Figure 4.

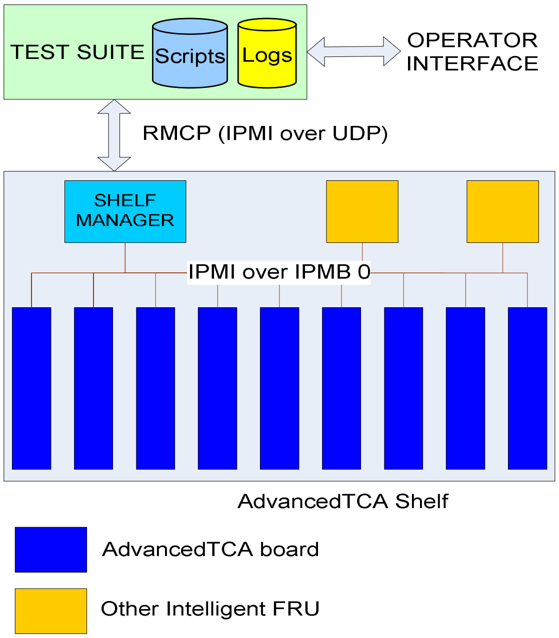

Figure 4: IPMI test architecture

In keeping with the spirit of open standards, this software test suite must be deemed impartial and be provided by a neutral vendor, one that does not own a stake in certification of their own AdvancedTCA products. There are already some test tools available in the industry which can be leveraged to develop an interoperability compliance test suite.

Intel offers its IPMI V2.0 Conformance Test Suite (ICTS), available for download in the public domain: http://www.intel.com/design/servers/ipmi/tools.htm. The ICTS was conceived for testing of basic IPMI compliance, and the IPMI messaging infrastructure provided by this suite can be leveraged to build other IPMI-based test tools. Another suite based on ICTS is called AdvancedTCA Compliance Test Suite (ACTS), a test framework focused on compliance test for a subset of requirements from the PICMG3.0 base specification.

There are other industry-recognized test suites that target requirements from the PICMG 3.0 specification. They represent a significant body of work that can be built upon when formulating a systematic interoperability compliance.

The test suite for interoperability will span beyond the PICMG defined domain; therefore, the test suite will include other types of tests in addition to IPMI-based interaction. Two such prominent areas from user standpoint are suites for HPI and SNMP as standard interfaces for the shelf manager. Architecturally, the IPMI, HPI and SNMP domains should be based on a common framework, unified by a user interface and common logging facility, referenced in Figure 5. This extensible test framework will evolve in modular fashion to keep up with future needs.

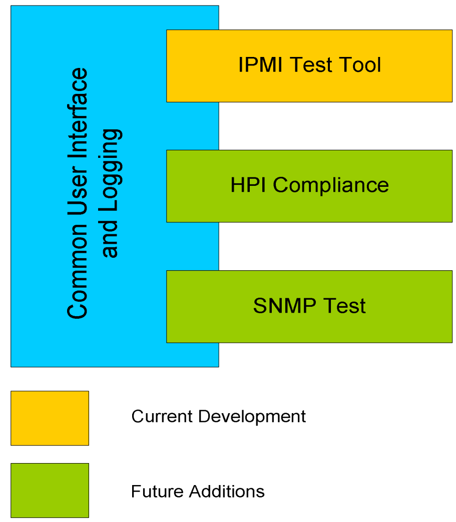

Figure 5: Automated test suite

Other Types of Tools

Other areas of interoperability testing don't lend themselves to automated software tools, rather they require golden test platforms to be defined and instrumented. One such application is the interoperability requirements framework of thermal requirements for AdvancedTCA shelves. These requirements share the principle that accurate slot airflow analysis is representative of a shelf's cooling capacity, and thus can be validated using a common airflow test methodology. In consultations with the industry, Intel has already implemented a functional test platform of this type.

The purpose of the flow benchmark is to measure the available airflow in each slot of the shelf, under a specified impedance load. The test platform consists of the shelf under test, provisioned with a standard reference board serving several functions:

- It provides for laminar airflow within the slot.
- It models the P-Q characteristics of a typical SBC.
- It facilitates CFM measurements across the depth of the board.

All slots of the shelf under test are configured with the standard reference board, presenting a pressure drop of 0.15 inches of water. The key advantage of this methodology is that it employs a managed and fully functional shelf, thus taking empirical flow measurements under real-life conditions, Examining Figure 6, it can be seen that several air pressure drops develop as the airflow travels from the shelf inlet to the shelf outlet.

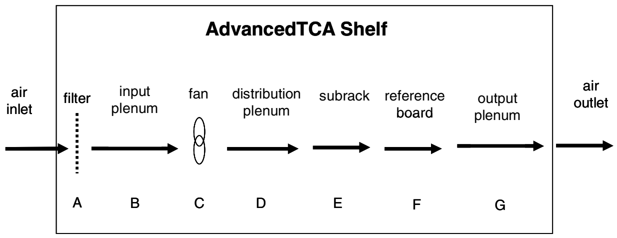

Figure 6: Airflow pressure drop reference diagram

These drops exist regardless of the location of the fans or blowers or any other component of the shelf. Measuring the volumetric airflow directly in each slot equipped with the reference board provides a very accurate picture of the actual amount of air that reaches the slot. This represents the airflow available for cooling each board of the shelf.

An example of the resulting shelf airflow profile for a 14-slot shelf is shown in Figure 7.

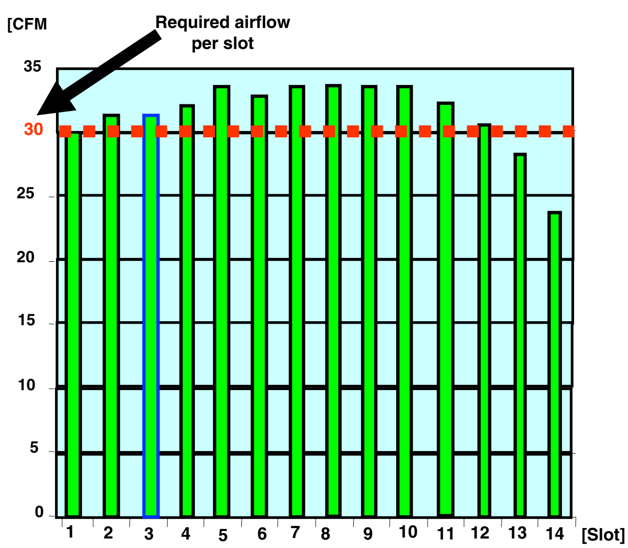

Figure 7: A typical shelf airflow profile

Mandating airflow requirements and adopting industry benchmarks to validate compliance will provide much desired transparency into the thermal capabilities of the shelf ecosystem, well in advance of the actual platform integration.

Another category of tools will also be required for electrical testing of backplane and interconnects. A small subset of environmental testing will likely be integral to the interoperability conformance validation. For instance, an acoustic chamber may be required for sound power and sound pressure testing. This is to ensure that a shelf meets regulatory requirements, while maintaining its capability to deliver sufficient airflow per slot.

Certification of Interoperability Compliance

Certifying for interoperability is a concept already established in many other technology areas. The AdvancedTCA industry has yet to organize itself around a functional certification program.

In addition to identifying interoperability requirements, and the creation of detailed test procedures and underlying test tools, there are two other components to an interoperability program. The first is to coalesce on a certification process, yet to be determined. The second challenge is to set up an operational certification infrastructure with all the necessary resources and specialized test equipment such as described in this paper.

Examples of well-executed interoperability certification programs are found across many industries. Much can be learned from the well-established certification program and labs for Ethernet interoperability testing, which are closely akin to the component certification expected for AdvancedTCA. Yet the unique demands for an AdvancedTCA interoperability certification will come from its expected breadth and relative complexity. Since the AdvancedTCA architecture encompasses electrical, mechanical, thermal, interconnect, and software areas, each type of component has to be tested for these attributes. This calls for a robust lab infrastructure, with critical mass of specialized test equipment, as well as personnel that are versed in all aspects of AdvancedTCA testing.

Founding of an interoperability certification program is the next logical step towards achieving the goal of multi-vendor interoperability in the AdvancedTCA ecosystem. Together, the industry will be able to fund the necessary infrastructure, as well as contribute its collective expertise to this noble cause.

CONCLUSION

As growing numbers of integrators race to deliver solutions on AdvancedTCA platforms, focusing on interoperability of components from different vendors becomes paramount. While there have been early efforts at standard compliance and sporadic interoperability testing, they have not been adequate to fully validate, document, or certify the level of interoperability deemed necessary by the integrators, and ultimately their customers, to help them launch AdvancedTCA platforms faster.

To mature to the next level, the AdvancedTCA industry must bring together the component suppliers, system vendors, and service providers in a concerted effort to specify, develop, certify, and deploy interoperable modular solutions. The identification of interoperability requirements takes the first step toward an industry-wide interoperability program. Born from broad industry collaboration, the first set of such requirements comprehends the basic interoperability requirements relevant across all the AdvancedTCA implementations, independent of any specific application segment. Later on, profile-specific interoperability requirements will be added for different segments. As shown, the supporting infrastructure behind a certification program must also include test procedures linked into the requirement set, test tools, and benchmarks as well as an operational interoperability lab, all governed by efficient certification processes.

As AdvancedTCA components designed and certified for baseline interoperability become available, integrators will have the flexibility to cost-effectively mix and match modular components from different vendors. The ultimate success of an interoperability certification program will be measured on the economic benefits and agility that a thriving interoperable ecosystem will bring to service providers.

ACKNOWLEDGMENTS

We acknowledge all members of the Modular Communication Platform Division who share the vision of AdvancedTCA-based interoperable Modular Communications Platforms.

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GLOSSARY

Interoperability	The ability of two components to provide intended functionality between the components while operating in a common system environment. The ability of software and hardware on different, but interfaced, machines to communicate with each other.
LVDS	Low voltage differential signaling.
M-LVDS	A later development of LVDS defined in TIA/EIA-644. It is specifically designed for multisource and multidrop signaling.
Shelf	AdvancedTCA shelf consists of subrack, backplane, front boards, cooling devices, rear transition modules, power supplies, etc. Also historically known as chassis.
System	A collection of components organized to accomplish a specific function or set of functions. For the purpose of this discussion it is a configuration of AdvancedTCA components such as shelf assembly, shelf manager, front boards and/or AMCs in order to achieve a specific function such as telco server.

AUTHORS’ BIOGRAPHIES

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