SPLY004—October 2003
White Paper

Interoperability – The Backbone of Broadband

Steven Bieser, Engineering Manager, TI's DSL Business Unit
Debbie Greenstreet, Product Management Director, TI's Voice over Packet Business Unit
Dennis Rauschmayer, Director of Marketing, TI's Cable Broadband Communications Business Unit
Ian Sherlock, Product Technologist, TI's Wireless Networking Business Unit

---

In the rapidly emerging broadband industry, interoperability is a complex concept that is critical to master in order to provide consumers with a pleasant experience. To the typical end user, broadband represents a simple idea – a proliferation of wired and wireless devices that allow high-speed, seamless communication. Cable Modem, DSL, Voice over Internet Protocol (VoIP) and 802.11 Wireless LAN (WLAN) systems are designed to make users' lives easier by giving them instant and reliable access to value-added services when and where they need them.

In the real world, a broadband network is a mix of end equipment defined by standards bodies, built by manufacturers and deployed by service providers. The various types of equipment used must co-exist and co-operate in a seamless and transparent way for the end user to experience "simple" services. It is not an easy task given the extreme complexities of the individual technologies and is compounded in systems that combine multiple broadband technologies.

Given the rapidly growing consumer acceptance of broadband technology worldwide, it comes as no surprise that interoperability has emerged as the fundamental requirement for broadband proliferation. So what is interoperability? Interoperability is the ability to connect hardware and software elements of infrastructure and customer premises equipment (CPE) from multiple manufacturers and have them seamlessly communicate and work together. Interoperability is a key consideration for broadband suppliers because it plays a vital role in whether the broadband device will meet the consumers' expectations. Because of this importance, interoperability has become a massive behind the scenes effort at the service provider, OEM and silicon manufacturer to ensure products deliver on the promises they have made to end users.

Although interoperability is an expected goal for all broadband technologies, each individual broadband market approaches it differently. In cable modems for instance, interoperability is a tops-down and prescribed approach. VoIP and DSL follow a less rigorous model. Here's a summary of interoperability approaches that this paper will outline in more detail.

Cable Modem – Driven by the industry standards group Cable Television Laboratories (CableLabs ®) interoperability among cable broadband systems is clearly defined. Three times each year CableLabs offers certification testing providing modem manufacturers with an opportunity to prove that their system complies with the CableLabs Certified Cable Modem Project Data Over Cable Service Interface Specification (DOCSIS™) standards. Systems that pass the certification testing are then deemed "certified."

DSL – Interoperability in the DSL world is currently loosely organized around industry and individual service provider requirements. TR-048 is a widely used set of requirements from the

DSL Forum which stemmed from a collaborative effort among service providers, manufacturers and silicon providers for DSL performance. While TR-048 is used as a guideline, real interoperability assurances come from individual system-to-system testing done by silicon providers, systems vendors and broadband service providers to ensure the platforms will meet service providers' guidelines.

VoIP – Developers of VoIP systems must comply with various IEEE and IETF standards for operation and interoperability. They must also interoperate with legacy telephony equipment, much of which requires rudimentary testing with such equipment, and interoperate with newer packet network protocols that offer plug fests for testing. Much as with DSL, actual interoperability testing responsibility falls on silicon manufacturers, OEMs and service providers.

WLAN – Interoperability in WLAN systems is ensured through the Wi-Fi Alliance as well as individual work among silicon providers. The Wi-Fi Alliance certifies interoperability of WLAN products based on IEEE 802.11 specifications. While the Wi-Fi® certification process provides a base-line for interoperability, silicon providers also perform additional interoperability tests.

The Important Role of the Silicon Manufacturer for Interoperability in the Broadband Value Chain

Given the complexities of delivering truly interoperable systems, the silicon provider is playing an increasingly important role in meeting industry and end-user demands. Silicon and software form the foundation of any broadband system, so it is here where interoperability must be addressed initially. From the silicon supplier, it requires access to the hundreds of different equipment combinations deployed worldwide, thousands of staff hours of testing, relationships with leading operators and equipment providers, and real-world deployment experience to offer the highest levels of interoperability. By focusing on them intently, silicon providers such as Texas Instruments are delivering a significant value-added service to all players in the broadband value-chain – OEMs, operators, and ultimately end-users.

Equipment manufacturers demand interoperability from silicon technology suppliers because it allows them to get their products to market quickly. Relying on their silicon partner reduces significant resources and capital expenses required to test new products and allows the manufacturer to concentrate on value-added product features. It also ensures that they will be able to meet the varying regional requirements to deploy their products in different operator networks and conditions to maximize revenues.

Interoperable systems allow operators to quickly deploy new equipment in the infrastructure and at the customers' premises with the assurance that it will work with what they have already deployed and what they will deploy in the future. For example, a new central office line card or DSL modem that has proven interoperability with the installed-base saves operators time and money since they will not have to replace the modems or line cards already in the field.

Ultimately the goal is that the end-user should never be concerned about the concept of interoperability. Consumers should feel confident that they will be able to use the full capabilities of any broadband product. WLAN users should be able to access the 802.11 network in an airport

from their laptop, without worrying about the compatibility of their PC card with the airport's access point. Likewise, cable modem users should feel confident that they are getting maximum performance from their modem, regardless of which company manufactured the cable modem termination system (CMTS).

Interoperability Challenges Across the Broadband Industry

Cable Modem

Among broadband technologies, the cable industry has been perhaps the most aggressive and organized in pursuing strong interoperability. In fact, interoperability is so important to cable multiple services operators (MSOs) that the industry banded together several years ago to form CableLabs, a consortium designed to centralize the definition and execution of standard requirements to achieve multiple vendor interoperability.

CableLabs works in close partnership with industry-leading suppliers to define requirements. It then certifies every piece of cable broadband equipment that goes to market, offering three opportunities for certification each year that give modem manufacturers the opportunity to prove their equipment is ready to be deployed.

Each cable modem that passes CableLabs certification undergoes thorough interoperability testing and validation to measure physical layer performance, media access controller (MAC) layer messaging, modem management compliance, privacy and encryption methodologies, quality of service, home interface functionality, and long-term stability and reliability.

Effective certification and interoperability testing for cable modems is very important due to the large number and variety of legacy cable modems and CMTS with which the new modem must demonstrate compliance. Although demanding, there are some valid reasons for such strict interoperability compliance. First, cable modems in a neighborhood are all interconnected and must be able to interoperate well together. Second, the modem must work with a myriad of deployed CMTS systems, even those that may vary slightly from compliance with the standards.

Since CableLabs only offers a limited number of certification opportunities per year, it is extremely important that the OEM enters the process with a maximum chance of success. This is where the silicon vendor adds significant value. With its own interoperability lab, TI offers a complete and field hardened hardware and software solution that gives manufacturers fast time to market with a proven solution.

Prior to submission of a TI-based modem to CableLabs certification, TI performs its own tests, including several complete cycles of the test execution plan that have been defined and developed at CableLabs. This pre-certification process, which greatly increases the likelihood of CableLabs certification, verifies and proves compliance with more than 5000 items that will be formally tested by CableLabs. This testing provides maximum confidence that the TI-based modem will be awarded certification by CableLabs and will be ready to produce revenue for the manufacturer.

ADSL

The challenges of providing interoperable products in the DSL industry began with the release of the initial American National Standards Institute (ANSI) T1.413 issue 2 standard. While the standard provided a base for the industry, the requirements were open for interpretation by manufacturers and silicon providers. On top of this, unlike the cable industry, there are no DSL industry certification labs that strictly regulate the introduction of ADSL products into the market. This has been left to service providers to qualify, approve and limit modems deployed in their own networks.

This has led to a deployed base of DSL solutions, all with different interpretations and implementations of key parameters such as allowable power spectral densities, Fast Fourier Transform sizes, noise margins and messaging protocols. There are dozens of equipment manufacturers in the DSL market, each with slightly different implementations of the ADSL standards and requirements. Plus, service providers have unique requirements for their networks. This causes interoperability to be a daunting task for silicon providers to tackle. And as a result interoperability is an issue that has slowed the deployment of ADSL systems.

The DSL industry is working to eliminate this gap and has implemented accepted performance requirements such as TR-048 from the DSL Forum to promote widespread interoperability. New requirements under discussion (WT-085) will potentially consolidate more requirements from different regions of the world. There are also proposals to include additional comprehensive test requirements to better validate the accuracy of key system parameters such as noise margin.

Beyond TR-048 and WT-085, the ADSL industry is beginning to qualify products based on the newly consented G.992.3 (ADSL2) standard. Besides new features and higher data rates, this evolution in the ADSL standard was designed to tighten the definition of the protocols, handshake and signals in order to reduce different interpretations.

Silicon suppliers like TI are playing a major role in advancing the DSL industry's interoperability efforts. Through its own interoperability lab, TI validates its DSL hardware and software against the major solutions available on the market. This is an expensive and time-intensive task that assures OEMs that TI-based products will work as advertised in a myriad of real-world environments.

Interoperability testing of ADSL modems consists of four major components: 1) verification of connectivity and the ability to exchange data; 2) verification of the ability to achieve specified or expected performance and bit error rates under various loop and noise conditions; 3) verification of stability and robustness under changing loop and noise conditions; 4) testing of applications that run on top of the modem, e.g. throughput and latency testing.

In TI's interOps Test Labs program new ADSL products are tested and validated against the large number of deployed infrastructure and CPE solutions in a complete, extensive and automated lab. Additionally, the time-intensive human testing is complemented with thorough processes, tools and databases to archive and mine the vast amount of data along with systems knowledge to correlate results and dissect interoperability issues.

Finally, given the challenges and history outlined above, designing for interoperability is a key requirement for success in the ADSL arena. This includes building systems based on programmable solutions like those offered from TI, structuring software for scalability, and adding intelligent algorithms to work with all deployed modems. Programmability allows products to be quickly adapted to ensure the highest levels of performance and interoperability, enabling equipment to be upgraded to meet evolving standards and to maintain interoperability with legacy equipment.

802.11 WLAN

The WLAN environment is very heterogeneous in nature. Laptops, PDAs and other Wi-Fi enabled end equipment are designed to provide broadband connectivity wherever they go. A person using a WLAN system might be sending e-mail from their neighborhood coffee shop and the next day be downloading a video file in an airport 2000 miles away. The desire for guaranteed operation and high performance among software and hardware from dozens of vendors makes interoperability of paramount importance. In addition, WLAN systems must maintain compliance with various governmental radio frequency regulatory requirements.

The IEEE 802.11a, 802.11b and 802.11g standards describe the core functions that WLAN systems must provide. In addition, the Wi-Fi Alliance, an industry consortium of companies involved in WLAN, provides Wi-Fi compliance testing that measures the ability of equipment to perform in numerous typical system implementations. 802.11 stations are tested against various access points, and likewise, access points are tested for compatibility with various 802.11 stations. As a result, Wi-Fi certification is an important seal of approval for all WLAN equipment.

Wi-Fi certification assures tested and proven interoperability among wireless computer equipment. This certification gives consumers and IT managers confidence that wireless LAN products bearing the Wi-Fi logo have passed interoperability certification requirements. Such Wi-Fi CERTIFIED™ products include PC Cards for notebooks, PCI Cards for desktops, USB modules (which can be used with notebooks or desktops), and wireless base stations like access points and gateways.

Many silicon vendors, including Texas Instruments, augment features and functions in wireless LAN products to provide enhancements and differentiation outside the 802.11 specifications. As a result, it remains a core function for silicon providers to ensure interoperability and seamless operation of a wide range of deployed end equipment when these enhancements are enabled.

Since WLAN connectivity is quickly being added to a wide-range of end-equipment, interoperability is becoming more important. In the enterprise/PC market segment an 802.11 interface has become a core function of new portable PCs. In the home networking/SOHO market the interoperability environment is highly heterogeneous since more often than not end-pricing determines what products the consumer is going to purchase, which leads to mixed brands over time. Then there are the emerging markets of mobile devices such as PDAs, cell phones and consumer electronics. Since these devices roam within different networks they must interoperate with any access point that might be deployed in an office, home or public hot spot.

As with the DSL industry, interoperability in WLAN equipment is a key objective that must be addressed by every party involved in product development and deployment, including wireless Internet service providers (WISPs), OEMs and silicon developers. Again, Texas Instruments is providing a model for silicon developers, taking much of the interoperability burden from the service provider and OEM. TI maintains a full, automated WLAN interoperability lab where it tests a wide range of access points and client station equipment from system and networking stack perspectives in a wide range of typical combinations. Texas Instruments is also a contributor of WLAN equipment to industry interoperability test beds; for example Texas Instruments equipment is part of the Wi-Fi Alliance's testbed for 802.11g.

Since 802.11g incorporates and supports both single frequency and orthogonal frequency division multiplexing (OFDM) modulation schemes, interoperability testing becomes much more complex than for 802.11a and 802.11b standards which support a smaller set of modulation schemes. 802.11g systems require careful testing to ensure interoperability with legacy 802.11b equipment, as well as with newer 802.11g equipment, and in networks consisting of both types of equipment. Again, TI brings interoperability expertise to this situation with its work on 22 Mbps multi-modulation implementations and associated protection mechanisms, which have been proven interoperable with 802.11b equipment. The Texas Instruments WLAN architecture is highly programmable which supports the software flexibility necessary for robust interoperability in a WLAN networking environment.

The rapidly expanding Wireless LAN standards ecosystem ensures that interoperability testing will continue to be of paramount importance for the industry as standards such as 802.11e (Quality of Service) and 802.11i (security) move toward ratification.

Voice over Internet Protocol (VoIP)

VoIP technology provides a platform for delivering telephony services over a digital broadband access network. The technology can support all of today's traditional voice services like toll-quality local and long distance calling, caller ID and call waiting as well as fax and dial-up modems. In addition, VoIP gives operators new ways to develop revenue from value-added IP services.

As with all emerging broadband markets, interoperability in VoIP is key for delivering on the immense deployment potential of the technology. The value of IP-based voice systems is clearly defined and accepted; however, the lack of standards-based, end-to-end solutions is an obstacle that the industry is working to overcome.

Traditional voice service has long enjoyed a strong set of international standards that specify and clarify design principles, communication processes, test procedures and environmental conditions. Since H.323, the first VoIP standard, was ratified in 1996 by the ITU, a host of standards and variations of VoIP standards have emerged from the ITU, IETF, CableLabs and other standards bodies. The challenge for equipment manufacturers lies in determining which elements of the standards to implement to ensure interoperability with VoIP equipment from other vendors.

Most VoIP applications today also use voice codecs, called vocoders, which were created for existing digital telephony applications. Like H.323, they are robust and proven, allowing designers to get interoperable products to market quickly. However, because many of these vocoders operate on a limited telephony signal band of 200-300 MHz with 8 kHz sampling, the level of quality is far below real-world, face-to-face communication that requires a much wider bandwidth of 50-7000 Hz.

To address these issues, the industry is now developing new wideband codec standards designed to push the technology to higher levels of service. The ITU G.722.1 vocoder, currently being used in some IP applications, delivers 24 kbps and 32 kbps data rates, and it enables wideband performance with a 16 kHz sampling rate. Meanwhile, another wideband standard, the Adaptive Multi-Rate Wideband (AMR-WB) at the 50-7000 Hz bandwidth, has been jointly developed by the ITU-T and the Third Generation Partnership Project (3GPP)/ETSI. Recently approved by the ITU and referred to as G.722.2, the standard further improves voice quality over G.722.1, and it enables seamless interface between VoIP systems and wireless base stations.

Underlining the importance of the silicon vendor in laying a proper foundation for VoIP systems, Texas Instruments is taking VoIP interoperability as a primary concern in its product development. TI has been very active in establishing many VoIP standards, including, among others, T.38 fax. Furthermore, TI has taken the intention of the echo cancellation standard a step further by ensuring that when all channels on a device are started simultaneously, the G.168 requirements will be met on each channel. TI's adherence to ITU H.248's strict tolerances on echo cancellation serves as a prime example of how a silicon manufacturer can influence the performance and interoperability of the system.

Beyond standards adherence, TI also extensively tests its VoIP hardware and software solutions against real-world VoIP equipment implementations in an interoperability lab. This ensures the customer's handset or VoIP infrastructure device works the way OEM and service provider intended.

Interoperability from the Ground Up

As a key technology provider for all major broadband technologies, TI fully understands the needs and varying requirements for interoperability. This is especially important as broadband systems become more converged, for example, with 802.11-enabled DSL routers and voice-enabled cable modems coming on the market.

TI has invested more than $7 million and thousands of staff-hours in its broadband interoperability labs in order to ensure that the company's broadband chipsets, processors and software meet the requirements of manufacturers, operators and end users. With a strong commitment to interoperability, TI provides peace of mind to OEMs that their systems are globally deployable in the real world. This focus and commitment allows manufacturers to accelerate the deployment of fully tested products, giving them the inside track with broadband operators.

For more information, visit the Texas Instruments Web site: www.ti.com