ABSTRACT

Home networking technologies and capabilities are receiving increased attention from consumers, software developers, hardware manufacturers, and service providers. Rapid innovation in home networking technology — advances in silicon, digital signal processing, and protocols — are improving the performance and lowering the cost of home network solutions. Cable system operators will depend on home networks for deployment of advanced services. The goal of the CableHome architecture is to establish a home network environment within which the delivery of quality cable-based services can be ensured.

OVERVIEW

Home networking technologies and capabilities are receiving increased attention from consumers, software developers, hardware manufacturers, and service providers. Several factors are accelerating home network solutions:

- **Declining price of digital technology:** Moore’s law continues to improve the performance and lower costs of all aspects of digital technology. Software continues to replace hardware subsystems in consumer electronics devices, which both lowers cost and improves functionality. Digital signal processing capacity can be applied to the problems of noisy network media as well as improve the quality of decompression algorithms for audio and video.
- **Significant penetration of PCs into homes and multiple PC households:** In the United States 43.8 million households have one PC, 13.4 million households have two PCs, and 3.8 million households have three PCs.
- **Increasing penetration of Internet access, particularly broadband:** The installed base of cable modems and DSL-equipped homes has already reached nearly 5 percent of United States households.
- **Proliferation of digital devices in the home:** New devices such as personal video recorders, advanced set-top boxes, personal digital assistants, digital cameras and camcorders, home automation, and intelligent appliances are creating the need to allow these devices to communicate with each other and the Internet.
- **Increasing availability of multimedia content:** Digitally formatted content is now widely available in packaged media, such as CD and DVD, in digital broadcasts, as well as over the Internet in digital compressed form such as JPEG images, MP3 audio, and MPEG videos.
- **Rapid innovation in home networking technology:** Advances in silicon, digital signal processing, and protocols are improving the performance and lowering the cost of home network technology solutions.

To the cable system operator, home networks present both opportunities and issues. The opportunity to have new advanced services accessible by a wide variety of devices throughout the home is critical for rapid adoption and acceptance by consumers. The consistent and high-quality rendering of these new services from one device to the next is a concern for both system operators and content owners. In the consumer world “consumption = convenience,” and home networking solutions must improve convenience rather than detract from it.

APPLICATIONS

Network effects, characterized by Metcalfe’s Law, predict that the value of a network and the devices connected to it will increase dramatically as the number of connected devices and users increase. This has already been demonstrated at the macro level (Internet), and most experts agree this will occur at the micro level (home) as well. Simply connecting devices is not enough; there must be an easily understood set of benefits for consumers to deploy a home network solu-
tion. These benefits are realized by applications today that are made compelling by the large numbers of households with more than one PC. Descriptions of a few key applications follow.

Peripheral sharing — Devices such as scanners and printers can be accessed from any device and any location in the home with a home network. This sharing can result in cost savings, but, more important, can allow a consumer to structure the physical placement of devices in keeping with their lifestyle, residential arrangements, and aesthetics.

File sharing — Data such as address books, calendars, content, or work-related documents can be accessed from any device in the home that has the capability to present the information. A home network of some form will be required to connect these devices.

Internet access sharing — Just as multiple telephone handsets installed in a home greatly increased the utility of the telephone system, the ability to share an Internet connection, particularly a broadband connection such as a cable modem, is a key driver of consumer adoption of home network solutions.

Audio and video distribution — As virtually all content becomes digital and home servers or jukeboxes become viable consumer products, the ability to access this content from any location in the home will be demanded by consumers.

Communications and collaboration — New communications services such as instant messaging, chat, alerting, voice over IP (VoIP), multiplayer games, and always-on open channel or intercom-style communications will become ubiquitous. Some form of home network will be required to enable these applications across multiple devices beyond the PC.

Remote control and monitoring — The traditional applications include automation of lighting, security, HVAC, and other home control systems. New applications such as demand-side energy management, health care monitoring, and Web-based surveillance cameras will require a home network. Remote monitoring and control applications are beginning to migrate from previously high-end consumers to larger segments of residential consumers.

As more devices are interconnected, we will see an explosion of interesting and compelling new applications that go beyond the need to connect multiple PCs within a household. The wide range of devices, content types, and applications are unlikely to be satisfied by a single home networking technology. The most likely scenario is that multiple technologies will be deployed in any one residence. We expect that these disparate home network solutions will evolve concurrently with each offering targeted to perform best in a narrow range of applications. For example, it is unlikely that the full capabilities of a high-bandwidth, low-latency and low-jitter, multiroom media distribution solution will be cost effective for a remote control and home automation application. Therefore, home network developers are faced with a complex and sometimes contradictory series of design considerations that must be evaluated and with trade-offs that must be made during the course of product development.

### DESIGN CONSIDERATIONS

The need to solve the problem of interconnecting multiple PCs in a household has dominated the design of home networks. The engineering task so far has focused on repurposing commercial local area network (LAN) solutions to the installation challenges presented by the residential environment and to reduce the price to consumers. The existing body of knowledge of the design, implementation, and operation of packet-based networks has served the commercial and consumer markets well. Many of the current hot topics in network engineering, such as quality of service (QoS), policy management, security, and reliability, are relevant to the design of home networking solutions. However, there are subtle differences.

Cable operators are deploying a new generation of services, including advanced telephony and communications, digital television, movies, music distribution, and high-speed Internet access. These new services represent a wide range of performance demands, functional requirements, and cost targets. Ultimately, the larger global network known as the Internet may provide the bandwidth, QoS, latency, and jitter requirements that will be required by home networks.

### PHYSICAL PERFORMANCE PARAMETERS

The ability of a home network to optimally deliver content to consuming devices is dependent on characteristics of the communications channel and performance of network elements between the content source and the consuming device. Performance of a home network can be defined by physical performance parameters, and are often traded off with other factors such as target cost, development schedule, and the need to support legacy equipment.

The physical performance parameters that affect the rate and quality at which information is transmitted across a home network include bandwidth, latency, jitter, efficiency, and error rate.

**Bandwidth** is usually considered to be the range of frequencies within which most of a transmitted signal’s energy is contained. Bandwidth, expressed in terms of cycles per second or hertz, is usually constrained by the sending device’s transmitter and the physical characteristics of the communications channel. Advances in modulation techniques and digital signal processing provide for the transport of multiple bits of information per hertz.

**Latency** is the delay incurred in the delivery of information from a source to a destination. It is usually measured in seconds, or in fractions of a second. Latency is an important parameter for time-sensitive traffic such as voice and video. If latency increases beyond a minimum threshold, the quality of the delivered signal as perceived by the user is degraded.

**Jitter** is variations in time of a digital signal from its ideal time position. Jitter can also be thought of as the magnitude of delay variation or as phase variation in a digital signal. Noise in the channel, clock instability, noise in timing recovery circuits, and errors in equalization can
cause jitter. Like delay, jitter degrades the quality of real-time communications such as video and particularly audio. Jitter can be reduced with the use of a delay buffer at the receiver, but this will introduce a delay in the signal. Certain applications, such as distribution of high-quality CD audio, are very sensitive to jitter. **Efficiency**, or utilization of a communications link with an error control mechanism, is the ratio of the time required to transmit a frame to the total time required to send the frame and receive an acknowledgment. The total time is the sum of the capacity acquisition time, frame transmission time, propagation time of the frame, propagation time of the acknowledgment to the frame, and any processing time.

**Error rate** is the rate at which data is lost or corrupted. The loss of transmitted data can result from noise interference, inadequate signal strength or channel attenuation, loss of timing synchronization, and other reasons. Errors affect the performance of a packet-based network by causing retransmission delays to be incurred. Errors in a synchronous-based network can cause significant information loss and may also cause a degradation of message quality, such as a distortion in an audio file or file corruption.

**DESIGN PROBLEMS**

Connecting PCs, printers, cable modems, and other computer peripherals in a packet-based network is relatively easy using existing LAN solutions. Entertainment and communications devices present challenges to the home network designer. As an example, assume a consumer wishes to connect a number of “digital” speakers throughout the house via a home network:

- During playback the coherence of digital stereo audio samples is critical; otherwise, the stereo effect will be lost. Audio quality will be noticeably degraded unless extremely low jitter is maintained in the home network.
- Audio sample playback coherence in home theater surround sound systems must be maintained to very exacting standards; otherwise, the carefully created spatial effects will be lost.
- Multiple independent digital audio players, such as MP3 decoders throughout a home network, must be synchronized to avoid objectionable audio effects such as chorusing, flanging, reverberation, or echoes.
- If uncompressed digital audio and compressed video streams are to be distributed over the home network, care must be taken to ensure synchronization between the audio and video content so that lip sync and sound effects timing are preserved.

Even simple telephony applications can become complex. It is relatively simple to handle low-speed VoIP sessions over a home network between the gateway and a single VoIP-enabled telephone. The implementation can become complex when multiple telephones are to be supported and consumers expect the system to behave just like their existing telephone extensions, where any number of users can join in a conversation simply by picking up an extension telephone. Conferencing multiple telephone connections outside of the home can also be challenging, since these calls may have originated on different service providers’ external networks and gateways within the home.

Finally, the random addition and removal of devices attached to the home network by the consumer will present design challenges both to ensure uninterrupted operation of the home network and to support many different manufacturers’ devices.

**STAKEHOLDERS**

The cooperation and self-interests of many stakeholders must be integrated in order to create a viable and robust home networking industry. These stakeholders include consumers, service providers (e.g., cable system operators), homebuilders, distributors and retailers, content owners and authors, system and applications software vendors, and device vendors. Together these stakeholders constitute an ecosystem that must work together to realize the full potential of home network solutions.

**Consumers**, whether renters or homeowners, or whether living in single or multiple family dwellings (including homes, apartments, townhouses, condominiums, high rises, boats, or recreational vehicles), are all potential users of home network technologies. In addition to the need for compelling applications identified earlier, consumers will be concerned with the simplicity, functionality, reliability, security, privacy, and low cost of a home network solution.

**Broadband service providers** will depend on home network technology for deployment of advanced services. Consumers will demand that service providers support their home networks to allow access to information, entertainment, and communications services throughout their homes. The participation of cable system operators in this ecosystem will be discussed in more detail.

**Homebuilders and contractors** are important stakeholders as well. Intelligent design decisions and integration of home network infrastructure into new construction will facilitate deployment of this technology. Remodeling contractors and new builders alike need to become well versed in the installation of home network interconnection components, gateways, user interface devices, and structured wiring. The value of a residence should increase as a result of including home network technology.

**Retailers and distributors** continue to play a key role in the diffusion of new consumer technologies. Retailers, system designers, installers, and maintenance providers must become familiar with home network technology solutions. Training of personnel will represent a considerable cost to retailers and distributors. Retailers have had an important role in picking which technologies will prosper and which will die. Today’s home network solutions are complex products that are difficult to demonstrate in a retail environment; it is not clear how home network products will best be sold to consumers.

**Content owners and authors** are already having a major impact on the evolution of home network solutions. Diversified media companies...
have a stake in home networking, where they can leverage existing content over a new platform. Opportunities to distribute movies, video, music, and software to every connected device in a home will be a benefit to content owners. With the implementation of appropriate protocols for connected devices, content authors may realize significant new control of the viewing or listening experience.

To date, media companies are adopting a wait-and-see attitude before investing heavily in new services based on home network solutions:

- Issues exist around the ability to create home-network-specific content and services.
- Media companies wish to avoid cannibalization of existing media sales.
- Significant issues exist around copy protection, and without the full support of content owners, home networks will not reach their full potential benefits to consumers.

**Equipment manufacturers** have a significant role to play in the evolution of home network solutions. Leading technology companies are already participating in consortia that are defining “open standards” to accelerate the home networking market. Integration of home networking technology into devices will increase the cost of goods of devices, and manufacturers want to be sure of consumer demand. Once a small set of standards emerges, the cost of integrating home networking technology will decline, and it will become a standard feature of most consumer electronics products.

**System and applications software vendors** play a key role in the development of operating systems, middleware such as home networking protocols, and applications such as media players, program guides, and IP-based communications. Consumer electronics devices provide relatively constrained runtime environments for software developers compared to PCs.

**The Home Networking Ecosystem**

A number of undesirable outcomes could result in the event of noncooperation between stakeholders in the home networking ecosystem:

- Potential disruption of current services due to the inability of home networks to properly support reliable data transport and transcoding, QoS, addressing, conditional access, copy protection, and other key cable system network functions.
- Proprietary architectures from each vendor will be encouraged as each broadband system operator (cable, digital subscriber line [DSL], fixed wireless, or satellite) makes individual volume commitments to favor vendors.
- Conflicts in access, such as consumers trying to gain access to the service provider’s advanced services, service providers trying to gain access to home network resources, and finally device vendors trying to gain access to the resources of both the service provider and the home network.
- Incompatible equipment built to proprietary architectures.
- Higher cost of service provisioning for the service provider due to higher support cost, inability to provision multiple solutions with different application programming interfaces (APIs), protocols, management methodologies, or unstable business models.
- Slower acceptance of new services due to consumer confusion and frustration.

**Cable Industry Perspectives**

The consumer acceptance of home network solutions will be driven by three factors: meaningful value propositions presented to consumers, increasing market penetration of advanced broadband services, primarily cable, and emergence of a few comprehensive home network technology standards that provide implementation guidance and economies of scale to hardware and software vendors.

Home network technology will continue to evolve and improve with or without the involvement of the cable industry; however, we believe that the cable industry will help home networking become a mass market reality.

Cable operators will be one of the primary providers of broadband services to residential customers, and as such they will have a keen interest in influencing the evolution of home network technology. Cable system operators have an opportunity to accelerate the development of home network technology by their proactive involvement in the development of standards and products. On the other hand, no involvement could result in home networks that do not seamlessly support cable-based advanced broadband services or are even unfriendly to cable-based service offerings.

Traditionally cable system operators have maintained a physical demarcation between their responsibility and the consumer’s responsibility for installation and maintenance. This demarcation is typically defined as the point where cable service enters the home. This is similar to the telephone system demarcation at the network interface outside the home. Cable system operators may limit their gain from home networking applications by ignoring this increasingly important technology. Extending their responsibility to include support of home network solutions in a partnership with consumers will present many new business opportunities.

Given the early stage of the home networking environment, the development of content and applications has been limited. This affords service providers with an opportunity to drive development. The benefits to the cable industry are:

- Home networks offer the opportunity to supplement core services.
- Home networks enhance planned rollouts of digital video, IP telephony, and other broadband applications.
- Home networks and connected devices, such as home servers, enable new classes of broadband services where some applications and services may be easier to deploy with resources in both the HFC network and the consumer’s home network.
- Home networks should reduce installation, support, and maintenance costs of deploying broadband services.
- Home networks can simplify the delivery of multiple-line telephony as well as support for multiple PCs and set-top boxes.
It is likely that the Internet Protocol (TCP/IP) will become the de facto standard for connecting diverse media throughout the home network.

Home networks can enable the delivery of streaming media to simultaneous users throughout the entire house. Home networks can support remote management and troubleshooting to improve the customer experience. Home networks can be integrated into the cable system end-to-end architecture for high-performance content distribution. Home networks can provide a new business opportunity for support and installation and management of the consumer’s home network. The cable industry consists of a small number of large operators and a larger number of small operators; each is an independent business and each has their own approach to the business. At the same time, there are a number of shared core values that have evolved in the modern cable industry:

- Innovation is best achieved by standards and open systems that promote competition among many vendors.
- Consumer choice of how, when, and from whom to purchase is critical to the emergence of a mass market.
- Industry engagement between all ecosystem participants is the only successful strategy.

The nascent home networking industry is facing two pressing questions: who pays for it, and when does it happen? Vendors, service providers, and retailers are currently exploring a variety of business models that deal with the question of who pays for it. Development activities and standards efforts are underway which, when combined with rational business models, will determine the answer to the question of when.

CURRENT HOME NETWORKING TECHNOLOGIES

The current home networking technologies [1] can be divided into wired and wireless offerings. Wired offerings currently support copper solutions employing either new or existing twisted pair wires, existing power line wiring, or coaxial cable as well as optical, fiber-based solutions. Wired systems include Ethernet, HomePNA [2], HomePlug, IEEE 1394, and low-data-rate control networks such as X-10, LonWorks, and CEBus.

Wireless systems eliminate the need for installation of copper or optical infrastructure in a home, but today’s wireless solutions are more expensive and offer much lower performance than wired solutions. Ultimately wireless solutions hold the advantage for consumer convenience. Wireless systems include HomeRF [3], IEEE 802.11, and Bluetooth.

PROTOCOLS

It is likely that the Internet Protocol (TCP/IP) will become the de facto standard for connecting diverse media throughout the home network. Additional protocols will be needed to deal with discovery, addressing, dynamic adding and removing of devices, as well as the details of controlling conditional access, copy protection, and streaming on a wide variety of consumer electronics devices.

HAVi

The Home Audio/Video Interoperability (HAVi) [4, 5] architecture specifies a set of APIs that allow consumer electronic manufacturers and software engineering companies to develop applications for IEEE 1394-based home networks. HAVi comprises software elements and protocols that facilitate interoperability between different brands of entertainment devices within the home. It is an open and platform-independent specification that developers can use to write home networking applications. HAVi focuses on the transfer of digital audio and video content among digital appliances, as well as the processing of this content by HAVi-enabled devices. The HAVi middleware system is independent of any particular operating system or CPU and can be implemented on a range of hardware platforms.

UPnP

The Universal Plug and Play (UPnP) Forum is an industry group of companies that promote UPnP networking protocols and device interoperability functions based on established networking standards.

The original objective of UPnP was to extend the zero-configuration simplicity for joining discrete devices and networks into a system that provides functionality similar to the Plug and Play (PnP) initiative for the PC platform. UPnP defines simple and flexible connectivity for networked consumer devices that work over a wide range of home networking solutions. When UPnP-enabled devices are connected to the network, they automatically configure themselves and discover other devices and services. In contrast to Jini, UPnP uses a data-oriented communications protocol rather than an object-oriented protocol; however, UPnP can easily be encapsulated with an object-oriented API.

JINI

Jini is a technology designed to make it easier for a variety of entertainment, communications, and computing devices to connect together in a network without planning, configuration, or human intervention.

The Jini runtime environment is based on a Java Virtual Machine (JVM) and provides a set of services to enable a dynamic network of devices. When a Jini-enabled device joins a network, it goes through discovery and join processes, during which it discovers the network and uploads its service interfaces for use by other devices in the network. This enables other devices to use its services without needing to have preinstalled drivers to describe how to interface with and use the device.

THE OPERATING SYSTEM AND MIDDLEWARE

Home networks will need a common set of protocols for communications and a standard API for software applications to enable remote management and provisioning of broadband services. One solution would be to have all home net-
working devices implement the same operating system, API, and network protocols; however, this is neither desirable nor practical.

Achieving a single API across these different operating systems and runtime environments is possible with a middleware solution. Middleware is a software component that provides an abstraction of the operating system and runtime environment. Middleware provides the standard software API that allows a single version of a software application to run on many different systems.

Sun’s Java platform and Microsoft’s .NET (C#) platform are middleware technologies that are designed to resolve the remote distribution and management of software applications and services. The Open Services Gateway Initiative (OSGI) provides a middleware solution for home gateway devices that connect the home network to the broadband service provider network.

DEVICES

The majority of home networking devices will not be PCs; rather, they will be embedded systems. These embedded devices are designed to perform a few specific functions extremely well. Examples include personal digital assistants, digital cameras, digital camcorders, wireless Web pads, wireless phones, security system components, and home appliances.

Due to the cost constraints of the consumer market, embedded devices have limited memory and processing power compared to PCs. This reality will pressure manufacturers to make home network communication protocols and content processing algorithms (e.g., advanced compression, encryption, and copy protection) as simple as possible.

AN OVERVIEW OF THE CABLEHOME PROJECT

CableLabs member companies (cable system operators) initiated the CableHome home networking project in the summer of 1999 to assess the strategic importance of home networking to the cable industry and to determine how home networks can benefit the cable industry, its subscribers, and content providers. A survey of home networking technologies conducted in late 1999 revealed that home networking technologies were not necessarily optimized for the delivery of advanced broadband services.

CableHome project staff worked with CableLabs member companies to develop a set of requirements for home networking equipment to facilitate the delivery of advanced services and to extend the advantages of cable-based broadband access to cable customers. The CableLabs document, Home Networking Requirements for Cable-Based Services, was completed in June 2000 and a call for participation was issued to the home networking vendor community. To date, more than 100 companies have joined the CableHome home networking project. During the second half of 2000, an intellectual property rights (IPR) pool was established, and vendors who became IPR pool participants began writing specifications and technical reports.


THE CABLEHOME ARCHITECTURE

AN ARCHITECTURAL OVERVIEW

The goal of the CableHome architecture is to establish a home network environment within which the delivery of quality cable-based services can be ensured. The CableHome architecture focuses on the management of home networks as well as QoS mechanisms. Designing home network architectures to meet these needs presents a number of interesting challenges:

• A very dynamic and rapidly evolving transport technology environment
• A proliferation of devices with a wide spectrum of capabilities
• Integration, support, and service delivery to non-CableHome-compliant devices
• Protection of the upstream network

In order to meet these diverse requirements the CableHome architecture introduces a loose physical model integrated with a logical model that includes network domains and functional elements.

THE PHYSICAL MODEL

A CableHome network is composed of devices and functionality within the home, as well as a variety of servers within the cable operator’s network. The CableHome architecture is designed to integrate with other CableLabs architectures as shown in Fig. 1.

The CableHome physical model consists of device classes (Fig. 2). There are three classes of CableHome devices, referred to as HA, HB, and HC, which are loosely distinguished by their placement in a CableHome home network. These device classes are informative only, and no requirements are placed on how they are to be physically implemented.

The HA device extends CableHome capabilities from the DOCSIS network into the home network. The HA device has a single DOCSIS RF-compliant interface and may have zero or more CableHome-compliant interfaces. The HB device extends CableHome capabilities to additional CableHome-compliant networks and has at least two CableHome-compliant interfaces. The HC device originates and terminates CableHome messaging and has one or more CableHome-compliant network interfaces. Finally, endpoints (EPs) represent noncompliant devices and applications that know nothing about CableHome messaging. Endpoints may source or sink data content. With respect to CableHome devices, an EP may be an internal application, an embedded device, an external device, or a device residing on a noncompliant network.
LOGICAL MODEL

The CableHome logical model is the heart of the architecture. It consists of two distinct types of functional elements referred to as gateways (GWs) and boundary points (BPs), as shown in Fig. 3. GWs and BPs are logically bounded functional entities that reside within devices. They include the ability to gather and communicate information as needed to manage and deliver services over CableHome networks. They also contain the functionality necessary to carry out CableHome-defined control of home network traffic. CableHome logical entities operate at the network protocol layer and above, thus remaining independent of any particular physical network technology.

Gateway logical elements propagate CableHome messaging into the home and onto multiple home networks. In addition, GWs may perform packet routing and filtering functions (e.g., to contain in-home traffic). Finally, GWs may perform functional tasks such as network address translation and firewall security. BP logical elements originate and terminate CableHome messaging. In addition, BPs interconnect noncompliant home networks, devices, and applications to a CableHome-compliant network. A BP can be thought of as an agent acting on behalf of one or more EPs, enabling them to consume cable services. BPs may optionally act as a proxy function or translation function for the EPs. The proxy function allows the BP to act on behalf of one or more EPs, while the translation function translates the CableHome-compliant protocols to non-CableHome-compliant protocols.

Figure 3 also illustrates the concept of CableHome domains, which are diagrammatically represented as shaded regions. These regions serve as visual tools to clearly identify compliant devices that are manageable by cable operators and able to take advantage of cable-based service offerings. The CableHome domain is composed of two subdomains: the QoS domain (Q-domain) and management domain (M-domain). The Q-domain consists of the set of CableHome QoS-compliant devices that are able to deliver quality-guaranteed cable-based services. Similarly, the M-domain consists of the set of CableHome provisioning and management compliant devices that can be provisioned and managed by the cable operator.
The Q-domain is defined as a subset of the M-domain, ensuring that cable operators can manage devices delivering QoS-based services to the degree needed to fulfill service quality guarantees. In addition, the M-domain is defined to extend beyond the Q-domain, allowing CableHome management of products that are not CableHome QoS-compliant.

Figure 4 illustrates several points. First, the BP and GW logical elements have been further refined to reflect the CableHome focus on QoS and network management. The BP and GW logical elements that are focused on QoS concerns are known as the QBP and QGW. They provide the functionality needed to support CableHome QoS. Similarly, the BP and GW logical elements that are focused on network management are known as the MBP and MGW, and they provide the functionality needed to support CableHome network management. In addition, the figure illustrates how logical elements and devices interrelate to support a variety of home network configurations. The CableHome solution space was designed for flexibility, and developers of home networking equipment may implement one or more of the logical elements in a device to suit the needs of the desired product feature set.

PROBLEMATIC APPLICATIONS

A number of popular in-home capabilities exist today that will likely prove problematic during the delivery of advanced cable services to the home. These capabilities include applications such as network address translation (NAT) and firewall security. Although the CableHome architecture does not preclude the existence of such applications, full access to advanced cable-based services cannot be guaranteed when these applications are present. The development of cable-friendly extensions to these standardized capabilities will fully enable advanced cable services. These extensions are currently under consideration within the CableHome project.

The concept of open access is a subject of considerable discussion among cable operators, Internet service providers (ISPs), and regulators. Open access requires that the consumer be able to select an ISP independent of their cable operators’ ISP offering.

SECURITY CONSIDERATIONS

CableHome security requirements are currently under development within the CableHome project. A number of home network security threats are considered:

- Leakage of information transmitted on the home network outside of the home
- Subscriber or third party theft of service
- Service denial attacks on the home network and cable network
- Firewall security and VPN support
- Security of management traffic, including service, data, and control traffic
CABLEHOME WORKING GROUPS

The CableHome project has to date created four working groups to address technical issues: Architecture, Quality of Service, Management and Provisioning, and Network Address Management.

The focus of the Architecture team is to create a flexible and unifying architectural framework to provide a reference for the CableHome working groups.

The Quality of Service team’s focus is to extend the existing CableLabs DOCSIS and PacketCable QoS mechanisms to devices in the home. There are two primary challenges:

- Mapping application service requirements to the QoS mechanisms of the various home networking technologies, which are still evolving
- Defining and measuring device/technology performance characteristics and determining how they should integrate into the CableHome QoS specification

The focus of the Management and Provisioning team is to create a home environment that enables simple provisioning processes as well as robust remote management capabilities. This is key to ensuring a positive consumer experience. The challenges include:

- Identifying the set of manageable parameters for home networking equipment that will enable the cable operators' requirements for seamless service delivery, delivery confirmation, problem diagnosis, performance monitoring, and security to be satisfied
- Identifying a capable, open, scalable management protocol that will integrate with popular provisioning and management platforms such as UPIp and JINI
- Operation of the home network during periods of lost cable network connectivity

The Network Address Management team is focused on the addressing and traffic handling needs of home networks. A number of interesting problems are being examined:

- Assignment and management of IP addresses through GW devices with NAT, firewalls, and other functions
- Traffic handling and IP address management for multiple ISP support to meet the goals of open access compliance
- Providing services across multiple home network solutions
- Providing access to noncompliant and legacy devices

DEPLOYMENT OF HOME NETWORK SOLUTIONS

The ability of cable system operators to provision advanced broadband services and a home network effectively is limited on several fronts. These limitations will tend to slow the widespread adoption of home network solutions:
• The business decision and investment each cable system operator must make on how to approach the home networking opportunity.
• Access to broadband services, particularly high-speed Internet access, is limited in the short term.
• Installation needs to be very simple. Consumers will look to service providers to play the role of system integrators and single-source suppliers for “making it work.”
• Customer care, order entry, policy management, security, provisioning, and billing systems must be enhanced to support service delivery and provisioning of home networks.
• Customer service representatives and installers will need to be trained on how to use the capabilities of CableHome-compliant equipment to better serve their customers.
• CableHome compliance testing procedures must be developed and will need to be conducted on home networking equipment to guarantee device interoperability.

CABLEHOME’S RELATIONSHIP TO OTHER CABLELABS INITIATIVES
CableHome complements existing CableLabs DOCSIS, PacketCable, and OpenCable projects. CableHome will extend DOCSIS provisioning, management, QoS, and security capabilities beyond the cable modem to compliant equipment attached to the home network. CableHome will employ PacketCable-compatible back office policy servers and other services to extend dynamic QoS (DQoS) to devices in subscribers’ homes. Eventually CableHome will support the distribution of video from OpenCable platforms over multiple network segments in subscribers’ homes. The integration of DOCSIS, PacketCable, OpenCable, and CableHome capabilities will provide a platform for the seamless extension of advanced cable-based services.

SUMMARY
A significant task lies ahead for cable operators, but the operators, their subscribers, and CableHome-compliant home networking equipment vendors alike stand to gain from deployment of equipment and services extending cable’s broadband capabilities into consumers’ homes. Home networks will enable many new advanced services.

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