CableHome™ Architecture Framework Technical Report

CH-TR-ARCH-I01-010716

Interim

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Document Status Sheet

Document Control Number:	CH-TR-ARCH-I01-010716			
Document Title:	CableHome™ Architecture Framework Technical Report			
Revision History:	W07-010205: 1st release for MSO review D01-010320: Revisions based on W07 MSO feedback D02-010327: Converted to ITU format I01-010716: Add text addressing vendor comments			
Date:	July 16, 2001			
Status:	~~Work in Progress~~	~~Draft~~	Interim	~~Released~~
Distribution Restrictions:	~~Author Only~~	~~CL/Member~~	~~CL/ Member/ Vendor~~	Public

Key to Document Status Codes:

Work in Progress	An incomplete document, designed to guide discussion and generate feedback, that may include several alternative requirements for consideration.
Draft	A document in specification format considered largely complete, but lacking review by Members and vendors. Drafts are susceptible to substantial change during the review process.
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Released	A stable document, reviewed, tested and validated, suitable to enable cross-vendor interoperability.

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Abstract

This technical report describes the architectural framework for the CableHome™ project including all major system components and network interfaces necessary for delivery of CableHome functionality. The intended audience for this document includes developers of equipment intended to conform to CableHome specifications, and network architects who need to understand the overall CableHome architectural framework.

1 INTRODUCTION

Cable-based services are defined as application services that are delivered via an hybrid fiber/coax (HFC)/cable infrastructure. Cable operators currently offer a wide variety of cable-based services; additional service opportunities are enabled by the advent of home networks. Examples include high-speed data, streaming audio and video, packetized telephony, network management, home security, environmental monitoring, medical monitoring, gaming, interactive television, and video conferencing.

1.1 CableHome Overview

CableHome™ is a project conducted by Cable Television Laboratories, Inc. (CableLabs®) and its member companies. The CableHome project will define interface specifications that facilitate the delivery of cable-based services into the home. The initial project efforts focus on enabling core DOCSIS™ and PacketCable™ functionality on home networks, with an additional focus on home network management capabilities.

The objective of the CableHome architectural effort is to establish a flexible and forward-looking home networking framework that provides a unifying theme for developing a coherent set of CableHome interface specifications, while at the same time lending itself to future enhancement. The CableHome infrastructure is designed to be complementary to those of DOCSIS and PacketCable, but distinct and operational in the absence of PacketCable deployment. This technical report identifies a set of fundamental architectural elements that can be flexibly combined in a large number of configurations, allowing for the consideration of a wide variety of home networking solutions.

1.2 Motivations

The cable television physical plant provides the most capable means of delivering broadband Internet-based services to a majority of households. It is in the best interest of consumers and cable operators to extend this fundamental bandwidth advantage into the home. This will benefit the consumer by improving their home network and cable service experience, and this will benefit cable operators by enabling new technologies that will differentiate their services and provide additional revenue opportunities. In addition, producers of home networking equipment will enjoy increased demand for their products.

In order to extend the advantages of cable delivery to devices connected to the home network, it is necessary for home networks to satisfy a number of requirements [1]. As such, CableLabs has undertaken the CableHome project to address these requirements.

1.3 Challenges

Designing an architecture to enable cable-based management and service delivery over home networks presents a number of challenges, including:

- Home networking presents a very dynamic technology environment; it is difficult to predict how transport technologies will evolve over time.
- There will be a proliferation of devices with a wide spectrum of capabilities within the home. It is desirable to create an architecture that is flexible enough to support the many new service possibilities associated with these devices.
- Existing and future non-CableHome equipment will be present within the home. It is desirable to enable service delivery to such devices.
- The home network will likely be populated with lightweight inexpensive devices. It is desirable to enable service delivery to such devices.
- As new protocols, services, and management philosophies emerge, it is desirable to readily accommodate these capabilities without requiring the wholesale replacement of the existing equipment.
- Encourage peer-to-peer communications on coaxial networks in the home at frequencies greater than 1GHz (currently out of scope).

1.4 Project Scope

The CableHome project focuses on capabilities of networks within the home, and the cable infrastructure needed to support these capabilities. Consideration of specific services being delivered over home networks is outside the scope of this project.

The CableHome team plans to release a CableHome document suite. This package will include a number of technical reports and specifications relevant to building products that deliver cable-based services over home networks in a standardized fashion. CableHome efforts will enable PacketCable telephony, high-speed IP data transport, as well as a number of other home network capabilities. The following functionality concerns are core capabilities delivered over DOCSIS and PacketCable networks, and will similarly be addressed by CableHome.

- Provisioning
- Network Management
- Quality of Service (QoS)
- Network Address Management
- Security

We plan to specify a suite of home network capabilities that may be applied to a wide range of services that exist today, as well as to services that will exist in the future.

A set of requirements [1] for CableHome networks has been identified for the provisioning, network management and QoS arenas. These requirements are reiterated in Table 1 through Table 3. Table entries in gray are beyond the near term scope of CableHome, and will be addressed during follow-on efforts.

1.4.1 CableHome Provisioning Requirements

Configuring home networks and initiating service are fundamental tasks that must be accomplished by the CableHome infrastructure. The requirements listed in Table 1 provide the basic functionality needed to enable these tasks and to provide reliable network operation once service is established.

Table 1. CableHome Provisioning Requirements

Number	Requirement
S.1	**Ease of Installation.** Home network devices must be easy to install and configure for operation, much like a home appliance.
S.2	**Self-Provisioning.** Devices connected to the home network must support self- and remote provisioning of broadband services, including network configuration and device-specific service-enabling tasks.
S.3	**Network Management.** All network management features and functions relevant to services provisioned to devices on the home network must be preserved across home network interfaces. Examples include IP address assignment, security, remote provisioning, and diagnostics.
S.4	**Protocol Translation.** Home network bridging devices must properly perform required protocol translations.
S.5	**Device Connection.** Home networks must support connection and disconnection of terminal devices without interrupting service or degrading the performance of other devices connected to the network.
S.6	**Firewall Security.** Home networks require protection from malicious attacks or access across external networks, such as the protection offered by firewall. The protection service must be easy for the subscriber to manage and must function over multiple active gateway devices.
S.7	**Local Storage.** The home network must accommodate a means for storing and/or caching data files and streamed media for local access and playback by the subscriber.
S.8	**Service Discovery** (Optional). Devices connected to the home network must be able to automatically announce capabilities and discover services offered by other devices connected to the network.

1.4.2 CableHome Network Management Requirements

As networks are installed in consumers' homes, the need for network management support will soon follow. Reducing the complexity of managing home networks will be a key issue for both consumers and service providers, and will increase the rate at which home networks are deployed and the overall success of the home networking market.

End-to-end network systems management requirements identified in Table 2 relate to how cable operators monitor, configure and remotely manage home networks.

Table 2. CableHome Network Management Requirements

Number	Requirement
N.1	**Interface for Management and Diagnosis.** Interfaces should support the management and diagnosis features and functions required to support cable-based services provisioned across the home network.
N.2	**Diagnostic Tools.** Diagnostic tools having local and remote monitoring capabilities must be provided that can monitor home network operation and help the consumer and cable operator identify problem areas.
N.3	**IP Address Management.** The home network must accommodate cable network-based IP address management as first priority and provide an in-home IP address assignment mechanism to keep the home network functioning properly if the network-based service becomes unavailable. IP address assignment and configuration must occur automatically as devices are connected to the network and IP address management must be scalable to support the expected increase in the number IP devices in homes.
N.4	**Gateway Synchronization.** Cable network access device (gateway) – based applications and management services such as firewalls, DHCP servers, address translators, and IP security applications like VPN clients must be capable of synchronizing with each other to ensure reliable home network operation in multiple-gateway environments. Gateways must also synchronize traffic routing to devices on the home network.
N.5	**Management Message Priority.** Network management messages associated with the health of the cable or home network (fault management) must have the highest forwarding priority.
N.6	**Stand-alone Operation.** Loss of connection between broadband service provider(s) and the home network must not disable or degrade the operation of internal home networking functions.
N.7	**Recovery.** The home network must recover gracefully from a power outage and devices connected to the home network must return to the operational state they were in prior to the outage.
N.8	**Primary IP Line Telephony** (Optional). Primary IP telephone service must be maintained when electric power to the subscriber's residence is interrupted.

1.4.3 CableHome Quality-of-Service (QoS) Support Requirements

As the number of home-networking devices and services increase, so will data traffic congestion. This will cause increases in variable packet and data propagation delays that may exceed end-to-end service latency requirements. These effects will have a negative impact on real-time services and degrade overall performance of the home network.

Therefore, home-networking technologies must incorporate the QoS features described in Table 3 to reduce the impact on real-time services.

Table 3. Quality-of-Service Support Requirements

Number	Requirement
Q.1	**QoS Mechanism.** All home networks must have a QoS mechanism capable of extending DOCSIS QoS to the device of consumption
Q.2	**Smart Forwarding.** To reduce traffic on low bandwidth networks, bridging points between networks (physical or logical) must forward only data destined for known addresses on the network.
Q.3	**Service Priority.** Services provided by the cable operator must have higher priority on the home network than traffic generated by devices connected to the home network unless overridden by the subscriber.
Q.4	**Service Integrity Through Gateway.** If cable network access (gateway) applications such as firewalls and address translators are active in the home network they must not corrupt or degrade the forwarding or reception of broadband services.
Q.5	**Standard QoS Signaling.** The home network must use a standard QoS signaling protocol for activating technology-specific (like DOCSIS) QoS mechanisms as data services traverse end-to-end over various network technologies to the device of consumption in the home.
Q.6	**Data Throughput.** Network interface devices must transfer data at a rate that meets or exceeds the aggregate load of connecting networks. The packet loss rate should average 10^{-8} under normal conditions.

1.4.4 Network Address Management Requirements

Detailed CableHome network address management requirements are currently under consideration and have not been fully developed as of the release of this document. As such, CableHome network addressing is discussed in a general manner throughout the remainder of this document. When the CableHome network addressing requirements have been completely identified, they will be published and the implications for the CableHome architecture will be fully described.

1.4.5 CableHome Security Requirements

Detailed CableHome security requirements are currently under consideration and have not been fully developed as of the release of this document. As such, home network security is discussed in a general manner throughout the remainder of this document. When the CableHome security requirements have been completely identified, they will be published and the implications for the CableHome architecture will be fully described.

1.5 Putting CableHome Into Perspective

The CableHome project is complementary to other CableLabs project efforts. Figure 1 depicts where the CableHome efforts fit within the framework of other CableLabs projects.

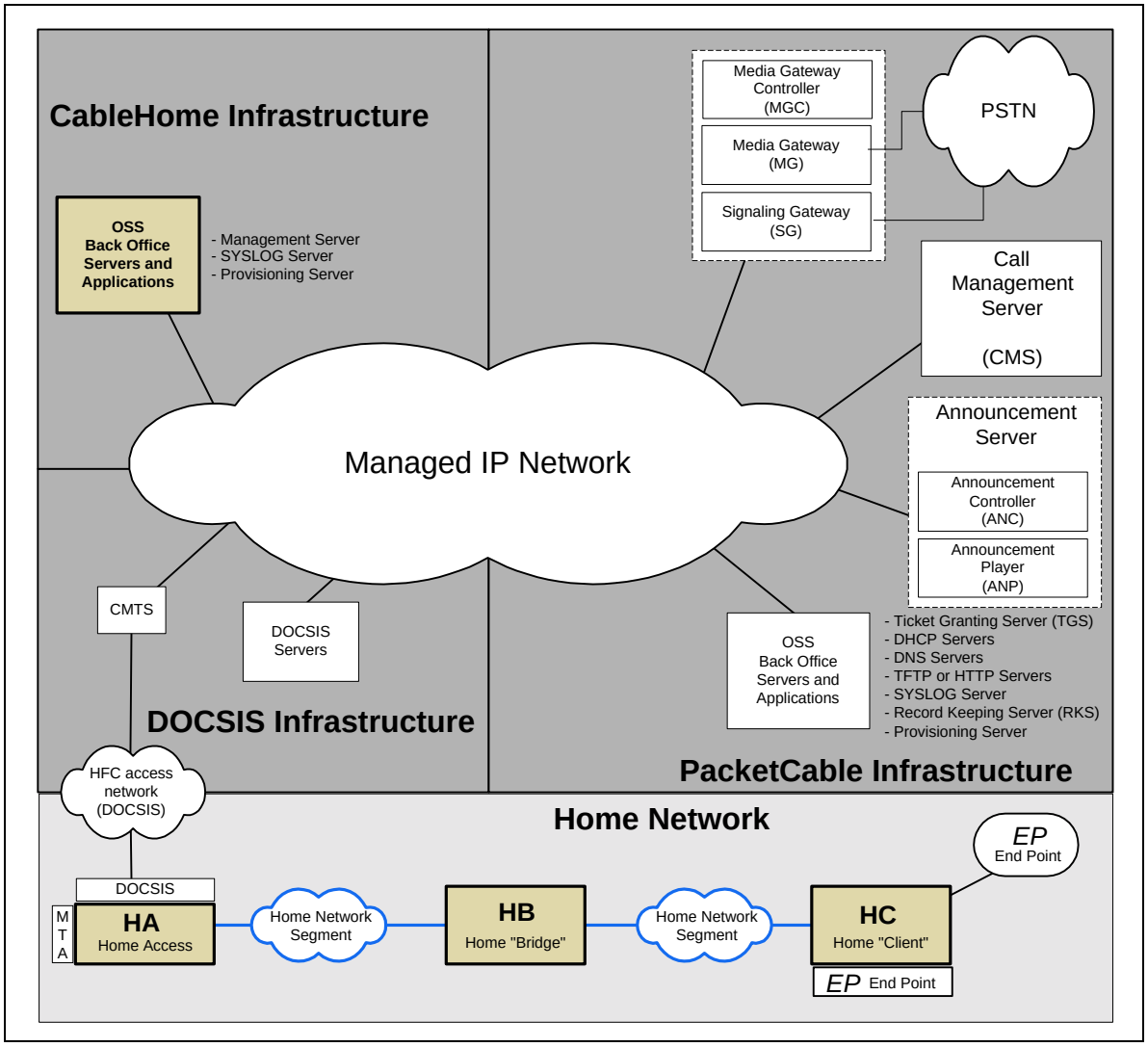


Figure 1. A CableHome Perspective

CableHome infrastructure equipment and processes are designed to be modular and independent of DOCSIS and PacketCable. However, it is assumed that access to cable-based high-speed IP data transport will be provided by a DOCSIS network.

The CableHome project strives to reuse PacketCable mechanisms to the extent possible, but the operation of a CableHome network will not require the deployment of the PacketCable infrastructure. The unique provisioning and management needs introduced by CableHome devices will likely necessitate the introduction of a suite of dedicated CableHome OSS servers within the CableHome infrastructure, as depicted in Figure 1.

1.5.1 Interfacing to DOCSIS 1.1

The CableHome network makes use of, and is built upon, the DOCSIS 1.1 network. CableHome relies on DOCSIS 1.1 for data transport capabilities.

1.5.2 Interfacing to PacketCable

The PacketCable project is aimed at establishing functionality needed to support the delivery of general packet-based services. PacketCable is an IP-based solution and, as a result, is largely independent of DOCSIS and other physical transport media. The first phase of this project, PacketCable 1.0, targets voice services. Entertainment is a core business for cable operators and the PacketCable 2.0 project is considering the extension of the PacketCable 1.0 embedded-IP telephony service to include several broad categories such as: streaming media, interactive gaming, PBX extensions, and unified messaging.

The current PacketCable 1.0 specification defines an Embedded MTA (Multimedia Terminal Adapter), located in the DOCSIS CM, which provides voice processing functionality and uses the DOCSIS infrastructure as its transport mechanism. The CableHome infrastructure is able to provide the transport layer for future PacketCable Stand Alone MTAs, similar to the manner in which DOCSIS currently provides the transport layer for Embedded MTAs.

PacketCable 1.0 defines only Embedded MTAs that connect directly to a DOCSIS cable modem (CM). However, the existing specifications include most of the information for implementation of a standalone MTA function. The CableHome specification attempts to facilitate a simple implementation of a stand-alone MTA based on the currently available information in the PacketCable specification. Table 4 identifies some of the issues introduced when PacketCable telephony functionality is enabled on CableHome networks.

In addition to the distribution of telephony applications, the IP-based distribution of high bit-rate digital services over CableHome networks is briefly considered here. Cable operators can present video to a home in several ways, including digital cable, real-time streaming video over DOCSIS, and locally cached digital video. Time-shifting and space-shifting of these digital sources are natural applications on the CableHome infrastructure. Analog cable sources also can participate with the inclusion of video transcoding in the gateway between the analog HFC and CableHome.

Digital video streams typically occupy bandwidths on the order of 1 to 5 Mbps and generally have relatively tight jitter characteristics. Thus, digital video streaming QoS characteristics will impose different requirements on network infrastructure resources than, for example, telephony services. The CableHome QoS architecture and mechanisms support a wide variety of high bit-rate digital services, including video.

Table 4. PacketCable Reuse Issues

PacketCable Functionality	Issues when applied to devices within the home
CODEC: RTP and RTCP media transport	• No changes to PacketCable defined protocols anticipated.
NCS: Call signaling between MTA and CMS	• No changes to PacketCable defined protocols anticipated. • Presence of 3rd party network address translation functionality problematic.
Security	• Minor changes to PacketCable defined protocols discovered to date. • Presence of 3rd party network address translation functionality problematic. • Further review required.

DQoS:
Dynamic quality of service.
	• RSVP+ defined in PacketCable but not official in version 1.0.
	• Minor corrections to PacketCable spec required
	  • Echo for RSVP-Tear from CMTS
	  • Optional RSVP objects for QoS management

Provisioning	• Problem with DHCP server identification for the MTA • Presence of 3rd party network address translation functionality problematic.
Event Messages: CMS to CMTS	• No changes to PacketCable defined protocols anticipated.

1.6 Purpose of Document

This technical report describes an architectural framework for the CableHome home-networking project. CableLabs has issued this technical report to facilitate an understanding of the elements contained within a CableHome network and to communicate, at a high level, the capabilities of these elements.

1.7 Organization of Document

This document is organized into the following sections:

Section 1: Introduction

Section 2: References

Section 3: Terms and Definitions

Section 4: Abbreviations and Acronyms

Section 5: CableHome Architecture Framework

Section 6: CableHome Premise Elements

Section 7: Provisioning

Section 8: Network Management

Section 9: Quality-of-Service

Section 10: Network Address Management

Section 11: Security

Section 12: Open Issues and Future Considerations

1.8 Change history

2 REFERENCES

2.1 Normative

2.2 Informative

[1] "Home Networking Requirements for Cable-Based Services" Cable Television Laboratories, Inc. [Date unknown].

[2] DHCP: "Dynamic Host Configuration Protocol" IETF RFC 2131

[3] NAT: "The IP Network Address Translator (NAT)" IETF RFC 1631

[4] Firewall: "Behavior of and Requirements for Internet Firewalls" IETF RFC 2979

[5] ITU-T M.3000 (02/00) - Overview of TMN Recommendations

[6] Network Management, Principles and Practice, M. Subramanian, Addison-Wesley; ISBN 0-201-35742-9

[7] CableHome Quality-of-Service Specification, CH-SP-QOS-I01-010619

3 TERMS AND DEFINITIONS

Boundary point (BP)	A logical element that terminates a CableHome compliant network segment.
CableHome	The CableLabs Home Networking Initiative.
CableHome Device Class	A collection of one or more logical elements. Classes of devices are distinguished by their relative position and purpose in the home network.
CableHome Domain	The extent of CableHome compliant direct influence.
CableHome Network	A network composed of one or more CableHome segments
CableHome Product	An instantiation of a CableHome device class by a vendor.
CableHome Segments	Interfaces sharing the same L1/L2 or internal link.
Function	Capabilities that compromise logical elements.
Gateway (GW)	A logical element that connects CableHome compliant network segments. ***Warning**: the CableHome usage of the term gateway is not the same as the IETF definition - see section 5.1.2 for the complete definition of gateway in the context of CableHome*
Logical Element	A collection of one or more functions.
HA Device	A grouping of logical elements used to achieve HFC access for CableHome network(s)
HB Device	A grouping of logical elements used to achieve interconnection of CableHome networks
HC Device	A grouping of logical elements used to source and accept CableHome compliant messages, and possibly to connect compliant networks with non-compliant networks or devices.
MTA	Multimedia Terminal Adaptor. Defined by PacketCable spec. an element that provides IP packetized multimedia services.
PacketCable	CableLabs specification of packetized service delivery system.

4 ABBREVIATIONS AND ACRONYMS

BP	Boundary Point
BPI	Baseline Privacy Interface
C-DHCP	CableHome DHCP
C-HTTP	CableHome HTTP
C-NAT	CableHome Network Address Translation
C-TFTP	CableHome TFTP
CIM	
CM	Cable Modem
CMTS	Cable Modem Termination System
CQoS	CableHome Quality of Service
DHCP	Dynamic Host Configuration Protocol
DOCSIS	Data-Over-Cable Service Interface Specification
DQoS	Dynamic Quality of Service (See PacketCable)
EP	Endpoint
GW	Gateway
HA	Home “Access”
HB	Home “Bridge”
HC	Home “Consumption”
HFC	Hybrid Fiber Coax
HPNA (HomePNA)	Home Phoneline Networking Association
HPPA	Home Plug Powerline Alliance
IEEE	Institute of Electrical and Electronic Engineers
IP	Internet Protocol
IPSEC	IP Security Protocols
KDC	Key Distribution System
M-Domain	Management Domain
MSO	Multimedia Service Organization
MTA	Multimedia Terminal Adapter (See PacketCable)
NAT	Network Address Translation
NCS	Network-Based Call Signaling (See PacketCable)
OSS	Operations Support System
POTS	Plain Old Telephone Service
PROV	Provisioning
Q-Domain	Quality of Service Domain
QoS	Quality of Service
RSVP	Resource ReSerVation Protocol
RTP	Real-time Transport Protocol
RTSP	Real Time Streaming Protocol

SNMP	Simple Network Management Protocol
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
UPNP	Universal Plug and Play
USB	Universal Serial Bus
VPN	Virtual Private Network

5 CABLEHOME ARCHITECTURE FRAMEWORK

In order to extend the advantages of cable-based services to all devices connected to a home network, the CableHome architecture provides a framework for home networks. The goal of this architectural framework is to provide cable-based services to devices within the home, complimenting the DOCSIS and PacketCable infrastructure and enabling delivery of their services, as well as new services. Wherever possible, the architecture framework incorporates existing standards.

In additional to cable-based services, CableHome-compliant networks are capable of carrying peer-to-peer local services. These local services include, but are not limited to, entertainment, gaming, personal computer file sharing and network printing. Local services provided on the home network are outside the scope of this effort. However, the CableHome architecture framework will allow existing local services to function without requiring modifications to existing hardware or software.

It is a goal of the CableHome project to remain independent of physical and data link protocols; the CableHome architectural framework described in this document does so. It is possible, as the project progresses, that future specifications may need to introduce physical and data link protocol dependencies.

The CableHome architecture is primarily focused on IP traffic in the home, however the usage of non-IP traffic is not precluded. All protocols used in CableHome are IP based, but other data traffic protocols may potentially be used. If a vendor's product facilitates the usage of other data traffic protocols, then that vendor is responsible for maintaining the integrity of the CableHome environment.

5.1 Key Concepts

The CableHome architectural framework introduces several concepts that form the foundation for the extension of cable services to devices connected to the home network. These concepts will help in understanding the CableHome architectural framework. As shown in Figure 2, this section introduces the concepts of domains, logical elements, and device classes.

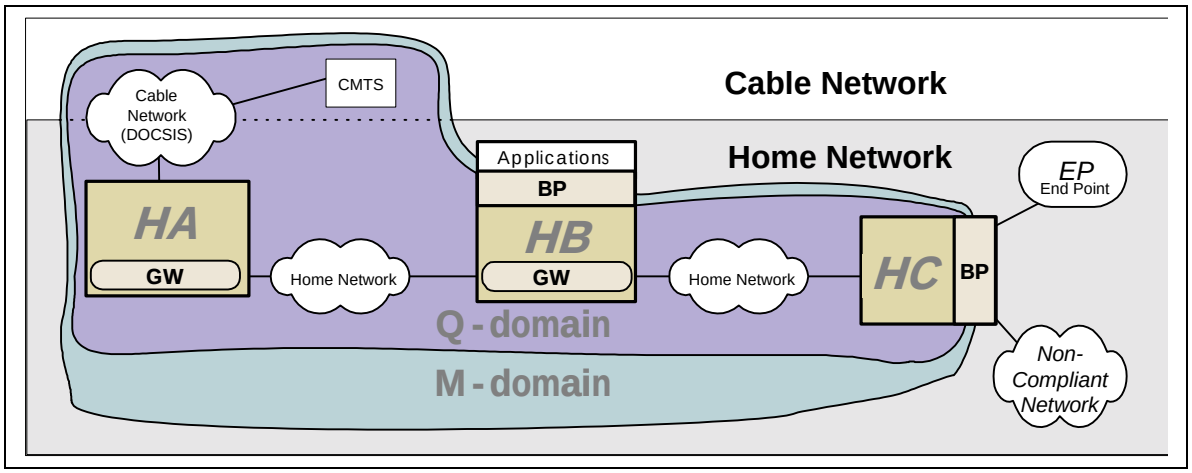


Figure 2. CableHome Key Concepts

5.1.1 Domains

The CableHome architectural framework introduces the concept of domains. A domain represents a set of home network elements that are compliant with a set of requirements. Within the CableHome architecture, the CableHome domain consists of a set of CableHome architectural elements that are compliant with the CableHome specifications. CableHome domains are diagrammatically represented as shaded regions. These regions serve as a visual tool to clearly identify those elements within the home network that are CableHome compliant. Elements that reside within the CableHome domain (i.e., compliant elements) are directly manageable by cable operators and can take advantage of cable-based service offerings.

Shown in Figure 2, the CableHome domain is composed of two sub-domains referred to as the Q-domain (QoS domain) and the M-domain (Management-domain). The Q-domain consists of the set of elements that are compliant with the CableHome QoS (CQoS) specifications, and can therefore deliver quality guaranteed cable-based services. Similarly, the M-domain consists of the set of elements that are compliant with the CableHome provisioning and management specifications, and can therefore be provisioned and managed by the cable operator.

As shown in Figure 2, the Q-domain is a subset of the M-domain; all network elements providing CQoS are fully CableHome manageable. This ensures that cable operators can manage products delivering CQoS-based services to the degree needed to fulfill service quality guarantees. In addition, the M-domain extends beyond the Q-domain, allowing CableHome management of products that are not CQoS compliant. This enables CableHome management for legacy products that are not QoS capable, as well as for products delivering low-bandwidth applications for which QoS may not be appropriate.

5.1.2 Logical Elements

Shown in Figure 2, the CableHome architectural framework introduces the concept of logical elements. There are two distinct classes of logical elements defined by the CableHome architecture framework; these are referred to as gateways (GW) and boundary points (BP).

> The term *gateway* is used in networking to describe an entity that through a combination of software and hardware links two networks segments. In the CableHome definition it remains true to this general definition. Be warned though that industry has unfortunately misused the term "gateway" to label among other things a basic router, and also is broadly used to define a *residential gateway* CPE product that provides Internet services to a home. To further the confusion, the CableHome HA class of device will likely be labeled by the industry to the consumer as a *(residential) Gateway.*

GWs and BPs are logically bounded functional entities that can generate and respond to CableHome-compliant messages. 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 network traffic. CableHome logical entities operate at the network protocol layer and above, thus remaining independent of any particular physical network technology.

As shown in Figure 3, gateways and boundary points are used to extend the CableHome domain or terminate the CableHome domain. Non-compliant devices, known as endpoints (EP), are isolated from the CableHome-compliant network by the boundary point. This prevents the EP from adversely affecting the CableHome-compliant network.

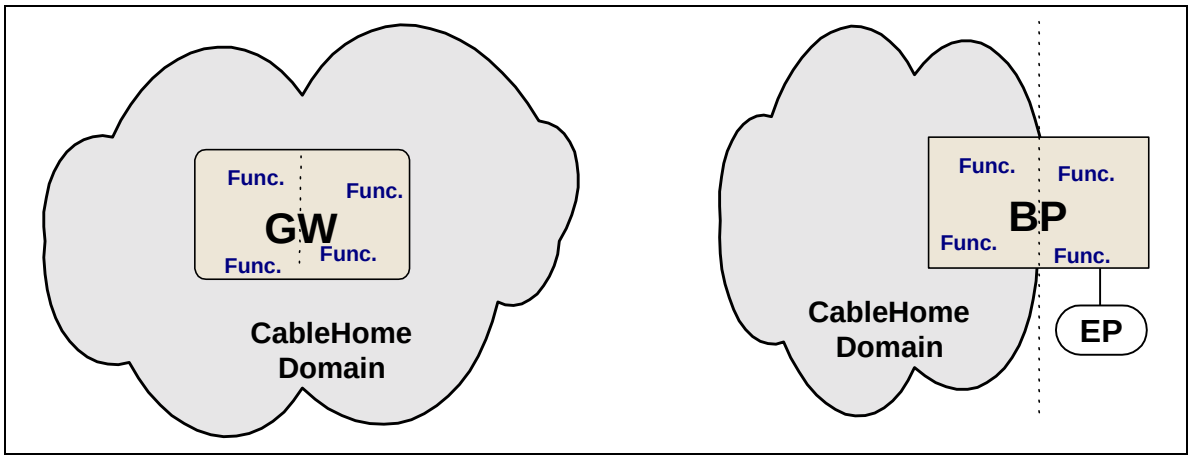


Figure 3. CableHome Logical Elements

5.1.2.1 Gateways (GW)

A gateway is a logical element that interconnects CableHome-compliant networks and extends the CableHome domain between networks. Within the CableHome class of gateways, two specific gateways are defined, one each for the Q and M domains. They are the QoS gateway (QGW) and the management gateway (MGW).

- QGW: a logical element that interconnects two or more CableHome QoS-compliant home networks
- MGW: a logical element that interconnects two or more CableHome provisioning- and management-compliant home networks.

5.1.2.2 Boundary Points (BP)

A boundary point is a logical element that interconnects non-compliant home networks, devices and applications to a compliant CableHome network. Within the CableHome class of boundary points, two specific boundary points are defined. They are the QoS boundary point (QBP), and the management boundary point (MBP).

- QBP: a logical element that connects non-compliant home networks, devices and applications to a CableHome QoS-compliant home network
- MBP: a logical element that connects non-compliant home networks, devices and applications to CableHome provisioning- and management-compliant home networks.

5.1.2.3 Logical Elements are the CableHome Network

The BP and GW logical elements form the foundation of the CableHome architecture and they fully define a CableHome network within the home. While CableHome domains (introduced earlier) and device classes (introduced in section 5.1.3) are structural aides only, CableHome logical elements completely supply the in-home functionality defined by the CableHome specifications. Each BP and GW logical

element is assigned a unique IP address, and it is the CableHome logical elements that are provisioned and managed.

A CableHome network can be conceptualized as a set of BPs and GWs that are discovered and managed, and that interact with each other and with the CableHome support infrastructure as needed to deliver cable-based services. The thrust of the CableHome effort is the specification of logical element interfaces.

5.1.2.4 A Closer Look at Boundary Points

The CableHome boundary point is a key concept that warrants further discussion. As mentioned before, a BP connects a CableHome network to non-compliant entities known as endpoints. Endpoints may source or sink data content, but they reside outside of the CableHome domain. As such, an EP knows nothing about CableHome messaging and no requirements can be placed on them. These non-compliant entities may range from simple analog audio and video presentation devices to complex non-compliant networked devices.

Boundary points may connect CableHome networks to the following example types of EPs:

- embedded EP
- external EP
- EPs residing on non-compliant networks
- EP-like applications

A CableHome boundary point can be thought of as an agent acting on behalf of one or more EPs, enabling them to consume services. In essence, a BP is a functional entity that indirectly enables CableHome management of, and service delivery to, EPs. A BP presents a common specified interface on behalf of connected EPs independent of the actual characteristics of the EP being represented. A single BP may represent any number of EPs, and may choose to acquire a unique IP address for each EP that it exposes.

In the case of a simple embedded analog EP, a BP may do nothing more then convert IP streams to the appropriate format and pass the data on to the EP for consumer presentation. In contrast, a BP may be connected to a functionality-rich EP, in which case the BP and EP might engage heavily in bi-directional communications.

BPs may optionally act as a proxy function or as a 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.

In all cases, the mechanisms by which a BP interacts with an EP are unspecified and are left to the discretion of the manufacturer.

5.1.3 Device Classes

The CableHome architectural framework introduces the concept of device classes to lend tangible context to the CableHome logical elements and combinations of these logical elements. The CableHome architectural framework concept of device classes places no restrictions on physical devices or combinations of logical elements within physical devices.

There are three classes of CableHome devices, referred to as HA (Home Access), HB (Home Bridge) and HC (Home Client). The HA, HB, and HC devices are loosely distinguished by their placement in a CableHome network. These device classes provide an informative way of depicting collections of logical elements but are not considered definitive or restrictive. HA, HB, and HC are not addressable entities within the CableHome architecture.

As shown in Figure 2, vendors implement one or more logical elements in a device to create a product. The specific set of logical elements in a given device is left to the discretion of the vendor.

The HA device class represents a collection of one ore more logical elements that extend the CableHome domain between the DOCSIS network and zero or more CableHome-compliant networks. The HA device has a single DOCSIS RF-compliant interface and may have zero or more CableHome-compliant interfaces.

The HB device class represents a collection of one ore more logical elements that extend the CableHome domain to additional CableHome-compliant networks and has at least two CableHome-compliant interfaces.

Finally, the HC device class represents a collection of one or more logical elements that terminates the CableHome domain and has one or more CableHome-compliant network interfaces.

As previously mentioned, CableHome device classes are loosely defined and non-restrictive. A CableHome device of a particular type may contain functionality typically associated with other device classes. For example, an HA device, in addition to containing a DOCSIS-compliant interface, may contain HB-like GW functionality that connects two compliant home networks. The following “equations” (where “+” means combine and “=” means yields) are intended to foster a further understanding of the informal nature of CableHome device classes:

- HA + HB = HA
- HA + HC = HA
- HA + HB + HC = HA
- HB + HB = HB
- HB + HC = HB
- HC + HC = HC

5.1.4 Relationship Between Logical Elements and Device Classes

The CableHome architectural framework, shown in Figure 4, illustrates how logical elements and devices interrelate in support of various home network configurations. Developers of home networking equipment and software implement one or more of the logical elements depending on the desired feature set of the product.

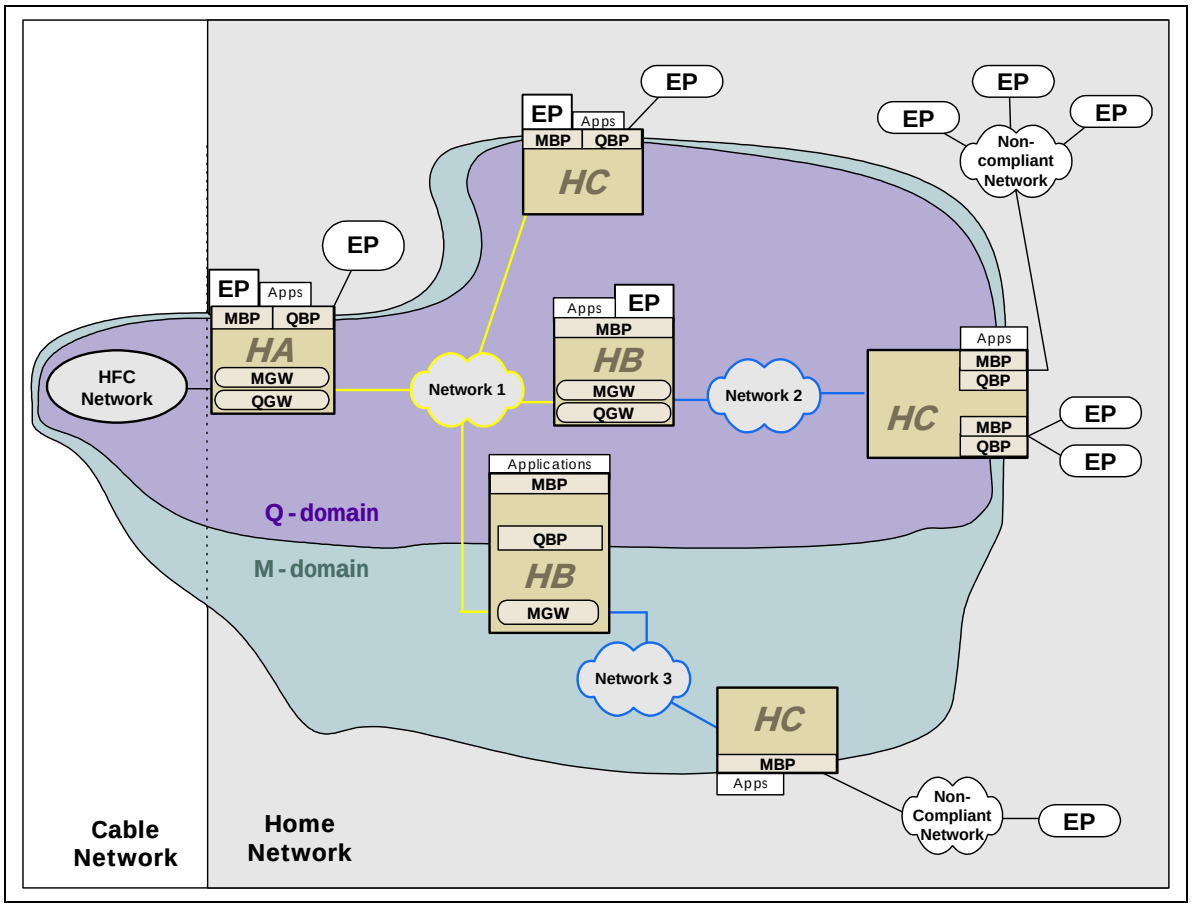


Figure 4. CableHome Reference Architecture Framework

5.2 Other Considerations

Although shown and briefly described in this document to provide context, there are several elements that are out of scope of the CableHome specification effort. Three examples of out-of-scope elements include: endpoints, applications, and non-compliant networks. Within the CableHome architectural framework, these elements are for illustrative purposes only. Endpoints (such as personal computers, printers, and telephone handsets) may provide the user interface and may be the ultimate sink or source of the content service. Any of the classes of HA, HB, or HC devices may interconnect or embed applications, endpoints or non-compliant home networks to the CableHome domain. As previously mentioned, venders implement the BP as a proxy function or a translation function. The proxy function allows the BP to act on behalf

of the EP, while the translation function translates the CableHome-compliant protocols to non-CableHome-compliant protocols.

The CableHome architecture framework does not preclude the existence of standard legacy applications, such as DHCP, NAT and Firewalls. Within the CableHome architectural framework, these standard applications may provide services to either compliant or non-compliant home networks. When present in compliant networks, full access to new cable-based services by CableHome devices is not guaranteed. In the future, CableHome may define cable friendly extensions to these standardized applications that fully enable the delivery of new cable-based services (e.g., cable NAT - CNAT, cable DHCP – CDHCP). This may involve definition of additional logical elements in future versions of this architecture.

5.3 Benefits of the CableHome Architecture

- Clearly identified CableHome domain that enables cable operators to manage networks to the degree necessary to deliver quality-guaranteed services.
- A logical element focus that places minimal restrictions on device capability configurations.
- The boundary point logical element provides the ability to interface with non-compliant technologies. This enables service delivery to existing and future proprietary technologies, to non-IP-based network technologies, to thin client devices, etc.
- Interoperable products within the CableHome domains.
- Transport technology independence leaves a broad set of choices open for both cable operators and for consumers
- Transport technology independence allows cable operators to leverage the existing, and rapidly progressing home networking technology base.
- Flexible implementation space both within and beyond the CableHome domains will foster vendor innovation.
- Flexible architecture allows the addition of more CableHome devices after the initial install.
- The flexibility and expandability afforded by the CableHome architecture is desirable to consumers, and leaves future revenue opportunities open for cable operators.
- The ability to use various types of home networking technologies allows for a large range of installation costs.
- The ability to use various types of home networking technologies allows for a large range of monthly subscription prices.

5.4 CableHome Specifications

The CableHome architecture provides a framework for networks to be constructed. Specifications providing requirement details for developing CableHome-compliant devices will be developed which cover provisioning, network management, quality-of-service, network address management, and security concerns.

6 CABLEHOME PREMISE ELEMENTS

This section describes premise elements of a general CableHome network designed to meet home networking requirements for cable-based services [1]. Element descriptions are not intended to define or imply product implementation requirements, but instead are indended to describe the functional role of each element within the CableHome architecture.

Figure 5 depicts the premise elements of a simple CableHome network that extends the fundamental advantages of the DOCSIS cable access technology within the home. CableHome does not specify physical layer protocols and does not specify physical home networking devices. However, for illustrative purposes, products conforming to CableHome specifications can be considered to be in one of three classes of devices based on specific combinations of logical elements and topological location. These device classes are referred to as HA, HB and HC. Vendors combine BP or GW logical elements, physical interfaces, and vendor added functionality to create CableHome products. The specific combination of logical elements and physical interfaces in a given product is left to the discretion of the vendor.

The general characteristics of device class HA are as follows:

- One DOCSIS physical network interface
- Zero or more CableHome compliant network interfaces
- Zero or more CableHome non-compliant interfaces
- A minimum of one GW logical element or one BP logical element
- Zero or more GW logical elements
- Zero or more BP logical elements

The general characteristics of device class HB are as follows:

- Zero DOCSIS physical network interfaces
- Two or more CableHome compliant network interfaces
- One or more GW logical elements
- Zero or more CableHome non-compliant interfaces
- Zero or more BP logical elements

The general characteristics of device class HC are as follows:

- Zero DOCSIS physical network interfaces
- One or more CableHome compliant network interfaces
- One or more BP logical elements
- Zero GW logical elements

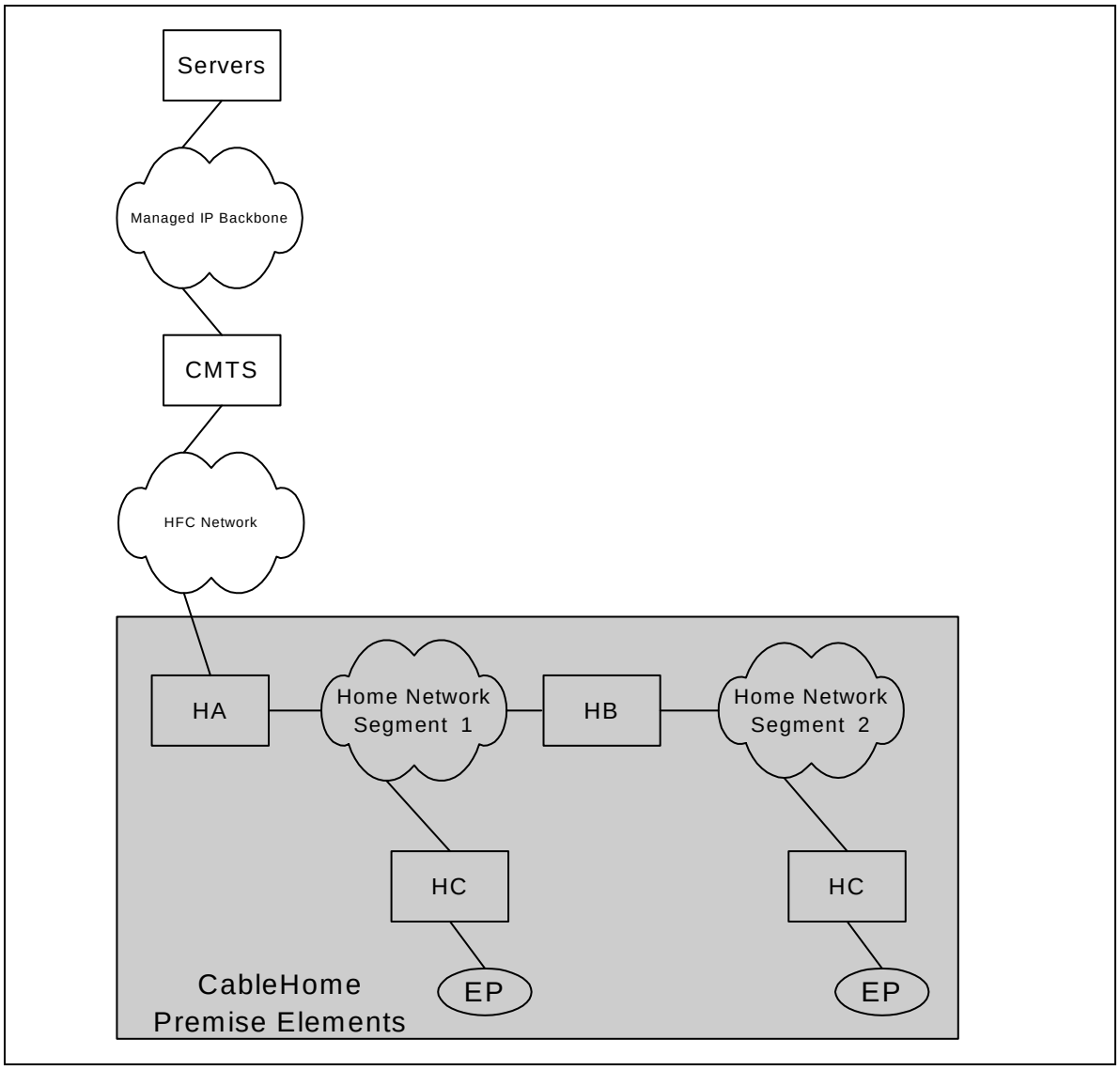


Figure 5. Simple CableHome Reference Architecture

6.1 Home Network

The CableHome network is a short-range communications system designed for the residential environment. The CableHome architecture is independent of the home network physical media, and this media may include, but is not limited to:

- Coaxial cable
- CAT 5 and CAT 6
- Telephone wire
- Power mains
- Optical fiber

- RF wireless
- IR wireless

The CableHome architecture also is independent of the home network physical layer and data link layer protocols. The CableHome architecture allows the interconnection of multiple home networks having different physical layer and data link protocols. The home network physical layer protocol and data link protocol may include, but are not limited to:

- Bluetooth™
- Ethernet or IEEE 802.3
- HomePlug™ (Home Powerline Alliance)
- HomePNA™ (Home Phoneline Networking Alliance)
- HomeRF™ (HomeRF Working Group)
- IEEE 802.11a/802.11b

As can be seen from the above list, there are many network technologies; it may not be possible to deliver all CableHome services over the network technologies listed above.

DOCSIS services and PacketCable services utilize the Internet Protocol (IP). As such, CableHome utilizes IP as the network layer protocol.

Devices connected to the CableHome network are manageable from cable headend equipment. As such, the CableHome networks support TCP and UDP at the transport layer, but may support other transport protocols as well.

The CableHome network physical layer, data link layer, network layer and transport layer protocol stack are shown in Figure 6.

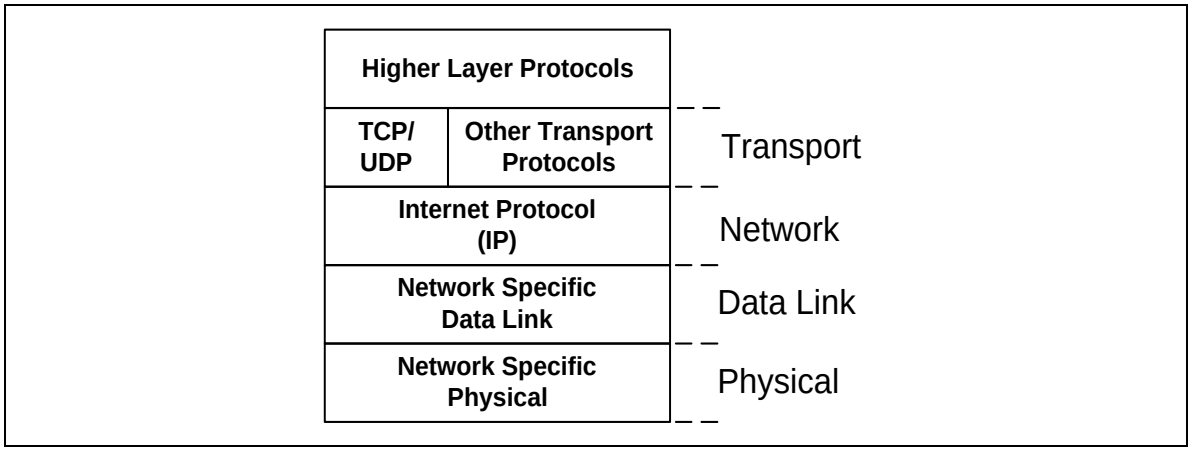


Figure 6. Home Network Protocol Stack

6.2 HA Device Class

The HA device class extends the CableHome domain between the DOCSIS network and compliant CableHome networks using the GW logical element. Additionally, the HA device can connect applications, embedded endpoints, external endpoints, and non-compliant home networks to the CableHome domain using the BP logical element.

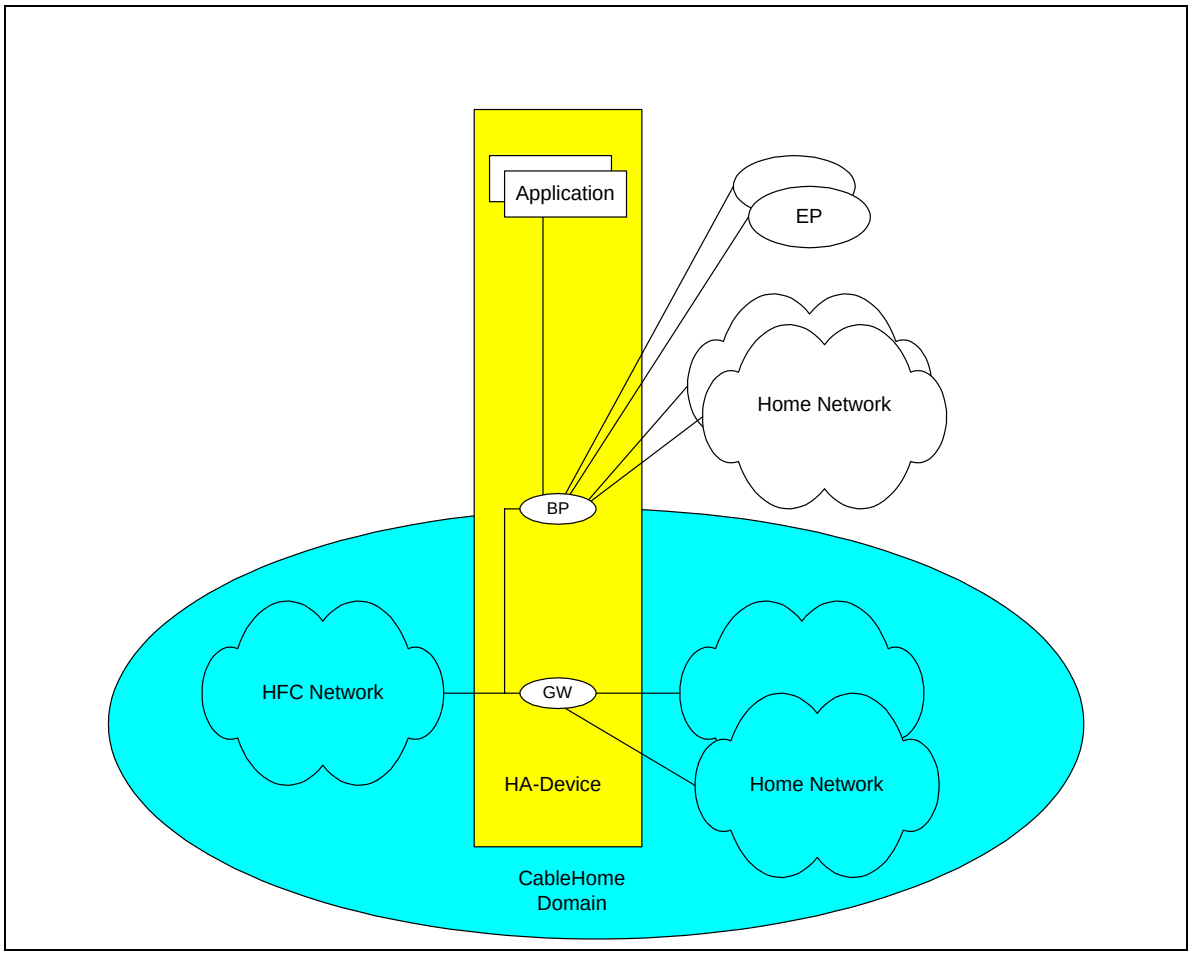


Figure 7. HA Device Class

The CableHome architecture does not preclude the existence of multiple HA devices within a home (i.e., multiple points of cable network connectivity may exist). The support of multiple HA devices may introduce loops in forwarding of traffic from and to the home. The detailed CableHome specifications will resolve this issue.

The GW logical element supports a wide range of capabilities including, but not limited to, multi-port routers. Figure 8 represents protocols associated with an HA device providing the GW logical element. The yellow areas represent protocols defined by CableHome, green areas represent existing protocols defined as part of DOCSIS or PacketCable, and the red area represents protocols not specified by CableHome.

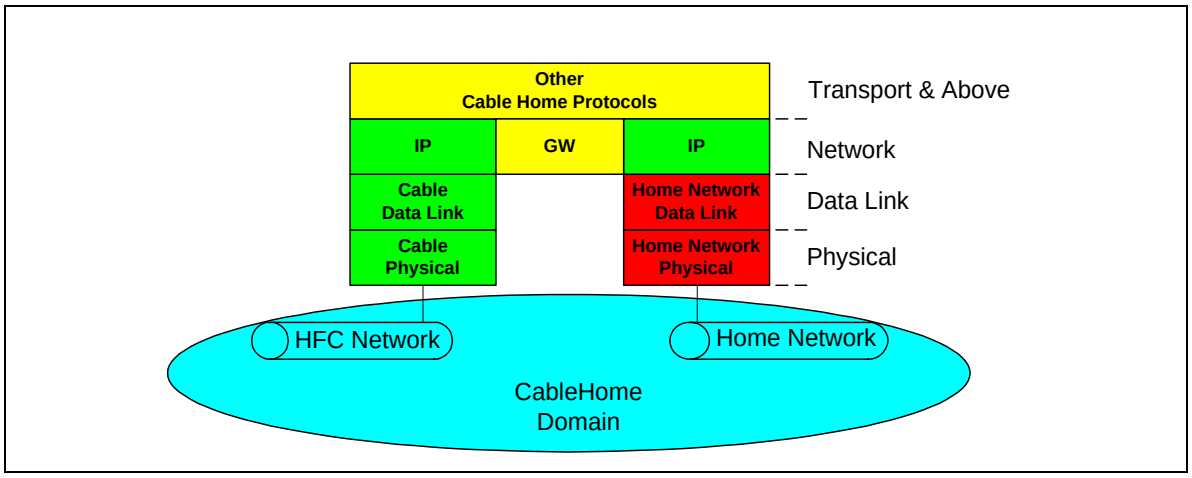


Figure 8. HA-compliant Network Connection

External endpoints that can be connected to an HA device include, but are not limited to, TVs, printers, personal computers, telephones, and audio/video devices. Protocols for connecting external endpoints to the HA device include, but are not limited to, IEEE 1394, universal serial bus (USB), RS-232, POTS and non-compliant home network protocols such as Ethernet providing non-compliant QoS. Specifications for interconnection of external endpoints to the HA device are outside the CableHome project scope. However, CableHome specifies the messaging protocols and management data structures to be utilized by HA-resident BPs when presenting a standard interface on behalf of external endpoints.

The HA device can connect embedded endpoints and applications to the CableHome domain. CableHome specifies the messaging protocols and management data structures to be utilized by HA-resident BPs when presenting a standard interface on behalf of embedded endpoints and applications.

Figure 9 to Figure 11 represent examples of the protocols associated with an HA device providing the BP logical element for home networking components outside the CableHome domain. The yellow areas represent protocols defined by CableHome, green areas represent existing protocols defined as part of DOCSIS or PacketCable, and the red area represents protocols not specified by CableHome.

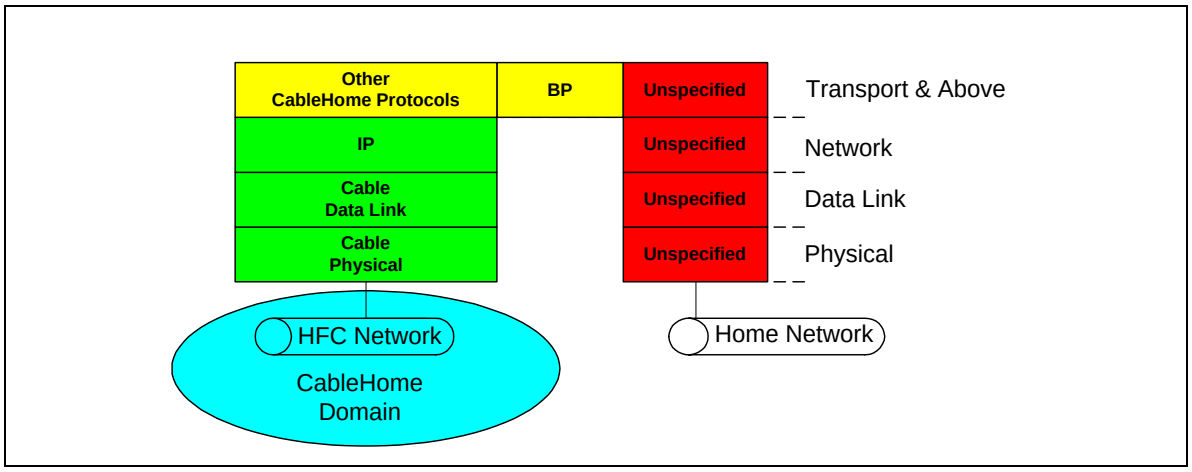


Figure 9. HA Non-compliant Network Connection

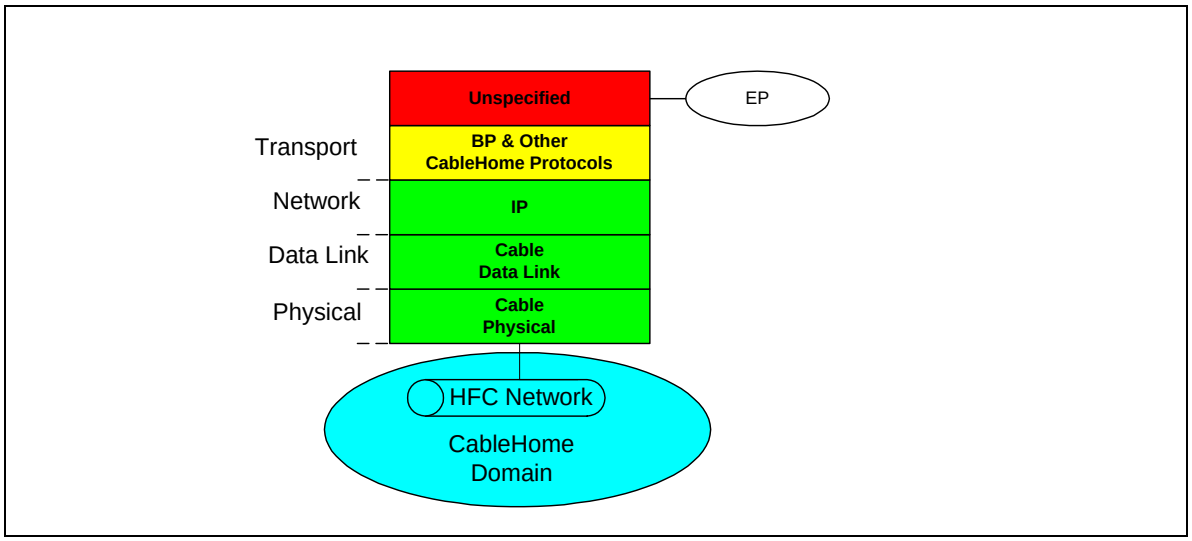


Figure 10. HA External Endpoint Connection

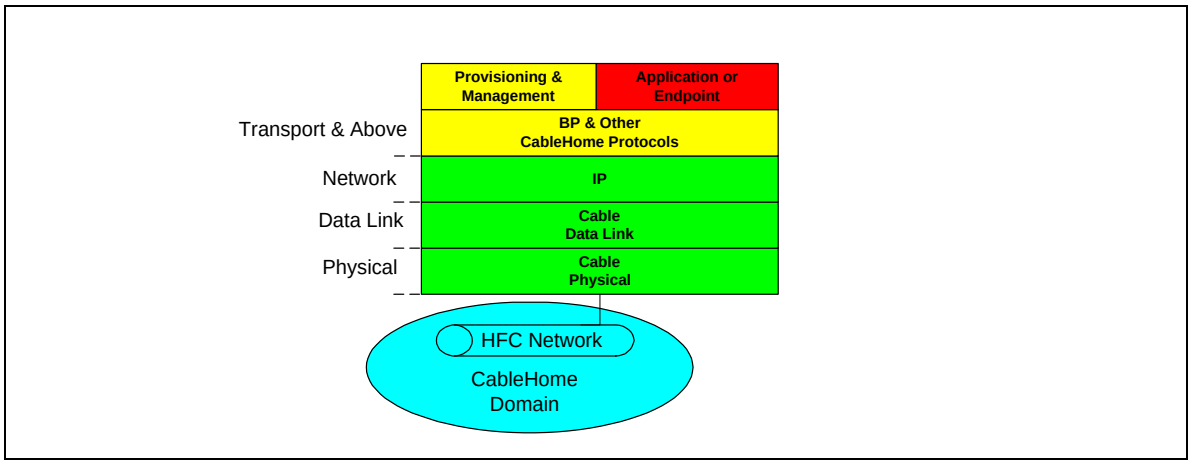


Figure 11. HA Embedded Endpoint or Application Connection

6.3 HB Device Class

The HB Device Class extends the CableHome domain between multiple CableHome compliant networks using the GW logical element. The HB device is similar to the HA device, however the HB device interfaces are not constrained by the DOCSIS specifications. Additionally, the HB device can connect applications, embedded endpoints, external endpoints, and non-compliant home networks to the CableHome domain using the BP logical element.

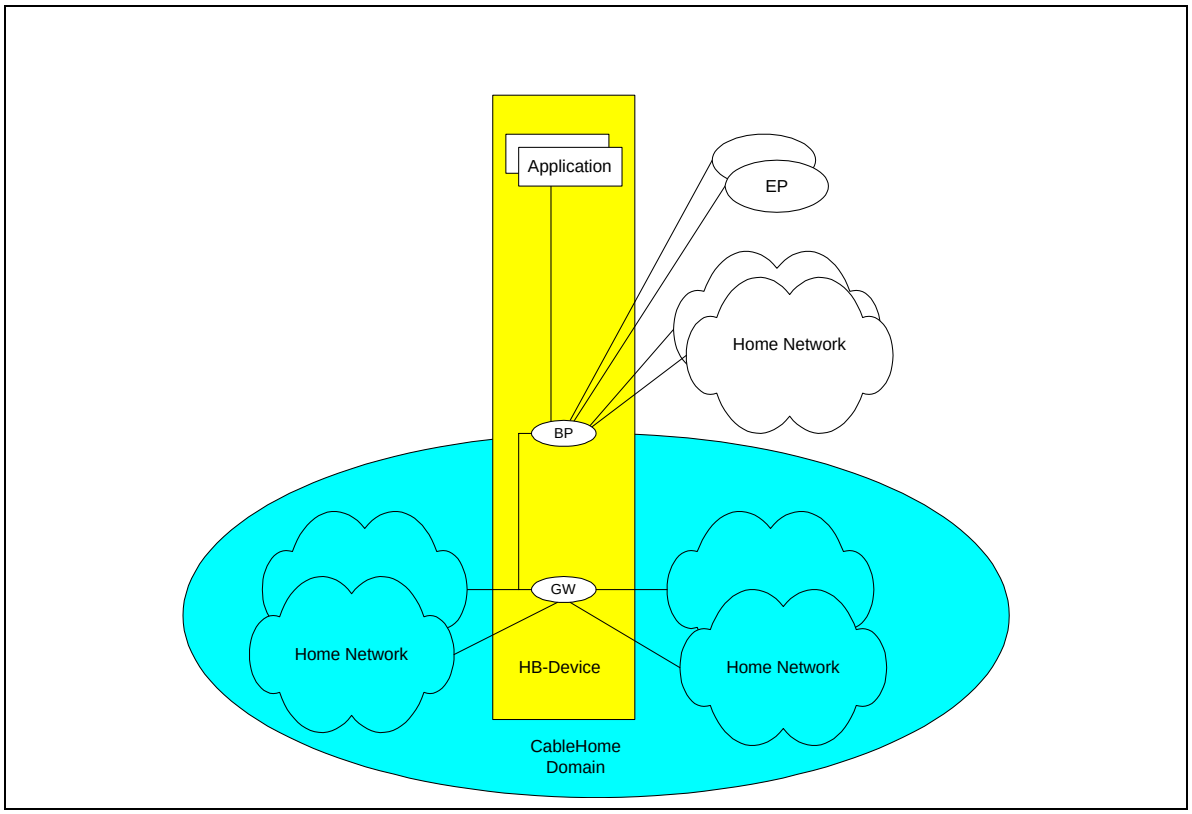


Figure 12. HB Device Class

The GW logical element supports a wide range of capabilities including but not limited to multi-port routers. Figure 13 represents the protocols associated with an HB device providing the GW logical element. The yellow areas represent protocols defined by CableHome, green areas represent existing protocols defined as part of DOCSIS or PacketCable, and the red area represents protocols not specified by CableHome.

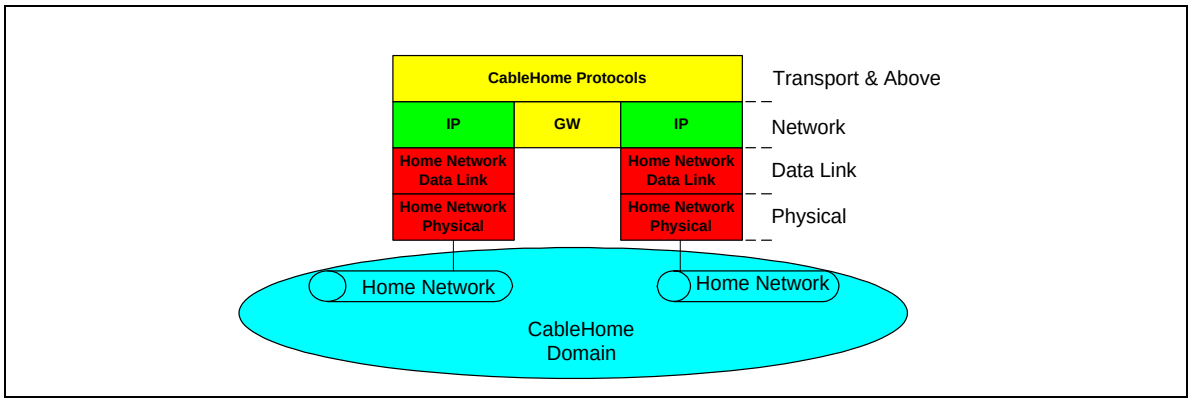


Figure 13. HB-compliant Network Connection

External endpoints that can be connected to an HB device include, but are not limited to, TVs, printers, personal computers, telephones, and audio/video devices. Protocols for connecting external endpoints to the HB device include, but are not limited to, IEEE 1394, universal serial bus (USB), RS-232, POTS and non-compliant home network protocols such as Ethernet providing non-compliant QoS. Specifications for interconnection of external endpoints to the HB device are outside the CableHome project scope. However, CableHome specifies the messaging protocols and management data structures to be utilized by HB-resident BPs when presenting a standard interface on behalf of external endpoints.

The HB device can connect embedded endpoints and applications to the CableHome domain. CableHome specifies the messaging protocols and management data structures to be utilized by HB-resident BPs when presenting a standard interface on behalf of embedded endpoints and applications.

Figure 14 to Figure 16 represent examples of the protocols associated with an HB device providing the BP logical element for home networking components outside the CableHome domain. The yellow areas represent protocols defined by CableHome, green areas represent existing protocols defined as part of DOCSIS or PacketCable, and the red area represents protocols not specified by CableHome.

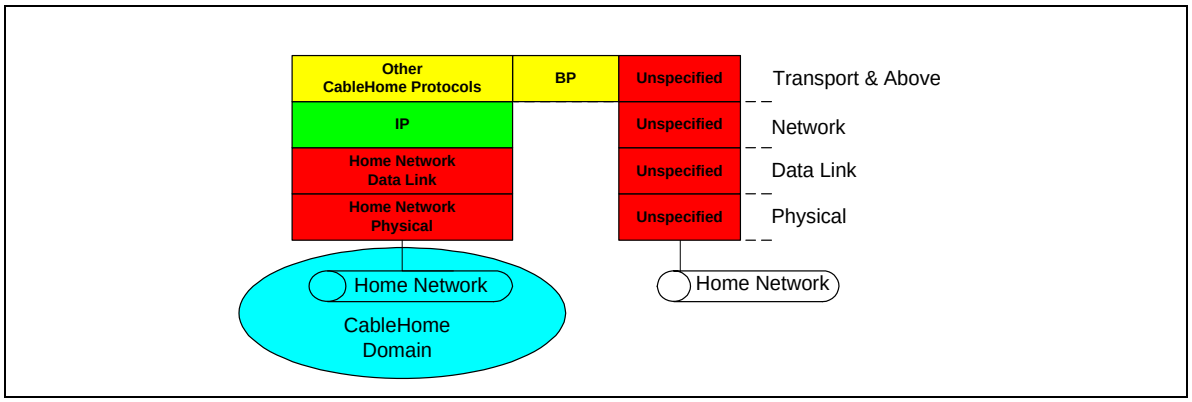


Figure 14. HB Non-compliant Network Connection

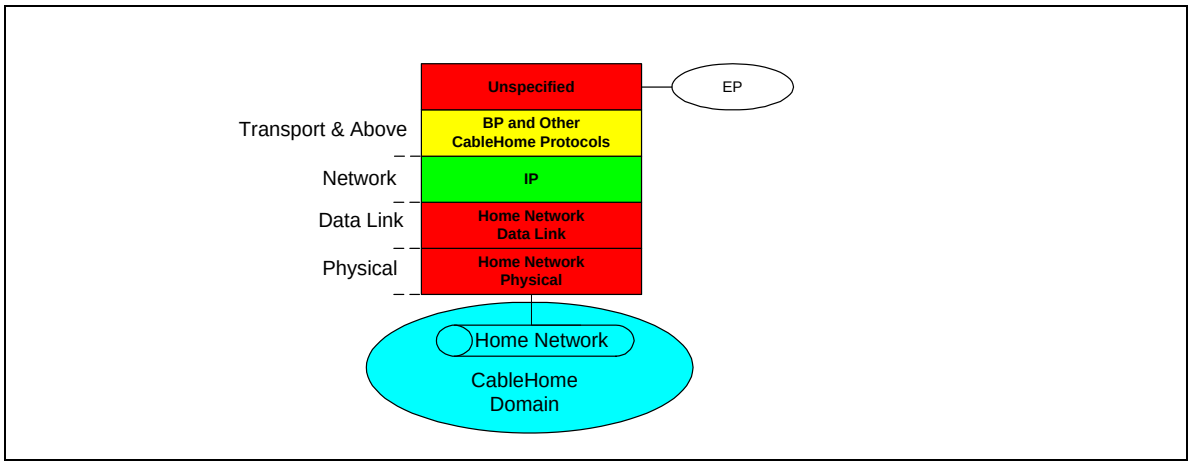


Figure 15. HB External Endpoint Connection

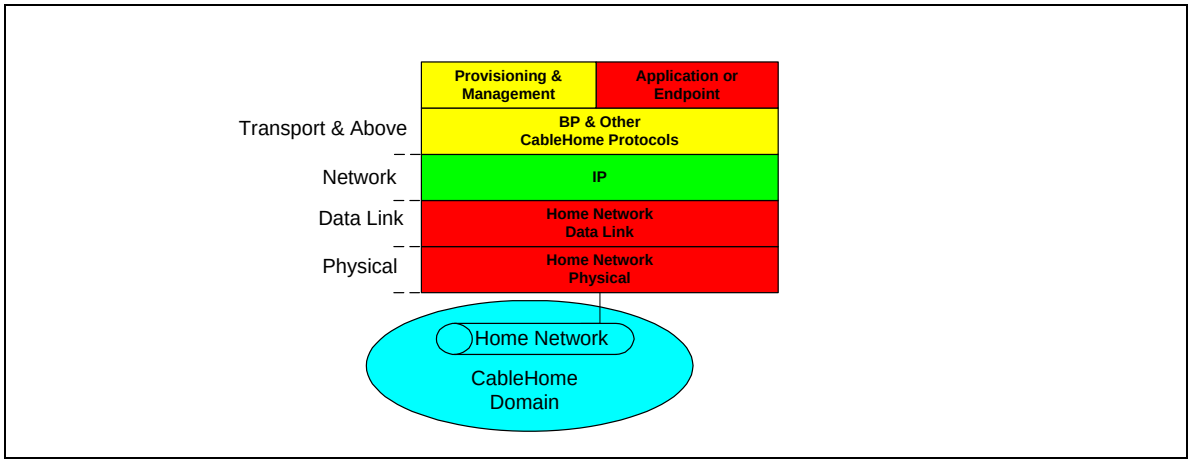


Figure 16. HB Embedded Endpoint or Application Connection

6.4 HC Device Class

The HC device class terminates the CableHome domain using the BP logical element. The HC device connects applications, embedded endpoints, external endpoints, and non-compliant home networks to the CableHome domain.

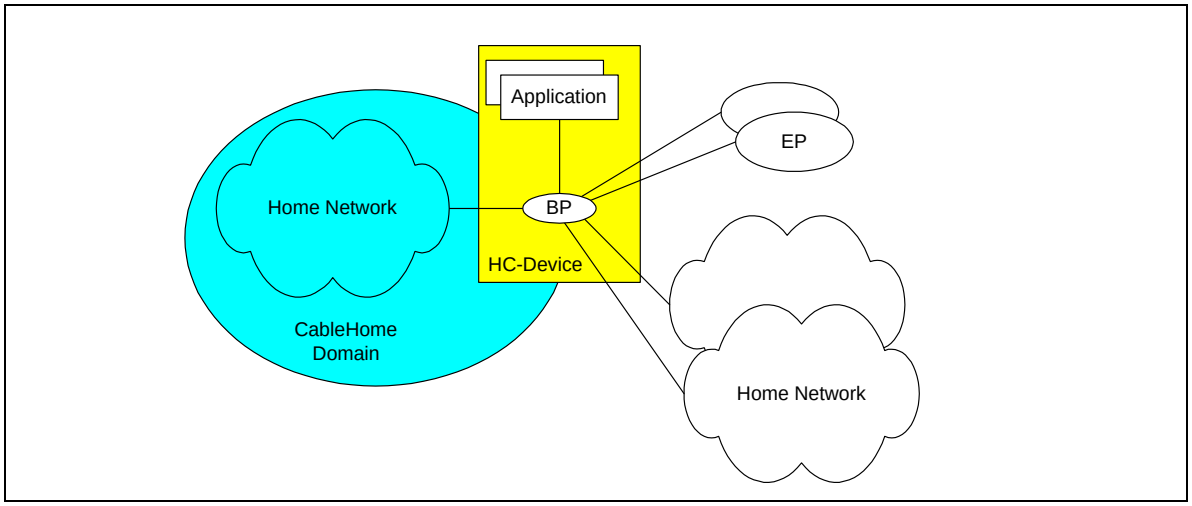


Figure 17. HC Device Class

External endpoints that can be connected to an HC device include, but are not limited to, TVs, printers, personal computers, telephones, and audio/video devices. Protocols for connecting external endpoints to the HC device include, but are not limited to, IEEE 1394, universal serial bus (USB), RS-232, POTS and non-compliant home network protocols such as Ethernet providing non-compliant QoS. Specifications for interconnection of external endpoints to the HC device are outside the CableHome project scope. However, CableHome specifies the messaging protocols and management data structures to be utilized by HC-resident BPs when presenting a standard interface on behalf of external endpoints.

The HC device can connect embedded endpoints and applications to the CableHome domain. CableHome specifies the messaging protocols and management data structures to be utilized by HC-resident BPs when presenting a standard interface on behalf of embedded endpoints and applications.

Figure 18 to Figure 20 represent examples of the protocols associated with an HC device providing the BP logical element for home networking components outside the CableHome domain. The yellow areas represent protocols defined by CableHome, green areas represent existing protocols defined as part of DOCSIS or PacketCable, and the red area represents protocols not specified by CableHome.

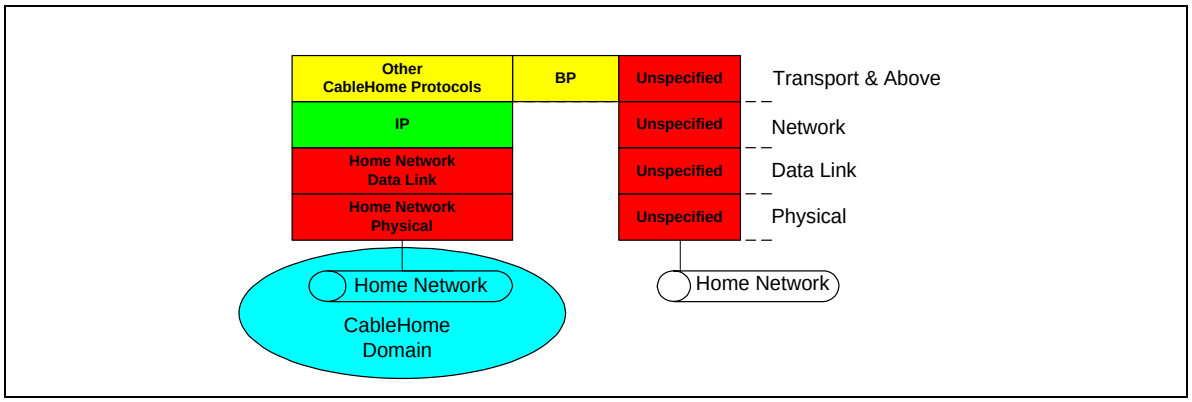


Figure 18. HC Network Connection

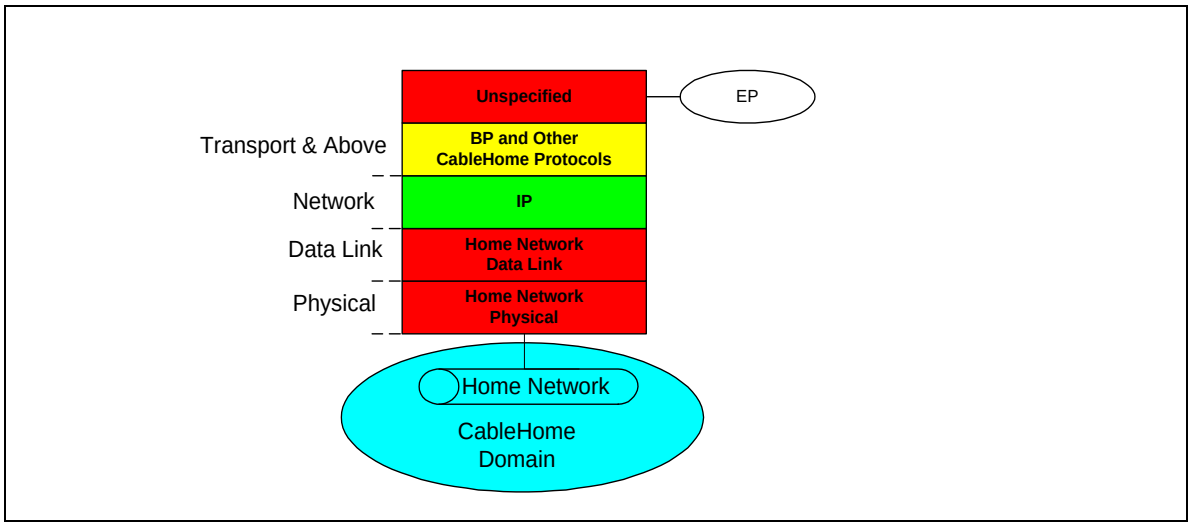


Figure 19. HC External Endpoint Connection

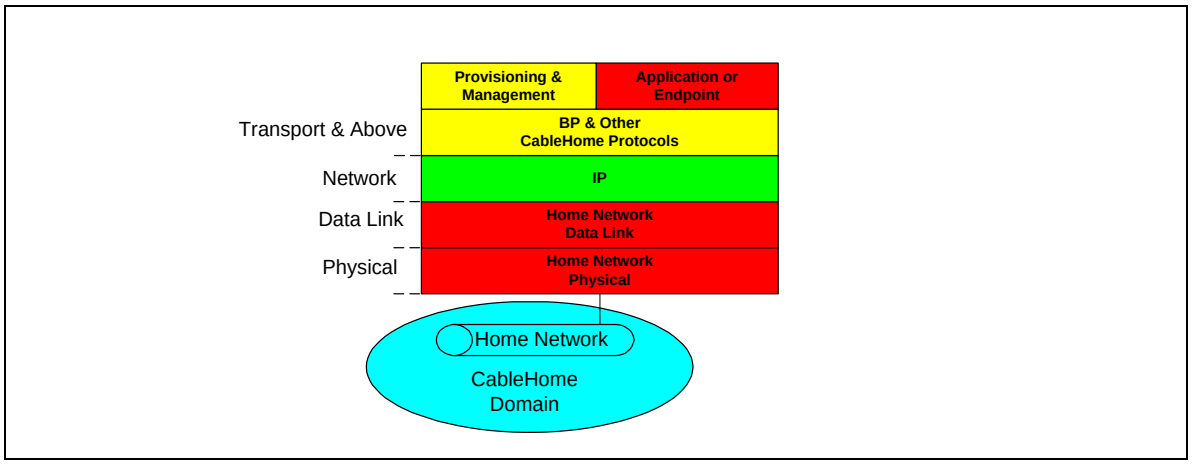


Figure 20. HC Application Connection

6.5 Capabilities

The CableHome architecture supports the services defined in the Home Networking Requirements for Cable-based Services [1] and supports existing services including:

- Data services as define by the DOCSIS specifications and,
- Telephone services as defined by the PacketCable specifications.

The CableHome architecture supports existing home network equipment and existing endpoints (i.e., printers and personal computers). This support is accomplished by providing a boundary point (BP) for attaching existing home network equipment, existing applications and existing endpoints to a home network.

The CableHome architecture supports a variety of standardized network capabilities. However, full access to new cable-based services is not guaranteed. Legacy standardized capabilities supported by the home networking architecture include, but are not limited to:

- Dynamic Host Configuration Protocol [2]
- Network Address Translator [3]
- Internet Firewalls [4]

CableHome architecture supports a wide range of gateway capabilities including, but not limited to, multi-port routers. In support of the Home Networking Requirements for Cable-based Services [1], and perceived end-user requirements, the CableHome project may define additional capabilities. These additional capabilities include, but are not limited to:

- Dynamic Host Configuration Protocol for Cable-based Services
- IP Network Address Translator for Cable-based Services
- Internet Firewalls for Cable-based Services

7 PROVISIONING

This section describes the provisioning of logical elements (i.e., Gateways (GWs) and Boundary Points (BPs)) within a CableHome-compliant environment. Provisioning descriptions for CableHome-compliant Gateways and Boundary Points are not intended to define or imply product implementation requirements, but instead are intended to describe the functionality required to support the provisioning processes within the CableHome networking architecture.

Provisioning includes initialization, creating a secure link, logical element configuration, and message exchange required to get an application up and running. Provisioning of specific services is outside the scope of the CableHome specification effort.

7.1 Treatment of CableHome Device Classes

Device classes HA, HB, and HC are conceptual notions of potential *position-specific* logical element instantiations. They are used as descriptive aids only in the CableHome architectural work, and their provisioning is not discussed.

7.2 Treatment of Endpoints

Although shown and briefly described in this document to provide context, direct provisioning of endpoints and non-compliant EP networks is out of scope of the CableHome specification effort. BPs provide the messaging interface and accessibility for EPs and collections of EPs on non-compliant networks. Thus, the desire to "provision an EP" is accomplished by provisioning them via a messaging interface exposed by the BP. BP venders may optionally process the provisioning messaging as a proxy function or a 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.

This provisioning capability is accomplished through the definition of a standard baseline messaging protocol and management data structure to be utilized by BPs when presenting a standard interface on behalf of endpoints. BPs provide the messaging interface and accessibility for applications, embedded EPs, external EPs and EPs on non-compliant networks. The manifestation of this protocol in the non-CableHome-compliant environment beyond the BP is left to vendors and is beyond the scope of the CableHome standard initiative.

7.3 Domains

The CableHome Reference Architecture currently defines the concepts of *domains*, one for quality-of-service *(Q-Domain),* and one for management *(M-Domain).* (Domains are defined in detail in Section 5.1.1.) CableHome provisioning will occur in the *M-Domain*. Some of the provisioned elements will control functionality of the *Q-Domain.*

The provisioning of CableHome logical elements is bounded by the management domain (which includes the Q domain). Gateways and Boundary Points resident within the M-domain must support CableHome provisioning messaging as stated above. EPs are represented by BP functions that must support CableHome M-domain messaging. For example, it is anticipated that vendors will wish to develop Boundary Points that allow existing and future non-CableHome-compliant networking technologies and related devices (Endpoints) to utilize CableHome services. In order to accomplish this, non-CableHome device discovery techniques will need to be transformed into CableHome compliancy. This integrating transformation is the responsibility of a CableHome Boundary Point. The specific M-domain provisioning scheme is planned for further study and specification in the future CableHome Provisioning/Management Specifications.

It is important to review requirements [1] defined for the CableHome provisioning function. Please refer to Table 1 for review of the CableHome provisioning requirements as currently defined.

7.4 Logical Elements, Components, and Inferfaces

The CableHome environment consists of CableHome logical elements, OSS components, and interfaces.

7.4.1 Logical Elements

Provisioning of logical elements covers initialization, authentication, and registration functions required for CableHome logical elements. Specifics of the provisioning protocol for the logical elements will be defined in the forthcoming detailed CableHome Provisioning specification.

Every Gateway logical element and Boundary Point logical element is uniquely addressable; each has a minimum of one associated IP address. GWs and BPs can be instantiated at various positions within the home environment as characterized by the CableHome device classes.

Logical element provisioning within the CableHome environment is separate from DOCSIS and PacketCable provisioning functional mechanisms. In a product instantiation that contains all three capabilities, initial DOCSIS infrastructure provisioning will occur first. Since CableHome is provisioning additional infrastructure (versus services), initial CableHome provisioning occurs next. Initial PacketCable provisioning occurs after CableHome. CableHome re-provisioning, which is considered a management function, will take into consideration its need to be integrated with DOCSIS and PacketCable operations, management, and provisioning processes.

As a general statement of functionality, the provisioning of CableHome logical elements assumes the presence of a cable access network connection. No assumptions

are made with regard to the state of connectivity between elements in a home network.

7.4.1.1 Gateways

A GW will be provisioned with a minimum of one unique IP address as well as other parameters required to accomplish the appropriate level of interconnection between CableHome-compliant networks. Specifics of the provisioning content for Gateway logical elements will be defined in the forthcoming detailed CableHome Provisioning specification.

7.4.1.2 Boundary Points

A Boundary Point may interface with and perform proxy functions on behalf of Endpoints located outside of the CableHome-compliant environment, enabling consumption of CableHome services by these EPs. A BP will be provisioned with a minimum of one unique IP address as well as other parameters required to receive compliant messaging and to perform EP representation. Specifics of the provisioning content for the Boundary Point logical element will be defined in the forthcoming detailed CableHome Provisioning specification.

7.4.2 Components and Interfaces

In addition to the logical elements described above, CableHome defines certain Operations Support System (OSS) functions, components and interfaces specific to home network environments. CableHome is infrastructure oriented, specifying a home networking environment over which PacketCable and other services can be delivered. Figure 21 identifies anticipated CableHome components and interfaces that are discussed in this section.

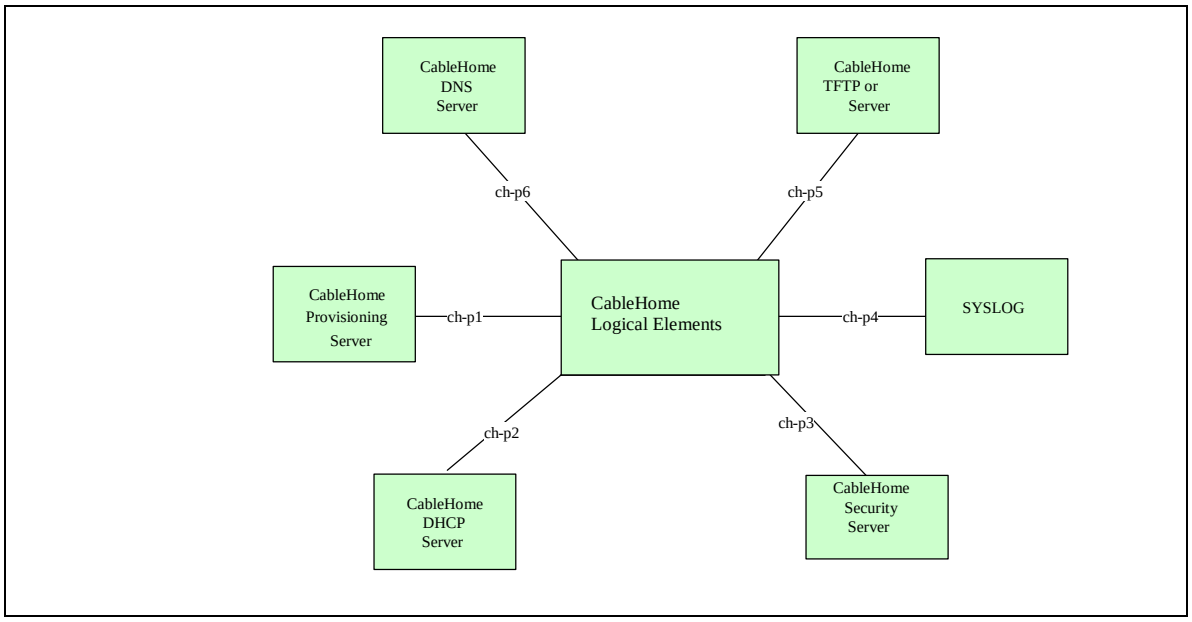


Figure 21. CableHome Provisioning Interfaces

7.4.3 OSS Components

Since CableHome does not specify subscriber services, the back-office CableHome components are oriented towards the configuration, provisioning, and management of the CableHome environment. These topics will be explored in detail in the CableHome Provisioning specification.

7.4.3.1 Dynamic Host Configuration Protocol Server (C-DHCP)

The CableHome DHCP server is a back-office component used during the logical element provisioning process to dynamically allocate IP addresses and other logical element configuration information.

7.4.3.2 Domain Name System Server (C-DNS)

The CableHome DNS server is a back office component used to map between ASCII domain names and IP addresses.

7.4.3.3 Trivial File Transfer Protocol Server or Hypertext Transfer Protocol Server (C-TFTP or C- HTTP)

The CableHome TFTP server is a back-office component used during logical element provisioning processes to download configuration files to the logical elements. An HTTP server may be used instead of a TFTP server to download configuration files to logical elements.

7.4.3.4 SYSLOG Server (SYSLOG)

The SYSLOG server is a CableHome back-office component used to collect events such as traps and errors from logical elements.

7.4.3.5 Provisioning Server

The CableHome Provisioning Server is a back-office component used to provision and re-provision CableHome logical elements.

7.4.3.6 Security Server

The CableHome Security Server is a back-office component used to create secure links in the provisioning process, as well as any other CableHome provisioning security needs.

7.4.4 Protocol Interfaces

Protocol specifications will define the logical element interfaces in the CableHome architecture. An overview of envisioned protocol interfaces is provided within this section. Final protocol interface definitions will be specified in the forthcoming detailed provisioning specification once all architectural considerations are resolved. Protocol interfaces for provisioning will be table-ized once finalized.

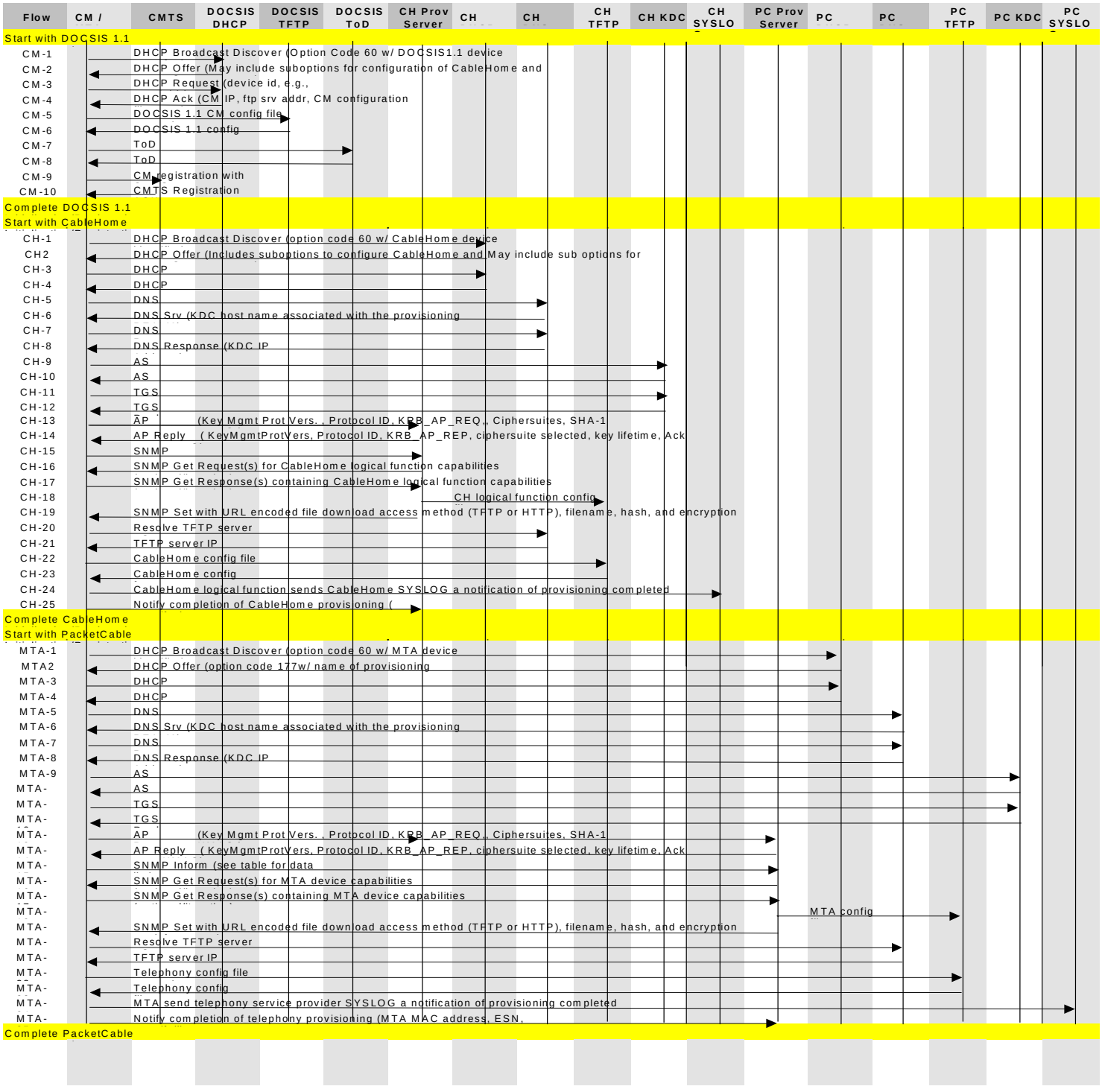
Interfaces between DOCSIS and/or PacketCable OSS functions, and CableHome logical elements, if any, will be defined during development of the forthcoming detailed CableHome Provisioning specification.

Table 5. CableHome Provisioning Interfaces

Interface	CableHome Components	Description
ch-p1	Logical Elements: PROV Server	Messaging flow to exchange logical element capability information between logical elements and the Provisioning Server using the designated management protocol. Logical elements also send notification of provisioning completion along with pass/fail indication.
ch-p2	Logical Element: DHCP Server	Messaging flow to assign IP addresses and other information to logical elements.
ch-p3	Logical Element: Security Server	Messaging flow to authenticate configuration information for logical elements and any other security services deemed necessary.
ch-p4	Logical Elements: SYSLOG Server	Messaging flow used by logical elements to signal the SYSLOG server of provisioning completion along with pass/fail indication.
ch-p5	Logical Elements: TFTP/HTTP Server	Messaging flow used to download logical element configuration files to logical elements from the TFTP Server or HTTP Server
ch-p6	Logical Element: DNS Server	Messaging flow used to obtain the IP address of a CableHome server given its fully qualified domain name.

7.4.5 Provisioning Messaging Flows

The following diagram is included as an example of possible detailed messaging flows on some CableHome interfaces during the provisioning process.



The diagram shows the provisioning flow that includes DOCSIS 1.1, CableHome and PacketCable provisioning. The CableHome provisioning steps CH-1 to CH-25 are performed per each instance of a CableHome logical function. If a device has two or more such functions, then these steps will be repeated for each one of these functions. A device that does not have a DOCSIS 1.1 interface will not perform the DOCSIS 1.1 provisioning process (CM-1 to CM-10) and if no PacketCable application exists then the PacketCable provisioning process will be skipped (MTA-1 to MTA-25). The order of the provisioning processes is as shown in the diagram: first DOCSIS then CableHome and last PacketCable.

The only connection between the provisioning processes is through DHCP sub-options that may be transferred from the provisioning process on one interface to the next (from DOCSIS to CableHome and from CableHome to PacketCable). These will be discussed in detail in the forthcoming provisioning specification.

The CableHome, DOCSIS 1.1 and PacketCable servers are logically separate entities, although it is possible to implement some of them in a single physical entity.

Steps CH-9 to CH-14 are used to establish SNMP-V3 security which is the bases for establishing a secured domain for the CableHome logical functions in this example. The flow assumes the usage of Kerberos Ticketing. The security mechanisms for CableHome are not finalized at this point, and these steps may change to reflect the future decisions of the CableHome security implementation.

8 NETWORK MANAGEMENT

This section provides the scope of capabilities the CableHome architecture team is striving to achieve in defining the management of CableHome products and related services. Management in the CableHome architecture addresses two aspects: 1) CableHome Logical element and low layer network management; and 2) a general operator service management framework.

8.1 Overview

The home is an evolving environment under constant transformation by a variety of emerging technologies and related services; thus not all services (e.g., video, data, voice, audio) and support scenarios have been identified to date. This fact is guiding the development of a broad management framework from which CableHome-defined elements and networks can be managed, and within which capabilities for managing current and future CableHome based services can be developed. The CableHome team believes this broad management framework will provide cable operators with the capabilities needed to achieve and maintain customer convenience amid the anticipated complexities of the evolving home.

The management concepts implied by the CableHome architecture, and the envisioned services market it enables, will govern the development of detailed specifications of the management functions of CableHome products and services. The level of detail used to describe CableHome management in this section is intended to provide a broad-brush description of the envisioned CableHome management capability consistent with other descriptions within this framework document. The intent of this section is to:

- establish the core capabilities within the CableHome architecture needed to enable management of CableHome elements and networks,
- describe a rich service management framework within which a broad spectrum of capabilities and services enabled by the CableHome architecture becomes possible.
- establish the underlying foundation that enables upper level management applications to: manage CableHome products, offer additional cable-based services, allow the generatation of topology maps, remotely evaluate service-related complaints, identify faulty CableHome equipment, and identify possible problems within the home with non-CableHome equipment.

Management is defined as identifying, status monitoring, logging or recording, and reporting on CableHome infrastructure elements and the related distribution of content services over these elements, as well as detecting, isolating (filtering), and reporting captured data results and status. Important capabilities include the identification of service issues prior to subscriber calls, identification of newly installed elements in and updates to in-home network topology, and the ability to

provide interim customer solutions prior to truck rolls or infrastructure modifications. All of the above reduce or eliminate time and effort required during visits to customer premises.

8.1.1 Goals

Management descriptions are not intended to define or imply product implementation requirements, but instead are intended to provide a summary description of the functional capabilites of the CableHome management tools for remote management of networks and services.

The purpose of the CableHome management function is primarily to provide network operators with a standardized means of visibility into subscriber home networks, and a standardized means of controlling CableHome logical elements. An additional focus is placed on creating a robust service management framework within which the management of a broad set of services is enabled.

From the network management capability perspective, the CableHome management architecture is designed to manage CableHome-defined elements. To accomplish this purpose an extensible, standards-based management framework is being defined that will support operator efforts to

- ensure reliable service delivery over the CableHome-compliant infrastructure through management of CableHome logical elements,
- troubleshoot, isolate, and resolve equipment and service issues within subscribers' home networking environments where CableHome infrastructure is deployed, and
- build value-added management services for existing and evolving home environments.

8.1.2 Challanges

Management of home networking environments presents a unique set of challenges. This is due primarily to the infancy of home networking, including the variety of competing transport technologies available to consumers today and anticipated in the near future. The absence of any pervasive applications (services) delivered via these technologies also impedes the development of momentum in any specific home networking technology direction, amplifying uncertainties about future management needs. Given the CableHome requirements to extend PacketCable™ and DOCSIS™ functionality into the CableHome compliant networks, combined with the uncertain state of the home networking industry, several fundamental challenges must be addressed by the CableHome standards initiative :

- DOCSIS/PacketCable™ – CableHome Integrity

  Management of the CableHome environment can not compromise the integrity of the network side of DOCSIS™ and the ability to support PacketCable™ service flows.

- CableHome and Emerging Home Technologies

  CableHome management must consider the flexibility that may be necessary to interface with the variety of management systems that may accompany still-emerging home technologies.

- CableHome™ Scalability

  CableHome management scalability needs to reflect the number of potential manageable elements that may emerge in the home and the implications this may have on the bandwidth consumed by CableHome management.

8.2 Element Management

8.2.1 Logical Elements

Management of logical elements is monitoring, measuring, controlling, logging, and reporting performance; detecting, isolating, reporting, and correcting network related faults; rebooting and re-configuring logical elements; and monitoring, logging, and reporting status. Specifics of the management protocol for the logical elements will be defined in the CableHome Management specification.

Every Gateway (GW) logical element and Boundary Point (BP) logical element is uniquely addressable (i.e., each has at least one associated IP address). GWs and BPs can be established at various positions within the home environment within the defined CableHome device classes.

The management of logical elements within the CableHome environment is separate from DOCSIS and PacketCable management. However, it is expected that many of the same protocols and mechanisms will be used in order to manage CableHome, PacketCable, DOCSIS, and other mangement aspects. It is possible that a broader managment framework will be necessary to satify the CableHome network management requirements. Section 8.4 considers one possible management framework that expands upon the managment of logical elements.

8.2.1.1 Management of Gateway (GW) Functions

GWs may reside within any of the HA or HB. GWs maintain the management information required for the support of their associated CableHome network segments. This management information includes; status, error statistics, IP addresses, device capabilities, customer usage information, etc. Specifics of the

management messaging for Gateway logical elements will be defined in the CableHome Management specification.

8.2.1.2 Management of Boundary Point (BP) Functions

The boundary point is a logical element resident within any of the HA, HB or HA device instantiations. A Boundary Point may proxy for non-complaint device management information between CableHome-compliant networks and non-compliant networks. Boundary Points that expose non-compliant Endpoints beyond the M-Domain will do so by exposing a CableHome-specified messaging interface designed to enable indirect visibility and management of those Endpoints. Specifics of the management messaging for Boundary Point logical elements will be defined in the CableHome Management specification.

8.2.2 The M-Domain

The CableHome Architecture defines a Management or M-domain manageable by cable operators. The M-domain encompasses the Quality or Q-Domain, as well as all CableHome logical elements. The *M-domain* consists of elements capable of receiving, transmitting, interpreting and acting upon CableHome management messages. Elements incapable of supporting CableHome messaging are considered to be outside the M-domain, and are not directly manageable.

8.2.3 Treatment of Device Classes

CableHome device classes (HA, HB, and HC) are position specific abstract collections of CableHome logical elements. They are used as descriptive aids only in the CableHome architectural work, and their direct management is not discussed. Management of the physical aspects of logical element instantiations, if any, will be determined during development of the CableHome Management Specification.

8.2.4 Treatment of Endpoints

Although shown and briefly described in this document to provide context, direct management of Endpoints (EP) and non-compliant networks of EPs is out of scope of the CableHome specification effort. BPs provide the messaging interface and accessibility for applications, embedded EPs, external EPs, and collections of EPs on non-compliant networks. Thus, the desire to “manage an EP” is accomplished by managing them indirectly via a messaging interface exposed by the BP. At the option of vendors, BPs may optionally process the management messaging as a proxy function or a 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.

This management capability is accomplished through the definition of a standard baseline messaging protocol and management data structure to be utilized by BPs. The manifestation of this protocol in the non-CableHome-compliant environment

beyond the BP is left to vendors and is beyond the scope of the CableHome standard initiative.

If a non-compliant device is attached to an M-compliant network, the management capability of the compliant devices residing on the same network will not necessarily be disabled. In such a case, the M-domain remains intact for all compliant devices on the network (under normal conditions). The CableHome architecture will not preclude limited management of such non-compliant devices in a non-specified manner.

8.3 OSS Functions and Interfaces

In addition to the logical elements described above, CableHome defines certain Operations Support System (OSS) functions specific to the home network environment. CableHome is infrastructure oriented, specifying a home networking environment over which PacketCable and other related services can be delivered, managed, and supported. Existing OSS fuctions defined within the DOCSIS and PacketCable infrastractures will be considered for resuse when practical, and in addition other management mechanisms will be investigated.

The ability to identify the functional elements, and the physical products connected to the CableHome network is essential in the development of a network topology of logical elements, and a physical topology of products. The logical topology enables the services to be provisioned and managed, while the physical topology provides the information necessary for customer service and on site service technicians to better perform their jobs. The information required to accomplish theses tasks will be defined in the CableHome Management specification.

8.3.1 OSS Functions

Since CableHome does not specify subscriber services, the back-office CableHome functions are oriented towards the configuration, provisioning, and management of the CableHome environment. The capabilities of these OSS functions will be defined in detail in the CableHome Management specification.

The anticipated OSS functions for the CableHome provider's back office are listed below. Each of these servers will require management information from individual logical and functional elements within the M-domain. Details of these requirements will be specified in the CableHome Management specification.

- DHCP Server
- DNS Server
- TFTP or HTTP Server
- Provisioning Server

- Security Server
- SYSLOG Server

In addition to those listed above, other Management Server functions are being discussed for inclusion in the CableHome OSS document. The need for additional CableHome OSS functions will be determined during development of the CableHome Management and Provisioning specifications.

8.3.2 OSS Interfaces and Messaging flows

The CableHome environment requires the development of specific information necessary to manage these complex network topologies and services. The management interface of logical elements utilizes a specified management information structure. That management information structure allows a set of CableHome required information and also provides a structure for private or unspecified information.

Detailed management messaging flows will be defined once the management protocol has been determined. The protocol used to remotely manage the Home Network will be chosen from industry standard or existing protocols, which are available today and will grow with the evolution of the CableHome initiative. CableHome may extend standard management protocols and interfaces if needed to meet specific CableHome networking needs. SNMP or Simple Network Management Protocol is one possible candidate amongst others under consideration.

The management protocols currently supported in the DOCSIS 1.1 and Packet-Cable 1.0 specifications will be supported in the CableHome management specification. The following existing management protocols among others may be examined as well: UPNP, 1394B, Jini, LONWorks, and CIM. These protocols may influence the detailed definition of CableHome management.

8.4 CableHome Expanded Management Framework Considerations

This section overview is to encourage the MSO community to look forward while the initial CableHome management solutions are under development. At some point, it may be appropriate to integrate the CableHome management architecture into a well established feature rich management model. The next two sub-sections will provide a high level description of an existing management model used in the telecommunications industry today, the Telecommunications Management Network or TMN model, and how it could be applied to CableHome management. The first sub-section describes how the current modeling of the CableHome management scheme can be a subset of the TMN model. The second sub-section deals with the description of the future capabilities available through use of this model, which should integrate smoothly with the currently defined CableHome architecture. A white paper, which is a work in progress, explores the potential application of the

TMN model to CableHome management in greater detail, and reflects work to date on this concept.

8.4.1 Motivation

The rationale for pursuing the adaptation of the TMN model to CableHome management is the anticipated importance of a robust management capability in the increasingly competitive, evolving telecommunications services climate. Past management challenges for cable operators have been to accommodate the relatively bounded environments of high-speed data (DOCSIS) and MTA-oriented packet cable services (PacketCable). The uncertainties associated with future home environments impose an *un-bounded* environment on CableHome management.

In addition, successful adaptation of the TMN model to CableHome management will provide a common platform for integrating legacy DOCSIS and PacketCable management capabilities, as well as accommodate future management needs as they arise in the uncertain home environment.

8.4.2 CableHome as a Subset of the TMN Model

Pursuit of a broad management platform for CableHome expands on the work begun in PacketCable for its OSS framework, which is derived from the TMN model. While the TMN model defines capabilities much broader than will be required to manage CableHome Gateways and Boundary Points, it is anticipated that the expanded capabilities defined in the TMN model will be necessary manage the complexity anticipated in the evolving home environment.

The TMN model divides network management into three integrated architectures: functional architecture, physical architecture, and information architecture. As a first step in exploring the applicability of the TMN model to CableHome management, we overlay CableHome constructs onto the three integrated TMN architectures as shown in Figure 22.

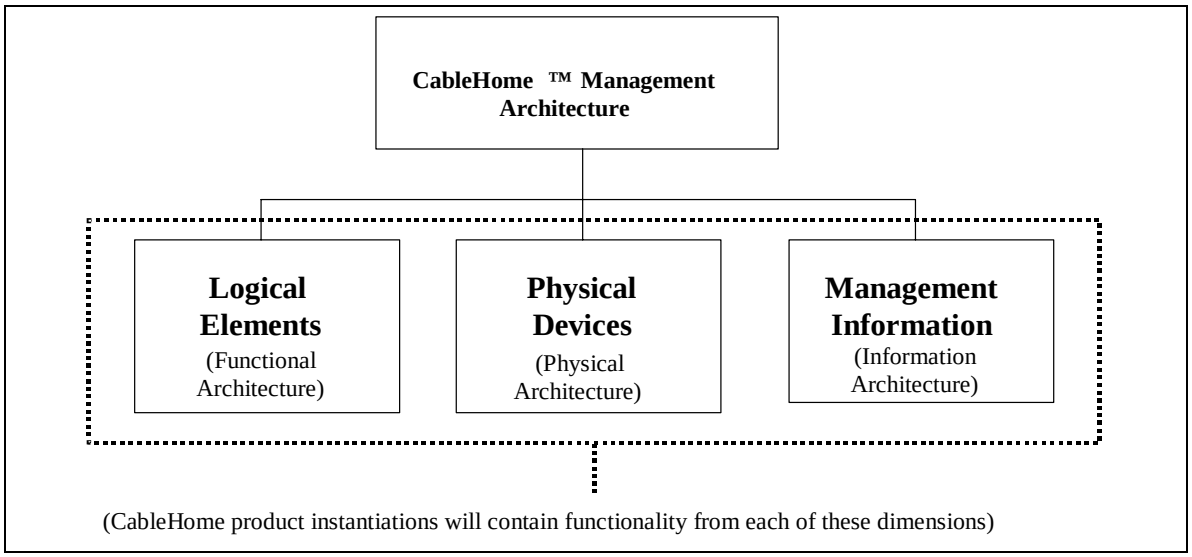


Figure 22. CableHome Management Architecture

As can be seen in the above figure, the mapping of CableHome onto the TMN model is not precise, as CableHome does not rigidly define physical elements (recall that CableHome device classes are abstract notions used as descriptive aids only). However, CableHome logical elements (i.e., Gateways and Boundary Points) will be implemented within CableHome products. Although the CableHome architecture currently requires only the specification of logical elements (as opposed to physical devices), it may become necessary during development of the CableHome Management specification to impose requirements on physical devices as well. Should this prove to be the case, the inclusion of a physical dimension in the CableHome management model will facilitate the specification of any physical requirements for CableHome products.

Additional motivation for including a physical dimension in the CableHome management model is its applicability to DOCSIS cable modems and PacketCable MTAs, which do have defined physical properties such as Ethernet or USB interfaces.

CableHome logical elements perform Gateway and Boundary Point functions, and thus appear to map well into the TMN functional architecture. Gateways operate on information passing through them, similar to Mediation Functions in TMN. Boundary Points represent non-compliant Endpoints located beyond them, similar to how Q-Adapters in the TMN model enable indirect management of legacy devices incapable of processing TMN management messages. A near term white paper is currently under development that explores this mapping in more detail.

The information architecture will be comprised of management information definitions and structure with regard to what information needs to be collected, where it is collected from, which element collects it, and how it is used in the CableHome management environment. The CableHome environment will enable the operation of a wide variety of products in the home, possibly leading to a proliferation of elements to be managed by the cable operator. These CableHome networks will require the

development of specific information necessary to manage these complex network topologies and services. The CableHome management information structure will take into account the current capabilities of the existing management structure used today in the DOCSIS 1.1 and Packet-Cable 1.0 programs. In designing CableHome management information structures we will attempt to accommodate vendor specific management information structures, and new management information structures discovered through the development of new CableHome technologies. The management specification will clearly list the minimum requirements for the management of the CableHome environment.

Figure 23 provides a second step in the mapping of CableHome onto the TMN model. It compares one approach for a CableHome management functional architecture to the TMN functional architecture model. It is assumed that the reader is familiar with the TMN model. *ITU-T Recommendation M.3000* [5] provides a TMN overview, and the text *Network Management, Principles and Practice* [6] provides an in depth discussion of this topic.

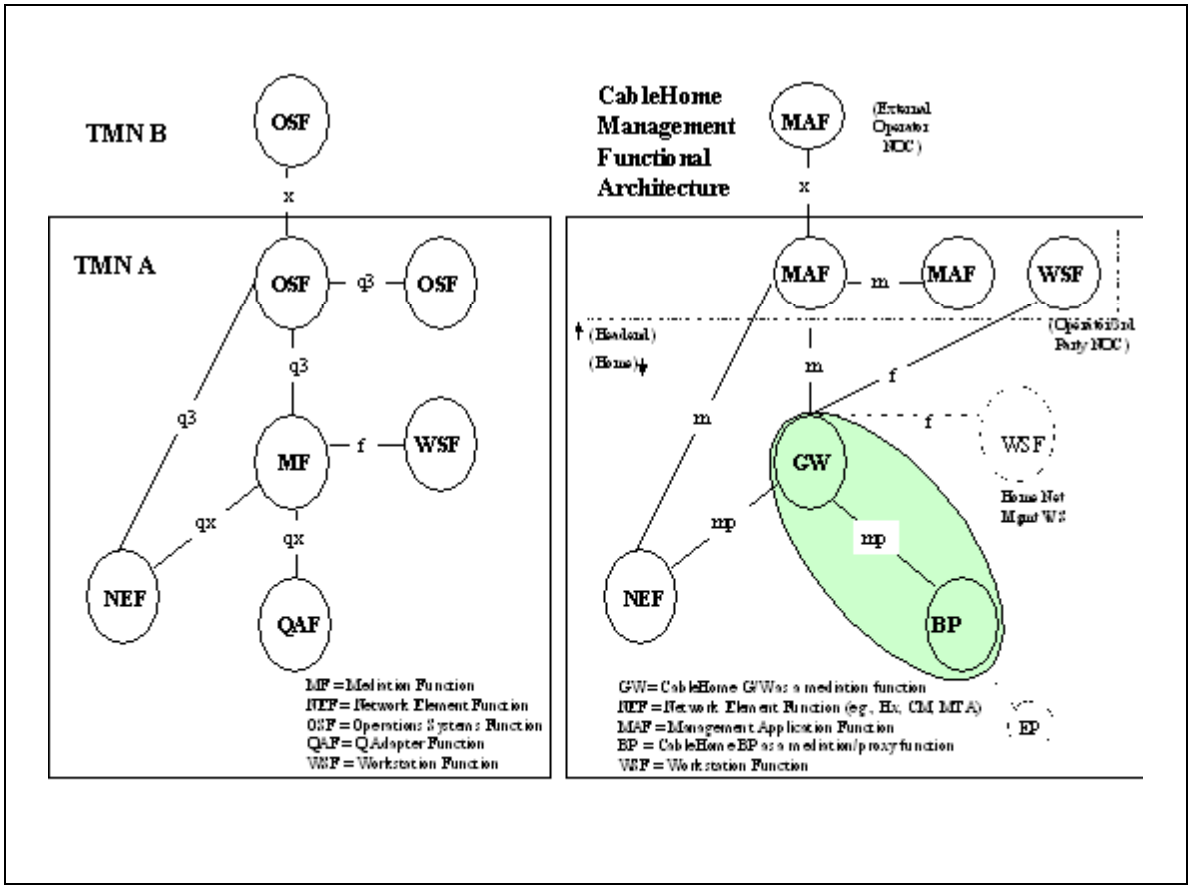


Figure 23. CableHome Management as TMN Subset

The shaded area in Figure 23 corresponds to the CableHome M-Domain, and suggests one possible mapping of CableHome into the TMN model. The figure also suggests how TMN functions could be applied to CableHome topography.

8.4.3 MSO Benefits of an Expanded Management Framework

The TMN model provides a rich management environment for logical elements, devices, applications, and services. It appears to be well-suited to support current as well as future network operator needs. The TMN model defines the following functional management dimensions:

- Fault management
- Configuration management
- Account management
- Performance management
- Security management

The CableHome management modeling effort will attempt to incorporate the following functional area into the TMN model:

- General Service & Content management & reporting capabilities

The TMN model also defines management (system) services in the areas of :

- Business management
- Service Management
- Network Management
- Element Management

The CableHome team is considering the TMN model as the basis for the expanded CableHome management framework under consideration.

8.4.4 Management Future Considerations

Additional issues for future consideration include

- Web-based management accommodation (HTTPS, etc.)
- additional network and service management capabilities needed
- content and consumer network security management
- accommodation of third party services.

9 QUALITY-OF-SERVICE

The CableHome Quality-of-Service (CQoS) architecture is composed of logical elements and the functions that comprise them. Developers of CableHome networking equipment (e.g. hardware and software) implement one or more of these elements depending on the desired feature set of these products. Specified minimum sets of capabilities are required to participate in the CQoS-Domain. This logically based method of specifying the CQoS architecture allows interoperability between products with various features connected in various topologies.

The CQoS domain and logical elements are presented in section 9.1. CQoS device classes are presented in section 9.2. Mappings between the CQoS-Domain and the CableHome architecture Domain are presented in section 9.3.

Devices and networks of devices that do not support the CQoS minimum functionality may be indirectly joined to the CQoS domain provided that they are joined through intermediaries (i.e., Quality-of-service Boundary Points (QBPs) - described in section 9.1.2.1) that prevent degradation to the CQoS-Domain operation. It is expected that these intermediaries will ensure reliable delivery of data services beyond the CQoS domain to non-compliant devices, although this document does not specify how this is accomplished.

9.1 CQoS Domain and Elements

A brief overview and then detailed description of the CQoS Domain and Elements is presented in this clause.

9.1.1 Logical Domain and Elements Overview

The CableHome QoS Architecture in this technical report is composed of three logical entities:

- CQoS-Domain
- QGW logical element
- QBP logical element

The CQoS-Domain defines the boundary of the sphere of direct influence where CableHome QoS functionality is extended into the home. The QGW and QBP are the building blocks of the CQoS architecture and are shown in Figure 24. QGWs are wholly within the CQoS-Domain and are specified. QBPs are the boundary elements between the CQoS-Domain and the non-CQoS-Domain.

In addition to these three entities that compromise the CQoS architecture, EPs are wholly outside the CQoS Domain and are not specified, however the CQoS domain exists to provide services to EPs.

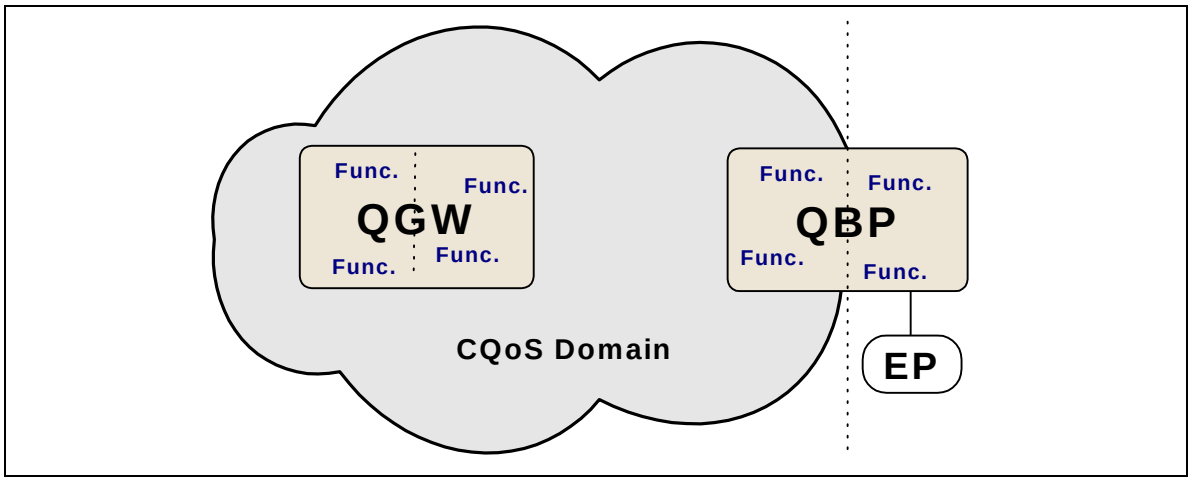


Figure 24. CQoS Architecture Logical Domain and Elements

9.1.2 Logical Domain and Elements Description

The characteristics of each of the CQoS entities are described in more detail.

9.1.2.1 QBP Logical Element – Quality of Service Boundary Point:

A CableHome Quality of Service Boundary Point (QBP) is the logical element that indicates the beginning and end of CQoS flows. A QBP has the following characteristics:

1. A QBP receives or sends CQoS signaling information and content (payload) using a defined QoS signaling method in the CQoS network segment. The specific CQoS signaling protocol is defined in the CQoS [7] specification.
2. A QBP provides admission control functionality to the CQoS domain based on the network segment's ability to support requested QoS levels. The specific admission control functionality is described in the CQoS [7] specification.
3. A QBP must be capable of being a client of a defined network segment QoS manager scheme and able to synchronize the bandwidth management activities of other QGWs or QBPs that may exist in the CableHome network. The specific QoS network segment manager scheme is described in the CQoS [7] specification.
4. The relationship between Endpoints (EP) and QBP can be one of three types:
    1. Embedded in the QBP
    2. Directly connected to the QBP
    3. Connected with non-CableHome-compliant network via proxy.

5. If a QBP provides proxy services, it must guarantee that CQoS parameters are maintained in the CQoS-Domain regardless of the activity on the non-CQoS interfaces to the EP. It is expected that the QBP will ensure reliable delivery of data services beyond the CQoS domain to the EP(s), although it is not specified how this is done and is therefore not guaranteed.

If the CQoS interface of the QBP embeds a DOCSIS interface, the entity is referred to as a DQBP.

QBP operation is described in the CQoS specification [7].

9.1.2.2 QGW Logical Element – Quality-of-Service Gateway:

A QGW receives and forwards CQoS signaling information and content (payload) between CQoS network segments using a defined QoS signaling method. A QGW has the following characteristics:

1. Provides admission control functionality based on the CQoS network segment's ability to support requested QoS levels.
2. The QGW interfaces must be capable of being both a client and master in a defined QoS network segment manager scheme and able to synchronize the bandwidth management activities of other QGWs or QBPs that may exist on the network. The specific QoS network segment manager scheme is defined in the CQoS [7] specification.
3. The defined QoS network segment manager scheme in the QGW handles data packet priority mapping between network segment's lower layer QoS mechanisms using the CQoS signaling information. The specific mapping is defined in the CQoS [7].

If one of the CQoS interfaces of the QGW embeds a DOCSIS interface, the entity is referred to as a DQGW.

QGW operation is described in detail in the CQoS [7] specifcation

9.1.2.3 CQoS Domain

The CQoS Domain is the sphere of influence for CableHome Quality of Service controllability emanating from the HFC network into the home. The CQoS Domain exists on a per-home basis. Individual homes are separate and have independent CQoS Domains. The QBPs bound the CQoS Domain in the home. The HFC cable access for a given home is also in the CQoS Domain for that home. Many topologies of the CQoS architecture are possible. Figure 25 and Figure 26 illustrate some of the possible connections of QGWs and QBPs to form a CQoS Domain.

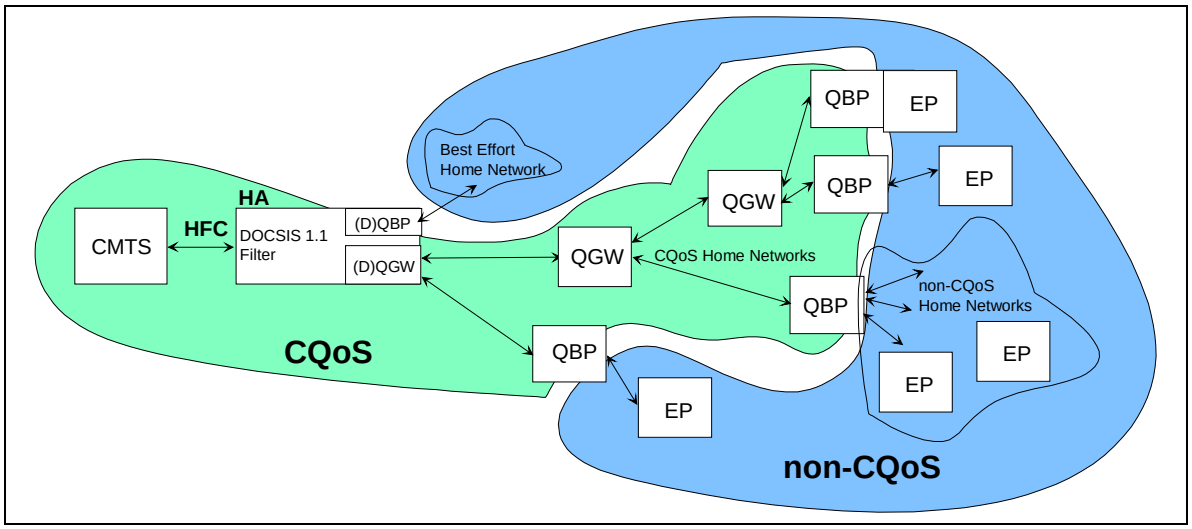


Figure 25. Example 1 Home Network Topology including QoS

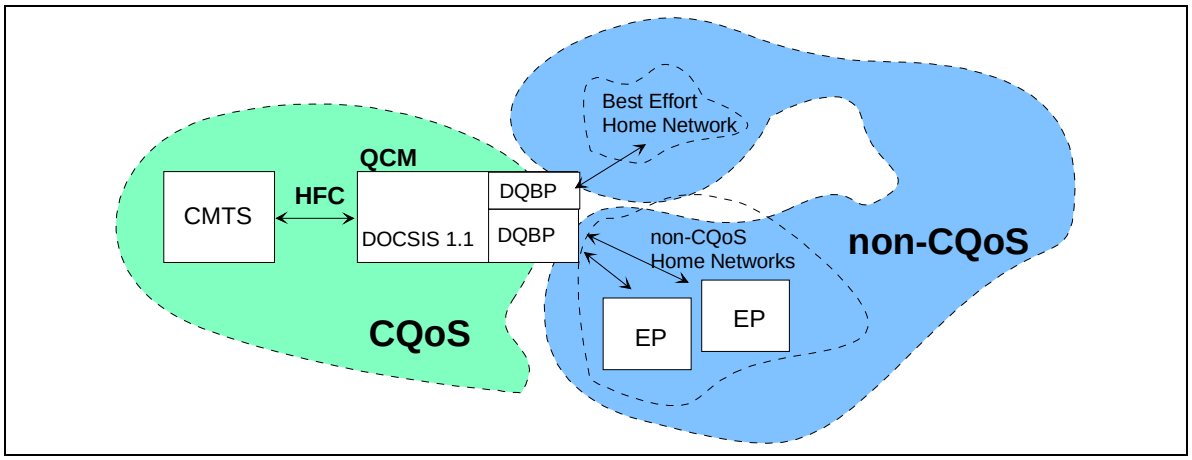


Figure 26. Example 2 Home Network Topology including QoS

9.1.3 Endpoint

Although an Endpoint (EP) is defined in section 2, the following characteristics are applicable to EP with respect to CQoS:

1. An EP is an entity in the home that sources or sinks data content that may require QoS support.
2. An EP is not within the CQoS domain although it may explicitly or implicitly request a QBP to provide services with specific quality characteristics. The mechanisms by which an EP interacts with a QBP are not specified by CableHome and is left to the product manufacturer.

9.2 CQoS Device Classes composed of Logical Elements

Each device in a CableHome network is composed of one or more logical elements. Three types of CQoS devices classes are shown in Figure 27 and defined:

- QA device – a cable network access device that includes an embedded DOCSIS interface with either a QGW, QBP, both, or multiple instances of each.
- QB device - a home network extension device that extends the CableHome QoS domain between multiple networks within the home. A QB device must contain a QGW and may contain a QBP. More than one QB device may be present within a CQoS Domain.
- QC device – a home network termination device that terminates the CableHome QoS domain. A QC device must contain at least one QBP. More than one QC device may be present within a CQoS Domain.

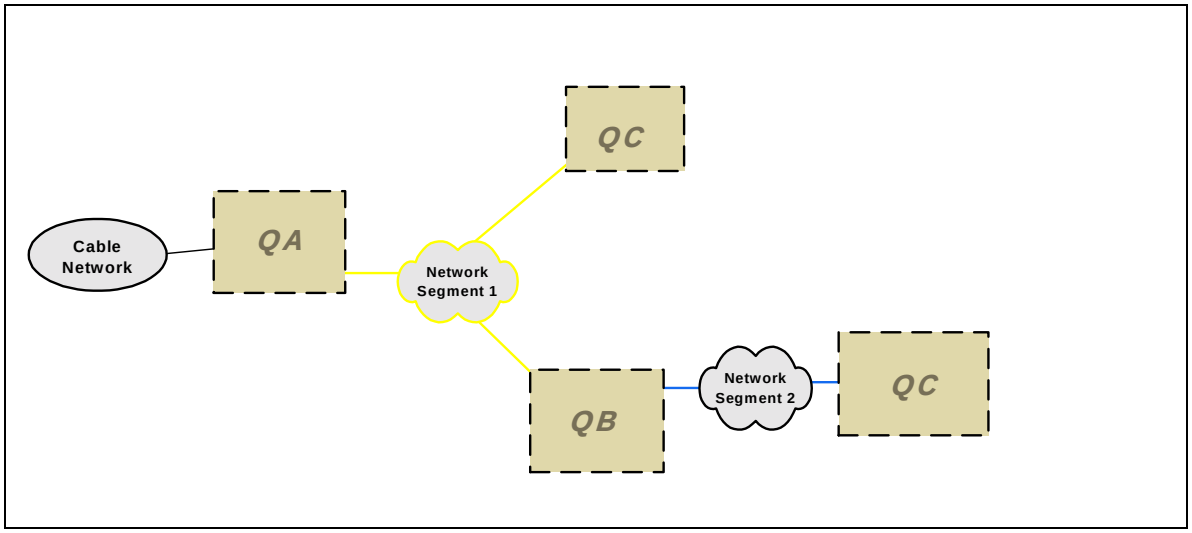


Figure 27. CQoS Device Classes

Note: a device that solely includes a DOCSIS interface and consumes the bandwidth (similar to a HC device) does not really involve a home *network* so it is not specifically considered in this document. A PacketCable 1.0 Embedded-MTA is such a device. A PacketCable 1.0 Embedded MTA can be included within a QA.

9.3 CQoS to CableHome Mappings

This section identifies the mappings between the CQoS components (logical elements and device classes) to the CableHome elements.

In the CableHome architecture, various "x-Domains" bound the sphere of influence that is directly observable, manageable, and certifiable by Cable operators. For Quality of Service aspects, the CableHome architecture introduces the CQoS-Domain. The Mapping between the CQoS elements and the HA, HB, & HC device is shown in Figure 28.

- A QA is the CQoS instantiation of a HA device.
- A QB is the CQoS instantiation of a HB device.

- A QC is the CQoS instantiation of a HC device.

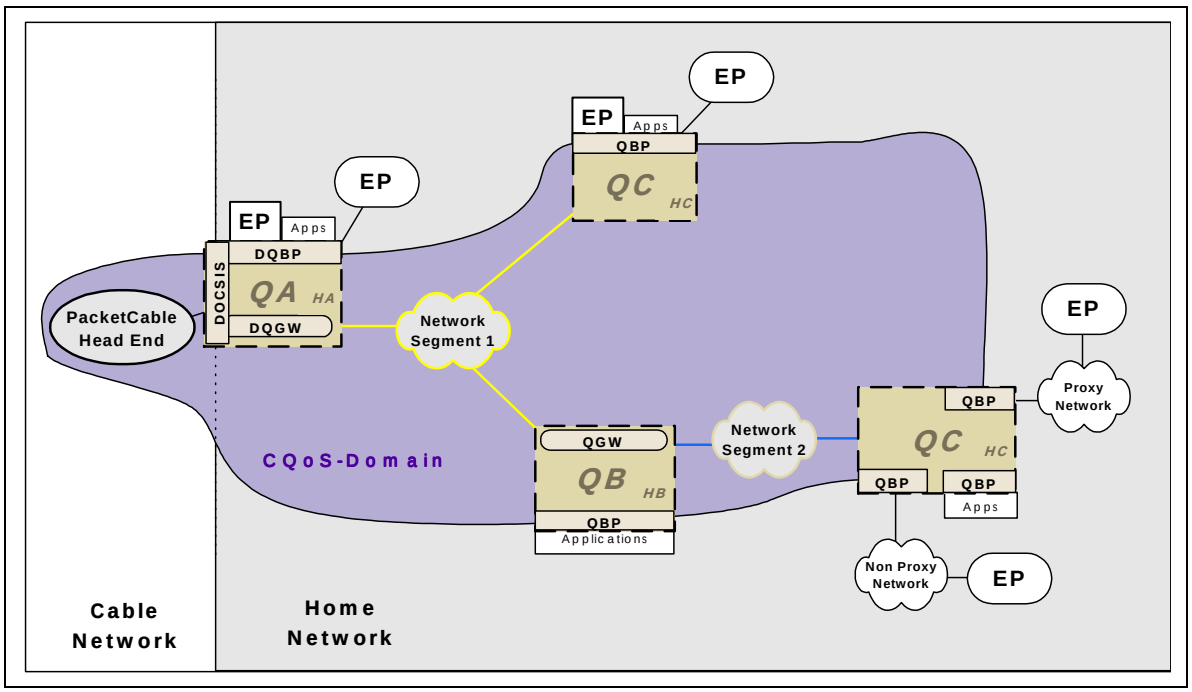


Figure 28. CQoS mapping to CableHome-Domain

9.4 Non-CQoS Devices

These three frames in Figure 29 show what happens when one attempts to plug a non-CQoS device into a CQoS network. In the second frame, the CQoS-Domain collapses since the non-CQoS device is unable to conform to CableHome QoS control. Although CQoS mechanisms may still continue to function, QoS guarantees (i.e. reservations) may not be able to be maintained. To reinstate the CQoS-Domain, a QBP (BP) adapter must be used.

Methods of detection of insertion of a non-CableHome element into a CQoS Domain or detection of a CQoS-Domain collapse are not currently specified. Methods of prevention of insertion of non-CableHome home elements into a CQoS Domain are also not currently specified. Management capabilities may allow an MSO to detect the occurrence of a non-CQoS element.

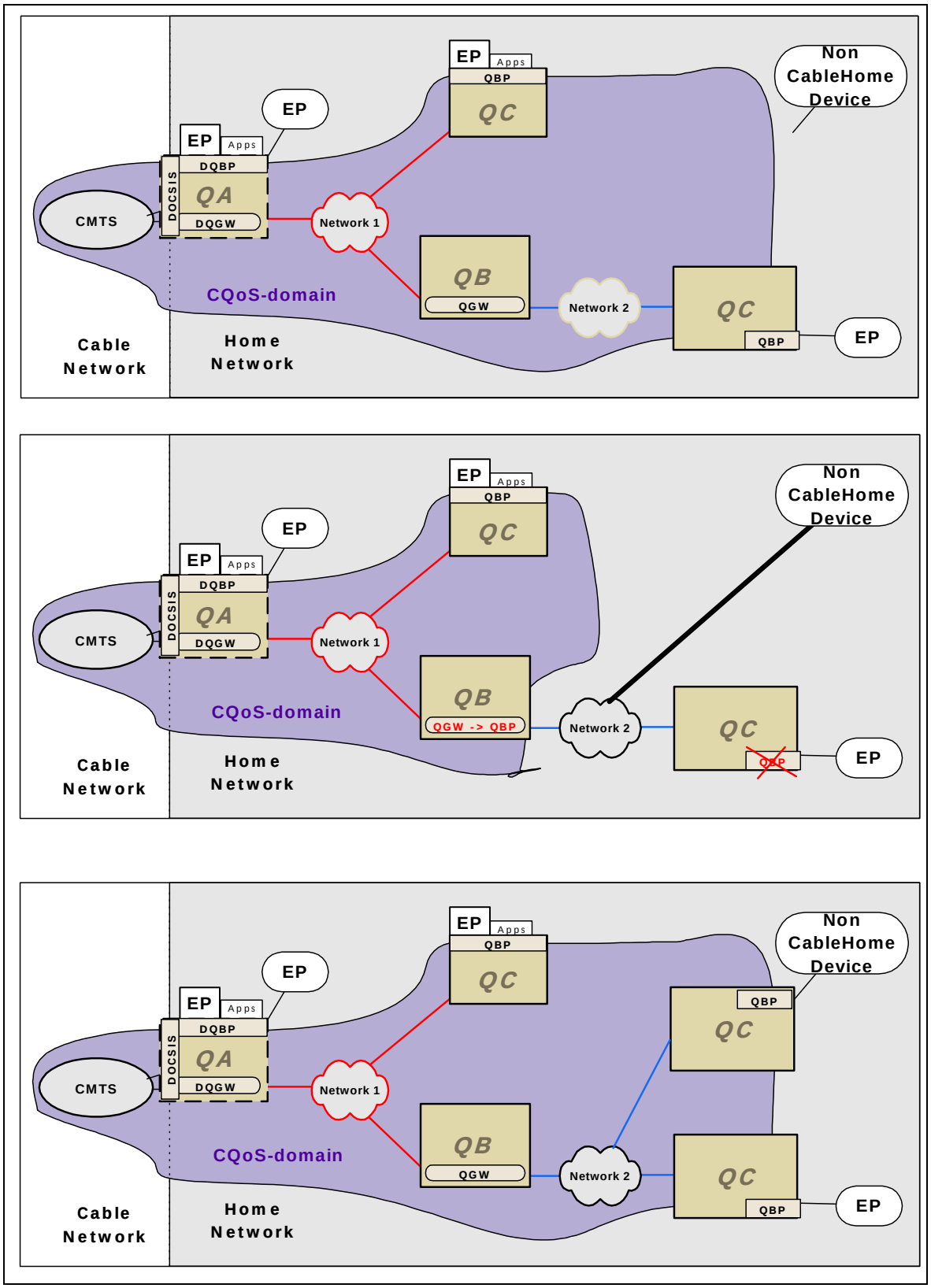


Figure 29. Connecting a non-CQoS device

10 NETWORK ADDRESS MANAGEMENT

To date, CableHome network address management requirements have not been fully developed. As such, this section only provides an informative overview of the network address management issues that are currently under consideration. Two types of issues are being examined: the assignment of IP network addresses and the handling of IP addressed packets. These and other issues must be resolved in order to fully enable the delivery of cable-based services to devices in the home.

10.1 Address Assignment

Each CableHome-compliant BP and GW logical element must be associated with at least one IP address in order for the cable network operator to configure, manage, and monitor these elements. Address assignment requirements are likely to surface that will necessitate the need to consider a number of complications. The uncertainty of the state of connectivity to primary address assignment services may be problematic. In addition, addressing schemes which lead to multiple logical sub-nets on the same physical network must be taken into consideration. This situation will arise during the delivery of PacketCable services, and may also arise as a result of a subscriber's choice of multiple Internet Service Providers (ISPs).

10.1.1 Network Address Translation (NAT)

The existence of NAT functionality within the home may prove particularly problematic during the delivery of advanced cable services to the home. Although the CableHome architecture does not preclude the existence of NAT applications, full access to advanced cable-based services cannot be guaranteed beyond a NAT function. The insertion of NAT functionality into a CableHome network may collapse the CableHome domain to the exclusion of previously compliant devices beyond the NAT. The cable network may not be made aware of devices provisioned behind NAT functionality and such devices may not be manageable by cable operators. In these cases it may not be possible to establish quality of service levels, and network monitoring and trouble shooting may become impossible. It should be noted that CableHome devices located upstream of NAT functionality remain within the CableHome domain, and are fully capable of delivering CableHome service.

The development of cable friendly extensions to NAT could fully enable advanced cable services and is currently under consideration within the CableHome project.

10.2 Addressing of Non-Compliant Devices

A BP requires an IP address to enable its configuration, management, and monitoring. Additional IP addresses may be acquired by a BP in order to expose EPs. A BP may connect any number of EPs to a CableHome network by providing proxy or translation capabilities for these non-compliant devices. Essentially, a single BP may expose potentially numerous EPs via a standardized interface. The addressing

schemes that enable a BP to perform such duties are not straight forward, and are under investigation.

10.3 Packet Handling

The handling of IP datagrams includes packet forwarding and filtering services that may be provided through GWs and BPs. IP packet handling may also involve inspection and selective forwarding services provided by commonly deployed networking functions. Packet handling requirements are likely to surface that will necessitate the need to consider a number complications. PacketCable services and multiple ISP provisioning can lead to multiple logical sub-nets on the same physical network; this gives rise to a number packet handling challenges (for example the containment of in home traffic). Packet handling may also present issues of providing continuity of data transport service across functions that translate between different address domains (NATs).

11 SECURITY

To date, CableHome security requirements have not been fully developed. As such, this section provides an informative overview of the security threats and basic security tools that will be considered for detailed specification during ongoing CableHome specification efforts.

11.1 Threat Analysis

The following sections describe possible threats to CableHome security.

11.1.1 Confidentiality of Information and Leakage Outside of the Home (Wireless or Wire-line)

A device in the CableHome network that uses wireless technology, power-line technology or connects to a home wiring infrastructure that is not completely isolated from the outside world may leak data that can be received by a third party outside of the home.

11.1.2 Theft of Service from the User by a Third Party

A device outside of the home may gain access to the CableHome network and steal services, and the homeowner would be charged for them. The theft of service may be deliberate or non-intentional (e.g. two adjacent apartments that use the same home networking technology).

11.1.3 Service Denial Attacks on the Home Network or the HFC Network

A third party may inject transmissions that cause disturbance in the service to the home or even failure to the entire MSO network. An example of this would be repeated requests for bandwidth allocation on the home network through the DOCSIS gateway. The CableHome logical elements may interface to the DOCSIS MAC layer reservation mechanisms and as such opens it for possible attacks that need to be addressed.

11.1.4 Security of the Information End-to-End

The issue of end-to-end security may not be completely addressed by the CableHome specification, as devices in the home network may communicate with devices that reside outside of the MSO control. As such, there is no general way to enforce security to them. CableHome envisions providing security services without causing disturbance to the home network, while maintaining the confidentiality and security mechanisms defined by DOCSIS & PacketCable.

11.2 Traffic Types

The CableHome specifications support multiple types of traffic that may be passing inside the home. Different types of traffic must be handled in different ways in order to provide security while at the same time maintaining proper network functioning and backward compatibility.

The following section provides an overview of the different traffic types and the different security interfaces that may be used to secure them.

11.2.1 PacketCable traffic

The security for PacketCable services delivered over CableHome networks will rely on the extension of the security interface defined by the PacketCable specification.

The current PacketCable 1.0 specification provides for end–to-end security for media streams and the PacketCable signaling protocol. There is no change required to the PacketCable specification in order to support security on the home network.

The tools used to secure PacketCable transmissions are IP based (IPSEC and RC4 RTP encryption) and as such can be supported by a CableHome network that uses the IP protocol.

The intention of the CableHome network specifications is to provide continuous support of new PacketCable specifications as they emerge, including new security services that are defined.

11.2.2 Data traffic

Data traffic includes all traffic that is not covered by the PacketCable specification and is not part of the control protocols of the CableHome network (e.g., RSVP, SNMP etc.).

There are two basic scenarios for data traffic routes:

1. Data passing between devices in the home
2. Data passing between a device in the home and a device that resides outside of the house. The route in this second scenario is divided in to three segments:
    - From the compliant source device (BP) inside the home to the access point (HA)
    - From the access point HA to the target access point (i.e., another CM or the MSO edge router)
    - From the target access point to the target itself.

The security of the traffic traveling inside the home for both scenarios is under consideration. The second segment of scenario two (i.e., the HFC network) is protected by the DOCSIS BPI+ specification.

If the target for the data is in another home connected to the same HFC plant, then by securing CableHome complaint portions within the home as well as the HFC, we can accomplish full security across the CableHome network.

For the case where the end device does not reside in a home connected to the HFC plant, and thus is outside the control of the MSO, CableHome may provide a set of recommended tools to enable full end-to-end security.

11.2.3 Control Traffic

CableHome provides control protocols that support QoS, management and provisioning services. Some of these protocols require different security interfaces to support their functionality. CableHome envisions providing the security interfaces for these protocols as well as for key distribution and authentication.

11.3 Security Solutions Scope and Coverage

The CableHome specification envisions describing tools and protocols for devices that reside inside the M-domain. This includes all devices that are part of the network in the home, the HFC network and any devices in other homes that are connected to the HFC network. The CableHome specifications may detail a set of optional tools be used to extend the security to devices that reside outside of the M-domain.

The CableHome security specification will use, to the extent possible, concepts and protocols that have already been defined and developed for the DOCSIS and PacketCable specifications.

12 OPEN ISSUES AND FUTURE CONSIDERATIONS

In the process of compiling this CableHome Architecture Technical Report, a number of issues to be examined were raised. The majority of these issues were either completely addressed in the prior sections of this Technical Report, or were deferred to the focus teams due to their low-level and/or detailed nature. In either case, they no longer appear as items in this section, although a record of them is kept in a separate historical issue-tracking document.

Other issues that have not yet been completely addressed remain present in this section, and fall into one of two categories:

1. ***Open Issues:*** These are items that could potentially be addressed by this technical report and by CableHome project specification teams, pending further detailed review and analysis by the specification teams and cable operators. In many cases it will be reasonable to defer particular open issues to the CableHome specification teams.

2. ***Future Considerations:*** These are issues that cable operators and CableHome focus teams have determined are associated with advanced, forward-looking capabilities that are beyond the scope of current CableHome requirements. They may or may not be addressed in a future version of this Technical Report and by future CableHome project specifications.

The open issues and future considerations are described in the subsections below, with many of them including details and a lengthy preliminary analysis. Reviewers of this document are encouraged to further define and comment upon these open issues.

12.1 Open Issues

12.1.1 Security

The current CableHome Architecture Technical Report currently addresses security in general terms. A more comprehensive treatment of CableHome security requirements and architectural implications may be appropriate.

12.1.2 Home Network Loops

How do we handle multiple HA devices within the same home?

Commentary: DOCSIS states that cable modems intended for commercial usage MUST support the 802.1d spanning tree protocol. How does this affect us?

Preliminary/partial resolution: CableHome will not disallow network loops, but we will instead rely upon routing functionality to solve the problems associate with loops. It is resolved from our point of view, but we need to drive the DOCSIS team to take ownership of this issue.

12.1.3 Inbound Connections

Today, cable modem service provides general purpose Internet access that includes support for arbitrary inbound connections to the home. The CableHome architecture must preserve support for inbound connections, as there are many compelling applications (e.g., nanny-cam, access to home files from work, etc.) that we need to remain competitive.

Certainly, globally unique IP addresses (managed by the cable network) present no barriers for inbound connections. If a Network Address Translation (NAT) function is present either in the cable network or the home, there must be some mechanism available to map inbound connections to the appropriate machines. CableHome is currently considering the proposal that Realm-Specific IP (RSIP), defined by the IETF, be required for CableHome™ compliant NAT devices (CNAT), as well as for any operator headend NAT (HNAT).

12.1.4 Gateway-centricity vs. Distributed Intelligence

In considering the possibility of a residential gateway-centric CableHome network design, a number of advantages to such an approach have been identified:

1. ***Smaller overall product cost***: The cost of the network is smaller if concentrated in the gateway. Alternatively, if each device in the home network is required to have a large management stack (resembling that of a DOCSIS cable modem), then each device instance will incur additional costs for hardware (more flash and RAM, sophisticated processor) and software (IP stack, operating system license, etc).

2. ***Fewer points of contact for the cable operator***. If the management of the network is concentrated into the gateway, the cable operator will not have to generate as many transactions when managing home networks.

3. ***More compatible with current implementations***: Many home networking devices already being shipped will typically not have headroom available to accommodate a huge incremental management plane. If we deliver a "fat client" solution, the industry will balk at it. Those that do decide to conform will have to re-architecture their hardware/software.

4. ***Easier visibility of legacy devices***: We have previously concluded that many legacy devices (non-CableHome-compliant) will exist, where the ability to detect their presence is desirable. If a CNAT exists in the home, a gateway centric model facilitates the propagation of this information to the cable operator.

5. ***Consistent with queuing of management events***: In the event that the network is down, a gateway centric approach is more consistent with the ***option*** for the home network to queue management events for both legacy and CableHome devices.

12.1.5 Fault tolerance

It may be within CableHome scope to assess the most likely points of failure within the CableHome network, and to consider specifying fault tolerant mechanisms for these higher risk failure points.

12.1.6 Dynamic Bandwidth

Will CableHome support general-purpose dynamic bandwidth allocation for endpoints in the home for apps such as telephony, perhaps gaming, and other pay-per-use services, etc? If so, what is the end-to-end impact (including HA device, access network, backbone, billing server, headend policy, etc.)? How do tier levels fit it?

12.1.7 Multi-ISP Home/WAN Interfaces

In a multi-ISP "open access" environment, how is an IP interface acquired/exposed to both the in-home LAN and the WAN for management/provisioning of HA/HB devices? This is a low-level issue that may soon be deferred to the Network Address Management focus team.

12.1.8 Compliant Device Modification

If a compliant device in the CQoS domain suddenly adds some "foreign" functionality via end-user installation of a product or software module (e.g., an IPX or NetBEUI transport, or ???), what happens? How do we detect and diagnose this condition? What effect does this have on certification?

12.1.9 IP Version 6 Support

The CableHome team plans to study the implications of Ipv6 upon the CableHome specification suite.

12.1.10 Lost Connectivity

This issue relates to the implications of lost cable network connectivity on the in-home network. Of concern is the proper functioning of traffic inside the home network after connection loss, and re-establishing coherency/state with the headend once the connection is restored.

12.2 Future Considerations

12.2.1 IP address management

There are 3 relevant modes of operation for IP address management in the home:

1. **In-home managed IP addresses (*i.e.*, CNAT or LNAT)**. In this case, the management of IP addresses within the home behind this type of device is not impacted by lost connectivity to the cable network – no problems here…

2. **Cable network-managed discontiguous IP addresses**. Here the subscriber accesses multiple ISPs within the same household, where the globally unique IP address of each client is associated with a particular ISP's subnet. If the headend DHCP server becomes inaccessible, hosts that are new, renewing, or rebooted would perform auto-IP thus acquiring a private IP address, potentially resulting in malfunctioning home applications and services during associated lease transitions. It has been suggested that a local DHCP server could lessen outage durations, but this notion has not yet been fully explored.

3. **Cable network managed IP addresses using headend NAT**. Here, inaccessible headend DHCP servers would cause similar difficulties. However, there is the *potential* for improvements if the MSO is able to allocate a sufficiently huge IP address pool to a DHCP server in the home network to satisfy any needs that should arise if/when the headed server becomes inaccessible. The problem is that new methods will be required to manage pools of addresses and their parameters, and to re-establish coherency with the headend NAT function upon return of network connectivity.

12.2.2 Management/Provisioning Events

If the cable network connection is interrupted, it is desirable to update the cable operator with any change in state of the home network during the outage. The most desirable changes in state to recognize are:

1. Fault detection/reporting

2. New device instances

Some function (e.g., the gateway) in the home could queue new device instances and/or faults for the headend to be processed upon return of cable network connectivity. Should the queuing of these events be required of the home network?

12.2.3 Convergence of Video, Voice and Data

CableLabs DOCSIS specification had been targeted to provide high speed IP data services to the home. PacketCable 1.0 specification has expended this to the delivery of Voice over IP and future generations of PacketCable are expected to extend that to cover Video over IP services. The CableHome specification extends the services of both DOCSIS and PacketCable to the distribution system in the home. Since both these services are IP based, and since CableHome is defining a mechanism for enabling a reliable delivery of both services, then there is no real problem for an Endpoint in the home to consume IP based data, voice, audio, and video services. Timing synchronization between these services may be required in some cases, but this subject is not covered as part of this specification and may be addressed separately by PacketCable future specifications.

Another important source of both data and mainly video and voice is broadcast transmission. CableLabs OpenCable™ specification is addressing the issue of digital broadcast services, and it uses MPEG-TS encapsulation as well as MPEG-2 video compression and AC-3 audio. The current specification of OpenCable addresses partially the issue of distribution of digital broadcast content. The chosen interface for that is IEEE-1394 (using the synchronous mode). This interface is defined in order to provide connectivity to HD decoders/displays and is not really intended to provide a full solution for home connectivity.

A specification to describe a bi-directional conversion from/ the defined OpenCable IEEE-1394 and MPEG-TS interface to a general IP transport mechanism may provide an efficient tool to enable true convergence of these sort of services, and ability to use the same infrastructure and mechanisms to distribute them. This sort of convergence layer may be part of the scope of the CableHome, OpenCable or PacketCable specifications.

12.2.4 Headend NAT Configuration (per client instance)

Current consumer NAT-based gateway products provide a means for the end-user configuration to meet the needs of their multiple applications and services. Some examples of this include the mapping of inbound port connections to a particular device (web camera, etc.).

Will we provide mechanisms for configuration and management of headend NAT by clients in the home? Is this even necessary if RSIP is implemented?

12.2.5 Gateway Selection

In an environment with multiple HA devices or with gateways to more than one access technology, what is our strategy in locating the “correct” gateway to provide a particular service of interest?

Appendix A. Acknowledgements

This technical report was developed and influenced by numerous individuals representing many different organizations. CableHome hereby wishes to thank everybody who participated directly or indirectly in this effort. In particular, CableHome wishes to recognize the following individuals for their significant involvement and contributions to this technical report:

Michael Mannette	3Com
Stephen Palm	Broadcom
Terry Wright	Broadband Home
Stuart Hoggan	CableLabs
Kevin Luehrs	CableLabs
Steven Saunders	CableLabs
Stephen Wasson	Conexant
Russ Croucher	Ericsson
Frank Koperda	HighSpeed Surfing
Chuck Brabenac	Intel
Ben Lubetsky	Navic Systems
Martin Freeman	Philips Digital Video
Leigh Chinitz	Proxim
Greg Parks	ShareWave
Itay Sherman	Texas Instruments