Superseded

Data-Over-Cable Service Interface Specifications

Cable Modem to Customer Premise Equipment Interface Specification

SP-CMCI-I02-980317

INTERIM

Document Status Sheet

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Key to Document Status Codes

Work in Process 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 MCNS and vendors. Drafts are susceptible to substantial change during the review process.

Interim A document which has undergone rigorous MCNS and vendor review, suitable for use by vendors to design in conformance with, and suitable for field testing.

Released A stable document, reviewed, tested and validated, suitable to enable cross-vendor interoperability.

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Cable Modem to Customer Premise Equipment Interface Specification

1 Scope and Purpose

1.1 Scope

This interface specification is one of a family of interface specifications designed to facilitate the implementation of data services over Hybrid Fiber Coax (HFC) cable networks, as well as over coaxial-only cable networks. Figure 1-1, on the following page, provides the context for this specification in relation to the data over cable reference architecture and the other interface specifications in the family. This specification defines the interface requirements for data over cable services between a cable modem and the customer premise equipment (CPE). The CPE may include PCs, Macintoshes, workstations, network computers, and other electronic equipment. This specification defines the applicable communications standards and protocols as needed to implement a cable modem interface to the CPE. It applies to cable systems employing HFC and coaxial architectures. Specifically, the scope of this specification is to:

- Describe the communications protocols and standards to be employed
- Specify the data communication requirements and parameters that will be common to all units
- Describe any additional application-unique interface requirements to ensure support for data over cable services

The intent of this document is to specify open protocols, with a preference for existing, well-known and well-accepted standards. This interface specification is written to provide the minimal set of requirements for satisfactory communication between the cable modem and CPE.

“Cable Modem to CPE Interface” (CMCI) shall be the general term used to describe this interface.

1.2 Requirements

Throughout this document, the words that are used to define the significance of particular requirements are capitalized. These words are:

"MUST"	This word or the adjective "REQUIRED" means that the item is an absolute requirement of this specification.
"MUST NOT"	This phrase means that the item is an absolute prohibition of this specification.
"SHOULD"	This word or the adjective "RECOMMENDED" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.
"SHOULD NOT"	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
"MAY"	This word or the adjective "OPTIONAL" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

Other text is descriptive or explanatory.

1.3 Background

1.3.1 Service Goals

Cable operators are interested in deploying high-speed data communications systems on cable television systems. Comcast Cable Communications, Inc., Cox Communications, Tele-Communications, Inc., Time Warner Cable, MediaOne, Inc., Rogers Cablesystems Limited, and Cable Television Laboratories, Inc. (on behalf of the CableLabs member companies), have decided to prepare a series of interface specifications that will permit the early definition, design, development and deployment of data-over-cable systems on an uniform, consistent, open, non-proprietary, multi-vendor interoperable basis.

The intended service will allow transparent bi-directional transfer of Internet Protocol (IP) traffic, between the cable system headend and customer locations, over an all-coaxial or hybrid-fiber/coax (HFC) cable network. This is shown in simplified form in Figure 1-1.

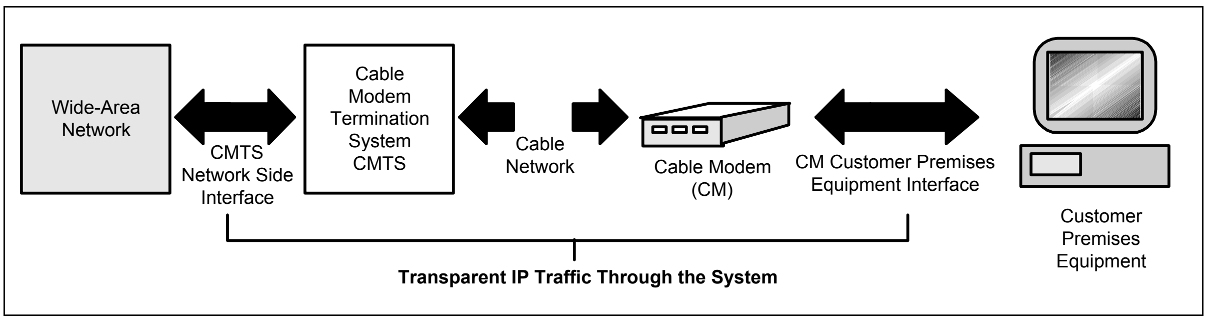

Figure 1-1 Transparent IP Traffic Through the Data-Over-Cable System

The transmission path over the cable system is realized at the headend by a Cable Modem Termination System (CMTS), and at each customer location by a Cable Modem (CM). At the headend (or hub), the interface to the data-over-cable system is called the Cable Modem Termination System - Network-Side Interface (CMTS-NSI) and is specified in [MCNS3]. At the customer locations, the interface is called the cable-modem-to-customer-premises-equipment interface (CMCI) and is specified in this document. Note, the CMCI interface can be either external or internal to the CPE; both types of interfaces are described in this document.

The intent is for the DOCSIS operators to transparently transfer IP traffic between these interfaces, including but not limited to datagrams, DHCP, ICMP, and IP Group addressing (broadcast and multicast).

1.3.2 Reference Architecture

The reference architecture for the data-over-cable services and interfaces is shown in Figure 1-2.

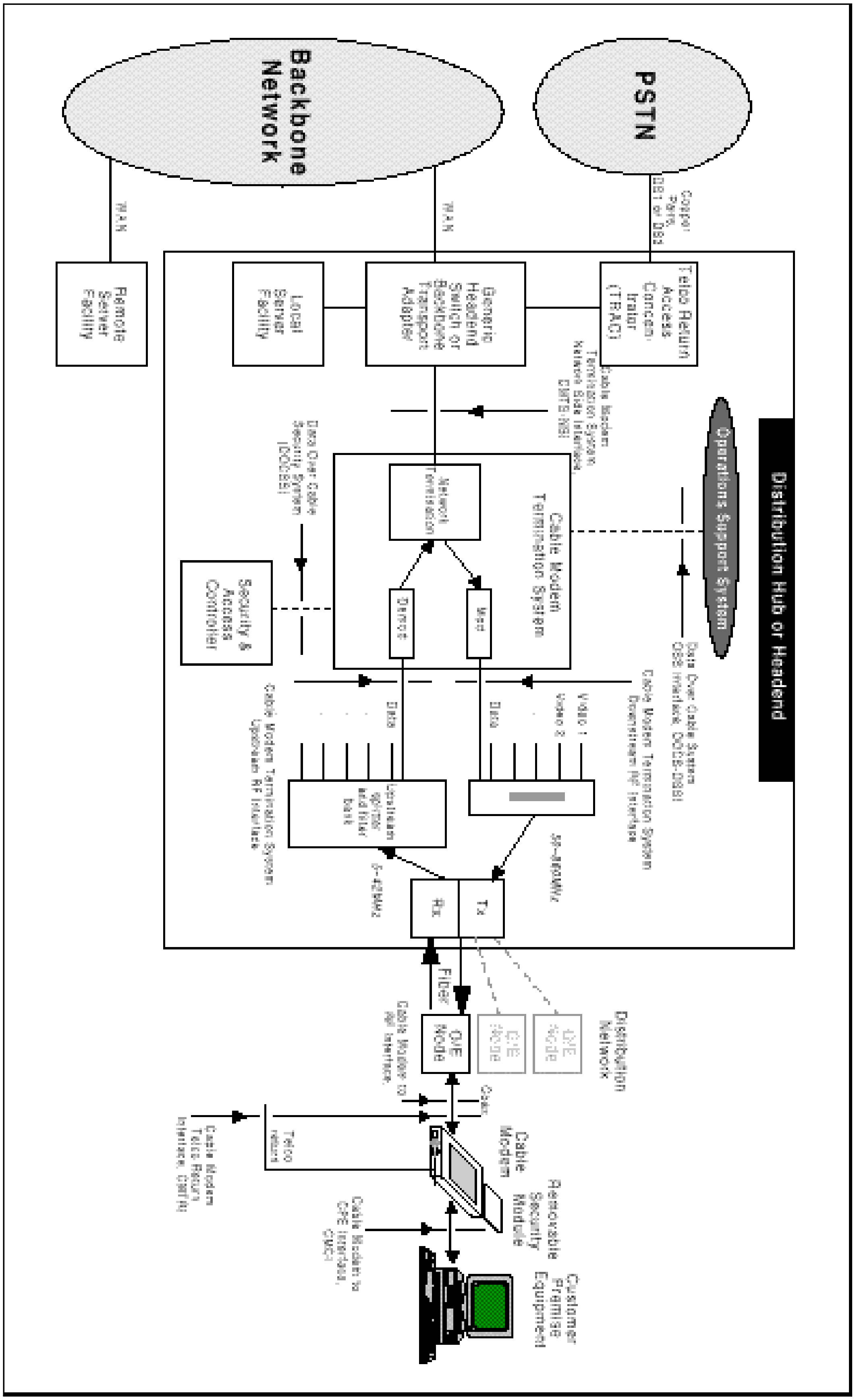

Figure 1-2 Data-Over-Cable Reference Architecture

1.3.2.1 Categories of Interface Specification

The basic reference architecture of Figure 1-2 involves three categories of interface. These are being developed in phases.

a. Phase 1

Data Interfaces - These are the CMCI [MCNS4] and CMTS-NSI [MCNS3], corresponding respectively to the cable-modem-to-customer-premises-equipment (CPE) interface (for example, between the customer's computer and the cable modem), and the cable modem termination system network-side interface between the cable modem termination system and the data network.

b. Phase 2

Operations Support Systems Interfaces - These are network element management layer interfaces between the network elements and the high-level OSSs (operations support systems) which support the basic business processes, and are documented in [MCNS5].

Telephone Return Interface - CMTRI - This is the interface between the cable modem and a telephone return path, for use in cases where the return path is not provided or not available via the cable network, and is documented in [MCNS6].

c. Phase 3

RF Interfaces - The following RF interfaces are defined:

- Between the cable modem and the cable network.
- Between the CMTS and the cable network, in the downstream direction (traffic toward the customer)
- Between the CMTS and the cable network, in the upstream direction (traffic from the customer).

Security requirements -

- The DOCSIS Security System Interface Specification (SSI) is defined in [MCNS2].
- The DOCSIS Removable Security Module Interface Specification (RSM) is defined in [MCNS7].
- The DOCSIS Baseline Privacy Interface Specification (BPI) is defined in [MCNS8].

1.3.2.2 Data-Over-Cable Interface Documents

A list of the documents in the Data-Over-Cable Interface Specifications family is provided in Table 1-1. For updates, please refer to URL http://www.cablemodem.com.

Designation	Title
SP-CMCI	Cable Modem to Customer Premises Equipment Interface Specification
SP-CMTS-NSI	Cable Modem Termination System Network Side Interface Specification
SP-CMTRI	Cable Modem Telephone Return Interface Specification
SP-OSSI	Operations Support System Interface Specification
SP-RFI	Radio Frequency Interface Specification
SP-SSI	Security System Interface Specification
SP-RSM	Removable Security Module Specification
SP-BPI	Baseline Privacy Interface Specification

Table 1-1 DOCSIS Specifications Family

Key to Designations:

SP Specification

TR Technical Report (provides a context for understanding and applying the specification—documents of this type may be issued in the future.)

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2 Functional Reference Model

2.1 External Cable Modem

The intended service will allow IP traffic to achieve transparent bi-directional transfer between the Cable Modem Termination System—Network Side Interface (CMTS-NSI) [MCNS3] and the Cable Modem to CPE Interface.

There are other functional requirements placed on the cable modem beyond transparency to IP traffic, including the following:

- The cable modem MUST be capable of filtering all broadcast traffic from the local LAN, with the exception of DHCP (as identified by the destination port number in the UDP header) and ARP packets. This filtering function should be SNMP configurable as described in the DOCSIS Radio Frequency Interface (RFI) specification [MCNS1].
- The ICMP protocol type MUST be passed upstream.
- Cable modems designed to support LAN segments containing other bridges SHOULD employ the Spanning Tree Algorithm and Protocol per ISO/IEC 10038 (ANSI/IEEE Std 802.1D): 1993, with modifications as described in the DOCSIS Radio Frequency Interface (RFI) specification [MCNS1].

2.1.1 Customer Equipment Assumptions

The following assumptions do not preclude other alternatives but illustrate the initial set of likely customer premise equipment.

Hardware Platform:	IBM/PC or compatible; Apple PC; DEC, HP, Sun, or other workstations; or network server
Operating System:	Windows 3.1 or higher, Windows ‘95, Windows NT, MAC System 7.0 or higher, OS/2 WARP 3.0 or higher, or other OS capable of supporting TCP/IP stacks with DHCP/BOOTP (e.g. UNIX)
CPE Interfaces:	– Ethernet 10BASE-T network interface (existing, otherwise to be purchased by customer or supplied by cable service provider) – Universal Serial Bus (USB)
Communications Software:	TCP/IP stack software capable of supporting DHCP/BOOTP, SNAP addressing, and multicast (existing, otherwise to be purchased by customer or supplied by cable service provider)

A cable modem vendor does not have to manufacture products that support all the hardware platforms or operating systems in the above list in order to be compliant.

2.1.2 CPE Configuration Assumptions

CPE consists of one or more devices with the cable modem connected either by an Ethernet LAN or over a Universal Serial Bus (USB) connection (e.g., one or more PCs, workstations, servers, printers, etc.).

2.2 Internal Cable Modem

The intended service will allow IP traffic to achieve transparent bi-directional transfer between the Cable Modem Termination System—Network Side Interface (CMTS-NSI) [MCNS3] and the Cable Modem to CPE Interface. This CM MUST be a single-user device as it is internal to the host CPE.

There are other functional requirements placed on the cable modem beyond transparency to IP traffic, including the following:

- The cable modem must be capable of filtering all broadcast traffic from the host CPE, with the exception of DHCP (as identified by the destination port number in the UDP header) and ARP packets. This filtering function should be SNMP configurable as described in the DOCSIS RFI specification [MCNS1].
- The ICMP protocol type must be passed upstream.
- Since this device is internal to the host CPE, it is assumed there will be no LAN connections. Specific data forwarding rules are described in the DOCSIS Radio Frequency Interface (RFI) specification [MCNS1].

2.2.1 Customer Equipment Assumptions

For both operational and security reasons, the internal interface to the host CPE will be specified.

Hardware Platform:	IBM/PC or compatible; Apple Power PC are defined at this time.
Operating System:	Windows 3.1 or higher, Windows ‘95, Windows NT, MAC System 7.0 or higher, OS/2 WARP 3.0 or higher.
CPE Interface:	Peripheral Component Interface (PCI) Card
Communications Software:	TCP/IP stack software capable of supporting DHCP/BOOTP, SNAP addressing, and multicast (existing, otherwise to be purchased by customer or supplied by cable service provider).

A cable modem vendor does not have to manufacture products that support all the hardware platforms or operating systems in the above list in order to be compliant.

2.2.2 CPE Configuration Assumptions

The CPE consists of one device (PC, workstation, server, etc.) that supports the PCI bus interface.

3 External CPE Interfaces

3.1 Ethernet

The Internet Protocol (IP) version 4 standard MUST be passed transparently through the CMCI. The CMCI MUST support both IEEE 802.3 and DIX Ethernet. The CMCI protocol stack and applicable specifications MUST comply with the summary provided in Figure 3-1 and Table 3-1, respectively.

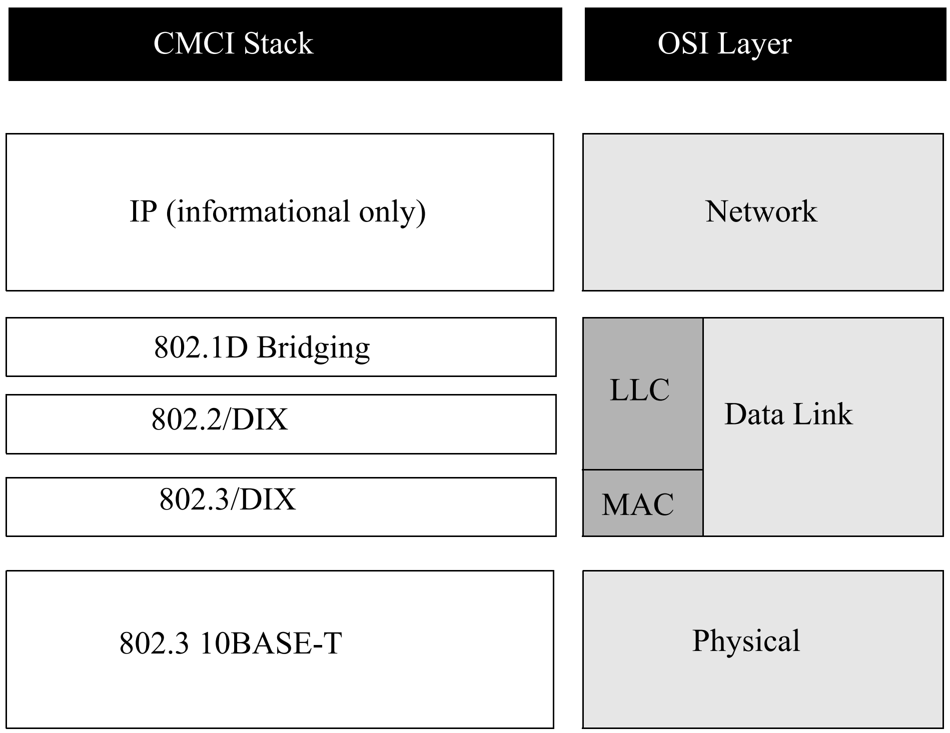

Figure 3-1 Ethernet Protocol Stack

Table 3-1 Ethernet Protocol Specification

Layer	Specification	Options/Features
Network	Internet Protocol (IP) (RFC 1042 & RFC 894, RFC 1883 - future use)	(For reference and information only)
Data Link (LLC)	ISO/IEC 10038 (ANSI/IEEE Std 802.1d): 1993 ISO/IEC 8802-2: 1994 and DIX Ethernet	Spanning Tree Algorithm and Protocol allowed but not required Class 1, Type 1 LLC/SNAP
Data Link (MAC)	ISO/IEC 8802-3: 1995 and DIX Ethernet	48 bit address
Physical	ISO/IEC 8802-3: 1995	10BASE-T / RJ-45

3.1.1 Network Layer

3.1.1.1 Internet Protocol (IP) (Informational)

Implementations of the CMCI MUST utilize the IP version 4 in accordance with IETF RFC 1042, “A Standard for the Transmission of IP Datagrams over IEEE 802 Networks” and RFC 894, “A Standard for the Transmission of IP Datagrams over Ethernet Networks.” This usage will evolve to support IP version 6 (IETF RFC 1883) as it becomes an accepted standard.

3.1.2 Data Link Layer

Data link interfaces MUST be compatible with IEEE 802.2/802.3 and DIX Ethernet v2.0 as defined in the following paragraphs.

3.1.2.1 Bridging

The cable modem MUST perform MAC bridging in accordance with ISO/IEC 10038 (ANSI/IEEE Std 802.1D): 1993. Implementation of the Spanning Tree Algorithm and Protocol is allowed but not required.

3.1.2.2 802.2 Logical Link Controller (LLC) Sublayer

The LLC sublayer interface MUST be in accordance with ISO/IEC 8802-2: 1994.

3.1.2.3 802.3 Medium Access Control (MAC) Sublayer

The MAC sublayer interface MUST be in accordance with ISO/IEC 8802-3: 1995.

3.1.2.4 Ethernet

The data link layer interface MUST be in accordance with Ethernet Version 2.0, 1982.

3.1.2.5 Address Length

A 48-bit address MUST be utilized for IEEE 802.3 and DIX Ethernet.

3.1.3 Physical (PHY) Layer

The physical layer interface MUST be in accordance with ISO/IEC 8802-3: 1995 for 10BASE-T operation, employing an RJ-45 connector with the crossover function embedded in the cable modem. Implementations which provide DTE/DCE autosensing will also be considered compliant.

3.2 Universal Serial Bus (USB)

3.2.1 Overview / goals

The Universal Serial Bus (USB) is a peripheral interconnect bus that is provided by many Customer Premises Equipment (CPE), particularly IBM/PC or compatible machines manufactured after December 1996. It delivers the following attributes of particular interest for cable modem peripheral equipment:

- An external CPE interface, where an end-user can easily plug in new peripherals without needing any specials tools or skills.
- Automatic device identification, configuration and mapping of device function to its software, further simplifying the installation process (“Plug and Play”)
- Transfer rates between the peripheral and the CPE up to several Mbits/sec.

USB creates the appearance of a private, point-to-point connection between its host (CPE) and devices attached to it over the USB. Unlike an Ethernet attached cable modem, a USB attached cable modem is, by definition, a single user device where only one CPE connects to it as its master. The result is that the cable modem conceptually resembles a simple Ethernet NIC that has been installed into a single CPE, where some complex functions (e.g., 802.1d bridging) are therefore not required in a USB cable modem.

Because the USB is NOT a network, but is truly a peripheral bus for attaching devices to a CPE, the specific details of how the USB is used and the format of messages between the CPE and the USB attached cable modem are NOT specified in this document. Instead this task is left up to cable modem vendors for optimizing the cost, performance, and functionality of their design to differentiate their product. Only functional requirements between the host CPE and the USB attached cable modem are defined in this specification. There is, however, an effort underway to define an industry approved reference driver for a DOCSIS USB attached CM that some MSOs may require as part of their purchase specifications. At such time as this reference driver specification is approved, it will be posted to the DOCSIS web site.

A vendor’s cable modem and associated CPE software MUST appear no different than an Ethernet attached cable modem, when viewed from its RF interface (CMRFI).

3.2.2 Signaling Stack Summary for USB CMCI

Both IEEE 802.3 and DIX Ethernet MAC layer frames MUST be passed transparently through the CMCI. The CMCI protocol stack and applicable specifications MUST comply with the summary provided in Figure 3-2 and Table 3-2, respectively.

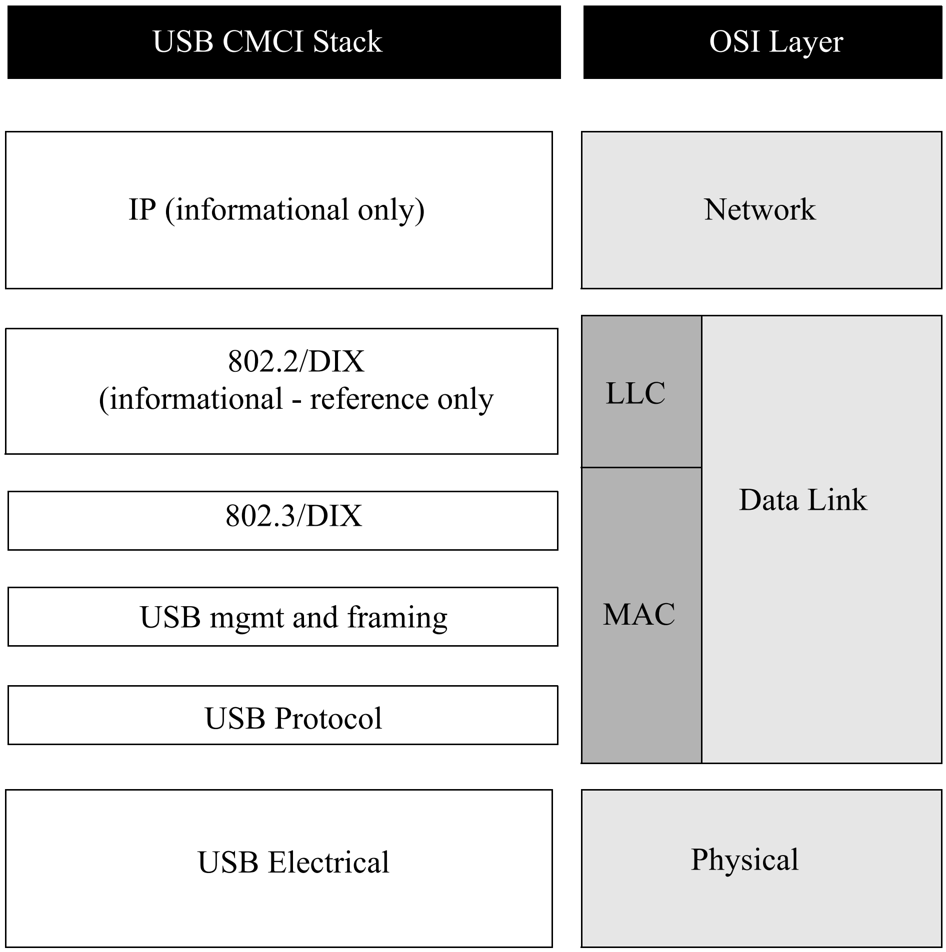

Figure 3-2 USB CMCI Protocol Stack

Table 3-2 USB Protocol Specification

Layer	Specification	Options/Features
Network	Internet Protocol (IP) (RFC 1042 & RFC 894, RFC 1883 - future use)	(For reference and information only)
Data Link (LLC)	ISO/IEC 8802-2: 1994 and DIX Ethernet	Class 1, Type 1 LLC/SNAP
Data Link (MAC)	ISO/IEC 8802-3: 1995 and DIX Ethernet	48 bit address
Data Link (USB mgmt and framing)	Defined by cable modem vendor	
Data Link (USB)	USB Revision 1.0, 1996	
Physical (USB)	USB Revision 1.0, 1996	Series A or Series B USB receptacle

3.2.3 End-to-end USB Cable Modem protocol stack

Figure 3-3 shows an end-to-end protocol stack (from CMTS to CPE), where a typical USB attached cable modem is involved. It should be used for additional perspective when reading descriptions of the USB CMCI signaling stack layers that follow. The USB cable modem, as shown in Figure 3-3, MUST have two 48-bit MAC addresses. The first 48 bit MAC address (herein referred to as the “Host CPE MAC address”) MUST be associated with forwarding frames to the host CPE through the 802.3/DIX Filter, where the host CPE perceives this MAC address as if this portion of the cable modem were a simple Ethernet NIC that is installed in the host. This is analogous to the “classic” Ethernet CMCI (see Figure 3.1), where this MAC address is in fact in a CPE Ethernet NIC card. The second 48-bit MAC address MUST be associated with the cable modem being an IP / LLC host for cable modem management functions. Future implementations may migrate the cable modem’s IP/ LLC host and cable modem management functions into the host CPE for the purpose of reducing equipment costs - this is for future study.

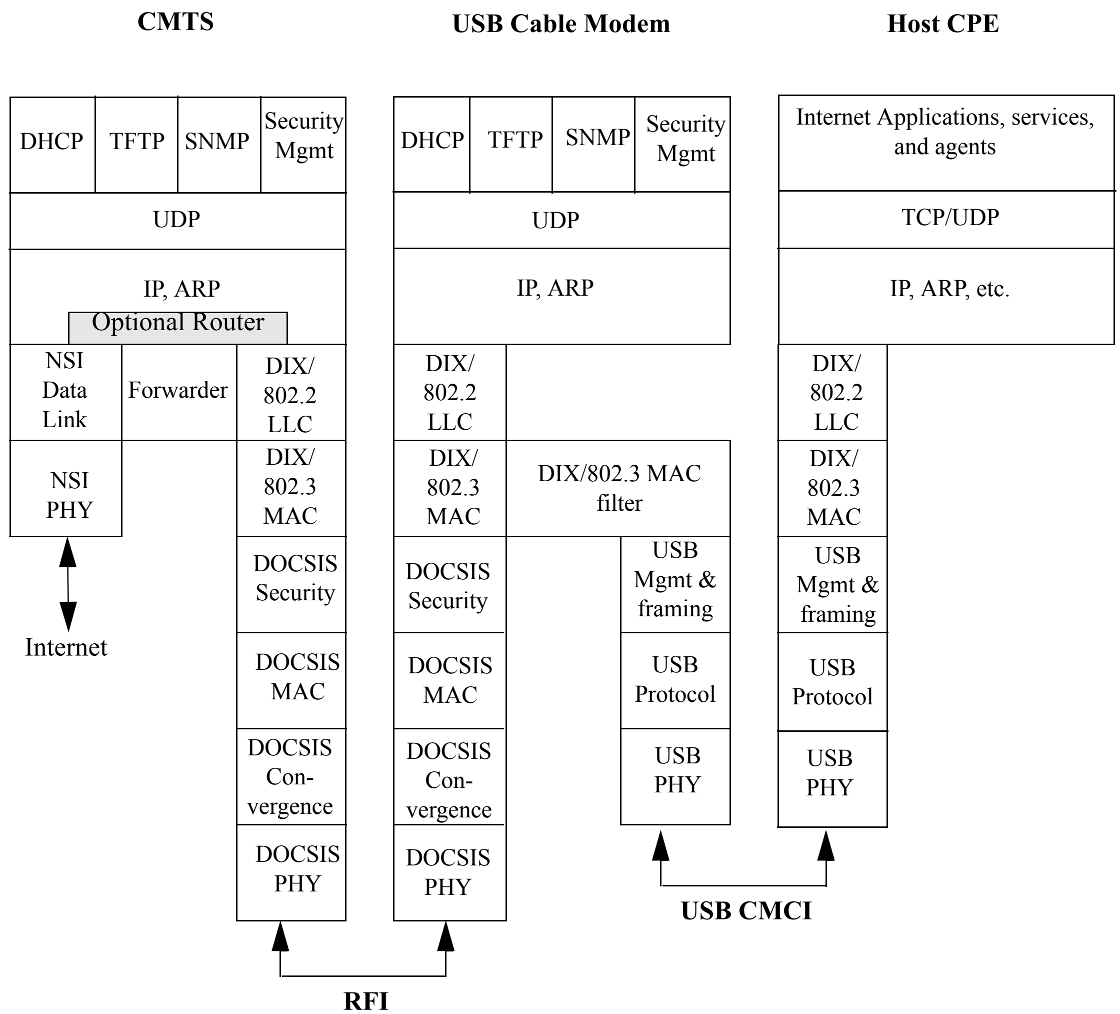

Figure 3-3 End-to-End USB Cable Modem Protocol Stack

3.2.4 Network Layer

3.2.4.1 Internet Protocol (IP)

Implementations of the USB CMCI MUST utilize IP version 4 datagrams in accordance with IETF RFC 1042, “A Standard for the Transmission of IP Datagrams over IEEE 802 Networks” and RFC 894, “A Standard for the Transmission of IP Datagrams over Ethernet Networks.” This usage will evolve to support IP version 6 (IETF RFC 1883) as it becomes an accepted standard. The USB attached cable modem is not expected to do any network layer processing of packets that are exchanged over the USB CMCI, but it MUST be able to pass them transparently.

3.2.5 Data Link Layer

The sub-layers within the USB CMCI data link layer are defined in the following sections.

3.2.5.1 802.2 Logical Link Controller (LLC) Sublayer

The LLC sublayer interface MUST be in accordance with ISO/IEC 8802-2: 1994. Note that the cable modem MUST NOT respond to [ISO8802-2] LLC host requests (TEST and XID) addressed to its Host CPE MAC address -- this is the responsibility of the host CPE. The cable modem MUST pass these frames transparently to the host CPE without responding to them on its own.

3.2.5.2 802.3/DIX Filtering

The notion of bridging is limited for a USB attached cable modem, since the connection to a CPE is, for all intents and purposes, point-to-point and private. There is no other equipment on the USB for the cable modem to perform bridging for, so this layer is reduced to some simple forwarding rules that resemble the behavior of a typical Ethernet NIC as follows:

Cable-Network-to-CPE forwarding MUST follow these specific rules:

- Frames addressed to the cable modem's Host CPE MAC address MUST be forwarded over the USB to the CPE.
- Broadcast frames MUST be forwarded over the USB to the CPE.
- Multicast frames MUST be forwarded over the USB to the CPE, in accordance with filtering configuration settings specified by the cable operator's operations and business support systems, with one recommended exception as follows: The host CPE SHOULD additionally be able to configure the attached cable modem (by some vendor specific device management messages) to do further restrictive filtering (beyond the MSO configured filters) to prevent the forwarding of multicast frames that the host CPE software has not indicated an interest in receiving. The host CPE MUST NOT be able to either access or alter MSO configured filters.
- Defined mechanisms exist for CPE networking devices (e.g., Ethernet NICs) to support a "sleep" mode where additional filtering is accomplished using programmable pattern filters as specified by the CPE networking stack. When a programmed pattern is detected, this causes the CPE to wake-up to service the incoming connection. A cable modem SHOULD support such a wake-up function, with the ability to perform USB resume signaling to the CPE in accordance with [USB1] and [NDC1].
- Ethernet frames with the cable modem's Ethernet MAC address MUST NOT be forwarded by the cable modem to the host CPE.

CPE to Cable Network forwarding MUST follow these specific rules:

- Since a USB attached cable modem has a virtual private connection to the host CPE, everything received from the CPE over USB that has been designated as an outbound data PDU frame MUST be forwarded to the cable network in accordance with filters set in the modem.

Unlike a simple Ethernet NIC, the USB attached cable modem MUST NOT operate in a "promiscuous mode" where all frames are forwarded over the USB, since the aggregate of downstream frames for all MAC addresses would exceed the bandwidth capacity of the USB. This requirement implies that the attached CPE itself MUST NOT function as a bridge.

3.2.5.3 802.3 Medium Access Control (MAC) Sublayer

The MAC sublayer interface MUST be in accordance with ISO/IEC 8802-3: 1995.

3.2.5.4 Ethernet

The data link layer interface MUST be in accordance with Ethernet Version 2.0, 1982.

3.2.5.5 Address Length

A 48-bit address MUST be utilized for IEEE 802.3 and DIX Ethernet.

3.2.5.6 USB Management and Framing Sublayer

This vendor-defined layer is specific to a particular cable modem implementation. Its purpose is to adapt 802.3/DIX MAC frames and device management into a format that can be exchanged over the USB. It provides two primary functions:

1. Framing: Since the underlying USB protocol provides a streaming pipe interface to its clients, this sublayer MUST be implemented in both the CPE and cable modem to provide the necessary synchronization, 802.3/DIX frame delineation, and stream error handling functions. This MAY involve the usage of additional headers.
2. Device management: Management message interfaces MUST be provided that enable the host CPE to query and configure the cable modem to work properly with the CPE and its networking stack.

As mentioned in the overview (see Section 3.2.1), it is beyond the scope of this specification to describe either the USB transfer types used, or detailed frame formats. A USB attached cable modem conceptually resembles an installed Ethernet NIC from the CPE's point of view. To support that model, some level of device management capability is required for the CPE and its networking stack to operate properly as described below:

- The TCP/IP stack residing in the host CPE MUST be able to discover the 48-bit host CPE MAC address of the USB cable modem to allow the CPE to respond correctly to frames from the CMTS (e.g., an ARP request). Since there is no Ethernet NIC used with USB, a USB modem must implement a MAC address for frames destined to the host CPE.
- The host CPE SHOULD be able to configure the cable modem to forward only multicast frames that the host CPE is interested in receiving. The host CPE MUST NOT be able to either access or alter MSO configured filters.
- Similar to the way host CPE networking stacks are able to negotiate with Ethernet NICs, the host CPE SHOULD be able to negotiate with the cable modem to specify pattern filters to be used to wake-up the CPE when it is in a power-managed "sleep" state. See [NDC1] for further details on network device pattern filtering.

In the future, an implementation may be defined that migrates aspects of cable modem operation and management functionality into host CPE software for the purpose of reducing the equipment cost of a USB cable modem.

3.2.5.7 USB Protocol Sublayer

The USB protocol sublayer contains the link protocol used for various types of transactions over the USB, and is usually implemented by a low level USB controller. The USB protocol sublayer MUST be in accordance with the USB protocol as described in Chapter 8 of [USB1].

3.2.6 Physical (PHY) Layer

The physical layer interface MUST be in accordance with the USB specification, Revision 1.0, 1996 [USB1].

4 Internal CPE Interfaces

4.1 Architecture Considerations

Cable data system operators are concerned both about the security and the operations of their cable data networks. These considerations are more fully explained in this section.

Not only is it necessary to protect the data of subscribers, the MSO backend systems must be safeguarded. Since the cable modem is in the subscriber's home, it would most likely be the first avenue of attack on an MSOs system. For this reason, the cable modem should not present an easy avenue of attack. There are many ways to architect an internal cable modem, with some implementations being more secure than others.

Most of the data used by a cable modem is sensitive and must be protected to ensure the security of the MSO network. For instance, the SNMP agent, IP address, DES encryption keys, etc., should all be kept secure in order to ensure the integrity of the network. These data, and others, must be protected in a reasonably secure manner. While no architecture is totally attack-proof, a DOCSIS cable modem must implement a security architecture with the intent of discouraging most attacks.

At issue with internal cards is utilizing host resources for cable modem functions. Storing sensitive cable modem data on the host computer makes that data more easily attacked. For instance, using the host memory for cable modem functions makes that data more easily accessible to the a malicious user. Even just having the cable modem share the host processor means that certain sensitive cable modem data must pass through the host computer, again making that data accessible to a malicious user. Implementations such as these are not considered secure by the MSO’s.

By way of reference, the external DOCSIS modem implements a reasonably secure architecture. The external modem both physically and logically partitions its data and services from the subscriber's host computer. Physically, it does this by having a different processor and memory. Logically, it has it's own IP address. Partitioning services this way seems both reasonable and prudent in order to maintain the integrity of MSO networks.

Additionally, relying on the host for important parts of the cable modem functionality may place the modem at risk to being adversely impacted by software problems on the host CPE. MSOs have no control over the software on the host PC and hence, interactions with the internal cable modem. When modem functions are run on the host CPE, there is no longer a clear demarcation between the modem and the host, hence MSOs are exposed to the potential of service calls, even though the modem is not at fault.

As an outgrowth of host software interaction issues, the MSOs have concerns about supporting multiple driver interface software packages for internal cable modems. As a result, the driver interface software packages for host CPEs are required to use industry standard specifications. The intention of this requirement is to decrease the number of issues involving internal card software interfaces and to expedite trouble-shooting, when required.

A logical extension of the external modem architecture could be applied to an internal modem. In this case, the internal modem might include its own processor, memory, and IP address. While the internal modem would still be inside the host computer, its functions would not be realized by using host computer resources. By keeping the sensitive data and functions partitioned on the internal card, a reasonable security architecture can be realized.

A possible alternative internal card architecture, still under study by the MSOs, would have certain cable modem functions running on the host computer. The MSOs are studying what functions may be permissible to port to the host computer without sacrificing the operational efficiency and the overall security of the network.

In summary, the architecture of the internal cable modem is of concern to the MSOs. Certain architectures are more secure and more stable than others, and the MSOs would be willing to specify these for increased network security and simpler operational support.

4.2 Reference Architecture

The protocol stack for an internal modem MUST be as shown in Figure 4-1.

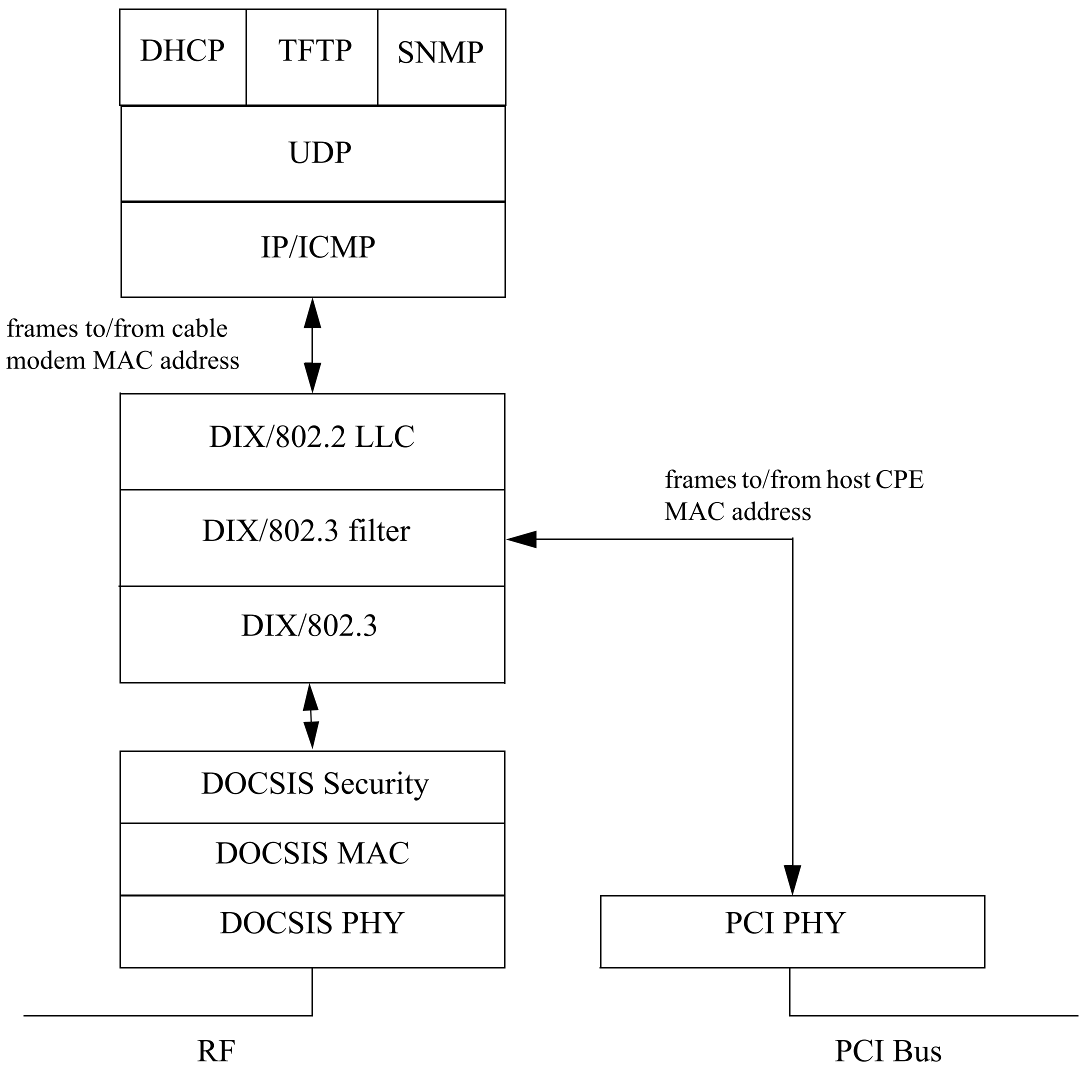

Figure 4-1 Protocol Stack for Internal Cable Modems

The internal cable modem MUST implement an IP protocol stack. The internal cable modem MUST implement Ethernet LLC forwarding for traffic between the cable modem and the host CPE. The internal cable modem MUST implement MAC forwarding to transfer Ethernet frames to and from the host CPE.

The internal cable modem MUST implement two 48-bit Ethernet addresses, one for itself and one for the host CPE.

When an Ethernet frame destined for the host CPE, as identified by having the Ethernet address of the host, is received by the internal modem, it MUST forward the Ethernet frame to the host CPE over the Peripheral Component Interface (PCI) bus. The cable modem MUST only forward frames to the host CPE that have the MAC address for the host CPE. The NDIS driver in the PC host will then forward the frame to the PC host IP stack. Frames received over the RF interface with the Ethernet MAC address of the cable modem MUST be recognized by the internal cable modem and forwarded to the cable modem stack. Ethernet frames with the modem's Ethernet MAC address MUST NOT be forwarded by the cable modem to the host CPE.

Figure 4-2 shows an end-to-end protocol stack (from CMTS to CPE) where a typical internal PCI attached cable modem is involved.

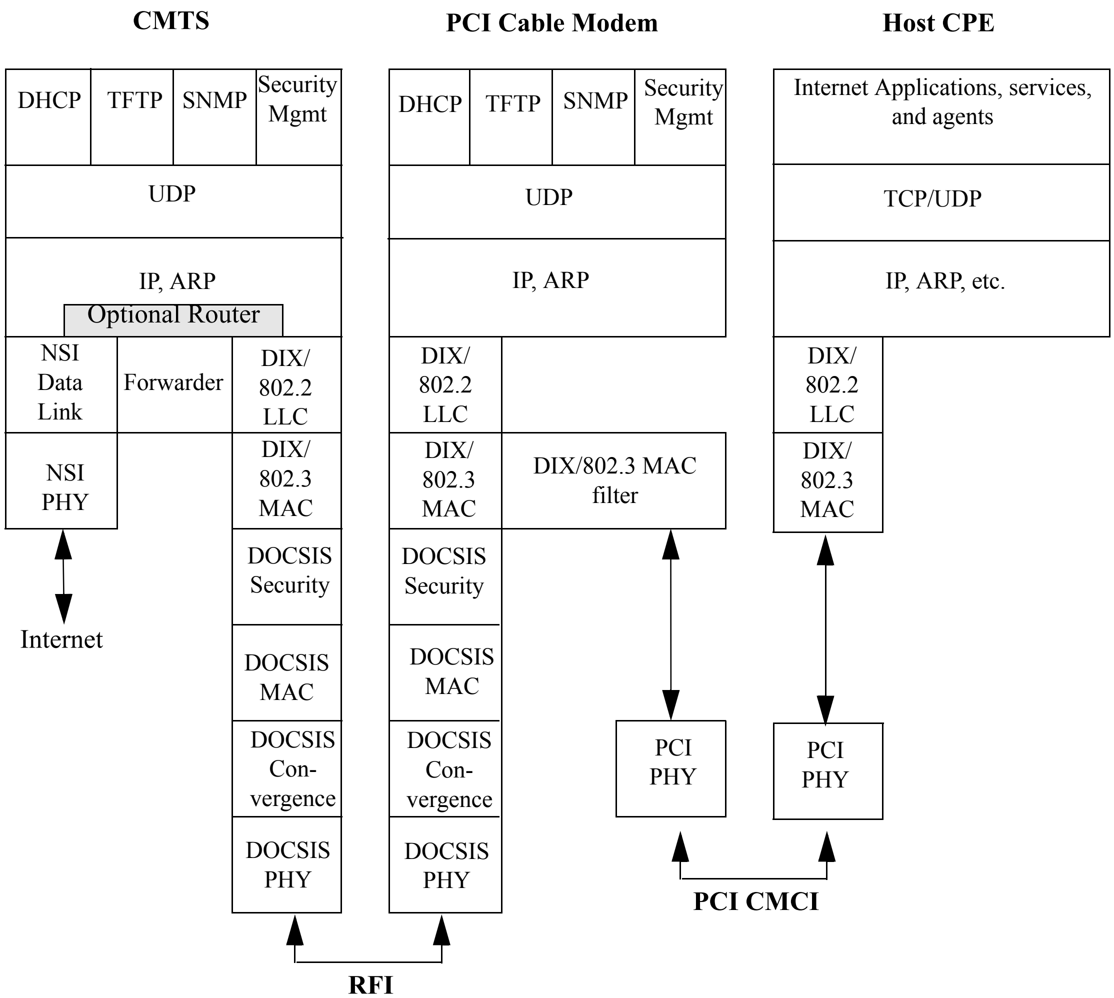

Figure 4-2 End-to-End PCI Cable Modem Protocol Stack

The internal cable modem MUST be supplied with an NDIS v3.1 (or later) compliant driver software package to present the card to the host PC. NDIS is an application interface. The NDIS driver software is dependent on implementation and is not expected to work with other DOCSIS internal modems; however, each unique driver software package MUST be compliant to the NDIS driver specification.

4.3 IBM PC (or Clone) PCI Bus

The Internet Protocol (IP) version 4 standard MUST be passed transparently through the CMCI. The CMCI MUST support both IEEE 802.3 and DIX Ethernet. The CMCI protocol stack and applicable specifications MUST comply with the summary provided in Figure 4-3 and Table 4-1, respectively.

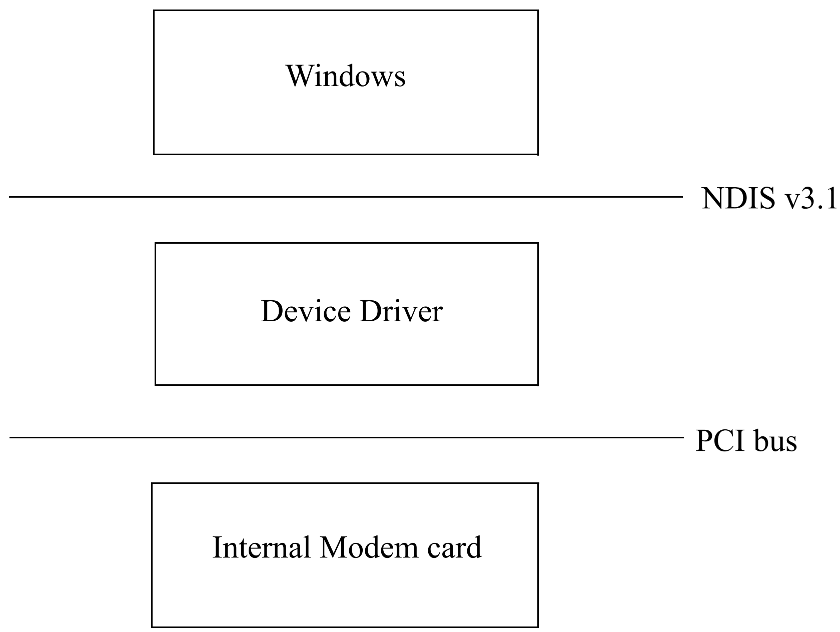

Figure 4-3 PC Block Diagram

Table 4-1 PC Protocol Specification

Layer	Specification	Options/Features
Network	Internet Protocol (IP) (RFC 1042 & RFC 894, RFC 1883 - future use)	(For reference and information only)
Data Link (LLC)	ISO/IEC 10038 (ANSI/IEEE Std 802.1d): 1993 ISO/IEC 8802-2: 1994 and DIX Ethernet	Spanning Tree Algorithm not required. Class 1, Type 1 LLC/SNAP
Data Link (MAC)	ISO/IEC 8802-3: 1995 and DIX Ethernet	48 bit address
Physical	PCI Bus	

4.3.1 Device Driver Software

DOCSIS internal modem cards for IBM PCs and compatible machines MUST supply a software driver that complies with the Network Driver Interface Specification (NDIS) version 3.1 or later and MAY also supply software drivers which comply with NDIS 2.0 or later

4.3.2 Network Layer

4.3.2.1 Internet Protocol (IP)

Implementations of the PCI CMCI MUST utilize IP version 4 in accordance with IETF RFC 1042, "A Standard for the Transmission of IP Datagrams over IEEE 802 Networks" and RFC 894, "A Standard for the Transmission of IP Datagrams over Ethernet Networks." This usage will evolve to support IP version 6 (IETF RFC 1883) as it becomes an accepted standard.

4.3.3 Data Link Layer

Data link interfaces MUST be compatible with IEEE 802.2/802.3 and DIX Ethernet v2.0 as defined in the following paragraphs.

4.3.3.1 802.2 Logical Link Controller (LLC) Sublayer

The LLC sublayer interface MUST be in accordance with ISO/IEC 8802-2: 1994. Note that the cable modem MUST NOT respond to [ISO8802-2] LLC host requests (TEST and XID) addressed to its Host CPE MAC address -- this is the responsibility of the host CPE. The cable modem MUST pass these frames transparently to the host CPE without responding to them on its own.

4.3.3.2 802.3/DIX Filtering

The notion of bridging is limited for a PCI bus attached cable modem, since the connection to a CPE is, for all intents and purposes, point-to-point and private. There is no other equipment on the PCI bus for the cable modem to perform bridging for, so this layer is reduced to some simple forwarding rules that resemble the behavior of a typical Ethernet NIC as follows. Forwarding of Ethernet frames between the modem and the CPE MUST be as shown in Figure 4-4.

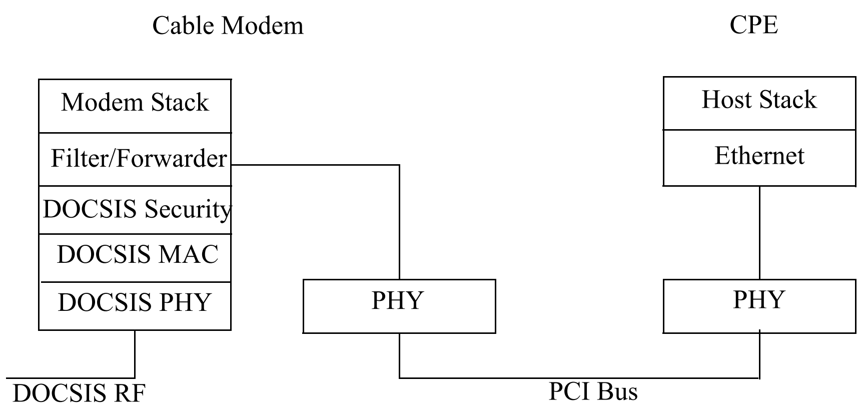

Figure 4-4 CM-to-PC Forwarding

The cable modem MUST perform MAC forwarding in accordance with ISO/IEC 10038 (ANSI/IEEE Std 802.1D): 1993. Implementation of the Spanning Tree Algorithm and Protocol is not required.

Cable-Network-to-CPE forwarding MUST follow these specific rules:

- Frames addressed to the cable modem’s Host CPE MAC address MUST be forwarded over the PCI bus to the CPE.
- Broadcast frames MUST be forwarded over the PCI bus to the CPE.
- Multicast frames MUST be forwarded over the PCI bus to the CPE, in accordance with filtering configuration settings specified by the cable operator’s operations and business support systems, with one recommended exception as follows: The host CPE SHOULD additionally be able to configure the attached cable modem (by some vendor specific device management messages) to do further restrictive filtering (beyond the MSO configured filters) to prevent the forwarding of multicast frames that the host CPE software has not indicated an interest in receiving. The host CPE MUST NOT be able to either access or alter MSO configured filters.
- Defined mechanisms exist for CPE networking devices (e.g., Ethernet NICs) to support a “sleep” mode where additional filtering is accomplished using programmable pattern filters as specified by the CPE networking stack. When a programmed pattern is detected, this causes the CPE to wake-up to service the incoming connection. A cable modem SHOULD support such a wake-up function, with the ability to assert PCI bus PME# to the CPE in accordance with [PCI1] and [NDC1].
- Ethernet frames with the cable modem's Ethernet MAC address MUST NOT be forwarded by the cable modem to the host CPE.

CPE to Cable Network forwarding MUST follow these specific rules:

- Since a PCI bus attached cable modem has a private connection to the host CPE, everything received from the CPE over the PCI bus that has been designated as an outbound data PDU frame MUST be forwarded to the cable network in accordance with filters set in the modem.

4.3.3.3 802.3 Medium Access Control (MAC) Sublayer

The MAC sublayer interface MUST be in accordance with ISO/IEC 8802-3: 1995.

4.3.3.4 Ethernet

The data link layer interface MUST be in accordance with Ethernet Version 2.0, 1982.

4.3.3.5 Address Length

A 48-bit address MUST be utilized for IEEE 802.3 and DIX Ethernet.

4.3.4 Physical (PHY) Layer

The physical layer interface MUST be in accordance with the PCI bus specification, Revision 2.1S, 1996 [PCI1].

4.4 Apple Macintosh Power PC (or clone) PCI Bus

The Internet Protocol (IP) version 4 standard MUST be passed transparently through the CMCI. The CMCI MUST support both IEEE 802.3 and DIX Ethernet. The CMCI protocol stack and applicable specifications MUST comply with the summary provided in Figure 4-5 and Table 4-2, respectively.

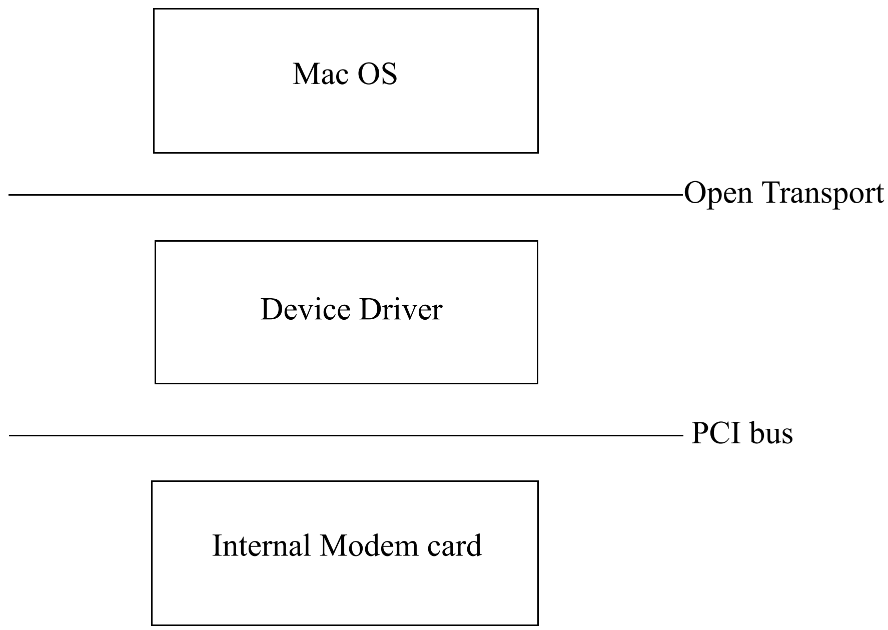

Figure 4-5 Macintosh Block Diagram

Table 4-2 Macintosh Protocol Specification

Layer	Specification	Options/Features
Network	Internet Protocol (IP) (RFC 1042 & RFC 894, RFC 1883 - future use)	(For reference and information only)
Data Link (LLC)	ISO/IEC 10038 (ANSI/IEEE Std 802.1d): 1993 ISO/IEC 8802-2: 1994 and DIX Ethernet	Spanning Tree Algorithm not required Class 1, Type 1 LLC/SNAP
Data Link (MAC)	ISO/IEC 8802-3: 1995 and DIX Ethernet	48 bit address
Physical	PCI Bus	

4.4.1 Device Driver Software

DOCSIS internal modem cards for Macintosh computers MUST use a software driver that complies with the Open Transport/STREAMS Data Link Provider Interface (DLPI), version 1.1.2 or later.

4.4.2 Network Layer

4.4.2.1 Internet Protocol (IP)

Implementations of the PCI CMCI MUST utilize IP version 4 in accordance with IETF RFC 1042, “A Standard for the Transmission of IP Datagrams over IEEE 802 Networks” and RFC 894, “A Standard for the Transmission of IP Datagrams over Ethernet Networks.” This usage will evolve to support IP version 6 (IETF RFC 1883) as it becomes an accepted standard.

4.4.3 Data Link Layer

Data link interfaces MUST be compatible with IEEE 802.2/802.3 and DIX Ethernet v2.0 as defined in the following paragraphs.

4.4.3.1 802.2 Logical Link Controller (LLC) Sublayer

The LLC sublayer interface MUST be in accordance with ISO/IEC 8802-2: 1994. Note that the cable modem MUST NOT respond to [ISO8802-2] LLC host requests (TEST and XID) addressed to its Host CPE MAC address -- this is the responsibility of the host CPE. The cable modem MUST pass these frames transparently to the host CPE without responding to them on its own.

4.4.3.2 802.3/DIX Filtering

The notion of bridging is limited for a PCI bus attached cable modem, since the connection to a CPE is, for all intents and purposes, point-to-point and private. There is no other equipment on the PCI bus for the cable modem to perform bridging for, so this layer is reduced to some simple forwarding rules that resemble the behavior of a typical Ethernet NIC as follows. Forwarding of Ethernet frames between the modem and the CPE is as shown in Figure 4-6.

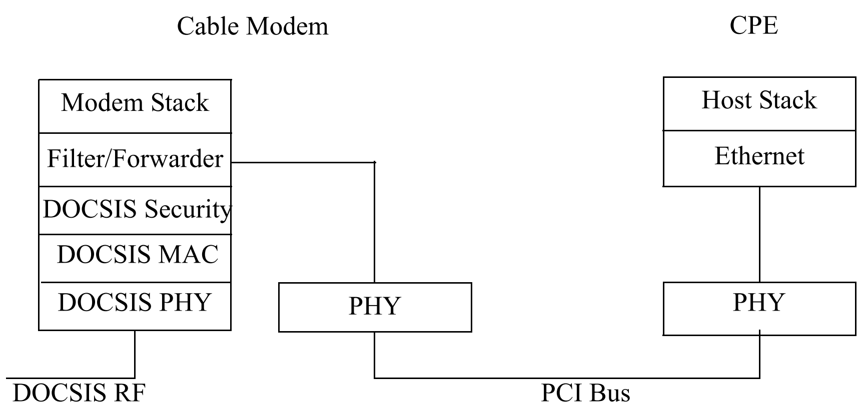

Figure 4-6 CM-to-Mac Forwarding

The cable modem MUST perform MAC forwarding in accordance with ISO/IEC 10038 (ANSI/IEEE Std 802.1D): 1993. Implementation of the Spanning Tree Algorithm and Protocol is not required.

Cable-Network-to-CPE forwarding MUST follow these specific rules:

- Frames addressed to the cable modem’s Host CPE MAC address MUST be forwarded over the PCI bus to the CPE.

- Broadcast frames MUST be forwarded over the PCI bus to the CPE.
- Multicast frames MUST be forwarded over the PCI bus to the CPE, in accordance with filtering configuration settings specified by the cable operator's operations and business support systems, with one recommended exception as follows: The host CPE SHOULD additionally be able to configure the attached cable modem (by some vendor specific device management messages) to do further restrictive filtering (beyond the MSO configured filters) to prevent the forwarding of multicast frames that the host CPE software has not indicated an interest in receiving. The host CPE MUST NOT be able to either access or alter MSO configured filters.
- Defined mechanisms exist for CPE networking devices (e.g., Ethernet NICs) to support a "sleep" mode where additional filtering is accomplished using programmable pattern filters as specified by the CPE networking stack. When a programmed pattern is detected, this causes the CPE to wake-up to service the incoming connection. A cable modem SHOULD support such a wake-up function, with the ability to assert PCI bus PME# to the CPE in accordance with [PCI1] and [NDC1].
- Ethernet frames with the cable modem's Ethernet MAC address MUST NOT be forwarded by the cable modem to the host CPE.

CPE to Cable Network forwarding MUST follow these specific rules:

- Since a PCI bus attached cable modem has a private connection to the host CPE, everything received from the CPE over the PCI bus that has been designated as an outbound data PDU frame MUST be forwarded to the cable network in accordance with filters set in the modem.

4.4.3.3 802.3 Medium Access Control (MAC) Sublayer

The MAC sublayer interface MUST be in accordance with ISO/IEC 8802-3: 1995.

4.4.3.4 Ethernet

The data link layer interface MUST be in accordance with Ethernet Version 2.0, 1982.

4.4.3.5 Address Length

A 48-bit address MUST be utilized for IEEE 802.3 and DIX Ethernet.

4.4.4 Physical (PHY) Layer

The physical layer interface MUST be in accordance with the PCI bus specification, Revision 2.1S, 1996 [PCI1].

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Appendix A. Definitions

ANSI — American National Standards Institute

ARP — Address Resolution Protocol

Cable Modem (CM) — A modulator-demodulator at a subscriber location intended for use in conveying data communications on a cable television system.

Cable Modem Termination System (CMTS) — Cable modem termination system, located at the cable television system headend or distribution hub, which provides complementary functionality to the cable modems to enable data connectivity to a wide-area network.

Cable network — Refers to the cable television plant that would typically be used for data over cable services. Such plants generally employ a downstream path in the range of 54MHz on the low end to a high end in the 440 to 750MHz range and an upstream path in the range of 5 to 42MHz. Customers share a common communications path for upstream and a separate common path for downstream (i.e., effectively a pair of unidirectional busses).

CM — Cable modem (see above)

CMCI — Cable Modem to CPE Interface

CMTRI — Cable Modem Telco Return Interface is the upstream interface between a telco modem attached to, or inside of, a cable modem and the CMTS.

CMTS — Cable Modem Termination System (see above)

CMTS-NSI — Cable Modem Termination System—Network Side Interface

CPE — Customer Premise Equipment

DHCP — Dynamic Host Configuration Protocol (see below)

Downstream — In cable television, the direction of transmission from the headend to the subscriber.

Dynamic Host Configuration Protocol (DHCP) — An Internet protocol used for assigning network-layer (IP) addresses.

HFC — Hybrid Fiber Coax (see below)

Hybrid Fiber/Coax (HFC) System — A broadband bi-directional shared-media transmission system using fiber trunks between the headend and the fiber nodes, and coaxial distribution from the fiber nodes to the customer locations.

ICMP — Internet Control Message Protocol (see below)

IEEE — Institute of Electrical and Electronics Engineers (see below)

IETF — Internet Engineering Task Force

Institute of Electrical and Electronic Engineers (IEEE) — A voluntary organization which, among other things, sponsors standards committees and is accredited by the American National Standards Institute.

Internet Control Message Protocol (ICMP) — An Internet network-layer protocol.

Internet Protocol (IP) — An Internet network-layer protocol.

IP — Internet Protocol (see above)

Logical Link Control (LLC) procedure — In a local area network (LAN) or a Metropolitan Area Network (MAN), that part of the protocol that governs the assembling of data link layer frames and their exchange between data stations, independent of how the transmission medium is shared.

LLC — Logical Link Control (see above)

MAC — Media Access Control also Medium Access Control (see below)

MCNS — Multimedia Cable Network Systems Holdings, L.P. (see below)

Media Access Control (MAC) sublayer — The part of the data link layer that supports topology-dependent functions and uses the services of the Physical Layer to provide services to the logical link control (LLC) sublayer.

Multimedia Cable Network System (MCNS) Holdings, L.P. — A consortium of Comcast Cable Communications, Inc., Cox Communications, Tele-Communications, Inc., and Time Warner Cable, interested in deploying high-speed data communications systems on cable television systems.

NDIS — Network Driver Interface Specification

OSI — Open Systems Interconnection

PC — Personal Computer

PCI — Peripheral Component Interface

RFC — Request For Comments

SNAP — Subnetwork Access Protocol described in IEEE Std 802.2 Annex D

SNMP — Simple Network Management Protocol

UDP — User Datagram Protocol

USB — Universal Serial Bus

Upstream — The direction from the subscriber location toward the headend.

Appendix B. References

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