Data-Over-Cable Interface Specifications
C-DOCSIS

C-DOCSIS System Specification

CM-SP-CDOCSIS-I02-150305

ISSUED

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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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Closed	A static document, reviewed, tested, validated, and closed to further engineering change requests to the specification through CableLabs.

Trademarks

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1 SCOPE

1.1 Introduction and Purpose

This specification describes a method for distributed deployment and centralized control of a DOCSIS cable broadband access system, referred to as "C-DOCSIS". It has been developed to meet the operability and manageability requirements for cable networks that offer a variety of high-bandwidth services and provide QoS guarantees for these services in a distributed architecture. This architecture applies to the operations, administration and management (OAM) of cable broadband access networks.

This specification defines the functional modules within the CMTS, three different system architectures utilizing the functional modules, and the data and control interfaces between these modules for each of those architectures. It also defines general device requirements for the different distributed CMTS architectures.

1.2 Organization of Document

Section 1 provides an introduction to this specification.

Sections 2, 3, and 4 include the references, terms, and acronyms used throughout this specification.

Section 5 provides an informative technical overview of this specification.

Section 6 provides the definition and characteristics of a C-DOCSIS system.

Section 7 defines the C-DOCSIS functional modules and interfaces on different functional modules, and provides the data packet processing in a C-DOCSIS system.

Section 8 provides C-DOCSIS system requirements, and defines three typical implementation ways of a C-DOCSIS system.

Annex A provides the mapping from service flows to VLANs.

Annex B provides the format of CDMM and CDT.

Appendix I describes the process of dynamic service operations.

1.3 Requirements

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

"MUST"	This word 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 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 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.

2 REFERENCES

2.1 Normative References[1]

In order to claim compliance with this specification, it is necessary to conform to the following standards and other works as indicated, in addition to the other requirements of this specification. Notwithstanding, intellectual property rights may be required to use or implement such normative references.

All references are subject to revision, and parties to agreement based on this specification are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

[802.1Q] IEEE Std 802.1Q-2011, IEEE Standard for Local and Metropolitan Area Networks - Media Access Control (MAC) Bridges and Virtual Bridge Local Area Networks, August 2011.

[CANN DHCP] CableLabs DHCP Options Registry, CL-SP-CANN-DHCP-Reg-I10-130808, August 8, 2013, Cable Television Laboratories, Inc.

[CPD] Control Point Discovery Interface Specification, PKT-SP-CPD-C01-140314, March 13, 2014, Cable Television Laboratories, Inc.

[DOCSIS 3.0] The suite of DOCSIS 3.0 specifications consisting of [PHYv3.0], [SECv3.0], [DRFI], and [OSSIv3.0].

[DQoS] PacketCable™ Dynamic Quality-of-Service Specification, PKT-SP-DQOS-C01-071129, November 29, 2007, Cable Television Laboratories, Inc.

[DRFI] DOCSIS 3.0 Downstream RF Interface Specification, CM-SP-DRFI-I14-131120, November 20, 2013, Cable Television Laboratories, Inc.

[GCP] DOCSIS Remote Generic Control Plane, CM-SP-GCP-D01-140829, August 29, 2014, Cable Television Laboratories, Inc.

[MHAv2] References the DOCSIS suite of Remote PHY specifications, [R-PHY], [R-DEPI], [R-DTI], [R-UEPI], [GCP], and [R-OOB].

[MM] PacketCable Multimedia Specification, PKT-SP-MM-I06-110629, June 29, 2011, Cable Television Laboratories, Inc.

[MULPIv3.0] Media Access Control and Upper Layer Protocols Interface (MULPI) Specification, CM-SP-MULPIv3.0-I26-150305, March 5, 2015, Cable Television Laboratories, Inc.

[OSSIv3.0] DOCSIS 3.0 Operations Support System Interface Specification, CM-SP-OSSIv3.0-I25-150305, Cable Television Laboratories, Inc.

[PHYv3.0] DOCSIS 3.0 Physical Layer Specification, CableLabs,CM-SP-PHYv3.0-I12-150305, March 5, 2015, Cable Television Laboratories, Inc.

[R-DEPI] DOCSIS Remote Downstream External PHY Interface Specification, CM-SP-R-DEPI-D02-141216, December 16, 2014, Cable Television Laboratories, Inc.

[R-DTI] Remote DOCSIS Timing Interface Specification, CM-SP-R-DEPI-D02-141216, December 16, 2014, Cable Television Laboratories, Inc.

[RFC 2236] IETF RFC 2236, Internet Group Management Protocol, Version 2, November 1997.

[RFC 2710] IETF RFC 2710, Multicast Listener Discovery (MLD) for IPv6, MLD v1, October 1999.

[1] Added 6 normative references per CDOCSIS-N-14.1216-2 on 2/6/15 by KR.

[RFC 2748] IETF RFC 2748, The COPS (Common Open Policy Service) protocol.

[RFC 3376] IETF RFC 3376, Internet Group Management Protocol, Version 3.

[RFC 3810] IETF RFC 3810, Multicast Listener Discovery Version 2 (MLDv2) for IPv6, June 2004.

[R-OOB] DOCSIS Remote Out of Band Specification, CM-SP-R-OOB-D02-141216, December 16 2014, Cable Television Laboratories, Inc.

[R-PHY] DOCSIS Remote PHY Specification, CM-SP-R-PHY-D02-141216, December 16, 2014, Cable Television Laboratories, Inc.

[R-UEPI] DOCSIS Remote Upstream External PHY Interface Specification, CM-SP-R-UEPI-D01-140829, August 29, 2014, Cable Television Laboratories, Inc.

[SECv3.0] DOCSIS 3.0 Security Specification, CM-SP-SECv3.0-I15-130808, August 8, 2013, Cable Television Laboratories, Inc.

2.2 Informative References

[802.3] IEEE Std 802.3-2012, IEEE Standard for Ethernet, Section Five.

[GY/T266] GY/T 266:2012, NGB Broadband Access System C-DOCSIS Technical Specification.

[RFC 791] IETF RFC 791/STD0005, Internet Protocol. J. Postel. September 1981.

[RFC 793] IEFT RFC 793/STD0007 Transmission Control Protocol. J. Postel. September 1981.

2.3 Reference Acquisition

- Cable Television Laboratories, Inc., 858 Coal Creek Circle, Louisville, CO 80027; USA
  Phone +1-303-661-9100; Fax +1-303-661-9199; http://www.cablelabs.com
- Internet Engineering Task Force (IETF) Secretariat, 48377 Fremont Blvd., Suite 117, Fremont, CA 94538; USA, Phone: +1-510-492-4080, Fax: +1-510-492-4001; http://www.ietf.org
- Institute of Electrical and Electronics Engineers (IEEE), http://www.ieee.org/web/standards/home/index.html

3 TERMS AND DEFINITIONS

This specification uses the following terms.

Access Control	Used to control the CMs defined in this document to access networks. It is a process for connecting CMCs and controlling data communication.
Aggregation and Forwarding	An aggregation network device, such as a PON optical line terminal (OLT), a router, or a switch, receives data from CMCs and forwards the data to different uplinks for transmission based on the preset QoS priorities.
Cable Media Converter (CMC)	Converts data from a coaxial cable network to a digital optical packet network (such as PON or Ethernet). The CMC connects to a cable modem (CM) through the coaxial cable network in the downstream direction and to the CMC Controller through the digital optical packet network in the upstream direction.
CDMM	Used for exchanging configurations, status, and management information between the system control module and the radio frequency interface (RFI) module.
C-DOCSIS CM	A CM that complies with the CM requirements of the Annexes titled "Additions and Modifications for Chinese Specification" in [DOCSIS 3.0].
C-DOCSIS CMTS	A CMTS that complies with the CMTS requirements of the Annexes titled "Additions and Modifications for Chinese Specification" in [DOCSIS 3.0]. In the context of this specification, it consists of a CMC Controller and a CMC or multiple CMCs operating together.
C-DOCSIS Data Tags (CDTs)	Used to identify a service flow to which each data packet belongs.
C-DOCSIS System	A method for distributed deployment and centralized control of a DOCSIS cable broadband access system. The C-DOCSIS system consists of the CMC Controller, CMC, and CMs. It implements broadband data access and forwarding, service configuration, as well as management and maintenance of coaxial cable networks. It is synonymous with the term "distributed system architecture" which separates and distributes the components of a CMTS in the various parts of the HFC network.
Classified Mapping	Classified mapping is a mapping process, during which data packets are classified according to preset rules, CDTs are added to the Ethernet frame header of the data packets to identify the service flows to which they belong, and the classified forwarding module maps the CDTs to the service flags, such as service VLAN (S-VLAN), IP ToS, and EPON Logical Link ID (LLID), supported by the aggregation network.
CMC Controller	Forwards upstream and downstream service data and manages the configuration of the CMC.
Data Encapsulation and Decapsulation	A data processing method for converting data from one format to another. The conversion is implemented by adding or deleting data for identification in the header or tail of the original data packets.
Dynamic QoS	Quality of Service mechanism which dynamically creates, modifies, and deletes DOCSIS service flows based on call signaling to ensure the QoS for multimedia sessions, such as voice sessions. With this mechanism, the system provides guaranteed bandwidth resources during a session and releases the resources when the session ends.
Management Control	A process for CMC Controllers and CMCs to manage the access, data, status, and configurations of CMCs and CMs. The management control is based on the network architecture in distributed deployment mode defined in this document.

Physical Framing	Physical framing is a process of collating data according to the fixed data encapsulation format to meet the requirements of data transmission on the physical layer.
Service Flow	Transmits services at the MAC layer. The system shapes and polices traffic, and classifies traffic priorities based on QoS parameters defined in the service flow.

4 ABBREVIATIONS AND ACRONYMS

This specification uses the following abbreviations.

BPI+	Baseline Privacy Interface Plus
CCI	Control and Classifier Interface
CDMM	C-DOCSIS Management Message
C-DOCSIS	China DOCSIS
CDP	Control Point Discovery
CDT	C-DOCSIS Data Tag
CLI	Command Line Interface
CM	Cable Modem
CMC	Coax Media Converter
CMTS	Cable Modem Termination System
COPS	Common Open Policy Service
CoS	Class of Service
CPD	Control Point Discovery
DCID	Downstream Channel Identifier
DEPI	Downstream External PHY Interface
DHCP	Dynamic Host Configuration Protocol
DOCSIS	Data over Cable Service Interface Specification
DQoS	Dynamic QoS
DSC	Dynamic Service Change
DSx	Dynamic Service Operations
EAE	Early Authentication and Encryption
eDVA	Embedded Digital Voice Adapter
eMTA	Embedded Medial Terminal Adapter
EPON	Ethernet Passive Optical Network
FTTx	Fiber To The "x" NOTE: "x" includes node (FTTN), premise (FTTP), cabinet (FTTC), home (FTTH)
GCP	Generic Control Plane
GPON	Gigabit-capable Passive Optical Network
HFC	Hybrid Fiber-Coaxial
IEEE	Institute of Electrical and Electronics Engineers
IGMP	Internet Group Management Protocol
IMS	IP Multimedia Subsystem
IP	Internet Protocol
LLC	Logical Link Control
LLID	Logical Link IDentifier
MAC	Media Access Control
MAN	Metropolitan Area Network
MAP	Bandwidth Allocation Map
MLD	Multicast Listener Discovery

MPI	Main Path Interface
NAT	Network Address Translation
NLS	Network Layer Signaling protocol
NMS	Network Management System
NSI	Network Side Interface
OAM	Operations, Administration and Maintenance
OLT	Optical Line Terminal
OMCI	ONT Management and Control Interface
OMI	Operation and Management Interface
ONU	Optical Network Unit
OSSI	Operations Support System Interface
OUI	Organizationally Unique Identifier
PCMM	PacketCable Multimedia
PCP	Priority Code Point
PDU	Protocol Data Unit
PHY	Physical Layer
PON	Passive Optical Network
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RCS	Receive Channel Set
RF	Radio Frequency
RFI	Radio Frequency Interface
SF	Service Flow
SFID	Service Flow Identifier
SID	Service Identifier
SNMP	Simple Network Management Protocol
STB	Set-top Box
S-VLAN	Service VLAN
TCP	Transmission Control Protocol
TCS	Transmit Channel Set
TFTP	Trivial File Transfer Protocol
TLV	Type Length Value
ToS	Type of Service
TPID	Tag Protocol ID
UCID	Upstream Channel ID
UDP	User Datagram Protocol
UEPI	Upstream External PHY Interface
VID	VLAN ID
VLAN	Virtual Local Area Network

5 OVERVIEW

C-DOCSIS is based on proven DOCSIS3.0 technology and with objectives of carrying high bandwidth services and enabling cost effective system operation. C-DOCSIS presents a logical architecture of distributed deployment and centralized management for the cable broadband access system. It defines the logical functional modules of the system as well as related interfaces and protocols that support the architecture, through different combinations of the logical functional modules; it specifies three different system implementations and the corresponding systems devices.

As the key to implementing the architecture of distributed deployment and centralized management, C-DOCSIS defines the CMTS with a Coax Media Converter (CMC) and the CMC Controller to achieve the DOCSIS CMTS functionality, as shown in Figure 5-1. The CMC Controller implements the Metropolitan Area Network (MAN) interfaces, and the CMC implements the RF interfaces specified by the Annexes titled "Additions and Modifications for Chinese Specification" in [DOCSIS 3.0], which is a part of C-DOCSIS. The CMC Controller and CMC can be interconnected via a layer-2 or layer-3 network, such as digital optical packet network.

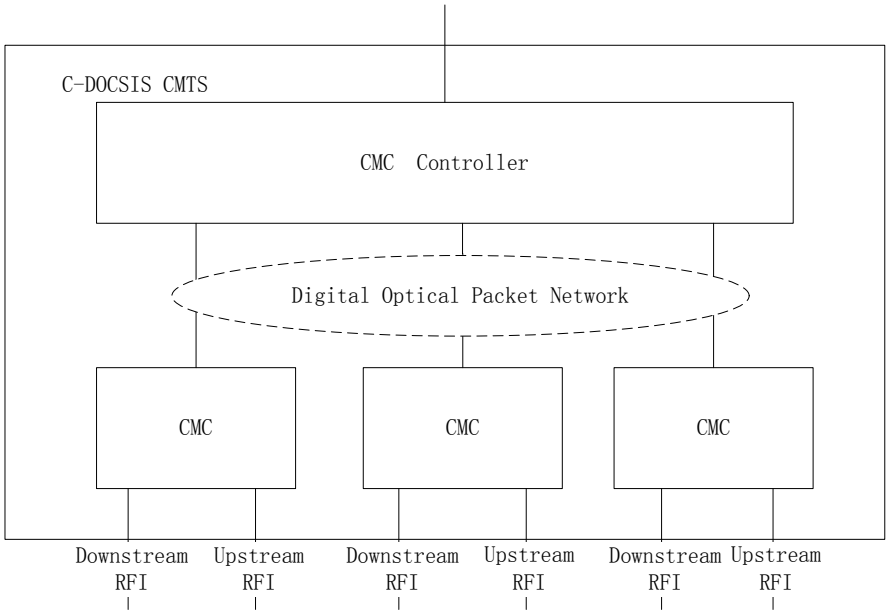

Figure 5-1 - C-DOCSIS CMTS Network Diagram

The CMC Controller is deployed in the central office or headend to realize the centralized system management, configuration, and scheduling, thus enabling the distributed CMTS to inherit the advantages of a centralized DOCSIS CMTS system. The CMC itself is distributed; it is deployed in the optical node, enabling the CMTS to introduce the space-division multiplexing on top of the time-division multiplexing and frequency-division multiplexing utilized by the centralized DOCSIS CMTS to achieve higher access bandwidth per user, which is highly desirable for the applications with large upstream bandwidth consumption. With the distributed deployment of CMC and coupled with the technical advantages of the digital optical packet network, the system can fully utilize the resources of the HFC network and existing CMs to realize a cost-effective system deployment and operation, it reduces the return noise and enhances the CMTS downlink channel SNR, and is thus able to implement a higher order modulation scheme to obtain higher bandwidth.

This specification describes three different types of CMC controllers and CMCs to implement the distributed CMTS.

- Type I CMC implements all the DOCSIS CMTS functions, and Type I CMC controller implements high-level and partial-system management and configuration functions.
- Type II CMC implements the data forwarding and CM access functions, and Type II CMC controller implements the system management, configuration, and scheduling functions.

- Type III CMC only implements the CMTS PHY function, and the Type III CMC controller implements the rest of the functions of the CMTS.

The distributed CMTS architecture is an open architecture, which nicely aligns with the traditional DOCSIS architectures and with the HFC migration toward the FTTx network. The implementation of the various system components is flexible. The CMC controller and CMC can be realized as stand-alone devices in accordance with the provisions of the specification, or they can be integrated with other existing devices to meet the needs of future development, such as the combination of CMC Controller with OLT, router and switches, and the combination of CMC with ONU, light stations, and IP QAMs.

6 SYSTEM DEFINITION AND CHARACTERISTICS

6.1 System Definition and Description[2]

The C-DOCSIS system defined in this specification consists of CMTSs and CMs. CMTSs consist of CMC Controllers and CMCs as shown in Figure 6-1. This specification defines the functional modules, interface, and requirements of CMTSs in detail, which are implemented by the CMC Controllers and CMCs.

A C-DOCSIS CMTS MUST comply with the Annexes titled "Additions and Modifications for Chinese Specification" in [PHYv3.0], [DRFI], [MULPIv3.0], [OSSIv3.0], and [SECv3.0]. C-DOCSIS CMs are compliant with the requirements for EuroDOCSIS CMs, with the addition of some optional functionality as described in the Annexes titled "Additions and Modifications for Chinese Specification" in [DOCSIS 3.0]. As such, EuroDOCSIS-compliant CMs can be used in a C-DOCSIS system without modification.

In this distributed system architecture, the CMC Controller manages the configuration of the CMC and/or forwards upstream and downstream service data. The CMC converts and forwards the upstream and downstream service data and the management and configuration data of the CMs. The CM terminates the upstream and downstream service data, as well as receiving and responding to management and configuration data. The CMC Controller connects to the CMC through a digital optical packet network. The CMC connects to the CMs through a coax RF network.

The configuration system configures services and devices on the distributed system architecture. It generates and issues configuration files and upgrades the software of the CMs. The configuration system consists of the DHCP server, configuration file server, software downloading server, and time protocol server. The NMS consists of the SNMP management system and the Syslog server.

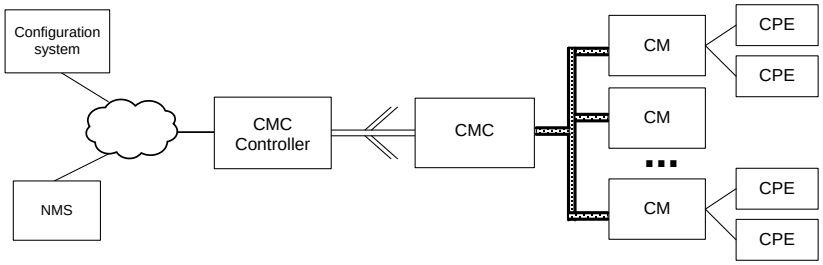

Figure 6-1 - C-DOCSIS System

6.2 Characteristics

This specification introduces several features based on a traditional DOCSIS system, as listed below:

- Distributed architecture for deep-fiber network: This specification introduces a three-level distributed architecture including the CMC Controller, the CMC, and the CM. In a typical deployment, a CMC Controller bridges the digital optical distribution network and the convergence network, a CMC bridges the digital optical network and the coax network, CM bridges the terminal and CPE devices.
- Centralized network administration: This specification introduces a centralized network administration approach, defines the corresponding interfaces and protocols, and supports the end-to-end administration, provisioning, and monitoring of equipment and services.
- Modular equipment and system: This specification defines a series of new system modules. It supports different equipment modules, systems equipment, service requirements and features.

[2] Added the name of another required spec per CDOCSIS-N-14.1216-2 on 2/9/15 by KR.

- CDT data plane interfaces: This specification defines a C-DOCSIS Data Tag (CDT) interface for service flow tagging among different modules, and provides a QoS guarantees for the system.
- CDMM interface: This specification defines a C-DOCSIS Management Message (CDMM) interface to support centralized administration requirement.
- Service flow convergence mapping: This specification defines a mapping protocol between DOCSIS service flows and VLAN tags to support QoS requirements and seamless connection with different type of networks.
- This specification applies to HFC networks featuring high-density residents, large number of users, various service types, and high QoS requirements.
- This specification has the advantages of simple networking operations, low product costs, and high management efficiency.

7 MODULES AND INTERFACES

7.1 Functional Modules

Figure 7-1 shows the functional modules of the distributed CMTS architecture.

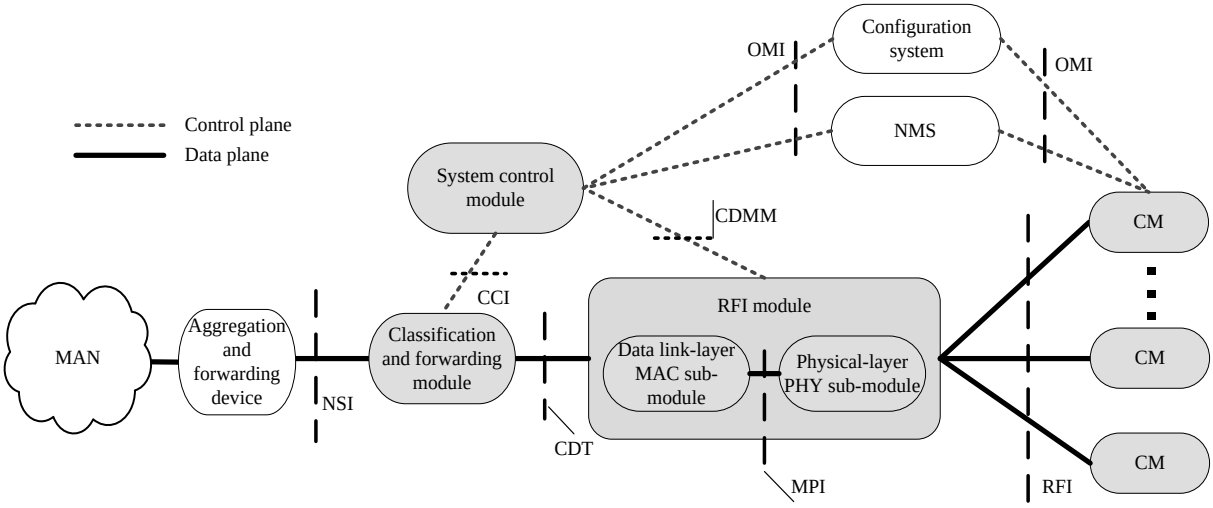

Figure 7-1 - Functional modules of the distributed CMTS architecture

The C-DOCSIS system consists of a distributed CMTS and CMs. All references to a CMTS within this specification generally refer to a Distributed CMTS architecture. While the distributed CMTS consists of two physical devices – the CMC and CMC Controller – it can contains several logical modules. These distributed CMTS logical modules are: the system control module; the classification and forwarding module; and the RFI module (including the data link-layer MAC sub-module and the physical-layer PHY sub-module).

The distributed CMTS logical modules are defined as follows:

- System control module: This logical module is responsible for Configuration and management of the RFI module and the classification and forwarding module. For example, during CM registration, the system control module parses service flows and classification information reported by the CM and configures the classification and forwarding module accordingly. In addition, the system control module works with the NMS and the configuration system for service configuration and management.
- Classification and forwarding module: For downstream data flows, the classification and forwarding module matches data packets based on fields, such as those in the TCP, UDP, IP, as well as LLC headers (for example, MAC address, IP address, and TCP or UDP port number) of the data packets, and inserts into the data packet header the C-DOCSIS Data Tag of the service flow to which the data packet belongs. For upstream data flows, the classification and forwarding module inserts service identifiers of the aggregation network based on service mapping rules and forwards data to the network side.
- RFI module: This logical module implements the functions of the data link-layer MAC sub-module and the physical-layer PHY sub-module defined in this specification. In the downstream direction, the RFI module implements service flow-based scheduling, queuing, and shaping, creates DOCSIS MAC frames, as well as modulates and transmits RF signals. In the upstream direction, the RFI module receives RF signals, processes the DOCSIS MAC frame header, implements queuing and scheduling, and processes DOCSIS MAC management messages.

The configuration system and the NMS are the support systems in the distributed system architecture.

The configuration system configures services and devices in the distributed system architecture. It generates and issues configuration files and upgrades the software of the CMs. The configuration system consists of the DHCP server, configuration file server, software downloading server, and time protocol server. The DHCP server provides initial configurations including IP addresses for CMs and CPEs. The configuration file server provides configuration files for downloading when a CM is initialized. Configuration files are in binary format and contain the configuration parameters of CMs. The software downloading server provides software images for downloading to upgrade CMs. The time protocol server provides correct time for time protocol clients, particularly for CMs.

The NMS consists of the SNMP management system and the Syslog server. The SNMP management system configures and monitors CMC Controllers, CMCs, and CMs through SNMP. The Syslog server collects device operation messages. Other functions supported by the configuration system and the NMS are based on carriers' application requirements.

The distributed CMTS connects to a metropolitan area network (MAN) through an aggregation and forwarding device, which can be an optical line terminal (OLT), an Ethernet switch, or a router.

7.2 Interfaces on Functional Modules

7.2.1 Radio Frequency Interface (RFI)

The RFI interface defines the interface specification at the data link and physical layers between the RFI module and the CMs, including:

1. Modulation modes and parameters for upstream and downstream channels
2. MAC layer characteristics
3. Electrical characteristics

For the application scenarios of the C-DOCSIS system, there are some changes compared with DOCSIS 3.0 in the requirements of RF interface, these are in the different aspects of the Physical layer, MAC layer, and electrical characteristics for downstream channels in an RFI interface.

7.2.2 Network Side Interface (NSI)

The NSI defines the physical interface and service flow mapping logic between the distributed CMTS and the aggregation network. The physical interface is not defined in this specification and can be a GE interface, a 10GE interface, an EPON interface, a GPON interface, or a 10G PON interface. The service flow mapping logic defines the mapping from service flows to Ethernet VLANs. For details, see Annex A.

When the distributed CMTS forwards data packets to the NSI and the CMTS does not implement routing, CMTS SHOULD carry the VLAN field in the data packets. If the CMTS does not implement routing, the CMTS MUST map the service flow sent to the NSI to a VLAN ID and the priority of the service flow to the VLAN priority, as defined in Annex A.

The CMTS MUST support the change of upstream IP priorities. The upper-layer aggregation device can schedule packets based on the VLAN or IP priority.

7.2.3 Operation and Management Interface (OMI)[3]

The operation and management interface (OMI) is used between the system control module and the NMS as well as the configuration system. It is also used between the CM and the NMS as well as the configuration system.

The NMS uses SNMP to configure, maintain, and monitor distributed CMTS components through the OMI and command line interface (CLI).

[3] Modified per CDOCSIS-N-14.1216-2 on 2/9/15 by KR.

Through the OMI, the NMS configures, maintains, and monitors devices, and the configuration system provides service configuration. The policy server uses the Common Open Policy Service (COPS) protocol to communicate with the system control module through the OMI. The initial OMI requirements are defined in the [OSSIv3.0] Annex entitled "Additions and Modifications for Chinese Specification" and will be further defined in a separate OSSI specification.

7.2.4 C-DOCSIS Data Tag (CDT)

The CDT interface defines the identifier format on the data plane between the classification and forwarding module and the RFI module inside the distributed CMTS. The CDT interface uses the format of the 802.1p/q VLAN tag. The VLAN ID identifies the CM to which a data packet belongs, and the class of service (CoS) field identifies the service flow to which a data packet belongs. For details, see Section B.1 in Annex B. The CMTS distinguishes QoS properties of multiple services based on service flows.

In the downstream direction, the classification and forwarding module within the CMTS MUST classify data packets based on the classifier information defined in the configuration file or dynamic service flow signaling messages, and insert a CDT into the Ethernet frame header to identify the service flow. The RFI module within the CMTS MUST identify the service flow based on the CDT, and it shapes, schedules, and forwards traffic based on the QoS parameters defined in the configuration file or dynamic service flow signaling messages.

In the upstream direction, the CM classifies and shapes traffic. The CMTS monitors upstream traffic classification and traffic shaping. The RFI module within the CMTS MUST insert a CDT into the Ethernet frame header in the data packet to identify the service flow. The classification and forwarding module within the CMTS MUST be able to map the CDT to the service flag, such as S-VLAN, IP ToS, and Ethernet LLID, supported by the aggregation network to support the QoS policies used on the aggregation network.

7.2.5 C-DOCSIS Management Message (CDMM)

The CDMM interface defines the control messaging between the system control module and the RFI module as well as the message format. CDMMs are used to exchange configurations, status, and management information between the system control module and the RFI module. The configurations, status, and management information include channel and parameter configurations, transmit or receive status and statistics, load balancing, CM status, CM registration information, operations on dynamic service flows, as well as multicast and security information. For details, see Section B.2 in Annex B.

7.2.6 Control and Classifier Interface (CCI)

The CCI is the control interface between the system control module and the classification and forwarding module. In this specification these two modules are always built within the same device, either in a CMC device or a CMC controller. As such this specification does not define the message format for this interface. A CMC device or a CMC controller implementing the system control module is capable of configuring the classification and forwarding module based on the service flow information reported by the RFI module. In addition, a CMC device or a CMC controller is capable of obtaining protocol packets, such as DHCP packets and control point discovery (CPD) packets required for system control functions and sending these protocol packets to the system control module.

7.2.7 Main Path Interface (MPI)[4]

The MPI is the data communication and management interface between the data link-layer MAC sub-module and the physical-layer PHY sub-module of the RFI module. When the data link-layer MAC sub-module and the physical-layer PHY sub-module are implemented separately, the system uses the MPI protocol for their communications. The MPI protocol and format are implemented as defined in [MHAv2].

[4] Modified per CDOCSIS-N-14.1216-2 on 2/9/15 by KR.

7.3 Data Packet Processing

Figure 7-2 and Figure 7-3 show the data packet processing in the downstream and upstream directions, respectively, in a distributed CMTS architecture.

In the downstream direction, data packets are forwarded to the classification and forwarding module from the aggregation network side. The classification and forwarding module identifies which CM and service flow the data packet belongs to (according to provisioned or learned rules), inserts a CDT tag correspondingly, and forwards packets to the RFI module. The RFI module puts data packets into the queue associated with specific service flow, performs scheduling and rate shaping on queues, packetizes the data into DOCSIS MAC frames, and transmits the DOCSIS MAC frames via RF.

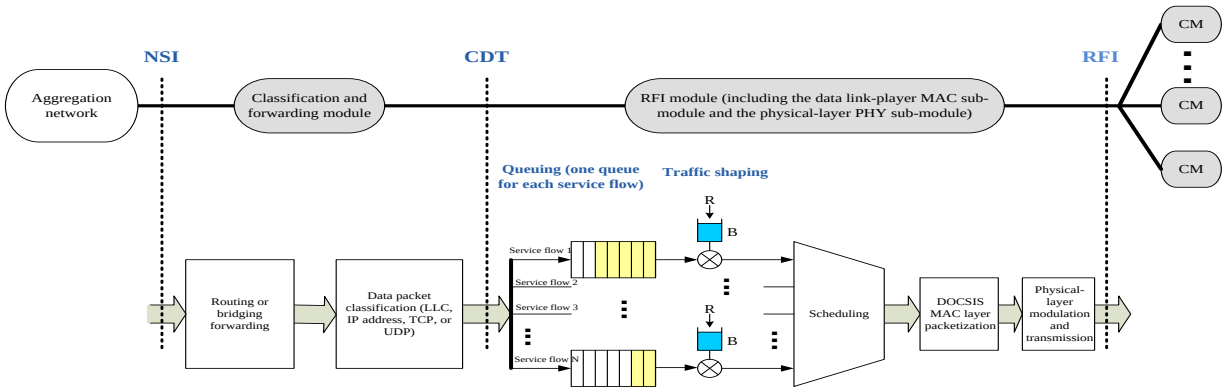

Figure 7-2 - Processing downstream data packets in the distributed CMTS architecture

In the upstream direction, data packets are forwarded to the CM from the home network. The CM classifies ingress data packets according to provisioned classification rules, performs queuing and rate shaping according to provisioned QoS parameters, then forwards packets to the RFI. The RFI module schedules upstream service flow transmissions according to the provisioned scheduling type, receives packets from the service flows, inserts a CDT tag as appropriate, and then forwards packets to the classification and forwarding module. The classification and forwarding module inserts service identifiers of the aggregation network based on provisioned service mapping rules (Section 8.1) and forwards packets to the aggregation network side.

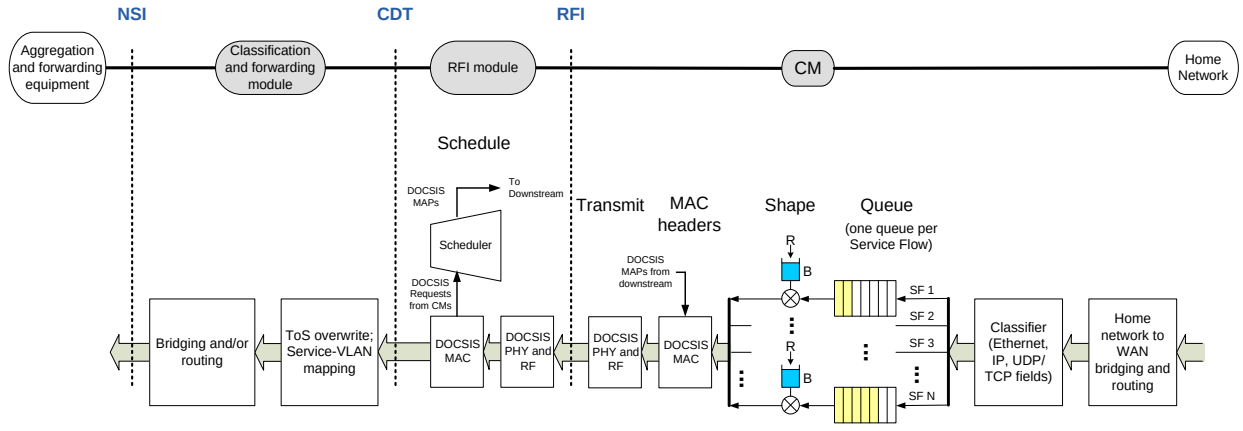

Figure 7-3 - Processing upstream data packets in the distributed CMTS architecture

8 SYSTEM REQUIREMENTS AND DEVICES

8.1 System Requirements

In the system implementation shown in Figure 7-1, the C-DOCSIS system can be the C-DOCSIS I, II, or III system according to different module combinations defined in Section 7. As previously defined, the distributed CMTS consists of a CMC and a CMC Controller. The requirements for CMCs and CMC Controllers are defined in this section.

The CMTSs (consisting of CMCs and CMC Controllers) MUST comply with the data forwarding, QoS, and security requirements defined in this section.

8.1.1 Data Forwarding Requirements

1. Basic Forwarding Requirements

   The CMTS MUST support bridging or routing forwarding. The CMTS MUST support mapping from service flows to VLAN IDs if only bridging forwarding is required. For details about the mapping mode, see Annex A.

2. Multicast

   The CMTS MUST support the IGMPv2 [RFC 2236] and MLDv1 [RFC 2710] multicast protocols. The CMTS MAY support the IGMPv3 [RFC 3376] and MLDv2 [RFC 3810] multicast protocols.

   The CMTS MUST support IGMP or MLD snooping if it's a bridging CMTS. The CMTS MAY support IGMP or MLD proxy.

   The CMTS MAY support multicast join authentication specified in [MULPIv3.0].

3. DHCP Relay Function

   On a DOCSIS access network, the CMs, CPEs, and configuration system can be on different physical network segments. In this case, the CMs and CPEs as DHCP clients cannot directly send DHCP broadcast packets to the DHCP server but they can be converted to unicast packets by the DHCP relay function and sent to the DHCP server. The CMTS MUST support DHCP relay. The specific requirements for DHCP relay are as follows:

   a) The devices that are supported by DHCP relay can be CMs, STBs, eMTAs, and other computational devices.

   b) Multiple DHCP servers can be configured for the CMTS.

   c) The CMTS MUST be capable of identifying DHCP Option 60 and DHCP Option 43, and selecting the DHCP server and the IP address of the relay proxy based on the value of these two options.

   d) The CMTS MUST support the insertion of DHCP Option 82. DHCP Option 82 is defined as follows:
      1) 82.1 Circuit ID: Information about the interface that receives DHCP request messages
      2) 82.2 Remote ID: MAC address of the CM sending DHCP messages
      3) 82.9 DHCPv4 Vendor-Specific Information relay agent sub-option [CANN DHCP]

      Among the above three items, only 82.2 Remote ID is mandatory.

DHCP Option 60 contains a string that describes capabilities of the DHCPv4 client. [CANN DHCP] describes the values of DHCP Option 60. Some of the values are described below as a reference in Table 8–1.

Table 8–1 - Values of DHCP option 60

Device	String in DHCP Option 60	Description
CM	String beginning with "docsis"	The subsequent string describes the DOCSIS version and capability supported by the CM. See [CANN DHCP] for details. The CM can be an independent CM or an embedded CM, such as the CM embedded to an STB.
eMTA	String beginning with "pktc"	The subsequent string can describe the DOCSIS version and capability supported by the eMTA. See [CANN DHCP] for details.
CMC	String beginning with "cmc"	The subsequent string can describe the DOCSIS version and capability supported by the CMC. See [CANN DHCP] for details. The CMC can be a CMC I device, CMC II device or CMC III device.

The definition of DHCPv4 Option 43 and Option 60 needs to comply with [CANN DHCP].

The CMTS MAY support DHCPv6. The CM complies with the DHCPv6 fields defined in [CANN DHCP].

The CMTS MAY support other DHCP relay requirements defined in [MULPIv3.0].

8.1.2 QoS Requirements

The CMTS MUST support DOCSIS 3.0-compliant service flow classification, scheduling, and QoS parameters as defined in [MULPIv3.0]. The CMTS MUST support at least 1024 upstream and downstream service flows.

The CMTS MUST support overwriting of IP priorities for upstream and downstream data packets according to the TLV parameter defined in [MULPIv3.0], and support the reconfiguration of the IP priorities of the data packets received on the RFI and NSI. In addition, the CMTS MUST support the mapping of DOCSIS service priorities to [802.1Q] priorities when they forward data upstream in bridging mode. For details about the mapping of service flows on NSI, see Annex A.

The CMTS MAY support the dynamic configuration of QoS policies, which can be implemented according to either PacketCable Dynamic QoS [DQoS] or PacketCable Multimedia [MM]. The dynamic configuration of QoS policies allows the CMTS to dynamically create, modify, or delete a service flow to ensure the QoS for multimedia sessions, such as voice sessions. With this mechanism, the system provides guaranteed bandwidth resources during a session and releases the resources when the session ends. A dynamic service flow can be initiated from a CMTS or a CM. For detailed information, see Appendix I.

8.1.3 Security Requirements

The CMTS MUST support security requirements defined in the Annex titled "Additions and Modifications for Chinese Specification" in [SECv3.0].

8.1.4 Operations Support Requirements[5]

The CMTS MUST support operations support as defined in the Annex titled "Additions and Modifications for Chinese Specification" in [OSSIv3.0].

8.2 C-DOCSIS I System and Devices

The C-DOCSIS I system consists of the CMC Controller I device, CMC I devices, and CMs. The CMC Controller I device works with the CMC I devices to implement CMTS functions.

In this architecture, the CMC I device contains the classification and forwarding module, the RFI module, which includes the data link layer MAC sub-module and the physical layer PHY sub-module, and the system control

[5] Modified per CDOCSIS-N-14.1216-2 on 2/9/15 by KR.

module. The CMC I device classifies and forwards service data, implements data link layer MAC framing, as well as data modulation and demodulation on the physical layer. The CMC I device is deployed closer to the user side on the network, typically at the fiber node. CMs implement the functions of the CM module specified in Section 7.1. In the C-DOCSIS I system, the system control module of the CMC I device controls protocols, configurations, and managements of services. The CMC Controller I device implements service aggregation and routing.

The CMC I device communicates with CMs through the RFI specified in Section 7.2.1 to implement HFC network communication. The CMC I device connects to aggregation networks through the NSI specified in Section 7.2.2 to forward data flows and map services defined in this specification. The CMC I device communicates with the configuration system and the NMS through the OMI interface specified in Section 7.2.3 over IP channels provided by the aggregation network to configure services and manage the network. The CMC I device communicates with the policy server to perform operations on dynamic service flows.

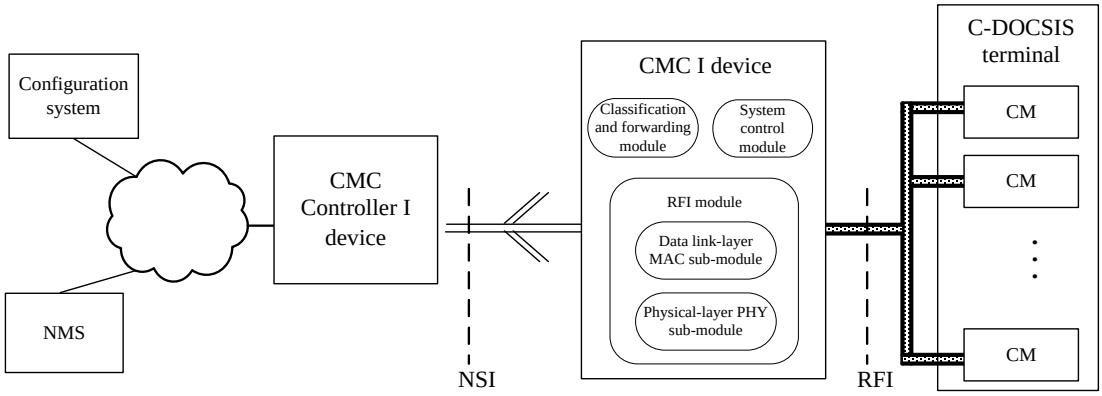

Figure 8-1 - C-DOCSIS I system

In a system implementation, the CMC Controller I device can be either a separate device or a component embedded in an aggregation and switching device, such as a router, a switch, or an OLT. Because the CMC I device contains a classification and forwarding module, a system control module, as well as an RFI module, the data forwarding and QoS functions defined in Section 8.1 SHOULD be implemented on the CMC I device.

8.3 C-DOCSIS II System and Devices [6]

The C-DOCSIS II system consists of the CMC Controller II device, CMC II devices, and CMs. The CMC Controller II device works with the CMC II devices to implement CMTS functions.

In this architecture, the CMC Controller II device contains the classification and forwarding module and the system control module to implement the following functions: service flow classification and forwarding, configuration and management of CMC II devices, and configuration and control of services. The CMC Controller II device is deployed at the hub site. The CMC II device contains the RFI module (refer to Section 7.1), including the data link-layer MAC sub-module and the physical-layer PHY sub-module, to implement the data link-layer MAC framing as well as data modulation and demodulation on the physical layer. The device is deployed close to the user side on the network. CMs implement the functions of the CM module specified in Section 7.1.

The CMC II devices and the CMC Controller II device use the CDT specified in Section 7.2.4 and the CDMM specified in Section 7.2.5 to mark service flows and to control and manage services. The CMC II device communicates with CMs through the RFI interface specified in Section 7.2.1 to implement HFC network communication. The CMC Controller II device connects to the aggregation networks through the NSI specified in Section 7.2.2 to forward data flows and map services defined in this specification. The CMC Controller II device communicates with the configuration system and the NMS through the OMI interface specified in Section 7.2.3 over

[6] Modified per CDOCSIS-N-14.1216-2 on 2/9/15 by KR.

IP channels provided by the aggregation network to configure services and manage the network. The CMC Controller II device communicates with the policy server to perform operations on dynamic service flows.

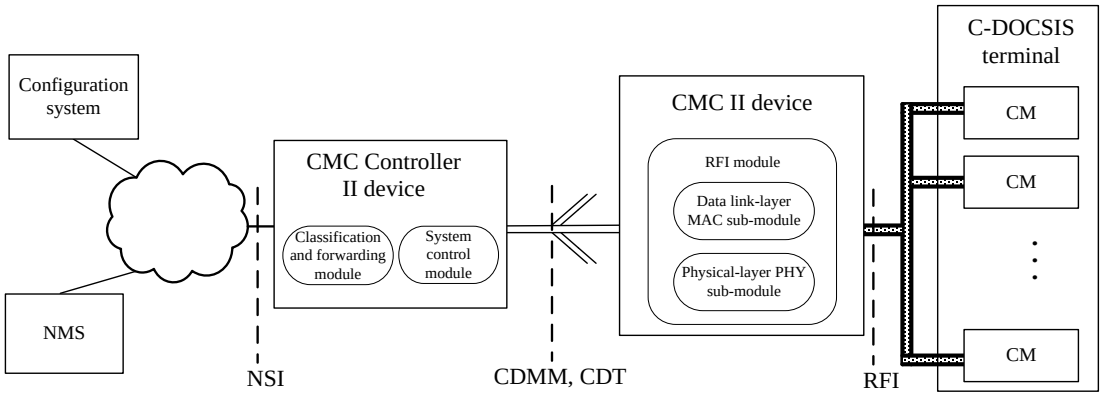

Figure 8-2 - C-DOCSIS II system

In a system implementation, the CMC Controller II device can be either a separate device or a component integrated in an aggregation and switching device, such as a router, a switch, or an OLT. The CMC Controller II device contains classification and forwarding modules and the system control module, and the bridging or routing forwarding function. The CMC Controller II device SHOULD implement the service-flow-to-VLAN mapping function, the multicast control function, the DHCP relay function, the service flow classification function, and the IP priority overwriting function defined in Section 8.1. The CMC II device SHOULD implement the service flow scheduling and the queuing and rate shaping functions.

8.4 C-DOCSIS III System and Devices [7]

The C-DOCSIS III system consists of the CMC Controller III device, CMC III devices, and CMs. The CMC Controller III device works with the CMC III devices to implement CMTS functions.

In this architecture, the CMC Controller III device contains the classification and forwarding module, the data link-layer MAC sub-module, and the system control module to implement the following functions: classify and forward service data, implement data link-layer MAC framing, control system protocols, configure and manage services, and manage the system and devices. The CMC Controller III device is deployed at the hub site. The CMC III device contains the physical-layer PHY sub-module to modulate data and change frequencies at the physical layer for service data. The device is deployed closer to the user side on the network, typically at the fiber node.

The CMC III device communicates with CMs through the RFI interface specified in Section 7.2.1 to implement HFC network communication. The CMC Controller III device communicates with the configuration system and the NMS through the OMI interface specified in Section 7.2.3 over IP channels provided by the aggregation network to configure services and manage the network. The CMC Controller III device communicates with the policy server to perform operations on dynamic service flows. The data link-layer MAC sub-module and the physical-layer PHY sub-module of the RFI module implement data communication and management through the MPI interface specified in Section 7.2.7.

[7] Modified per CDOCSIS-N-14.1216-2 on 2/9/15 by KR

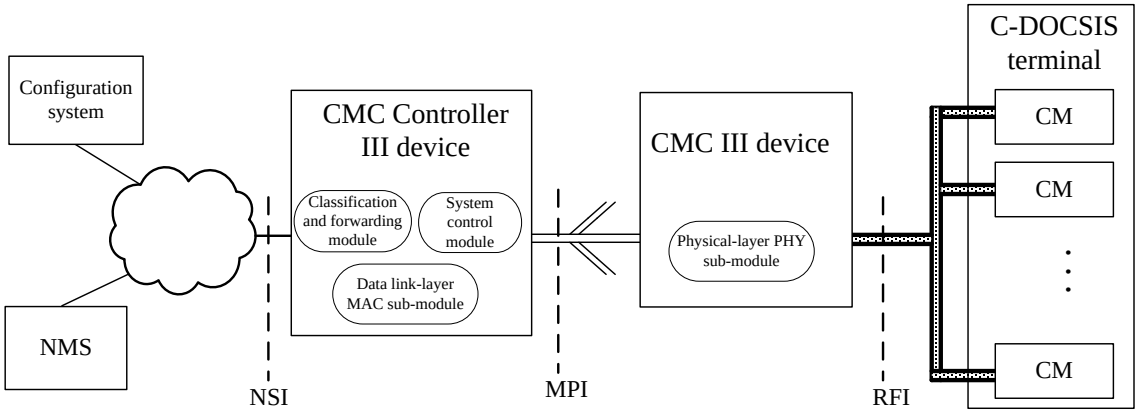

Figure 8-3 - C-DOCSIS III system

In this system, the CMC Controller III device can be either a separate device or a device supporting core CMTS functions, such as a CMTS, router, or switch. Accordingly, the physical channel between the CMC Controller III device and the CMC III devices can be an optical PON network or a GE Ethernet network. The CMC Controller III device manages all CMC III devices, CMs, and CPEs in a unified manner. It supports real-time detection of and responds to events such as a CMC III device going online or offline.

The CMC III Controller uses the MPI described in Section 7.2.7, which includes a Generic Control Plane (GCP) to manage CMC III devices, an Upstream External PHY Interface (UEPI), and a Downstream External PHY Interface (DEPI) to transmit data traffic between the CMC III controller and CMC III devices. GCP is based on TCP/UDP and can take over all network management for CMC III devices. UEPI and DEPI are based on the L2TPv3 protocol; it can pass through any L2 and L3 network. The C-DOCSIS III system architecture is described in a separate set of specifications known as Modular Headend Architecture v2 [MHAv2].

Because the CMC Controller III device contains a classification and forwarding module, the system control module, as well as a data link-layer MAC sub-module, it SHOULD implement the data forwarding and QoS functions defined in Section 8.1. The VLAN mapping defined in Section 8.1 is not required for the C-DOCSIS III system.

Annex A Service Flow Mapping to VLAN

The Service flow to VLAN mapping is implemented on the NSI. If the CMTS does not implement routing, it MUST support mapping from service flows to VLANs.

The classification and forwarding module in the CMTS MUST support the mapping from upstream service flows to VLAN IDs. The mapping from upstream service flow references or service class names to VLAN IDs can be configured. This configuration is global. That is, all the service flows with the same service flow reference or service class name are mapped to the same VLAN ID.

The classification and forwarding module in the CMTS MUST support the mapping from priorities of upstream service flows to [802.1Q] priorities. The mapping from the priorities defined by the upstream traffic priority or service class to [802.1Q] priorities can be configured. This configuration is global. That is, all the upstream service flows with the same traffic priority or service class name are mapped to the same [802.1Q] priority.

The classification and forwarding module in the CMTS MUST support the mapping from all dynamically created service flows to the same VLAN ID or [802.1Q] priority, or enable users to configure the mapping from service class names to VLAN IDs and [802.1Q] priorities.

- Examples of mapping DOCSIS services to VLANs: Assume that video, Internet access, and voice services are available and their upstream service flow references are SFrA, SFrB, and SFrC respectively. These three types of services can be mapped to different VLAN IDs, for example:
  - SFrA -> VLAN 1
  - SFrB -> VLAN 2
  - SFrC -> VLAN 3
- These three types of services can also be mapped to the same VLAN ID, for example:
  - SFrA -> VLAN 4
  - SFrB -> VLAN 4
  - SFrC -> VLAN 4

In addition, one type of service can have different upstream service flow references. For example, video services support SFrD and SFrE in addition to SFrA. These upstream service flow references are mapped to the same VLAN; that is, different users can use different upstream service flow references to identify the same service.

During priority mapping, the priority defined in the upstream traffic priority or service class is used directly as [802.1Q] priority.

In the downstream direction, the classification and forwarding module in CMTS strips off VLAN tags and adopts packet classification rules for service flows classification and QoS scheduling.

Service flow to VLAN mapping MUST be implemented on a CMC in C-DOCSIS I system, and implemented on CMC Controller in a C-DOCSIS II system and a C-DOCSIS III system.

Annex B CDMM and CDT

B.1 C-DOCSIS Tagging (CDT)

The C-DOCSIS data tag (CDT) format is a method of using VLAN tags to indicate the Service Flow to which a packet has been classified. It is used in the data plane to identify Service Flows on the link between the classification and forwarding module and the RFI module.

For downstream data traffic, the classification and forwarding module in the CMTS MUST add a CDT-formatted VLAN tag to each packet that is classified to a unicast Service Flow, indicating to which Service Flow the packet was classified. Other VLAN tags may be present, but CMTS MUST ensure that the CDT-formatted VLAN tag is in the outermost position when the packet reaches the RFI module in the CMTS.

In the upstream direction, the RFI module in the CMTS MUST add a CDT-formatted VLAN tag to each data packet that is forwarded from a cable modem, indicating on which Service Flow the packet was received. If other VLAN tags are present, the CDT tag MUST be in the outermost position at the point where the packet leaves the RFI module in the CMTS.

The format of the CDT VLAN tag is illustrated in Figure B–1.

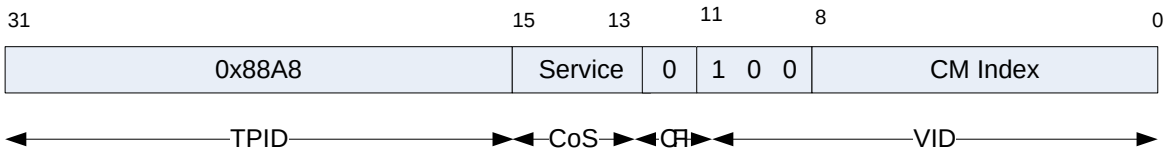

Figure B–1 - CDT VLAN Tag Format

The fields are as follows:

- TPID: The value 0x88A8 is defined by [802.1Q] as the TPID value for a Service Provider (S-VLAN) tag, which is the outer tag in a double-tagged packet.
- CoS/PCP bits: In [802.1Q], this field is defined as a Priority Code Point (PCP) and used to indicate the packet priority as specified by [802.1Q]. However, the RFI module does NOT use this field to indicate priority. The RFI module uses this field only as an identifier. In conjunction with the VID, this field identifies the Service Flow to which the packet belongs. The contents of the CoS/PCP field have no impact on the QoS treatment of the flow by the RFI module. The RFI module determines the priority and other QoS parameters of the flow based on the DOCSIS TLV encodings specified in the DOCSIS messages used to set up the flow.
- CFI bit: This bit is always set to zero for CDT.
- VID: The system control module in the CMTS MUST choose a VID value between 0x801 and 0x9D0. The lower 9 bits of this value are the "CM Index" and are always the same for Service Flows to or from the same cable modem.

The combination of VID and CoS bits identifies the Service Flow to which the packet has been classified. Each VID+CoS value corresponds to a single Service Flow in a given direction. The values of VID and CoS that correspond to a Service Flow are selected by the system control module at the time the flow is admitted or activated. The system control module always chooses the same VID for Service Flows to or from the same CM. Different values of CoS bits identify different flows to or from the CM. A particular value of CoS bits may be used once for a downstream flow and once for an upstream flow to/from the same CM. Since there are eight possible values for the CoS bits, a single VID can be used for up to eight downstream flows and up to eight upstream flows.

At the RFI module, in the downstream direction, all packets with a given VID+CoS combination in the CDT tag will be placed in a single queue in the order received. The RFI module then schedules the queue based on the DOCSIS QoS parameters for the corresponding Service Flow. The actual value of the CoS field is not important to the RFI module, and does not affect the priority of the Service Flow. The system control module MAY choose any value for the CoS bits for any flow without affecting the priority of the flow.

In the upstream direction, the RFI module allocates bandwidth to each Service Flow based on the DOCSIS QoS parameters for that flow. The RFI module adds a CDT tag to each received packet. The CDT tag contains the VID+CoS values indicating the Service Flow of the received packet. The value of the CoS field in the CDT tag for the flow has no effect on the RFI module's allocation of upstream bandwidth or its handling of packets after they are received.

Even though the RFI module does not interpret the CoS field as a priority, other system elements may recognize the CDT tag and use the CoS bits to indicate the priority of the packet. For example, a layer 2 switch in the network between the RFI module and the classification and forwarding module may recognize the CDT tag as a Service VLAN tag and interpret the CoS/PCP field in accordance with [802.1Q], where a CoS/PCP value of 0 represents lowest priority, and a CoS/PCP value of 7 represents highest priority. To accommodate these network elements, the system control module can choose CoS bits that reflect the relative priority of the flow (for example, it chooses higher values for flows with higher DOCSIS priority, and lower values for flows with lower DOCSIS priority). The system control module in the CMTS MUST choose different CoS values for different Service Flows in a given direction belonging to the same CM, even if the flows actually have the same DOCSIS scheduling priority. For example, if a CM has two identical active voice flows, the system control module in the CMTS chooses two different values for the CoS field for the two different flows, even though the DOCSIS priority and other QoS parameters for the two flows are identical. The RFI module will schedule flows only based on DOCSIS-specified QoS parameters.

The system control module uses CDMM messages (Section B.2) to indicate the values of VID and CoS/PCP that will correspond to a given Service Flow. These messages are exchanged at the time the flow is set up in or changed to an admitted or active state. An encoding to delete an association of VID+CoS with a Service Flow also exists. This encoding would be used if there were a need to free resources without actually deleting the flow. When a flow is deleted, the VID+CoS values corresponding to that flow are automatically freed.

B.2 C-DOCSIS Management Messaging (CDMM)

B.2.1 CDMM Overview

C-DOCSIS Management Messaging (CDMM) is the set of control-plane messages that are exchanged between the RFI module and other functional blocks in the system.

B.2.2 CDMM encapsulation

B.2.2.1 Encapsulation Format

A CDMM message can be encapsulated in the payload of various network transmit protocols or device internal communications protocols. For the CDMM, a CMTS SHOULD use IEEE OAM encapsulation if the convergence network is an EPON-based system, OMCI encapsulation if the convergence network is a GPON-based system, or TCP/IP encapsulation for other systems.

CDMM messages can be encapsulated in one of two formats: IEEE OAM as defined in [802.3], and the TCP/IP format defined in [RFC 791] and [RFC 793].

B.2.2.2 Encapsulation with OAM Transport Layer

The Operations, Administration, and Maintenance (OAM) sub layer, as specified by [802.3], provides a set of mechanisms for configuring, administrating, and monitoring a networked system setup.

The organization-specific OAM code (0xFE) is used for organization-specific extensions, as depicted in Figure B–2. The first element of the OAM Data field will always be a 3-byte structure that represents the 'Organization Unique Identifier' (OUI). This OUI will then dictate the rest of the structure in the provided "Data" field based on the organization's implementation.

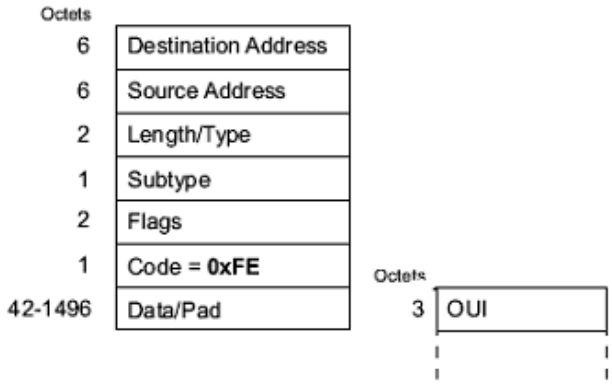

Figure B–2 - Organization Specific OAM Frame

B.2.2.2.1 Frame Structure

The OAM implementation utilizes the 'Organization specific vendor OAM' structure to encapsulate the CDMM messages exchanged between the system control module and the RFI module to meet the provisioning and management needs.

The overall format of the OAM frames is shown in Table B–1.

Table B–1 - OAM Frame Structure

Size (Octets)	Field	Value (hex)
6	Destination Address	01 80 C2 00 00 02
6	Source Address	MAC address
2	Type	0x88 09
1	Subtype	0x03
2	Flags	XX YY
1	Code	0xFE
OAM OUI		
3	OUI	0x001000
Transport Layer Header		
1	Version	0x01
1	Type	0x00 = message PDU 0x01 = ACK
2	Sequence number	n
2	Total Number of Expected Frames	m
1	Length	'LEN' bytes
PDU or Response Code		
n	PDU if Type = 0x00 Response co de if Type = 0x01	PDU or 1-byte response code

B.2.2.2.2 Transport Layer Header

The OAM encapsulation relies on a simple transport layer to support the fragmentation/reassembly of large CDMM messages and the retransmission of missed message fragments. The CMTS MUST support the formats for the header fields of the transport layer as shown in Table B–1 and explained below:

- Version: a 1-byte field representing the transport layer version. The version supported by the current specification be '0x01'.
- Type: a 1-byte field representing the data field following Transport Layer Header is PDU or ACK.
- Sequence Number: a 2-byte field representing the sequence number of the frame within the context of the CDMM message being sent. This field is reset for every new CDMM message.
- Total Number of Expected Frames: a 2-byte field representing the total number of frames for the CDMM message currently being sent.
- Length: a 1-byte field representing the number of bytes present in the encapsulated CDMM message inside the frame.

B.2.2.2.3 PDU

The fragments of a CDMM message are called PDUs of the message. The format of the first PDU for a message is shown in Table B–2. The format of any subsequent PDUs for a message is shown in Table B–3.

Table B–2 - Format of the First PDU

Size (Octets)	Field	Value (hex)
1	Version	0x01
1	Reserved	---
2	Message ID (correlation tag)	AA BB
2	Opcode	XX YY
LEN - 6	Data	The first fragment of a CDMM message contents defined in Section B.2.3

Table B–3 - Format of Subsequent PDU's

Size (Octets)	Field	Value (hex)
LEN	Data	A subsequent fragment of a CDMM message contents defined in Section B.2.3

The CMTS MUST support the formats for the PDU fields as described below:

- Version: a 1-byte field representing the CDMM message PDU version. The version supported by the current specification be set to '0x01'.
- Reserved: a 1-byte field reserved to identify RF interface number for future usage.
- Opcode: a 2-byte field representing the actual command and function being referenced by the CDMM message. All standard opcodes supported are listed in Section B.2.3.2.
- Message ID: a 2-byte field representing a unique identifier for the specific CDMM messaging transaction. The same identifier will be used in the CDMM request as well as the CDMM response, which will help correlate the full circle of CDMM messaging transaction.
- Data: a data structure that depends on the value of the opcode field. It contains a fragment of the CDMM message defined in Section B.2.3.

B.2.2.2.4 Acknowledgement

Each PDU received from the OAM Transport Layer MUST be acknowledged by the CMTS with an appropriate response code in the acknowledge frame shown in Table B–4. The CMTS MUST match the Transport Layer header fields of the acknowledge frame to those of the acknowledged PDU.

Table B–4 - Transport Layer Acknowledgement Format

Size (Octets)	Field	Value (hex)
1 byte	Response code	code

Table B–5 lists all applicable response codes used for transport-layer acknowledgement.

Table B–5 - Transport Layer Response Code

Response code	Description
0x00	Valid frame
0x01	Incompatible version
0x02	Out of sequence frame
0x03	Exceeded maximum number of expected frames

B.2.2.2.5 Protocol

For the logical modules within the CMTS the following requirements apply:

- The sender MUST send the PDU transport frames of a CDMM message in order by sequence number.
- The sender MUST send one PDU transport frame at a time and wait for an acknowledgement from the receiver before sending the next frame.
- If an acknowledgement is not received within a vendor-specific timeout period, or if the response code in the acknowledgement is anything other than "valid frame", the sender MUST retransmit the missing or failed frame.
- If the receiver receives back-to-back PDU frames with the same sequence number, it MUST acknowledge both frames with a "valid frame" response code and silently discard one of them.
- If the sender completes three retries (four attempts total) without receiving an acknowledgement indicating a valid frame, the sender signals a higher layer that the CDMM control channel has been lost. The behavior of the higher layer in response to this signal is vendor specific, but SHOULD include attempts to reinitialize or otherwise restore the channel.

B.2.2.3 Encapsulation with TCP/IP Transport Layer

When the transport layer of the CDMM interface is based on TCP/IP, CDMM messages defined in Section B.2.3 are encapsulated in TCP segments as the TCP data payload. In this case, the message fragmentation, error detection, and error recovery are all handled by TCP/IP protocols.

The TCP/IP encapsulation of CDMM messages is shown in Table B–6.

Table B–6 - TCP/IP Encapsulation

Size (Octets)	Field	Value (hex)
n	IP Header Fields	Per IP protocol
m	TCP Header Fields	Per TCP protocol
PDU		
1	Version	0x01
2	Message ID (correlation tag)	AA BB
2	Opcode	XX YY
4	Length	LEN
LEN	Data	CDMM message contents defined in Section B.2.3

B.2.3 CDMM Message Contents

B.2.3.1 Overview

All CDMM messages are defined in this section, with details of the contents of each message and expected behavior in response to the message described. These messages are related to the functions such as initialization and provisioning of the RFI module, ranging and registration of CMs, load balancing of CMs across upstream and downstream channels, dynamic service operations, as well as event notification and status information.

Each message defined in this section can be carried over the CDMM interface using either of the two encapsulation mechanisms specified in Section B.2.1.

B.2.3.2 CDMM Message Index

The following tables list out all CDMM messages. These CDMM messages are categorized by their logical functionality and indexed by their opcodes.

Table B–7 - Downstream Configurations

Opcode	Message	Description
0x01	Set Downstream Config Request	Request to configure downstream channel(s)
0x02	Set Downstream Config Response	Response to configure downstream channel(s)
0x03	Get Downstream Config Request	Request to retrieve current downstream channel(s) configuration
0x04	Get Downstream Config Response	Response to retrieve current downstream channel(s) configuration

Table B–8 - Upstream Configuration

Opcode	Message	Description
0x05	Set Upstream Config Request	Request to configure upstream channel(s)
0x06	Set Upstream Config Response	Response to configure upstream channel(s)
0x07	Get Upstream Config Request	Request to retrieve current upstream channel(s) configuration
0x08	Get Upstream Config Response	Response to retrieve current upstream channel(s) configuration

Table B–9 - Move CM Downstream

Opcode	Message	Description
0x09	Set Move CM Downstream Request	Request to configure CM with a particular Receive Channel Set
0x0a	Set Move CM Downstream Response	Response to configure CM with a particular Receive Channel Set
0x0b	Get Move CM Downstream Request	Request to retrieve CM's current Receive Channel Set
0x0c	Get Move CM Downstream Response	Response to retrieve CM's current Receive Channel Set

Table B–10 - Move CM Upstream

Opcode	Message	Description
0x0d	Set Move CM Upstream Request	Request to configure CM with a particular Transmit Channel Set
0x0e	Set Move CM Upstream Response	Response to configure CM with a particular Transmit Channel Set
0x0f	Get Move CM Upstream Request	Request to retrieve CM's current Transmit Channel Set
0x10	Get Move CM Upstream Response	Response to retrieve CM's current Transmit Channel Set

Table B–11 - Load Balancing

Opcode	Message	Description
0x15	Set Create Load Balancing Group Request	Request for creating a load balancing group
0x16	Set Create Load Balancing Group Response	Response for creating a load balancing group request
0x17	Get Load Balancing Groups Request	Request to get a list of load balancing groups
0x18	Get Load Balancing Groups Response	Response to get load balancing groups request
0x19	Set Add Downstreams to Load Balancing Group Request	Request to add downstreams to a load balancing group
0x1a	Set Add Downstreams to Load Balancing Group Response	Response to add downstreams to a load balancing group request
0x1b	Get Load Balancing Group Downstreams Request	Request to get list of downstreams in a load balancing group
0x1c	Get Load Balancing Group Downstreams Response	Response to get list of downstreams in a load balancing group request
0x1d	Set Add Upstreams to Load Balancing Group Request	Request to add upstreams to a load balancing group
0x1e	Set Add Upstreams to Load Balancing Group Response	Response to add upstreams to a load balancing group request
0x1f	Get Load Balancing Group Upstreams Request	Request to get list of upstreams in a load balancing group
0x20	Get Load Balancing Group Upstreams Response	Response to get list of upstreams in a load balancing group request

Opcode	Message	Description
0x21	Set Add CMs to Load Balancing Group Request	Request to add CMs to a load balancing group
0x22	Set Add CMs to Load Balancing Group Response	Response to add CMs to a load balancing group request
0x23	Get Load Balancing Group CM Configuration Request	Request to get load balancing group CM configuration
0x24	Get Load Balancing Group CM Configuration Response	Response to get load balancing group CM configuration request
0x25	Get Load Balancing Group Active CMs Request	Request to get the active list of CMs associated with the specified load balancing group
0x26	Get Load Balancing Group Active CMs Response	Response to the get active list of CMs associated with the specified load balancing group
0x27	Set Exclude CMs from Load Balancing Request	Request to exclude CMs from load balancing
0x28	Set Exclude CMs from Load Balancing Response	Response to exclude CMs from load balancing request
0x29	Get Excluded CMs Configuration Request	Request to get excluded CMs from load balancing configuration
0x2a	Get Excluded CM Configuration Response	Response to get excluded CMs from load balancing configuration request
0x2b	Get Excluded Active CMs Request	Request to get the active excluded CMs from load balancing list
0x2c	Get Excluded Active CMs Response	Response to get active excluded CMs from load balancing request
0x2d	Set Full Load Balancing Group Request	Request to configure the specified Load Balancing groups
0x2e	Set Full Load Balancing Group Response	Response to configuration request for Load Balancing groups
0x2f	Get Full Load Balancing Group Request	Request to retrieve detailed active Load Balancing Groups
0x30	Get Full Load Balancing Group Response	Response to retrieve detailed active Load Balancing Groups

Table B–12 - Upstream Input Power Level

Opcode	Message	Description
0x31	Set Upstream Input Power Request	Request to set the input power level for upstream channels
0x32	Set Upstream Input Power Response	Response to set input power levels of upstream channels
0x33	Get Upstream Input Power Request	Request to get the input power levels for upstream channels
0x34	Get Upstream Input Power Response	Response to get input power levels for upstream channels

Table B–13 - CM Arrival, Departure, and Deletion

Opcode	Message	Description
0x300	CM Arrival Request	Request authorization from the system control module for a new CM to join the network
0x301	CM Arrival Response	Response to the arrival of a CM
0x302	CM Departure	Inform the system control module about the departure of a CM
0x303	Set CM Delete Request	Request to delete a CM from the network
0x304	Set CM Delete Response	Response to delete a CM from the network

Table B–14 - QoS and Dynamic Services

Opcode	Message	Description
0x350	Set Service Class Name Request	Request to set the Service Class name
0x351	Set Service Class Name Response	Response to set the Service Class name
0x352	Service Flow Reservation Request	Request to reserve a Service Flow
0x353	Service Flow Reservation Response	Response to reserve a Service Flow
0x354	CDMM Registration Request	Forward to the system control module information about a CM REG-REQ or REG-REQ-MP
0x355	CDMM Registration Response	The system control module responds to the RFI module about a registration request
0x356	CDMM Registration Acknowledge	The RFI module forwards to the system control module the CM's registration acknowledge
0x357	Multicast Join Authorization Request	The RFI module requests authorization from the system control module for a CM to join a multicast group
0x358	Multicast Join Authorization Response	The system control module responds to the RFI module about a CM's request to join a multicast group
0x359	Security Association Auth Request	The RFI module requests authorization from the system control module to initialize BPI+ for a CM
0x35A	Security Association Auth Response	The system control module responds to the RFI module about a CM's BPI+ initialization
0x360	CDMM DSA-REQ CM-Initiated	The RFI module forwards information about a received DSA-REQ to the system control module
0x361	CDMM DSC-REQ CM-Initiated	The RFI module forwards information about a received DSC-REQ to the system control module
0x362	CDMM DSD-REQ CM-Initiated	The RFI module forwards information about a received DSD-REQ to the system control module
0x363	CDMM DSA-RSP CM-Initiated	The system control module responds to a received DSA-REQ
0x364	CDMM DSC-RSP CM-Initiated	The system control module responds to a received DSC-REQ
0x365	CDMM DSD-RSP CM-Initiated	The system control module responds to a received DSD-REQ
0x366	CDMM DSA-ACK CM-Initiated	The RFI module forwards to the system control module the CM's ACK for DSA-RSP
0x367	CDMM DSC-ACK CM-Initiated	The RFI module forwards to the system control module the CM's ACK for DSC-RSP

Opcode	Message	Description
0x368	CDMM DSA-REQ CMTS-Initiated	The system control module requests the RFI module to initiate a DSA-REQ
0x369	CDMM DSC-REQ CMTS-Initiated	The system control module requests the RFI module to initiate a DSC-REQ
0x36A	CDMM DSD-REQ CMTS-Initiated	The system control module requests the RFI module to initiate a DSD-REQ
0x36B	CDMM DSA-RSP CMTS-Initiated	The RFI module forwards the system control module a DSA-RSP from the CM
0x36C	CDMM DSC-RSP CMTS-Initiated	The RFI module forwards the system control module a DSC-RSP from the CM
0x36D	CDMM DSD-RSP CMTS-Initiated	The RFI module forwards the system control module a DSC-RSP from the CM
0x36E	CDMM DSA-ACK CMTS-Initiated	The system control module sends the RFI module the ACK for DSA-RSP
0x36F	CDMM DSC-ACK CMTS-Initiated	The system control module sends the RFI module the ACK for DSC-RSP

Table B–15 - CM and RFI module Statistics

Opcode	Message	Description
0x701	Get CM Status Request	Request to retrieve CM status information
0x702	Get CM Status Response	Response to retrieve CM status information
0x703	Get RF Interfaces Request	Request to retrieve RF interface attributes
0x704	Get RF Interfaces Response	Response to retrieve RF interface attributes
0x705	Get RF Interface MAC Statistics Request	Request to retrieve RFI module DOCSIS MAC statistics
0x706	Get RF Interface MAC Statistics Response	Response to retrieve RFI module DOCSIS MAC statistics
0x707	Get Services Statistics Request	Request to retrieve Service Flow statistics for a CM
0x708	Get Services Statistics Response	Response to retrieve Service Flow statistics for a CM
0x709	Get Signal Quality Request	Request to retrieve Upstream PHY Signal Quality data
0x70a	Get Signal Quality Response	Response to retrieve Upstream PHY Signal Quality data
0x70b	Get RF Interfaces Statistics Request	Request to retrieve RF interface statistics
0x70c	Get RF Interfaces Statistics Response	Response to retrieve RF interface statistics
0x70d	Get Downstream Bonding Group Status Request	Request to retrieve Downstream Bonding Group status information
0x70e	Get Downstream Bonding Group Status Response	Response to retrieve Downstream Bonding Group status information
0x70f	Get Upstream Bonding Group Status Request	Request to retrieve Upstream Bonding Group status information
0x710	Get Upstream Bonding Group Status Response	Response to retrieve Upstream Bonding Group status information

Table B–16 - Vendor-Specific Messaging

Opcode	Message	Description
0x0F01	Vendor-specific message	Opcode to indicate vendor-specific message

Table B–17 - RFI module Autonomous Events

Opcode	Message	Description
0x1001	RF Interface System Event message	Autonomous event to report an RFI module System message

B.2.3.3 CDMM Message Specification

The contents of all CDMM messages listed in Section B.2.3.2 are specified in this subsection. These messages are categorized by their logical functionality and ordered according to their opcodes. Some messages include an operation result code. Where result code values are not specified in the description of the message, the result codes in Table B–18 apply.

Table B–18 - CDMM Message Result Codes

Result Code	Description
0x00	Success
0x01	Fail
0x02	Invalid parameters
0x03-0xff	Reserved – Command specific error codes

B.2.3.3.1 DOCSIS Downstream Configuration

B.2.3.3.1.1 SET DOWNSTREAM CONFIG REQUEST (0x01)

This message is sent from the system control module to the RFI module.

This message is sent down to provision the downstream as desired. The number of channels and the per-channel properties to be provisioned are sent down as described below.

Table B–19 - SET DOWNSTREAM CONFIG REQUEST (0x01)

Bytes	Field	Description
1	Number of Downstream Channels	Number of Downstream channels to configure (1-16)
--	-- { Per Downstream Channel Properties } --	-- { Per Downstream Channel Properties } --
1	Downstream Channel ID	Downstream channel index for 1st channel
1	Enable \ Disable	1st channel state: Enabled = '1'; Disable = '0'
4	Center Frequency	1st channel center frequency in Hz
1	Modulation	1st channel modulation type - QAM-64 = '0'; QAM-256 ='1'; QAM-1024 = '2'
1	Annex	1st channel annex type: Annex_A='0'; Annex_B='1'

Bytes	Field	Description
1	Interleaver	1st channel interleaver depth value - 1={128,1}, 3={64,2}, 5={32,4}, 7={16,8}, 9={8,16} **NOTE:** Ignore for Annex_A
2	Power level	Power level for 1st channel (tenths dBmV)
2	RESERVED	RESERVED – needs to be included

B.2.3.3.1.2 SET DOWNSTREAM CONFIG RESPONSE (0x02)

This message is sent from the RFI module to the system control module.

This message is sent up in response to a 'Set Downstream Config Request' message that is structured as shown below. The per-channel result code value describes the final result of the requested operation.

Table B–20 - SET DOWNSTREAM CONFIG RESPONSE (0x02)

Bytes	Field	Description
1	Number of Downstream Channels	Number of Downstream channels configured (1-16)
1	Downstream Channel ID	Downstream channel index for 1st channel
1	Result code	Operation result code for 1st channel
….	……..	……..
1	Downstream Channel ID	Downstream channel index for nth channel
1	Result code	Operation result code for nth channel

B.2.3.3.1.3 GET DOWNSTREAM CONFIG REQUEST (0x03)

This message is sent from the system control module to the RFI module.

This message is sent down to query the current downstream channel setup. The number of channels and the respective 'Downstream Channel IDs' (DCIDs) to be queried are sent down as structured below.

Table B–21 - GET DOWNSTREAM CONFIG REQUEST (0x03)

Bytes	Field	Description
1	Number of Downstream Channels	Number of Downstream channels to query (1-16)
1	Downstream Channel ID	Downstream channel index for 1st channel
….	……..	……..
1	Downstream Channel ID	Downstream channel index for nth channel

B.2.3.3.1.4 GET DOWNSTREAM CONFIG RESPONSE (0x04)

This message is sent from the RFI module to the system control module.

This message is sent up in response to a 'Get Downstream Config Request' message containing all pertinent information with regards to the current Downstream setup. The number of channels and the per-channel properties are sent up as described below.

NOTE: For 'Annex_A' setup, ignore the value indicated in the 'Interleaver' field.

Table B–22 - GET DOWNSTREAM CONFIG RESPONSE (0x04)

Bytes	Field	Description
1	Number of Downstream Channels	Number of Downstream channels queried (1-16)
--	-- { Per Downstream Channel Properties } --	-- { Per Downstream Channel Properties } --
1	Downstream Channel ID	Downstream channel index for 1st channel
1	Enable \ Disable	1st channel state: Enabled = '1'; Disable = '0'
4	Center Frequency	1st channel center frequency in Hz
1	Modulation	1st channel modulation type - QAM64 = '0'; QAM256 ='1'; QAM1024 = '2'
1	Annex	1st channel annex type: Annex_A='0'; Annex_B='1'
1	Interleaver	1st channel interleaver depth value – 1={128,1}, 3={64,2}, 5={32,4}, 7={16,8}, 9={8,16} **NOTE:** Ignore for ANNEX_A.
2	Power level	Power level for 1st channel (tenths dBmV)
2	Interface index (ifIndex)	1st channel interface index

B.2.3.3.2 DOCSIS Upstream Configuration

B.2.3.3.2.1 SET UPSTREAM CONFIG REQUEST (0x05)

This message is sent from the system control module to the RFI module.

This message is sent down to provision the upstream as desired. The number of channels and the per-channel properties are sent down as described below.

NOTE: Valid values for 'Channel Width' are limited to 1.6 MHz, 3.2 MHz, and 6.4 MHz. The CMTS MUST include the Reserved field size of bytes in the packet per channel.

Table B–23 - SET UPSTREAM CONFIG REQUEST (0x05)

Bytes	Field	Description
1	Number of Upstream Channels	Number of Upstream channels to configure (1-4)
--	-- { Per Upstream Channel Properties } --	-- { Per Upstream Channel Properties } --
1	Upstream Channel ID	Upstream channel index for 1st channel
1	Enable \ Disable	1st channel state: Enabled = '1'; Disable = '0'
4	Center Frequency	1st channel center frequency in Hz
4	Channel Width	1st channel width in Hz **NOTE:** Valid values – 1.6 MHz, 3.2 MHz, 6.4 MHz
1	Channel Profile Type	1st channel burst profile type, Corresponding burst profile parameters are defined by system vendors.

Bytes	Field	Description
1	Docsis 3.0 Channel Mode	For SCDMA mode: 1st channel 'SAC2'\'SINC2'\'UCD35' support mode – Enabled = '1'; Disabled = '0' (**NOTE:** Disabled implies 'SAC1\SINC1\UCD29' mode) For ATDMA mode: 1st channel 'UCD35' support mode – Enabled = '1'; Disabled = '0' (**NOTE:** Disabled implies 'UCD29' mode)
17	RESERVED	RESERVED – Needs to be included
1	Channel Type	1st channel burst type – Unknown = '0'; TDMA='1'; ATDMA = '2'; SCDMA = '3'; TDMA/A-TDMA = '4'; All other values are unsupported.
3	RESERVED	RESERVED – Needs to be included

B.2.3.3.2.2 SET UPSTREAM CONFIG RESPONSE (0x06)

This message is sent from the RFI module to the system control module.

This message is sent up in response to a 'Set Upstream Config Request' message that is structured as shown below. The per-channel result code value describes the final result of the requested operation.

Table B–24 - SET UPSTREAM CONFIG RESPONSE (0x06)

Bytes	Field	Description
1	Number of Upstream Channels	Number of Upstream channels configured (1-4)
1	Upstream Channel ID	Upstream channel index for 1st channel
1	Result code	Operation result code for 1st channel
….	…….	……..
1	Upstream Channel ID	Upstream channel index for nth channel
1	Result code	Operation result code for nth channel

B.2.3.3.2.3 GET UPSTREAM CONFIG REQUEST (0x07)

This message is sent from the system control module to the RFI module.

This message is sent down to query the current upstream channel setup. The number of channels and the respective 'Upstream Channel IDs' (UCIDs) to be queried are sent down as structured in Table B–25.

Table B–25 - GET UPSTREAM CONFIG REQUEST (0x07)

Bytes	Field	Description
1	Number of Upstream Channels	Number of Upstream channels to query (1-4)
1	Upstream Channel ID	Upstream channel index for 1st channel
….	…….	……..
1	Upstream Channel ID	Upstream channel index for nth channel

B.2.3.3.2.4 GET UPSTREAM CONFIG RESPONSE (0x08)

This message is sent from the RFI module to the system control module.

This message is sent up in response to a 'Get Upstream Config Request' message containing all pertinent information with regards to the current Upstream setup. The number of channels and the per-channel properties are sent up as described below.

NOTE: Valid values for 'Channel Width' are limited to 1.6 MHz, 3.2 MHz, 6.4 MHz.

Table B–26 - GET UPSTREAM CONFIG RESPONSE (0x08)

Bytes	Field	Description
1	Number of Upstream Channels	Number of Upstream channels queried (1-4)
--	-- { Per Upstream Channel Properties } --	-- { Per Upstream Channel Properties } --
1	Upstream Channel ID	Upstream channel index for 1st channel
1	Enable \ Disable	1st channel state: Enabled = '1'; Disable = '0'
4	Center Frequency	1st channel center frequency in Hz
4	Channel Width	1st channel width in Hz **NOTE:** Valid values – 1.6 MHz, 3.2 MHz, 6.4 MHz
1	Channel Profile Type	1st channel burst profile type, Corresponding burst profile parameters are defined by system vendors.
1	Docsis 3.0 Channel Mode	For SCDMA mode: 1st channel 'SAC2'\'SINC2'\'UCD35' support mode – Enabled = '1'; Disabled = '0' (**NOTE:** Disabled implies 'SAC1\SINC1\UCD29' mode) For ATDMA mode: 1st channel 'UCD35' support mode – Enabled = '1'; Disabled = '0' (**NOTE:** Disabled implies 'UCD29' mode)
4	Channel Mini-slot Size	1st channel mini-slot size in terms of 6.25 microsecond ticks. Only for ATDMA. For SCDMA, return 0. [0 – (232 - 1)].
4	Channel Transmit Timing Offset	1st channel timing offset in 1/64th fraction of 6.25 microseconds. Return 0 if negative. [0 – (232 -1)]
1	Initial Ranging Backoff Window	1st channel initial ranging backoff window [0 – 16]
1	Final Ranging Backoff Window	1st channel final ranging backoff window [0 – 16]
1	Initial Data Backoff Window	1st channel initial transmission backoff window [0 – 16]
1	Final Data Backoff Window	1st channel final transmission backoff window [0 – 16]
1	Active SCDMA codes	1st channel active SCDMA codes. [0, 64 – 66, 68 – 70, 72, 74 – 78, 80 – 82, 84 – 88, 90 – 96, 98 – 100, 102, 104 – 106, 108, 110 – 112, 114 – 126, 128]
1	SCDMA codes per mini-slot	1st channel active SCDMA codes per minislot [0, 2 – 32]
1	SCDMA Frame size	1st channel SCDMA Frame size in units of spreading intervals [0 – 32]
2	SCDMA Hopping Seed	1st channel SCDMA code hopping seed [0 – 32767]

Bytes	Field	Description
1	Channel Type	1st channel burst type – Unknown = '0'; TDMA='1'; ATDMA = '2'; SCDMA = '3'; TDMA/A-TDMA = '4'; All other values are unsupported.
1	Pre-Equalization Setting	1st channel Pre-Equalization setting [1 – true, 2 – false]
2	Interface index (ifIndex)	1st channel interface index

B.2.3.3.3 Move CM Downstream

B.2.3.3.3.1 SET MOVE CM DOWNSTREAM REQUEST (0x09)

This message is sent from the system control module to the RFI module.

This message is sent down to configure a particular CM with a new Receive Channel Set (RCS) as described below.

Table B–27 - SET MOVE CM DOWNSTREAM REQUEST (0x09)

Bytes	Field	Description
6	Mac Address	CM MAC address
1	Number of Downstream Channels	Number of DS channels to configure on CM
1	Downstream Channel ID	Channel index of CM's new primary DS channel
1	Downstream Channel ID	Channel index of CM's 1st DS channel in new RCS
….	…….	……..
1	Downstream Channel ID	Channel index of CM's nth DS channel in new RCS

B.2.3.3.3.2 SET MOVE CM DOWNSTREAM RESPONSE (0x0a)

This message is sent from the RFI module to the system control module.

This message is sent up in response to a 'Set Move CM Downstream Request' message. The result code describes the end result of the requested 'SET' operation.

Table B–28 - SET MOVE CM DOWNSTREAM RESPONSE (0x0a)

Bytes	Field	Description
6	Mac Address	CM MAC address
1	Result code	Operation result code

B.2.3.3.3.3 GET MOVE CM DOWNSTREAM REQUEST (0x0b)

This message is sent from the system control module to the RFI module.

This message is sent down to request the current Downstream RCS of a particular CM.

Table B–29 - GET MOVE CM DOWNSTREAM REQUEST (0x0b)

Bytes	Field	Description
6	Mac Address	CM MAC address

B.2.3.3.3.4 GET MOVE CM DOWNSTREAM RESPONSE (0x0c)

This message is sent from the RFI module to the system control module.

This message is sent up in response to a 'Get Move CM Downstream Request' message highlighting the requested CM current Downstream RCS, as shown below.

Table B–30 - GET MOVE CM DOWNSTREAM RESPONSE (0x0c)

Bytes	Field	Description
6	Mac Address	CM MAC address
1	Number of Downstream Channels	Number of active DS channels on CM
1	Downstream Channel ID	Channel index of CM's current primary DS channel
1	Downstream Channel ID	Channel index of CM's 1st DS channel in RCS
….	……..	……..
1	Downstream Channel ID	Channel index of CM's nth DS channel in RCS

B.2.3.3.4 Move CM Upstream

B.2.3.3.4.1 SET MOVE CM UPSTREAM REQUEST (0x0d)

This message is sent from the system control module to the RFI module.

This message is sent down to configure a particular CM with a new upstream Transmit Channel Set (TCS).

Table B–31 - SET DOWNSTREAM CONFIG RESPONSE (0x0d)

Bytes	Field	Description
6	Mac Address	CM MAC address
1	Number of Upstream Channels	Number of US channels to configure on CM
1	Upstream Channel ID	Channel index of CM's 1st US channel in new TCS
….	……..	……..
1	Upstream Channel ID	Channel index of CM's nth US channel in new TCS

B.2.3.3.4.2 SET MOVE CM UPSTREAM RESPONSE (0x0e)

This message is sent from the RFI module to the system control module.

This message is sent up in response to a 'Set Move CM Upstream Request' message. The result code describes the end result of the requested 'SET' operation.

Table B–32 - SET MOVE CM UPSTREAM RESPONSE (0x0e)

Bytes	Field	Description
6	MAC Address	CM MAC address
1	Result code	Operation result code

B.2.3.3.4.3 GET MOVE CM UPSTREAM REQUEST (0x0f)

This message is sent from the system control module to the RFI module.

This message is sent down to request the current upstream TCS of a particular CM.

Table B–33 - GET MOVE CM UPSTREAM REQUEST (0x0f)

Bytes	Field	Description
6	Mac Address	CM MAC address

B.2.3.3.4.4 GET MOVE CM UPSTREAM RESPONSE (0x10)

This message is sent from the RFI module to the system control module.

This message is sent up in response to a 'Get Move CM Upstream Request' message indicating the CM's current upstream TCS.

Table B–34 - GET MOVE CM UPSTREAM RESPONSE (0x10)

Bytes	Field	Description
6	Mac Address	CM MAC address
1	Number of Upstream Channels	Number of active US channels on CM
1	Upstream Channel ID	Channel index of CM's 1st US channel in TCS
….	…….	……..
1	Upstream Channel ID	Channel index of CM's nth US channel in TCS

B.2.3.3.5 Load Balancing

B.2.3.3.5.1 SET CREATE/DESTROY LOAD BALANCING GROUP REQUEST (0x15)

This message is sent from the system control module to the RFI module.

This message is sent down to create a load balancing group.

Table B–35 - SET CREATE/DESTROY LOAD BALANCING GROUP REQUEST (0x15)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Load Balancing Method	1=Static, 2=Dynamic
1	Load Balancing Group Option	1=Create, 2=Destroy

B.2.3.3.5.2 SET CREATE/DESTROY LOAD BALANCING GROUP RESPONSE (0x16)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to the Set Create Load Balancing Group Request message.

Table B–36 - SET CREATE/DESTROY LOAD BALANCING GROUP RESPONSE (0x16)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Result code	Operation result code

B.2.3.3.5.3 GET LOAD BALANCING GROUPS REQUEST (0x17)

This message is sent from the system control module to the RFI module.

This message is sent down to a get the load balancing groups list. There are no parameters to this message.

Table B–37 - GET LOAD BALANCING GROUPS REQUEST (0x17)

Bytes	Field	Description
N/A	N/A	N/A

B.2.3.3.5.4 GET LOAD BALANCING GROUPS RESPONSE (0x18)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to a get load balancing groups list.

Table B–38 - GET LOAD BALANCING GROUPS RESPONSE (0x18)

Bytes	Field	Description
1	Number of Load Balancing Groups	The number of load balancing groups configured at the RFI module and returned in the response
1	Load Balancing Group ID number	Group ID number for the load balancing group 1
1	Load Balancing Method	1=Static, 2=Dynamic
…	…	…
1	Load Balancing Group ID number	Group ID number for the load balancing group n
1	Load Balancing Method	1=Static, 2=Dynamic

B.2.3.3.5.5 SET ADD/REMOVE DOWNSTREAMS TO/FROM LOAD BALANCING GROUP REQUEST (0x19)

This message is sent from the system control module to the RFI module.

This message is sent down to add/remove downstream channels to/from a load balancing group.

Table B–39 - SET ADD/REMOVE DOWNSTREAMS TO/FROM LOAD BALANCING GROUP REQUEST (0x19)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Number of downstreams	Number of downstream channels being added/removed to/from the load balancing group
1	Downstream channel ID	Downstream channel 1 to add to or remove from load balancing group
1	Downstream option	1=Add, 2=Remove
…	…	…
1	Downstream channel ID	Downstream channel n to add to or remove from load balancing group
1	Downstream option	1=Add, 2=Remove

B.2.3.3.5.6 SET ADD/REMOVE DOWNSTREAMS TO/FROM LOAD BALANCING GROUP RESPONSE (0x1a)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to adding or removing downstream channels to/from a load balancing group.

Table B–40 - SET ADD/REMOVE DOWNSTREAMS TO/FROM LOAD BALANCING GROUP RESPONSE (0x1a)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Number of downstreams	Number of downstream channels being added/removed to/from the load balancing group
1	Downstream channel ID	Downstream channel 1 associated with add/remove to/from the load balancing group request
1	Result code	Operation result code
…	…	…
1	Downstream channel ID	Downstream channel n associated with add/remove to/from the load balancing group request
1	Result code	Operation result code

B.2.3.3.5.7 GET LOAD BALANCING GROUP DOWNSTREAMS REQUEST (0x1b)

This message is sent from the system control module to the RFI module.

This message is sent down to get downstream channels associated with a load balancing group.

Table B–41 - GET LOAD BALANCING GROUP DOWNSTREAMS REQUEST (0x1b)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group

B.2.3.3.5.8 GET LOAD BALANCING GROUP DOWNSTREAMS RESPONSE (0x1c)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to getting the downstream channels associated with a load balancing group request.

Table B–42 - GET LOAD BALANCING GROUP DOWNSTREAMS RESPONSE (0x1c)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Number of downstreams	Number of downstream channels associated with the load balancing group
1	Downstream channel ID	Downstream channel 1 associated with the load balancing group
…	…	…
1	Downstream channel ID	Downstream channel n associated with the load balancing group

B.2.3.3.5.9 SET ADD/REMOVE UPSTREAMS TO/FROM LOAD BALANCING GROUP REQUEST (0x1d)

This message is sent from the system control module to the RFI module.

This message is sent down to add/remove upstream channels to/from a load balancing group.

Table B–43 - SET ADD/REMOVE UPSTREAMS TO/FROM LOAD BALANCING GROUP REQUEST (0x1d)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Number of upstreams	Number of upstream channels being added/removed to/from the load balancing group
1	Upstream channel ID	Upstream channel 1 to add to or remove from load balancing group
1	Upstream option	1=Add, 2=Remove
…	…	…
1	Upstream channel ID	Upstream channel n to add to or remove from load balancing group
1	Upstream option	1=Add, 2=Remove

B.2.3.3.5.10 SET ADD/REMOVE UPSTREAMS TO/FROM LOAD BALANCING GROUP RESPONSE (0x1e)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to adding or removing upstream channels to/from a load balancing group.

Table B–44 - SET ADD/REMOVE UPSTREAMS TO/FROM LOAD BALANCING GROUP RESPONSE (0x1e)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Number of upstreams	Number of upstream channels being added/removed to/from the load balancing group
1	Upstream channel ID	Upstream channel 1 associated with add/remove to/from the load balancing group request
1	Result code	Operation result code
…	…	…
1	Upstream channel ID	Upstream channel n associated with add/remove to/from the load balancing group request
1	Result code	Operation result code

B.2.3.3.5.11 GET LOAD BALANCING GROUP UPSTREAMS REQUEST (0x1f)

This message is sent from the system control module to the RFI module.

This message is sent down to get upstream channels associated with a load balancing group.

Table B–45 - GET LOAD BALANCING GROUP UPSTREAMS REQUEST (0x1f)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group

B.2.3.3.5.12 GET LOAD BALANCING GROUP UPSTREAMS RESPONSE (0x20)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to getting the upstream channels associated with a load balancing group request.

Table B–46 - SET DOWNSTREAM CONFIG RESPONSE (0x02)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Number of upstreams	Number of upstream channels associated with the load balancing group
1	Upstream channel ID	Upstream channel 1 associated with the load balancing group
…	…	…
1	Upstream channel ID	Upstream channel n associated with the load balancing group

B.2.3.3.5.13 SET ADD/REMOVE CM TO/FROM LOAD BALANCING GROUP REQUEST (0x21)

This message is sent from the system control module to the RFI module.

This message is sent down to add or remove CMs to/from a specified load balancing group.

NOTE: Multiple MAC case – Starting and Ending CM MAC addresses are not equal.
Single MAC case – Starting and Ending CM MAC addresses are equal.
OUI case – Starting and Ending CM MAC addresses are equal and the last 3 bytes of each are '0'

Table B–47 - SET ADD/REMOVE CM TO/FROM LOAD BALANCING GROUP REQUEST (0x21)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	CM option	1=Add, 2=Remove
6	Starting CM MAC address	Starting MAC address of range
6	Ending CM MAC address	Ending MAC address of range

B.2.3.3.5.14 SET ADD/REMOVE CM TO/FROM LOAD BALANCING GROUP RESPONSE (0x22)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to adding or removing CMs to/from a load balancing group request.

Table B–48 - SET ADD/REMOVE CM TO/FROM LOAD BALANCING GROUP RESPONSE (0x22)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Result code	Operation result code

B.2.3.3.5.15 GET LOAD BALANCING GROUP CM CONFIGURATION REQUEST (0x23)

This message is sent from the system control module to the RFI module.

This message is sent down to get the current configuration of CM's mapping to the specified load balancing group.

Table B–49 - GET LOAD BALANCING GROUP CM CONFIGURATION REQUEST (0x23)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group

B.2.3.3.5.16 GET LOAD BALANCING GROUP CM CONFIGURATION RESPONSE (0x24)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to the get current configuration of CM mapping to the specified load balancing group request.

NOTE: Single MAC case – Starting and Ending CM MAC addresses are equal.
OUI case – Starting and Ending CM MAC addresses are equal and last 3 bytes of each are '0'.

Table B–50 - GET LOAD BALANCING GROUP CM CONFIGURATION RESPONSE (0x24)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Number of entries	Number of entries in the CM mapping configuration
6	Starting CM MAC address	Starting MAC address of range
6	Ending CM MAC address	Ending MAC address of range

B.2.3.3.5.17 GET LOAD BALANCING GROUP ACTIVE CM REQUEST (0x25)

This message is sent from the system control module to the RFI module.

This message is sent down to get the current list of active CMs in the specified load balancing group.

Table B–51 - GET LOAD BALANCING GROUP ACTIVE CM REQUEST (0x25)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group

B.2.3.3.5.18 GET LOAD BALANCING GROUP ACTIVE CM RESPONSE (0x26)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to the get current list of active CMs in the specified load balancing group request.

Table B–52 - GET LOAD BALANCING GROUP ACTIVE CM RESPONSE (0x26)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Number of CMs	Number of active CMs in the load balancing group
6	CM MAC address	First active CM in the load balancing group
…	…	…
6	CM MAC address	Last active CM in the load balancing group

B.2.3.3.5.19 SET EXCLUDE CM FROM LOAD BALANCING REQUEST (0x27)

This message is sent from the system control module to the RFI module.

Message sent down to exclude (or not exclude) CMs from load balancing.

NOTE: Single MAC case – Starting and Ending CM MAC addresses are equal.
OUI case – Starting and Ending CM MAC addresses are equal and last 3 bytes of each are '0'.

Table B–53 - SET EXCLUDE CM FROM LOAD BALANCING REQUEST (0x27)

Bytes	Field	Description
1	CM option	1=Add, 2=Remove
6	Starting CM MAC address	Starting MAC address of range
6	Ending CM MAC address	Ending MAC address of range

B.2.3.3.5.20 SET EXCLUDE CM FROM LOAD BALANCING RESPONSE (0x28)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to exclude (or not exclude) CMs from load balancing request.

Table B–54 - SET EXCLUDE CM FROM LOAD BALANCING RESPONSE (0x28)

Bytes	Field	Description
1	Result code	Operation result code

B.2.3.3.5.21 GET EXCLUDED CM CONFIGURATION REQUEST (0x29)

This message is sent from the system control module to the RFI module.

This message is sent down to get the current excluded CMs configuration. The contents of this message are always empty. For a CDMM message of this type, an opcode of 0x29 in the PDU layer is sufficient to solicit a response from the system.

Table B–55 - GET EXCLUDED CM CONFIGURATION REQUEST (0x29)

Bytes	Field	Description
N/A	N/A	N/A

B.2.3.3.5.22 GET EXCLUDED CM CONFIGURATION RESPONSE (0x2a)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to the get current excluded CMs configuration request.

NOTE: Multiple MAC case – Starting and Ending CM MAC addresses are not equal.
Single MAC case – Starting and Ending CM MAC addresses are equal.
OUI case – Starting and Ending CM MAC addresses are equal and the last 3 bytes of each are '0'.

Table B–56 - GET EXCLUDED CM CONFIGURATION RESPONSE (0x2a)

Bytes	Field	Description
1	Number of entries	Number of entries in the CM mapping configuration
6	Starting CM MAC address	Starting MAC address of range
6	Ending CM MAC address	Ending MAC address of range

B.2.3.3.5.23 GET EXCLUDED ACTIVE CM REQUEST (0x2b)

This message is sent from system control module to the RFI module.

Message sent down to the get the current list of active CMs excluded from load balancing. The contents of this message are always empty. For a CDMM message of this type, an opcode of 0x2b in the PDU layer is sufficient to solicit a response from the system.

Table B–57 - GET EXCLUDED ACTIVE CM REQUEST (0x2b)

Bytes	Field	Description
N/A	N/A	N/A

B.2.3.3.5.24 GET EXCLUDED ACTIVE CM'S RESPONSE (0x2c)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to the get current list of active CMs excluded from load balancing.

Table B–58 - GET EXCLUDED ACTIVE CM'S RESPONSE (0x2c)

Bytes	Field	Description
1	Number of CMs	Number of active CMs excluded from load balancing
6	CM MAC address	First active CM excluded from load balancing
6	CM MAC address	Last active CM excluded from load balancing

B.2.3.3.5.25 SET FULL LOAD BALANCING GROUP REQUEST (0x2d)

This message is sent from the system control module to the RFI module.

This message is sent down to configure the specified Load balancing group.

NOTE: Multiple MAC case – Starting and Ending CM MAC addresses are not equal.
Single MAC case – Starting and Ending CM MAC addresses are equal.
OUI case – Starting and Ending CM MAC addresses are equal and the last 3 bytes of each are '0'.

Table B–59 - SET FULL LOAD BALANCING GROUP REQUEST (0x2d)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Type	1 = 'Static; 2 = 'Dynamic'

Bytes	Field	Description
1	Number of Downstream Channels	Number of Downstream Channels active in group (X)
1	Downstream Channel ID	Downstream channel index for 1st channel
……..		
Repeated 'X' times		
1	Number of Upstream Channels	Number of active Downstream Channels active in group (Y)
1	Upstream Channel ID	Upstream channel index for 1st channel
……..		
Repeated 'Y' times		
1	Number of MAC ID ranges	Number of active CM MAC address ranges in group (Z)
6	Starting MAC Address	Starting MAC address for CMs active in group
6	Ending MAC Address	Ending MAC address for CMs active in group
……..		
Repeated 'Z' times		

B.2.3.3.5.26 SET FULL LOAD BALANCING GROUP RESPONSE (0x2e)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to the 'Set Full Load Balancing Group request' returning the result code for the configured Load balancing group.

Table B–60 - SET FULL LOAD BALANCING GROUP RESPONSE (0x2e)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Result code	Operation result code

B.2.3.3.5.27 GET FULL LOAD BALANCING GROUP REQUEST (0x2f)

This message is sent from the system control module to the RFI module.

This message is sent down to retrieve the specified Load balancing group's configuration.

Table B–61 - GET FULL LOAD BALANCING GROUP REQUEST (0x2f)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group

B.2.3.3.5.28 GET FULL LOAD BALANCING GROUP RESPONSE (0x30)

This message is sent from the RFI module to the system control module.

This message is sent up in a response to 'Get Full Load Balancing Group Request' returning the specified group's active configuration.

NOTE: Multiple MAC case – Starting and Ending CM MAC addresses are not equal.
Single MAC case – Starting and Ending CM MAC addresses are equal.
OUI case – Starting and Ending CM MAC addresses are equal and last 3 bytes of each are '0'.

Table B–62 - GET FULL LOAD BALANCING GROUP RESPONSE (0x30)

Bytes	Field	Description
1	Load Balancing Group ID number	Group ID number for the load balancing group
1	Type	1 = 'Static'; 2 = 'Dynamic'
1	Number of Downstream Channels	Number of Downstream Channels active in group (X)
1	Downstream Channel ID	Downstream channel index for 1st channel
…….. Repeated 'X' times		
1	Number of Upstream Channels	Number of active Downstream Channels active in group (Y)
1	Upstream Channel ID	Upstream channel index for 1st channel
…….. Repeated 'Y' times		
1	Number of MAC ID ranges	Number of active CM MAC address ranges in group (Z)
6	Starting MAC Address	Starting MAC address for CMs active in group
6	Ending MAC Address	Ending MAC address for CMs active in group
…….. Repeated 'Z' times		

B.2.3.3.6 DOCSIS Upstream Input Power Level

B.2.3.3.6.1 SET UPSTREAM INPUT POWER REQUEST (0x31)

This message is sent from the system control module to the RFI module.

This message is sent down to configure the upstream channels with the specified input power levels in tenths of a dB.

Table B–63 - SET UPSTREAM INPUT POWER REQUEST (0x31)

Bytes	Field	Description
1	Number of Upstream Channels	Number of Upstream channels to configure (1-4)
--	-- { Per Upstream Channel Properties } --	-- { Per Upstream Channel Properties } --
1	Upstream Channel ID	Upstream channel index for 1st channel

Bytes	Field	Description
2	Input Power Level	Input power level for the specified upstream channel (tenths dBmV)
..	……	……
1	Upstream Channel ID	Upstream channel index for nth channel
2	Input Power Level	Input power level for the specified upstream channel (tenths dBmV)

B.2.3.3.6.2 SET UPSTREAM INPUT POWER RESPONSE (0x32)

This message is sent from the RFI module to the system control module.

This message is sent up in response to a 'Set Upstream Input Power Request' message. The input power levels (in tenths of a dBmV) in the response are what the RFI module actually set, which MAY not match what was sent in the request CDMM message. If a channel is disabled, the value returned will be 0.

Table B–64 - SET UPSTREAM INPUT POWER RESPONSE (0x32)

Bytes	Field	Description
1	Result code	Operation result code
2	Input Power Level for upstream channel 1	Input power level used for upstream channel 1 (tenths dBmV)
..	……	……
2	Input Power Level for upstream channel n	Input power level used for upstream channel n (tenths dBmV)

B.2.3.3.6.3 GET UPSTREAM INPUT POWER REQUEST (0x33)

This message is sent from the system control module to the RFI module.

This message is sent down to query the current values of the upstream input power levels.

Table B–65 - GET UPSTREAM INPUT POWER REQUEST (0x33)

Bytes	Field	Description
1	Number of Upstream Channels	Number of Upstream channels to query (1-4)
1	Upstream Channel ID	Upstream channel index for 1st channel
….	…….	……..
1	Upstream Channel ID	Upstream channel index for nth channel

B.2.3.3.6.4 GET UPSTREAM INPUT POWER RESPONSE (0x34)

This message is sent from the RFI module to the system control module.

This message is sent up in response to a 'Get Upstream Input Power Request' message indicating the current upstream input power levels in tenths of a dBmV across the requested upstream channels.

Table B–66 - GET UPSTREAM INPUT POWER RESPONSE (0x34)

Bytes	Field	Description
1	Number of Upstream Channels	Number of Upstream channels queried (1-4)

--	-- { Per Upstream Channel Properties } --	-- { Per Upstream Channel Properties } --
1	Upstream Channel ID	Upstream channel index for 1st channel
2	Input Power Level	Input power level for 1st upstream channel (tenths dBmV)

B.2.3.3.7 CM Arrival, Departure, and Deletion

B.2.3.3.7.1 CM ARRIVAL REQUEST (0x300)

This message is sent by the RFI module to the system control module.

The RFI module sends this message when it receives from a CM an INIT-RNG-REQ or B-INIT-RNG-REQ, or when it receives a RNG-REQ only if the RNG-REQ was received in a broadcast Initial Maintenance opportunity on a type 1 or 2 channel (see [MULPIv3.0]). The RFI module within the CMTS MUST not allow the CM to proceed past the Unicast Initial Ranging or Broadcast Initial Ranging steps of initialization until it receives a 'CM Arrival Response' message from the system control module.

Table B–67 - CM ARRIVAL REQUEST (0x300)

Bytes	Field	Description
6	MAC address	MAC address of the CM
1	Downstream Channel ID	Channel ID of downstream channel currently being used by the CM
1	Upstream Channel ID	Channel ID of upstream channel on which Ranging Request message was received
2	Temporary SID	The Temporary SID the RFI module will assign to the modem in the RNG-RSP message if the modem is allowed to join the network

B.2.3.3.7.2 CM ARRIVAL RESPONSE (0x301)

This message is sent by the system control module to the RFI module.

This message is in response to a 'CM Arrival Request' message.

The system control module indicates in this message whether the CM is allowed to join the network. If it is, the system control module includes encodings to set up CDT VID+CoS associations (Annex B) for the temporary downstream and upstream flows the modem will use prior to registration. At registration, the VID+CoS associations created here will automatically be replaced with new ones for the primary upstream and downstream flows created at that time.

If the system control module indicates in this message that the CM is not allowed to join the network, the RFI module does not allow the CM to proceed any further in the initialization process.

Table B–68 - CM ARRIVAL RESPONSE (0x301)

Bytes	Field	Description
6	MAC address	MAC address of the CM
1	Access Control	CM is allowed to join the network or not 1 = allow 2 = reject
1	CDT Association Action	Action on VID+CoS values for CDT tags: for this message, value MUST be 1 = add VID+CoS association This field is present if, and only if, Access Control = 1.

Bytes	Field	Description
1	Flow Count	Number of flows for which a VID+CoS to flow association is being added or deleted; for this message, MUST be 2. This field is present if, and only if, Access Control = 1.
--	---- { Per each flow } ----	---- { Per each flow } ----
4	Service Flow Identification	For the downstream temporary flow, use 1; for the upstream temporary flow, use 2. This field is present if, and only if, Access Control = 1.
2	Tag	VID+CoS bits to be used in CDT tags for this flow. Bits 15:13 – CoS bits; bits 12:0 – VID (0x801 – 0x9D0) This field is present if, and only if, Access Control = 1.

B.2.3.3.7.3 CM DEPARTURE EVENT (0x302)

This message is sent by the RFI module to the system control module.

The RFI module sends this message when a CM has left the network for any reason other than the RFI module deleting the CM in response to a 'Set CM Delete Request' message from the system control module. All resources assigned to the CM are released at this time.

Table B–69 - CM DEPARTURE EVENT (0x302)

Bytes	Field	Description
6	MAC address	MAC address of the CM
1	Reason Code	Reason for departure, selected from Confirmation Codes in [MULPIv3.0]

B.2.3.3.7.4 SET CM DELETE REQUEST (0x303)

This message is sent by the system control module to the RFI module.

This message commands the RFI module to delete a CM from the network. All resources allocated to the CM are released at this time.

A value of 0xFFFFFF_FFFFFF in the MAC address field commands the RFI module to delete all CMs from the network.

Table B–70 - SET CM DELETE REQUEST (0x303)

Bytes	Field	Description
6	MAC address	MAC address of the CM (0xFFFFFF_FFFFFF = all CMs)

B.2.3.3.7.5 SET CM DELETE RESPONSE (0x304)

This message is sent from the RFI module to the system control module.

The RFI module sends this message in response to a 'Set CM Delete Request' message.

Table B–71 - SET CM DELETE RESPONSE (0x304)

Bytes	Field	Description
6	MAC address	MAC address of the CM from 'Set CM Delete Request'

1	Response	Reason code for deletion: 1 = success 2 = failed for unspecified reason 3 = failed due to unknown MAC address

B.2.3.3.8 QoS and Dynamic Services

B.2.3.3.8.1 SET SERVICE CLASS NAME REQUEST (0x350)

This message is sent by the system control module to the RFI module.

The system control module sends this message when the operator provisions a Service Class Name. This message informs the RFI module of the QoS Parameter encodings to be used when expanding a Service Class Name into a complete set of Service Flow encodings for use by the CM. The RFI module always expands a Service Class Name into a complete set of Service Flow encodings when communicating with the CM. When communicating with the system control module, expansion of the Service Class Name is not required, but if the RFI module within the CMTS does expand the Service Class Name, it MUST also include the original Service Class Name encoding from the CM in its message to the system control module.

Table B–72 - SET SERVICE CLASS NAME REQUEST (0x350)

Bytes	Field	Description
1	Action	1 = add Service Class Name 2 = delete Service Class Name
1	Service Class Name Length	Length L of Service Class Name, including zero termination (L needs to be from 2-16 inclusive)
L	Service Class Name	Service Class Name expressed as a zero-terminated string of ASCII characters.
1	QoS Encoding Length	Length M of encodings specifying QoS parameters for this Service Class Name. This field exists if, and only if, Action=1.
M	QoS Parameters	QoS Parameters TLV encoded as specified in [MULPIv3.0]. This field exists if and only if Action=1.

B.2.3.3.8.2 SET SERVICE CLASS NAME RESPONSE (0x351)

This message is sent by the RFI module to the system control module.

It indicates the results of a 'Set Service Class Name Request'.

Table B–73 - SET SERVICE CLASS NAME RESPONSE (0x351)

Bytes	Field	Description
1	Result Code	Result of 'Set Service Class Name Request' (Table B–18)
1	Service Class Name Length	Length L of Service Class Name, including zero termination (L needs to be from 2-16 inclusive)
L	Service Class Name	Service Class Name expressed as a zero-terminated string of ASCII characters

B.2.3.3.8.3 SERVICE FLOW RESERVATION REQUEST (0x352)

This message is sent from the system control module to the RFI module.

It queries the RFI module as to whether a particular new Service Flow could be admitted, or whether an existing Service Flow's QoS parameters could be changed. If so, this message also instructs the RFI module to reserve resources for the flow. The RFI module does NOT initiate a DSx transaction to add or modify the flow; the flow is expected to be added or changed later via a CM-initiated DSx. Use of this message allows support for PacketCable DQoS (see Appendix I.).

The system control module only sends this message if its own policy and resource checks indicate the flow could be successfully added. As an example, if the system control module receives a request for a new flow from a call server via PacketCable DQoS, but the system control module determines that the request cannot be allowed, the system control module rejects the request and does not send this message to the RFI module.

The system control module formats its request to the RFI module as a DOCSIS DSx-REQ message as specified by [MULPIv3.0]. This DSx-REQ message will generally not be complete; for example, the RFI module is responsible for assigning SFIDs, SIDs, and SID Clusters, etc., so the system control module within the CMTS MAY not need to be included for these encodings (however, for example, an SFID would be needed in a DSC-REQ). Also, these or other encodings may only be needed when a flow is admitted or activated, so they may not be relevant to a reservation request and may not appear in this message.

Table B–74 - SERVICE FLOW RESERVATION REQUEST (0x352)

Bytes	Field	Description
2	DSx Message Length	Length L of included DSx message
L	DSx-REQ Message	Parameters of requested service flow, formatted as a DSx-REQ message per MULPI, starting from the first byte of the MMM header and continuing through the last byte of the CRC.

B.2.3.3.8.4 SERVICE FLOW RESERVATION RESPONSE (0x353)

This message is sent from the RFI module to the system control module.

It is sent by the RFI module to indicate the results of a 'Service Flow Reservation Request'.

If the request failed, the RFI module creates a message indicating the reasons for the failure using the format and encodings of a DSx-RSP message as specified by [MULPIv3.0], then encapsulates the DSx-RSP in this message.

If the request succeeds, the system control module is responsible for verifying that the subsequent CM-initiated DSx transaction matches the reservation set up by this message.

Table B–75 - SERVICE FLOW RESERVATION RESPONSE (0x353)

Bytes	Field	Description
1	Response Code	Result of 'Service Flow Reservation Request': 1 = flow allowed, reservation succeeded 2 = flow not allowed, reservation failed
2	DSX-RSP Message Length	Length L of DSx-RSP message describing failure. This field exists if, and only if, Response Code = 2
L	DSx-RSP Message	Encapsulated DSx-RSP message describing failure, starting from the first byte of the MMM header and continuing through the last byte of the CRC. This field exists if, and only if, Response Code = 2

B.2.3.3.8.5 CDMM REGISTRATION REQUEST (0x354)

This message is sent by the RFI module to the system control module.

It is sent when the RFI module has received and processed a DOCSIS Registration Request (REG-REQ or REG-REQ-MP) from a cable modem.

Upon receiving a Registration Request from a CM, the RFI module processes the message and constructs a Registration Response message in the format it would use to communicate with a CM, containing response codes indicating the results of its processing, including any applicable error codes and a final confirmation code. The RFI module encapsulates the proposed Registration Response in this message and sends it to the system control module. If the confirmation code of the encapsulated Registration Response indicates success, the RFI module waits for a response from the system control module before continuing with the registration process. If the confirmation code of the encapsulated Registration Response indicates a rejection, the RFI module proceeds with the steps specified by [MULPIv3.0], including sending the Registration Response to the CM.

Table B–76 - CDMM REGISTRATION REQUEST (0x354)

Bytes	Field	Description
1	Confirmation Code	1 = confirmation code indicates success 2 = confirmation code indicates a failure
2	Registration Response Message Length	Length L of Registration Response message
L	Registration Response Message	Registration Response message, encoded per [MULPIv3.0], formed as a single MAC Management Message. If the Registration Response sent to the CM would be a REG-RSP-MP (i.e., the Registration Response is long enough to require fragmentation into multiple parts), it is encoded here as a single message (i.e., as though no length restriction existed on a REG-RSP). All bytes are included from the first byte of the MMM header through the last byte of the CRC.

B.2.3.3.8.6 CDMM REGISTRATION RESPONSE (0x355)

This message is sent from the system control module to the RFI module.

It is sent in response to a 'CDMM Registration Request'.

Upon receiving a 'CDMM Registration Request', the system control module examines the included Registration Response. If the RFI module indicated a confirmation code of rejection for any reason, the system control module does not send a response to the 'CDMM Registration Request'. If the RFI module indicated a confirmation code of success, the system control module performs its own resource and policy checks to determine whether to allow or reject the Registration Request.

The system control module then modifies the Registration Response from the RFI module, or creates a new Registration Response, reflecting the results of its processing. If the new/modified Registration Response indicates success, the system control module adds any additional encodings that may be needed to complete the message. It also includes encodings to set up a CDT VID+CoS association (Annex B) corresponding to the admitted or active Service Flows being created in the Registration Response. If the new/modified Registration Response will indicate failure, the system control module includes the appropriate confirmation code and error sets to indicate the reason(s) for the failure.

Table B–77 - CDMM REGISTRATION RESPONSE (0x355)

Bytes	Field	Description
1	Result	Result of processing the registration response message: 1 = success 2 = failure
2	Registration Response Message	Length L of included Registration Response message

Bytes	Field	Description
L	Registration Response Message	Registration Response message, modified as needed, encoded per [MULPIv3.0], formed as a single MAC Management Message. If the Registration Response sent to the CM would be a REG-RSP-MP (i.e., the Registration Response is long enough to require fragmentation into multiple parts), it is encoded here as a single message (i.e., as though no length restriction existed on a REG-RSP). All bytes are included from the first byte of the MMM header through the last byte of the CRC.
1	CDT Association Action	Action on VID+CoS values for CDT tags: 1 = add VID+CoS association 2 = delete VID+CoS association This field exists if, and only if, Result = 1.
1	Flow Count	Number of flows for which a VID+CoS to flow association is being added or deleted (zero if no such associations are being added or deleted) This field exists if, and only if, Result = 1.
--	---- { Per each flow } ----	---- { Per each flow } ----
4	Service Flow Identification	Service flow reference or SFID (if both are present, the SFID is used) for corresponding flow (from DSx or Registration message) This field exists if, and only if, Result = 1.
2	Tag	VID+CoS bits to be used in CDT tags for this flow. Bits 15:13 – CoS bits; bits 12:0 – VID (0x801 – 0x9D0) This field exists if, and only if, Result = 1.

B.2.3.3.8.7 CDMM REGISTRATION ACKNOWLEDGE (0x356)

This message is sent by the RFI module to the system control module.

It is sent in response to a 'CDMM Registration Response' message.

After the RFI module has completed the registration message exchange with the CM, it sends this message to the system control module to inform it of the final results of the process. If the RFI module received a REG-ACK from the CM, it is included in this message. If registration failed or if the REG-ACK message was not received, the system control module and RFI module both back out the modem's registration and free resources as required by [MULPIv3.0].

Table B–78 - CDMM REGISTRATION ACKNOWLEDGE (0x356)

Bytes	Field	Description
1	Result	1 = transaction succeeded 2 = transaction failed 3 = timeout waiting for REG-ACK from CM
2	REG-ACK Message Length	length L of enclosed REG-ACK message. This field exists only if Result = 1 or 2.

Bytes	Field	Description
L	REG-ACK Message	REG-ACK message received from the CM, starting with the first byte of the DOCSIS MMM header and ending with the last byte of the CRC. This field exists only if Result = 1 or 2.

B.2.3.3.8.8 MULTICAST JOIN AUTHORIZATION REQUEST (0x357)

This message is sent by the RFI module to the system control module.

The RFI module sends this message when it receives an IGMP or MLD request from a cable modem to join a multicast session. The RFI module within the CMTS MUST not forward or act on the join request until it has sent this message and received a response.

Table B–79 - MULTICAST JOIN AUTHORIZATION REQUEST (0x357)

Bytes	Field	Description
2	Multicast Join Message Length	Length L of included multicast join message
L	Multicast Join Message	Multicast join message as received from the CM, beginning from the first byte of the MAC Destination Address and continuing through the last byte of the CRC.

B.2.3.3.8.9 MULTICAST JOIN AUTHORIZATION RESPONSE (0x358)

This message is sent by the system control module to the RFI module.

It is sent in response to a 'Multicast Join Authorization Request'.

Upon receiving a 'Multicast Join Authorization Request,' the system control module performs policy checks to determine if the modem is authorized to join the multicast session it is requesting. It uses this message to convey the results to the RFI module. If the join is denied, the RFI module within the CMTS MUST ignore and discard the join request. If the join is allowed, the RFI module forwards and processes the join request as required by [MULPIv3.0] and other applicable standards for the multicast protocol in use.

Table B–80 - MULTICAST JOIN AUTHORIZATION RESPONSE (0x358)

Bytes	Field	Description
1	Result	1 = join request is allowed 2 = join request is denied

B.2.3.3.8.10 SECURITY ASSOCIATION AUTH REQUEST (0x359)

This message is sent by the RFI module to the system control module.

It is sent when the RFI module receives a request from a CM to initialize BPI+ security, as described in [SECv3.0], and the RFI module's checking of the message format and contents indicates that the RFI module would authorize the modem. If the RFI module determines that it would not authorize the modem, it does not send this message, but proceeds with the process of sending an Authorization Reject and other steps as required by [SECv3.0].

The RFI module receives and stores the BPKM-REQ Authentication Information and Authorization Request messages from the CM. The RFI module encapsulates them in this message and sends it to the system control module. The RFI module within the CMTS MUST wait for a response to this message before proceeding with any subsequent steps in the BPI+ initialization process.

Table B–81 - SECURITY ASSOCIATION AUTH REQUEST (0x359)

Bytes	Field	Description
2	Auth Info Message Length	Length L of enclosed Authentication Information message
L	Auth Info Message	BPKM-REQ Authentication Information message received from the CM, starting from the first byte of the MMM header and ending with the last byte of the CRC
2	Auth Request Message Length	Length M of enclosed Authorization Request message
M	Auth Request Message	BPKM-REQ Authorization Request message received from the CM, starting from the first byte of the MMM header and ending with the last byte of the CRC.

B.2.3.3.8.11 SECURITY ASSOCIATION AUTH RESPONSE (0x35A)

This message is sent by the system control module to the RFI module.

It is sent in response to a 'Security Association Auth Request'.

Upon receiving a 'Security Association Auth Request,' the system control module authenticates the modem and performs any needed policy checks to determine if the modem is authorized to start Baseline Privacy. The results of these operations are returned in this message.

If this response message indicates that the CM is not authorized, the RFI module within the CMTS MUST send the CM an Authorization Reject message with the provided error code per [SECv3.0]. In this case the RFI module within the CMTS MUST NOT set up a Security Association for the CM.

If this response message indicates the CM is authorized, the RFI module proceeds to set up a Security Association as specified in [SECv3.0].

Table B–82 - SECURITY ASSOCIATION AUTH RESPONSE (0x35A)

Bytes	Field	Description
1	Result	1 = authorized, 2 = not authorized
1	Error Code	Error code per [SECv3.0] (this byte = 0 if Result = 1, authorized)
6	MAC address	CM MAC address

B.2.3.3.8.12 CDMM DSA-REQ CM-INITIATED (0x360), CDMM DSC-REQ CM-INITIATED (0x361), CDMM DSD-REQ CM-INITIATED (0x362)

These messages are sent by the RFI module to the system control module.

They are sent when the RFI module has received a DSx request from a Cable Modem.

Upon receiving a DSx-REQ from a CM, the RFI module parses the DSx-REQ, checks that it is valid, and determines whether the RFI module can allow the request based on its own resource availability and other considerations. The RFI module constructs a DSx-RSP message reflecting the results of this operation. If the RFI module will reject the request, the DSx-RSP message includes a confirmation code and error sets (if applicable) indicating the reason for the rejection.

The RFI module then encapsulates the DSx-RSP in this message and sends it to the system control module. The proposed DSx-RSP created by the RFI module is encapsulated in this message. If the RFI module indicates in the first byte of this message that the request will be rejected, it sends the DSx-RSP message to the CM without waiting for a response from the system control module. If the first byte of this message indicates that the request would

succeed, the RFI module waits for a response from the system control module before proceeding with any further steps in the DSx transaction.

Table B–83 - CDMM DSA-REQ CM-INITIATED (0x360), CDMM DSC-REQ CM-INITIATED (0x361)

Bytes	Field	Description
1	Result	1 = request will be allowed 2 = request will be rejected
2	DSx-RSP Message Length	Length L of enclosed DSx-RSP message
L	DSx-RSP Message	DSx-RSP message constructed by the RFI module, starting with the first byte of the DOCSIS MMM header and ending with the last byte of the CRC

Table B–84 - CDMM DSD-REQ CM-INITIATED (0x362)

Bytes	Field	Description
1	Result	1 = request will be allowed 2 = request will be rejected
2	DSx-RSP Message Length	Length L of enclosed DSx-RSP message
L	DSx-RSP Message	DSx-RSP message constructed by the RFI module, starting with the first byte of the DOCSIS MMM header and ending with the last byte of the CRC
1	Flow Count	Number of flows that will be deleted. This field exists if, and only if, Result = 1.
--	---- { Per each flow } ----	---- { Per each flow } ----
4	Service Flow Identification	Service flow reference or SFID, this SFID will be used by controller to delete a specified service flow This field exists if, and only if, Result = 1.

B.2.3.3.8.13 CDMM DSA-RSP CM-INITIATED (0x363), CDMM DSC-RSP CM-INITIATED (0x364), CDMM DSD-RSP CM-INITIATED (0x365)

These messages are sent by the system control module to the RFI module.

They are sent in response to a 'CDMM DSx-REQ CM-Initiated,' in which the RFI module has indicated that it would allow the CM's DSx-REQ.

If the system control module receives a 'CDMM DSx-REQ CM-Initiated' message in which the RFI module indicated the CM's DSx-REQ would be rejected, the system control module does not send a response.

Upon receiving the 'CDMM DSx-REQ CM-Initiated' message, which the RFI module indicated it would allow, the system control module checks its own resources and those of other functions it communicates with if applicable (e.g., the classification and forwarding module). It also performs any applicable policy checks. The system control module then determines if it would allow or reject the request.

If the request will be allowed, the system control module modifies or completes the encapsulated DSx-RSP message received from the RFI module if needed to reflect the results of its processing. The system control module also includes encodings to set up a CDT VID+CoS association (Annex B) for flows being created, admitted, or activated. In some cases, no new VID+CoS-to-flow associations are needed (e.g., for a DSC operation that does not change the QoS Param Set Type).

If the system control module determines that the DSx-REQ will be rejected, it modifies the DSx-RSP message or creates a new one to contain the confirmation code and error sets, if applicable, indicating the reason for the rejection. The format and encodings for the DSx-RSP message are as specified in [MULPIv3.0].

The system control module encapsulates the new or modified DSx-RSP in this message and sends it to the RFI module.

Upon receiving this message, the RFI module uses the encapsulated DSx-RSP to complete the transaction with the CM, either allowing or rejecting the transaction as instructed by the first byte of this message and the specifics of the encapsulated DSx-RSP.

Table B–85 - CDMM DSA-RSP CM-INITIATED (0x363)

Bytes	Field	Description
1	Result	1 = request will be allowed 2 = request will be rejected
2	DSx-RSP Message Length	Length L of enclosed DSx-RSP message
L	DSx-RSP Message	DSx-RSP message, formatted with encodings as specified by [MULPIv3.0], complete and ready to send to the CM, starting with the first byte of the DOCSIS MMM header and ending with the last byte of the CRC.
1	CDT Association Action	Action on VID+CoS values for CDT tags: 1 = add VID+CoS association 2 = delete VID+CoS association This field exists if, and only if, Result = 1.
1	Flow Count	Number of flows for which a VID+CoS to flow association is being added or deleted (zero if no such associations are being added or deleted). This field exists if, and only if, Result = 1.
--	---- { Per each flow } ----	---- { Per each flow } ----
4	Service Flow Identification	Service flow reference or SFID (if both are present, the SFID is used) for corresponding flow (from DSx or Registration message). This field exists if, and only if, Result = 1.
2	Tag	VID+CoS bits to be used in CDT tags for this flow. Bits 15:13 – CoS bits; bits 12:0 – VID (0x801 – 0x9D0). This field exists if, and only if, Result = 1.

Table B–86 - CDMM DSC-RSP CM-INITIATED (0x364), CDMM DSD-RSP CM-INITIATED (0x365)

Bytes	Field	Description
1	Result	1 = request will be allowed 2 = request will be rejected
2	DSx-RSP Message Length	Length L of enclosed DSx-RSP message
L	DSx-RSP Message	DSx-RSP message, formatted with encodings as specified by [MULPIv3.0], complete and ready to send to the CM, starting with the first byte of the DOCSIS MMM header and ending with the last byte of the CRC

Bytes	Field	Description
1	Flow Count	Number of flows for which a VID+CoS to flow association is being added or deleted (zero if no such associations are being added or deleted). This field exists if, and only if, Result = 1.

B.2.3.3.8.14 CDMM DSA-ACK CM-INITIATED (0x366), CDMM DSC-ACK CM-INITIATED (0x367)

These messages are sent by the RFI module to the system control module.

They are sent in response to a 'CDMM DSx-RSP CM-initiated'.

After the RFI module has completed the DSx operation with the CM, it sends this message to the system control module to inform it of the final status of the transaction. If the transaction failed or timed out, the RFI module and system control module back out the transaction and free resources as specified by [MULPIv3.0].

Table B–87 - CDMM DSA-ACK CM-INITIATED (0x366), CDMM DSC-ACK CM-INITIATED (0x367)

Bytes	Field	Description
1	Result	1 = transaction succeeded 2 = transaction failed 3 = timeout waiting for ACK from CM
2	DSx-RSP Message Length	Length L of enclosed DSx-ACK message. This field is present only if Result = 1 or 2.
L	DSx-ACK Message	DSx-ACK message received from the CM, starting with the first byte of the DOCSIS MMM header and ending with the last byte of the CRC. This field is present only if Result = 1 or 2.

B.2.3.3.8.15 CDMM DSA-REQ CMTS-INITIATED (0x368), CDMM DSC-REQ CMTS-INITIATED (0x369), CDMM DSD-REQ CMTS-INITIATED (0x36A)

These messages are sent by the system control module to the RFI module.

The system control module sends this message to initiate a dynamic service flow operation. This will generally be at the request of some external entity – for instance, a call server requesting QoS via PCMM – or due to an operator command received via SNMP or some other management interface. Except for PCMM or PacketCable DQoS requests (Appendix I), the reasons why a system control module would initiate a dynamic service flow operation are beyond the scope of this specification.

The system control module only sends this message if its own policy and resource checks indicate the flow could be successfully added. As an example, if the system control module receives a request for a new flow from a call server via PCMM, but the system control module determines that the request cannot be allowed, the system control module rejects the request and does not send this message to the RFI module.

The system control module formats its request to the RFI module as a DOCSIS DSx-REQ message as specified by [MULPIv3.0]. This DSx-REQ message will generally not be complete – for example, the RFI module is responsible for assigning SFIDs, SIDs, and SID Clusters, etc., so these encodings will be omitted by the system control module.

The system control module also includes encodings to add any needed associations of VID+CoS bits (Annex B) to flows being created, admitted, or activated. In some cases, no new VID+CoS-to-flow associations are needed (e.g., for a DSC operation that does not change the QoS Param Set Type).

Table B–88 - CDMM DSA-REQ CMTS-INITIATED (0x368), CDMM DSC-REQ CMTS-INITIATED (0x369), CDMM-DSD-REQ CMTS-INITIATED (0x36A)

Bytes	Field	Description
2	DSx-REQ Message Length	Length L of enclosed DSx-REQ message
L	DSx-RSP Message	DSx-REQ message, formatted per [MULPIv3.0], starting from the first byte of the MMM header and continuing through the last byte of the CRC.
1	CDT Association Action	Action on VID+CoS values for CDT tags: 1 = add VID+CoS association 2 = delete VID+CoS association
1	Flow Count	Number of flows for which a VID+CoS to flow association is being added or deleted (zero if no such associations are being added or deleted).
--	---- { Per each flow } ----	---- { Per each flow } ----
4	Service Flow Identification	Service flow reference or SFID (if both are present, the SFID is used) for corresponding flow (from DSx or Registration message)
2	Tag	VID+CoS bits to be used in CDT tags for this flow. Bits 15:13 – CoS bits; bits 12:0 – VID (0x801 – 0x9D0)

B.2.3.3.8.16 CDMM DSA-RSP CMTS-INITIATED (0x36B), CDMM DSC-RSP CMTS-INITIATED (0x36C), CDMM DSD-RSP CMTS-INITIATED (0x36D)

These messages are sent by the RFI module to the system control module.

The RFI module sends this message in response to a 'CDMM DSx-REQ CMTS-Initiated'.

Upon receiving the 'CDMM DSx-REQ CMTS-Initiated,' the RFI module checks resource availability and other parameters to determine whether the request can be allowed.

If the RFI module determines that it will reject the request, it will indicate this by creating a DSx-RSP containing the relevant confirmation code and error sets. This message is used to encapsulate the DSx-RSP and send it to the system control module.

If the RFI module determines that it will accept the request, it initiates a DSx transaction with the Cable Modem based on the DSx-REQ message received from the system control module by completing the DSx-REQ message as needed (for example, by adding encodings for SFID, SIDs, SID Clusters, etc.) and sending it to the CM. The RFI module waits for a DSx-RSP from the cable modem or for the applicable timeout, then sends this message to the system control module. If the transaction did not time out, the DSx-RSP received from the CM is included in this message, and the RFI module takes the appropriate actions based on the response. The details of this transaction are as specified by [MULPIv3.0].

Table B–89 - CDMM DSA-RSP CMTS-INITIATED (0x36B)

Bytes	Field	Description
1	Result	1 = allowed 2 = rejected by RFI module 3 = timeout 4 = rejected by CM

Bytes	Field	Description
2	DSx-RSP Message Length	Length L of included DSx-RSP from CM This field exists if, and only if, Result=1, 2, or 4. **NOTE:** If the first byte is 3 (timeout), no additional bytes will be present in this message.
L	DSx-RSP Message	DSx-RSP received from CM, beginning from the first byte of the MMM header and continuing through the last byte of the CRC. If the CM rejected the transaction, this encapsulated DSx-RSP includes the applicable rejection code and error sets. This field exists if, and only if, Result = 1, 2, or 4.
1	Flow Count	Number of flows that have been added
--	---- { Per each flow } ----	---- { Per each flow } ----
4	Service Flow Reference	The Service flow reference id that was created by DSA-REQ message for each service flow
4	Service Flow Identification	The SFID that was created by DSA-REQ message for each service flow.

Table B–90 - CDMM DSC-RSP CMTS-INITIATED (0x36C), CDMM DSD-RSP CMTS-INITIATED (0x36D)

Bytes	Field	Description
1	Result	1 = allowed 2 = rejected by RFI module 3 = timeout 4 = rejected by CM
2	DSx-RSP Message Length	Length L of included DSx-RSP from CM This field exists if, and only if, Result=1, 2, or 4. **NOTE:** If the first byte is 3 (timeout), no additional bytes will be present in this message.
L	DSx-RSP Message	DSx-RSP received from CM, beginning from the first byte of the MMM header and continuing through the last byte of the CRC. If the CM rejected the transaction, this encapsulated DSx-RSP includes the applicable rejection code and error sets. This field exists if, and only if, Result = 1, 2, or 4.

B.2.3.3.8.17 CDMM DSA-ACK CMTS-INITIATED (0x36E), CDMM DSC-ACK CMTS-INITIATED (0x36F)

These messages are sent from the system control module to the RFI module.

They are sent in response to a 'CDMM DSx-RSP CMTS-Initiated'.

If the 'CDMM DSx-RSP CMTS-Initiated' indicated that the transaction succeeded, the system control module completes activation of any resources reserved for the flow and not already activated, then sends this message to indicate the success or failure of this operation. If the operation failed, the system control module uses the DSx-ACK message format and encodings as specified by [MULPIv3.0] to indicate the reason for the failure. The RFI module waits to receive this message before sending a DSx-ACK to the CM. Upon receiving this message, the RFI module completes the transaction as specified by [MULPIv3.0] by constructing and sending a complete DSx-ACK to the CM consistent with the results indicated in this message.

Table B–91 - CDMM DSA-ACK CMTS-INITIATED (0x36E), CDMM DSC-ACK CMTS-INITIATED (0x36F)

Bytes	Field	Description
1	Result	1 = success 2 = failure
2	DSx-ACK Message Length	Length L of enclosed DSx-ACK message This fields exists if, and only if, Result=2.
L	DSx-ACK Message	Description of failure in DSx-ACK format as specified in [MULPIv3.0], starting from the first byte of the MMM header and continuing through the last byte of the CRC This fields exists if, and only if, Result=2.

B.2.3.3.9 CM and RFI module Statistics

These messages allow the system control module to access statistics about the RFI module and statistics about each CM that are kept by the RFI module.

B.2.3.3.9.1 GET CM STATUS REQUEST (0x701)

This message is sent from the system control module to the RFI module.

This message is sent down to retrieve status information for CM(s) registered on the RFI module.

Table B–92 - GET CM STATUS REQUEST (0x701)

Bytes	Field	Description
2	CM Count	Number of CM's to query (X) [0 – for all known CMs]
Object A:		
6	MAC Address	1st CM MAC address
…….		
……..		
'Object A' is repeated X times.		

B.2.3.3.9.2 GET CM STATUS RESPONSE (0x702)

This message is sent from the RFI module to the system control module.

This message is sent up in response to 'GET CM Status Request' along with per-CM status information.

Table B–93 - GET CM STATUS RESPONSE (0x702)

Bytes	Field	Description
2	CM Count	Number of CM's queried
--	---- { Per CM Properties } ----	---- { Per CM Property Descriptions } ----
4	CM Index	Unique index value to identify CM in the system
6	Mac Address	CM Mac address
Upstream Stats		
1	Number of Upstream Channels	Number of CM's active Upstream channels (K)

Bytes	Field	Description
Object A:		
1	Upstream Channel ID	CM's 1st Upstream Channel ID
2	Upstream Power Level	CM Upstream power level in tenths dBmV
4	High Resolution Timing Offset	CM Timing Offset in units of (6.25 microseconds/(64*256))
1	Equalization Data Length	Value (X) denotes size following field housing Equalization data
X	Equalization Data	Equalization data for CM
8	Unerrored Codewords	Number of unerrored codewords received from CM
8	Corrected Codewords	Number of codewords with correctable errors received from CM
8	Uncorrectable Codewords	Number of codewords with uncorrectable errors received from CM
4	Upstream SNR	CM's Upstream SNR in tenthdB
1	Micro-reflections	Total Micro-reflections measured in dBc [0 – 255]
'Object A' is repeated K times detailing info for each CM Upstream.		
1	Connectivity State	CM connectivity state – Other = '1'; InitialRanging ='2'; RangingAutoAdjComplete = '4'; startEae = '10'; startDhcpv4 = '11'; startDhcpv6 = '12'; Dhcpv4Complete = '5'; Dhcpv6Complete = '13'; StartConfigFileDownload = '14'; configFileDownloadComplete = '15'; startRegistration = '16'; registrationComplete ='6'; operational = '8'; BpiInit = '9'; forwardingDisabled = '17'; rfMuteAll = '18'
1	DOCSIS Version	CM's DOCSIS Version – Docsis10 = '1'; Docsis11 = '2' ; Docsis20 = '3' ; Docsis30 = '4'
1	IP Address Type	CM's IP address type – Unknown = '1'; IPv4 = '2'; IPv6 = '3'; IPv4z = '4'; IPv6z = '5'; DNS = '16'
1	IP Address Length	Value (Y) denotes size of following field housing the IP address
Y	IP Address	CM's IP address
4	Timestamp	Value of 'sysUptime' when last updated
1	Service Flow ID Count	Number of Service Flow IDs setup for CM (Z)

Bytes	Field	Description
4	Service Flow ID	CM's Service Flow ID
……..		
Repeated 'Z' times.		
1	Length of Link-Local Address	Link-local address length (K)
K	Link-Local Address	CM's link-local address
2	Mac Domain Index	RFI module's MAC Domain interface index where CM is registered
4	Service Group ID	Mac Domain Service Group id in which CM is registered
1	RCP-ID length	Length of CM's RCP id (X)
X	RCP-ID	CM's RCP-ID
4	RCC-ID	RCC-ID used to configure CM's Receive Channel Set
4	RCS ID	CM's Receive Channel Set id
4	TCS ID	CM's Transmit Channel Set id
4	Last Registered Timestamp	Timestamp when CM last registered
4	Address Resolution Requests Count	Number of requests received relating to IP resolution for CM

B.2.3.3.9.3 GET RF INTERFACES REQUEST (0x703)

This message is sent from system control module to the RFI module.

This message is sent down to retrieve status information for RF interfaces. The contents of this message are always empty. For a CDMM message of this type, an opcode of 0x703 in the PDU layer is sufficient to solicit a response from the system.

Table B–94 - GET RF INTERFACES REQUEST (0x703)

Bytes	Field	Description
N/A	N/A	N/A

B.2.3.3.9.4 GET RF INTERFACES RESPONSE (0x704)

This message is sent from the RFI module to the system control module.

This message is sent up in response to 'GET RFIs Request' along with per-interface information.

Table B–95 - GET RF INTERFACES RESPONSE (0x704)

Bytes	Field	Description
2	Total Number of Network Interfaces	Number of network interfaces present
4	Network Interface Table Timestamp	Timestamp when set of interfaces was last modified in timeticks
--	---- { Per Network Interface Properties } ----	---- { Per Network Interface Property Descriptions } ----
2	Network Interface Index	Unique identifier for 1st network interface

Bytes	Field	Description
1	Network Interface Description Length	Value (Y) denotes length of field housing 1st interface's description
Y	Network Interface Description	1st Interface's description
1	Network Interface Type	1st network interface type - 6 = 'EthernetCsMacd'; 24 = 'SoftwareLoopback'; 127 = 'docsCableMacLayer' ; 128 = 'docsCableDownstream'; 129 = 'docsCableUpstream';
1	Interface Physical Address Length	Length of 1st interface's physical address (L)
L	Interface Physical Address	1st interface's physical address
1	Interface Alias Name Length	Length of 1st interface's alias name (M)
M	Interface Alias Name	1st interface's alias

B.2.3.3.9.5 GET RFI MAC STATISTICS REQUEST (0x705)

This message is sent from system control module to the RFI module.

This message is sent down to retrieve RFI module MAC layer statistics. The contents of this message are always empty. For a CDMM message of this type, an opcode of 0x705 in the PDU layer is sufficient to solicit a response from the system.

Table B–96 - GET RFI MAC STATISTICS REQUEST (0x705)

Bytes	Field	Description
N/A	N/A	N/A

B.2.3.3.9.6 GET RFI MAC STATISTICS RESPONSE (0x706)

This message is sent from the RFI module to the system control module.

This message is sent up in response to 'GET RFI MAC Statistics Request' along with per-interface statistics.

Table B–97 - GET RFI MAC STATISTICS RESPONSE (0x706)

Bytes	Field	Description
2	MAC Interface Index	Unique identifier for 1st MAC interface
4	Invalid Range Requests Count	Number of invalid RNG-REQ messages received
4	Ranging Aborted Count	Number of ranging attempts aborted
4	Invalid Registration Request Count	Number of invalid REG-REQ messages received
4	Failed Registration Request Count	Number of failed registration attempts
4	Invalid Data Request Count	Number of invalid data request messages received
4	T5 Timeout Count.	Number of times 'T5' counter expired

B.2.3.3.9.7 GET SERVICES STATISTICS REQUEST (0x707)

This message is sent by the system control module to the RFI module.

This message requests per-Service-Flow statistics for all Service Flows for a particular CM.

Table B–98 - GET SERVICES STATISTICS REQUEST (0x707)

Bytes	Field	Description
6	CM MAC Address	MAC address of CM for which statistics are being requested

B.2.3.3.9.8 GET SERVICES STATISTICS RESPONSE (0x708)

This message is sent by the RFI module to the system control module.

This message is sent up in response to a 'Get Services Statistics Request' along with statistics for all Service Flows for the specified modem.

Table B–99 - GET SERVICES STATISTICS RESPONSE (0x708)

Bytes	Field	Description
6	CM MAC Address	MAC address of CM for which statistics were requested
1	Number of flows (N)	Number of Service Flows for this CM
Object A:		
4	SFID	Service Flow Identifier for Service Flow
4	Service Flow Packets	Number of packets sent (for downstream flows) or received (for upstream flows) on this Service Flow
8	Service Flow Octets	Number of octets sent (for downstream flows) or received (for upstream flows) on this Service Flow
…….		
……..		
'Object A' is repeated N times.		

B.2.3.3.9.9 GET SIGNAL QUALITY REQUEST (0x709)

This message is sent from system control module to the RFI module.

This message is sent down to retrieve signal quality statistics for specific RFI module Upstream interfaces.

Table B–100 - GET SIGNAL QUALITY REQUEST (0x709)

Bytes	Field	Description
1	Upstream Interface Count	Number of interfaces to query info for (X)
Object A:		
2	Upstream Interface Index	Unique identifier for 1st network interface
Note: 'Object A' is repeated X times.		

B.2.3.3.9.10 GET SIGNAL QUALITY RESPONSE (0x70a)

This message is sent from the RFI module to the system control module.

This message is sent up in response to 'Get RFI module Signal Quality Request' along with per-interface statistics.

Table B–101 - GET SIGNAL QUALITY RESPONSE (0x70a)

Bytes	Field	Description
1	Upstream Interface Count	Number of Upstream interfaces successfully queried
--	---- { Per Network Interface Properties } ----	---- { Per Network Interface Property Descriptions } ----
2	Interface Index	Unique identifier for 1st network interface
1	Contention Intervals	1 = True if present ; 2 = False if absent
8	Unerrored Codewords	Number of unerrored codewords received on interface
8	Corrected Codewords	Number of codewords with correctable errors received on interface
8	Uncorrectable Codewords	Number of codewords with uncorrectable errors received on interface
4	Upstream SNR	Upstream SNR in tenthdB
1	Micro-reflections	Total Micro-reflections measured in dBc [0 – 255]

B.2.3.3.9.11 GET RF INTERFACE STATISTICS REQUEST (0x70b)

This message is sent from system control module to the RFI module.

This message is sent down to retrieve statistics for a specific RFI module.

Table B–102 - GET RF INTERFACE STATISTICS REQUEST (0x70b)

Bytes	Field	Description
1	Network Interface Count	Number of interfaces to query info for (X)
Object A:		
2	Network Interface Index	Unique identifier for 1st network interface
Note: 'Object A' is repeated X times.		

B.2.3.3.9.12 GET RF INTERFACE STATISTICS RESPONSE (0x70c)

This message is sent from the RFI module to the system control module.

This message is sent up in response to 'GET RF Interface Statistics Request' along with per-interface statistics.

Table B–103 - GET RF INTERFACE STATISTICS RESPONSE (0x70c)

Bytes	Field	Description
1	Network Interface Count	Number of interfaces successfully queried
--	---- { Per Network Interface Properties } ----	---- { Per Network Interface Property Descriptions } ----
2	Network Interface Index	Unique identifier for 1st network interface
2	Interface Max Transmission Unit Size (MTU)	Size of largest packet that can be sent on interface in bytes

Bytes	Field	Description
4	Interface Bandwidth	Nominal bandwidth of interface in Megabits per second (Mbps)
1	Interface Admin State	State: 1 = 'up'; 2 = 'down'; 3 = 'testing'
1	Interface Operational State	State: 1 = 'up'; 2 = 'down'; 3 = 'testing'; 4 = 'unknown'; 5 = 'dormant'; 6 = 'notPresent'; 7 = 'lowerLayerDown'
4	Interface Timestamp	Timestamp when interface last entered current operational state in timeticks
8	Total Received Byte(s) Count	Total number of byte(s) received on interface
8	Inbound Unicast Packet(s) Count	Total number of inbound unicast packets on interface
8	Inbound Multicast Packet(s) Count	Total number of inbound multicast packets on interface
8	Inbound Broadcast Packet(s) Count	Total number of inbound broadcast packets on interface
4	Inbound Discarded Packet(s) Count	Total number of inbound packets discarded on interface
4	Inbound Errored Packet(s) Count	Total number of inbound errored packets on interface
4	Inbound Unknown Protocol Packet(s) Count	Total number of packets discarded by interface due to unknown/unsupported protocol
8	Total Transmitted Byte(s) Count	Total number of byte(s) transmitted by interface
8	Outbound Unicast Packet(s) Count	Total number of outbound unicast packets on interface
8	Outbound Multicast Packet(s) Count	Total number of outbound multicast packets on interface
8	Outbound Broadcast Packet(s) Count	Total number of outbound broadcast packets on interface
4	Outbound Discarded Packet(s) Count	Total number of outbound packets discarded on interface
4	Outbound Errored Packet(s) Count	Total number of outbound errored packets on interface
1	Interface Link Traps State	State: 1 = 'Enabled'; 2 = 'Disabled'
1	Interface Promiscuous Mode State	State: 1 = 'True'; 2 = 'False'
1	Interface Physical Connector	1 = 'True'; 2 = 'False'
4	Interface Counter Discontinuity Timestamp	Timestamp when interface counters last suffered a discontinuity

B.2.3.3.9.13 GET DOWNSTREAM BONDING GROUPS REQUEST (0x70d)

This message is sent from the system control module to the RFI module.

This message is sent down to retrieve all configured Downstream Bonding Groups. The contents of this message are always empty. For a CDMM message of this type, an opcode of 0x70d in the PDU layer is sufficient to solicit a response from the system.

Table B–104 - GET DOWNSTREAM BONDING GROUPS REQUEST (0x70d)

Bytes	Field	Description
N/A	N/A	N/A

B.2.3.3.9.14 GET DOWNSTREAM BONDING GROUPS RESPONSE (0x70e)

This message is sent from the RFI module to the system control module.

This message is sent up in response to 'GET Downstream Bonding Groups Request' along with all configured Downstream bonding groups.

Table B–105 - GET DOWNSTREAM BONDING GROUPS RESPONSE (0x70e)

Bytes	Field	Description
1	Downstream Bonding Group Count	Number of Downstream Bonding groups
--	---- { Per Bonding Group Properties } ----	---- { Per Bonding Group Properties Descriptions } ----
4	Channel Set ID	Unique identifier for the channel set associated
2	Config ID	Configured bonding group identifier in MAC Domain
1	Mac Domain Service Group ID (MD-SG-ID)	Mac Domain Service Group ID that contains all Downstream channels in the bonding group
1	Channel List Length	Length of string (X)
X	Channel List	List of channels in bonding group
4	Provisioned Attribute Mask	Provisioned attribute mask encoding for bonding group
1	DSID Resequencing Wait Time	Resequencing wait time for all DSIDs in hundredMicroseconds [1-180, 255]
1	DSID Resequencing Warning Threshold	Resequencing warning threshold for all DSIDs in hundredMicroseconds [0-179, 255]

B.2.3.3.9.15 GET UPSTREAM BONDING GROUPS REQUEST (0x70f)

This message is sent from the system control module to the RFI module.

This message is sent down to retrieve all configured Upstream Bonding Groups. The contents of this message are always empty. For a CDMM message of this type, an opcode of 0x70f in the PDU layer is sufficient to solicit a response from the system.

Table B–106 - GET UPSTREAM BONDING GROUPS REQUEST (0x70f)

Bytes	Field	Description
N/A	N/A	N/A

B.2.3.3.9.16 GET UPSTREAM BONDING GROUPS RESPONSE (0x710)

This message is sent from the RFI module to the system control module.

This message is sent up in response to 'GET Upstream Bonding Groups Request' along with all configured Upstream bonding groups.

Table B–107 - GET UPSTREAM BONDING GROUPS RESPONSE (0x710)

Bytes	Field	Description
1	Upstream Bonding Group Count	Number of Upstream Bonding groups
--	---- { Per Bonding Group Properties } ----	---- { Per Bonding Group Properties } ----
4	Channel Set ID	Unique identifier for the channel set associated
2	Config ID	Configured bonding group identifier in MAC Domain
1	MAC Domain Service Group ID (MD-SG-ID)	MAC Domain Service Group ID that contains all Upstream channels in the bonding group
1	Channel List Length	Length of string (X)
X	Channel List	List of channels in bonding group
4	Provisioned Attribute Mask	Provisioned attribute mask encoding for bonding group

B.2.3.3.9.17 VENDOR-SPECIFIC MESSAGE (0x0F01)

Vendor-specific messages may be sent in either direction on the CDMM functional interface.

For vendor-specific messages on the CDMM, the CMTS MUST ensure that the first three bytes of the message contain the Organizationally Unique Identifier (OUI) of the vendor. The contents of subsequent bytes are defined by the vendor.

Table B–108 - VENDOR-SPECIFIC MESSAGE (0x0F01)

Bytes	Field	Description
3	OUI	OUI of the vendor defining the message
vendor-specific	Vendor-specific message	Vendor-specific message with contents and formatting as defined by the vendor

B.2.3.3.9.18 RFI SYSTEM EVENT MESSAGE (0x1001)

This message is sent from the RFI module to the system control module.

This is an autonomous event message for the RFI module to report an RFI module System message.

Table B–109 - RFI SYSTEM EVENT MESSAGE (0x1001)

Bytes	Field	Description
6	MAC Address	MAC Address of the RFI module from which the system event is emanated
1	Subtype	Subtype of the System Event message
2	Length	Length of the subtype message that follows
x	Subtype payload	Subtype message

The "Subtype" field in this event message is further defined in Table B–110.

Table B–110 - Subtype Definition

Subtype Code	Definition	Description	Payload
1	RFI Ready	Subtype of the System event message	RFI module firmware version in ASCII bytes

B.2.4 CDMM Message Functional Flow

This section describes how CDMM messages are used for a few key operations in the distributed CMTS architecture.

B.2.4.1 RFI module Initialization

Upon being powered up or reset, the RFI module initializes itself into a vendor-specific state. This state may be affected by factors such as settings stored in non-volatile memory, configuration files, provisioning via a command line or similar "craft" interface, or other items beyond the scope of this specification. Different operators may have different requirements for this function.

After initializing itself, the RFI module looks for a control channel with which to connect to a system control module for CDMM messaging. The RFI module within the CMTS SHOULD not allow any modems to join the network until the control channel is set up.

The RFI module within the CMTS MUST first decide whether to look for a control channel via OAM encapsulation or TCP/IP encapsulation. This may be determined via a setting stored in non-volatile memory, a configuration file, CLI interface, hardware jumper, or any of a number of other vendor-specific or operator-specific ways.

B.2.4.1.1 OAM Control Channel Startup

To start up an OAM-encapsulated control channel, the RFI module first initializes OAM in accordance with [802.3]. Other system elements (e.g., Network Module) MAY also be required to initialize OAM; these processes are vendor-specific.

The RFI module then attempts to send an RFI module SYSTEM EVENT MESSAGE with a subtype of "RFI Ready" using OAM encapsulation. If this message is not successfully acknowledged, the RFI module retries transmission in accordance with the rules in Section B.2.2.2. If the message is successfully acknowledged, the RFI module waits for a response from the system control module. Reception of any valid CDMM message that can be sent by the system control module to the RFI module indicates to the RFI module that a valid control channel has been set up. The RFI module is now initialized and can proceed with further operation.

If, after sending an "RFI Ready" message that is successfully acknowledged, the RFI module does not receive a valid CDMM message within a vendor-specific timeout, the RFI module retransmits the "RFI Ready" message. The RFI module performs three retries (four attempts total) before giving up. At this point, the RFI module within the CMC MAY attempt to initialize a control channel with TCP/IP encapsulation.

The system control module within the CMTS SHOULD support multiple RFI modules by enabling OAM control channels with each RFI Module.

B.2.4.1.2 TCP/IP Control Channel Startup

To start up a TCP/IP-encapsulated control channel, the RFI module initializes its own IP stack, and then performs the following steps:

1. The RFI module sends a DHCP DISCOVERY message including its own MAC address and the DHCP option 60 (with the string beginning with "cmc" - see Table 8–1) as defined in [CANN DHCP]) to indicate that it is a RFI module. This and all other DHCP messages from the RFI module are sent on the CDMM uplink.
2. A DHCP relay agent, ideally included as part of the classification and forwarding module, identifies the option 60 encoding and directs the DHCP DISCOVERY to the correct DHCP server.
3. The server responds to the RFI module with a DHCP OFFER. For security purposes, the server SHOULD send a unicast offer.
4. The RFI module continues the process by sending a DHCP REQUEST to the server.
5. The server responds with a DHCP ACKNOWLEDGE message. For this message the System control module within the CMTS MUST include encodings (see [CANN DHCP]) indicating the IP address of the system control module assigned to the RFI module, and the TCP port numbers on which the connection can be set up.

6. The RFI module initiates a TCP connection to the IP address and TCP port number specified.
7. Once the TCP connection has been successfully set up, the RFI module sends an RFI module EVENT NOTIFICATION MESSAGE with a subtype code of "RFI Ready" using TCP/IP encapsulation.
8. The RFI module waits for a response from the system control module. Reception of any valid CDMM message that can be sent by the system control module to the RFI module indicates to the RFI module that the control connection has been successfully set up, and the RFI module proceeds with further operation.
9. If the RFI module does not receive a valid CDMM message after waiting a vendor-specific timeout, it retransmits the "RFI module Ready" message. The RFI module performs three retries (four attempts total) before giving up. At this point the RFI module within the CMC MAY attempt to initialize a control channel using OAM encapsulation.

B.2.4.2 CM Initialization and Registration

Per [MULPIv3.0], a CM begins the process of joining the network by sending a Ranging Request message in a broadcast initial maintenance region. Depending on the channel type and CM version, this message may be a B-INIT-RNG-REQ, an INIT-RNG-REQ, or a RNG-REQ. An RNG-REQ is only sent by a CM that did not receive an MDD message and is operating on a type 1 or 2 upstream channel.

Upon successfully receiving one of these messages from a CM attempting to join the network, the RFI module sends a CM ARRIVAL REQUEST message to the system control module. The system control module is responsible for determining whether the CM is allowed to join the network. It may make this determination based on the CM's MAC address and/or various policies, which are vendor- or operator-specific and outside the scope of this specification.

The RFI module waits to receive a CM ARRIVAL RESPONSE from the system control module before allowing the modem to proceed past the Broadcast Initial Maintenance or Unicast Initial Maintenance stages of the registration process, as specified by [MULPIv3.0]. If the system control module has not responded by the time the modem has successfully completed the necessary ranging adjustments and service group discovery, the RFI module within the CMTS MAY use vendor-specific techniques to delay completion of Broadcast Initial Maintenance or Unicast Initial Maintenance until the system control module has responded.

If the CM ARRIVAL RESPONSE message from the system control module indicates that the modem is not allowed to join the network, the RFI module does not allow the modem to proceed any further and deletes the modem from the network.

If the CM ARRIVAL RESPONSE message from the system control module indicates that the modem is permitted to join the network, the RFI module continues the initialization process with the CM. At this point the CM has not registered and no permanent QoS resources have been assigned to it. In order for the CM to complete pre-registration initialization, it uses temporary service flows to communicate with the operator's DHCP and TFTP servers. The CM ARRIVAL RESPONSE message contains the encodings necessary to enable the RFI module to set up these temporary flows.

The next step of CM initialization involving the RFI module is cable modem registration. Per [MULPIv3.0], the CM starts this process by sending a Registration Request message to the RFI module. The Registration Request message contains detailed information about the CM's capabilities. It also includes requests for QoS-related resources, such as Service Flows and classifiers. These QoS requests are echoed from the configuration file downloaded by the modem from the operator's TFTP server prior to registration. They represent the services the operator wants to set up for this particular modem.

The RFI module processes the Registration Request message and determines its response to each of the capabilities indicated by the CM. It also determines whether it can provide the QoS resources requested by the CM. It expresses the results of this processing in the form of a Registration Response message. This Registration Response is not sent to the CM immediately; it is first sent to the system control module, encapsulated in a CDMM REGISTRATION REQUEST message. If the RFI module approved the requested flows, the system control module then makes its own determination as to whether the requested QoS resources are authorized and can be supported; it MUST check that the classification and forwarding module can support the requested classifiers. Authorization criteria are specific to the vendor and/or operator and are beyond the scope of this specification. The system control module sends a CDMM REGISTRATION RESPONSE to the RFI module indicating the results of its processing. The RFI module

then either completes the registration process or rejects the modem's request, as indicated by the system control module.

The final step of CM initialization involving the RFI module is the initialization of BPI+. In systems enabling Early Authentication and Encryption (EAE), this step may occur before registration. If EAE is not enabled, or for modems not supporting EAE, BPI+ is initialized after registration. In either case, the process is the same.

As specified in [MULPIv3.0] and [SECv3.0], the CM begins BPI+ initialization by sending a BPKM-REQ Authentication Information message to the RFI module. The CM follows this with a BPKM Authorization Request message. The RFI module sends both of these messages to the system control module in a SECURITY ASSOCIATION AUTHORIZATION REQUEST message. The system control module authenticates the modem and determines whether it is authorized to receive a Security Association. The methods for doing this are beyond the scope of this specification. The system control module indicates the results of its processing in a SECURITY ASSOCIATION AUTHORIZATION RESPONSE message. If the system control module indicates that the modem is authorized, the RFI module proceeds to set up a Security Association for the modem; otherwise, the RFI module sends a BPKM-RSP Authorization Reject message to the CM as specified by [SECv3.0].

The process of CM initialization and registration is illustrated in Figure B–3.

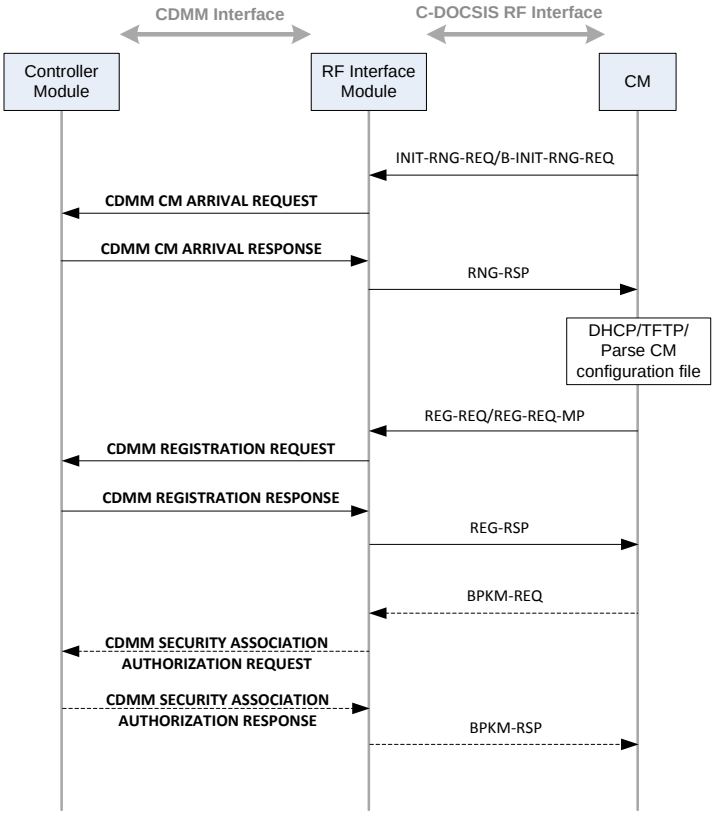

Figure B–3- CM Initialization and Registration

Appendix I Dynamic Service Operations

I.1 Dynamic Service Operations Overview

The distributed CMTS architecture supports the addition, change, and deletion of dynamic service flows. These dynamic service operations (DSx) enable the system to offer both priority-based QoS and parameterized QoS for a wide range of multimedia applications such as VoIP, video conferencing, and video streaming, etc. In particular, the system supports both CM-initiated and CMTS-initiated DSx messages, enabling client devices that are aware of QoS as well as client devices that are transparent to QoS mechanisms.

In the environment, DSx messages are triggered by the QoS infrastructure of the cable operator. Such infrastructure can be based on PacketCable Dynamic QoS (DQoS) (see [DQoS]), PacketCable Multimedia (PCMM) [MM], or a combination of both. PacketCable DQoS supports multimedia clients that are aware of QoS and allows these clients to initiate DSx with the RFI module to setup the dynamic service flows of appropriate QoS characteristics. PacketCable DQoS is mainly used for PacketCable 1.5 E-MTA. On the other hand, PCMM supports multimedia clients that are not aware of QoS and thus rely on the RFI Module to initiate DSx with the CM to setup the dynamic service flows. The typical clients that can be supported by PCMM are PacketCable 2.0 E-DVA, some types of IMS clients, and over-the-top (OTT) service clients that require QoS support.

The CMTS supports both PacketCable [DQoS] and PCMM [MM]. Specifically, the system control module within the CMTS supports the Common Open Policy Service (COPS). [RFC 2748] interfaces standardized in [DQoS] and [MM]. The system control module communicates with the RFI Module in support of DSx messaging and QoS setup, using the CDMM encapsulation mechanisms in Section B.2.2 and the CDMM messages for dynamic services in Section B.2.3.3.

To better define the interactions among the system control module, the RFI Module and the CM during dynamic service operations, the rest of this section describes these interactions during different stages of a typical multimedia session (or call): setup, mid-session maintenance, and termination. Without loss of generality, the descriptions assume that the session is initiated by a local client device. An incoming session initiated by a remote client device will involve the similar interactions among the system control module, the RFI Module and the CM, and does not impose any special functional requirements on these entities in terms of dynamic-service support.

I.2 Session Setup

When a local client initiates a call, it generates a call setup message to the call server with necessary information about the call attributes (such as codecs, media frame sizes, etc.) included in the message. The call server in turn interacts with the cable QoS infrastructure (DQoS or PCMM) to reserve the resources on the cable network for the call. In particular, the Policy Server (part of the QoS infrastructure) sends a COPS message to the system control module via the COPS interface to reserve or commit the resources on the RFI Module. This message, among other information, contains the QoS attributes and classifiers for the call.

Upon receiving this message from the Policy Server, the system control module reformats the QoS and classifier information into the corresponding formats for DSx messages and includes them in a 'CDMM DSA-REQ CMTS-Initiated' message defined in Section B.2.3.3. The system control module sends the message to the RFI module using an encapsulation method in Section B.2.2.

If the RFI module can meet the resource requirements implied by the QoS parameters in the 'CDMM DSA-REQ CMTS-Initiated' message, it initiates a DSA transaction with the target CM. The DSA-RSP received from the CM is relayed by the RFI Module to the system control module using 'CDMM DSA-RSP CMTS-Initiated'. If the system control module accepts the DSA response, it generates a partially-filled DSA-ACK and sends it to the RFI Module as 'CDMM DSA-ACK CMTS-Initiated'. The RFI module completes the ACK message and sends it to the target CM. Successful completion of the DSA transactions provisions or commits the service flows necessary for the call, and allows the system control module to acknowledge the original resource request from the Policy Server. It also allows the call server to start to contact the remote client associated with the call.

Upon acceptance of the call by the remote client (e.g., the remote user picks up the phone), the call server can interact with the QoS infrastructure again to request the commitment of the cable network resources, if the initial resource request was just for resource reservation (not commitment) of the resources. This in turn will trigger another run of CDMM message exchanges between the system control module and the RFI Module, as well as a

DSC transaction between the RFI Module and the target CM to change the status of the previously provisioned service flows to be "committed". The successful commitment of the cable network resources enables the call server to complete the call setup initiated by the local client.

The procedure described above assumes that the local client is not aware of the QoS mechanism, thus the client relies on the RFI Module for the initiation of the DSx transactions. This assumption is true for a PacketCable 2.0 E-DVA or an IMS client, for example.

However, some other clients (such as PacketCable 1.5 E-MTA) do have the ability to control the embedded CM, and thus are able to initiate DSx from the CM side. In this case, during the call setup, the call server still needs to first contact the system control module and the RFI Module via a Policy Server to get the confirmation about the availability of required resources. However, instead of triggering the RFI Module to initiate the DSx transactions, the call server requests the client itself to initiate DSx from the CM side. This procedure is shown in Figure I–1.

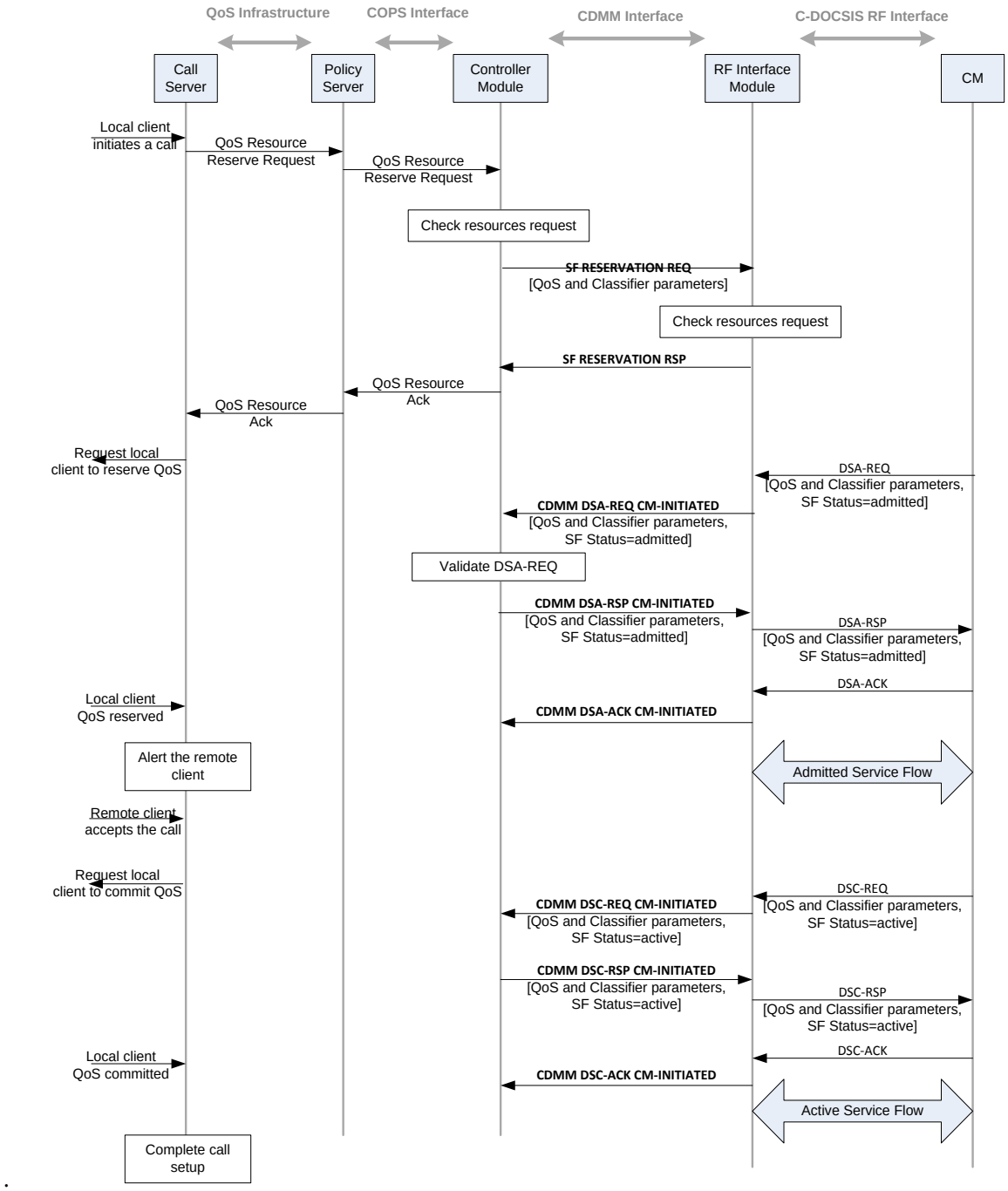

Figure I–1 - CM-Initiated DSA and DSC for Session Setup

I.3 Session Maintenance

During an active session, either the local or the remote client can request to change the attributes (e.g., to change audio or video codec) of the media stream. Such a request may change the QoS attributes associated with the session. If this is the case, the call server can detect the requested QoS changes by examining the call signaling messages. In turn, the call server invokes the QoS infrastructure to change the service flows associated with the call.

The procedures for the mid-call QoS changes are shown in Figure I–2 and Figure I–3, for CMTS-initiated and CM-initiated DSx, respectively.

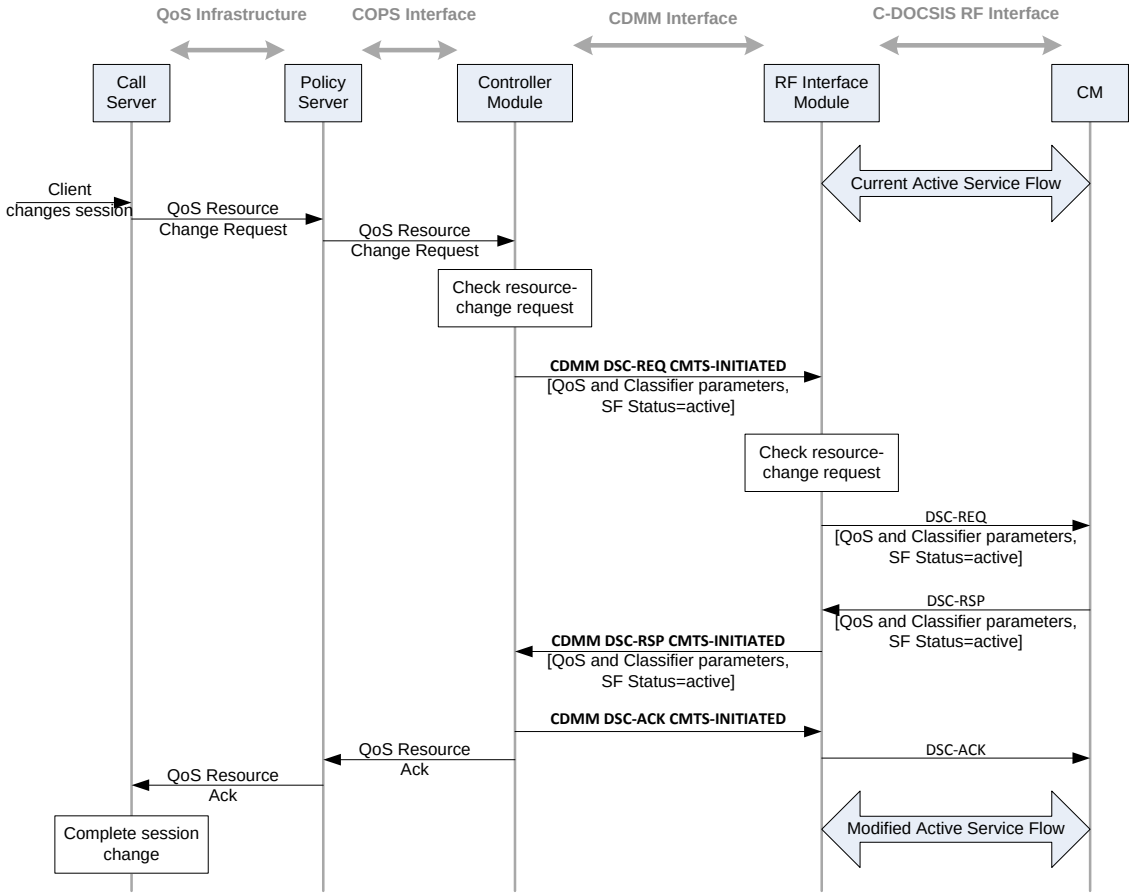

Figure I–2 - Headend-Initiated DSC for Session Maintenance

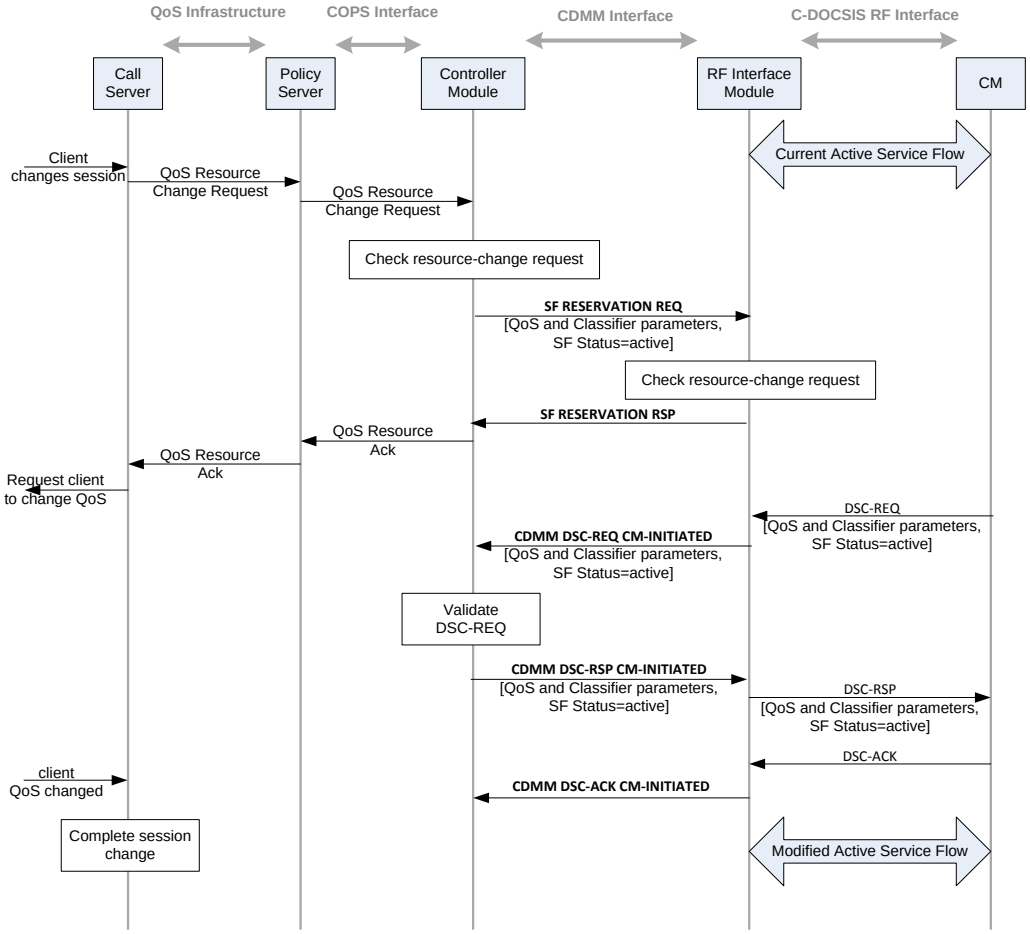

Figure I–3 - CM-Initiated DSC for Session Maintenance

I.4 Session Termination

When the session is terminated (e.g., the user hangs up the call), the call server invokes the QoS infrastructure to delete the service flows associated with the call. The DSD transaction can be initiated by either the RFI module or the CM, depending on the QoS infrastructure is based on PCMM or DQoS, as shown in Figure I–4 and Figure I–5, respectively.

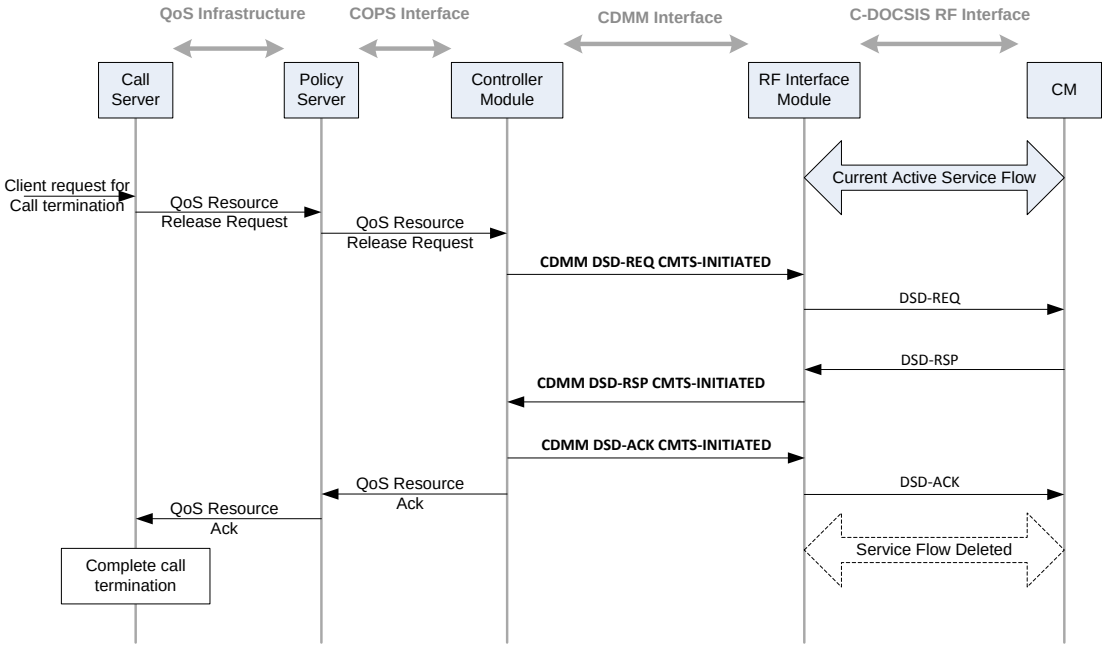

Figure I–4 - Headend-Initiated DSD for Session Termination

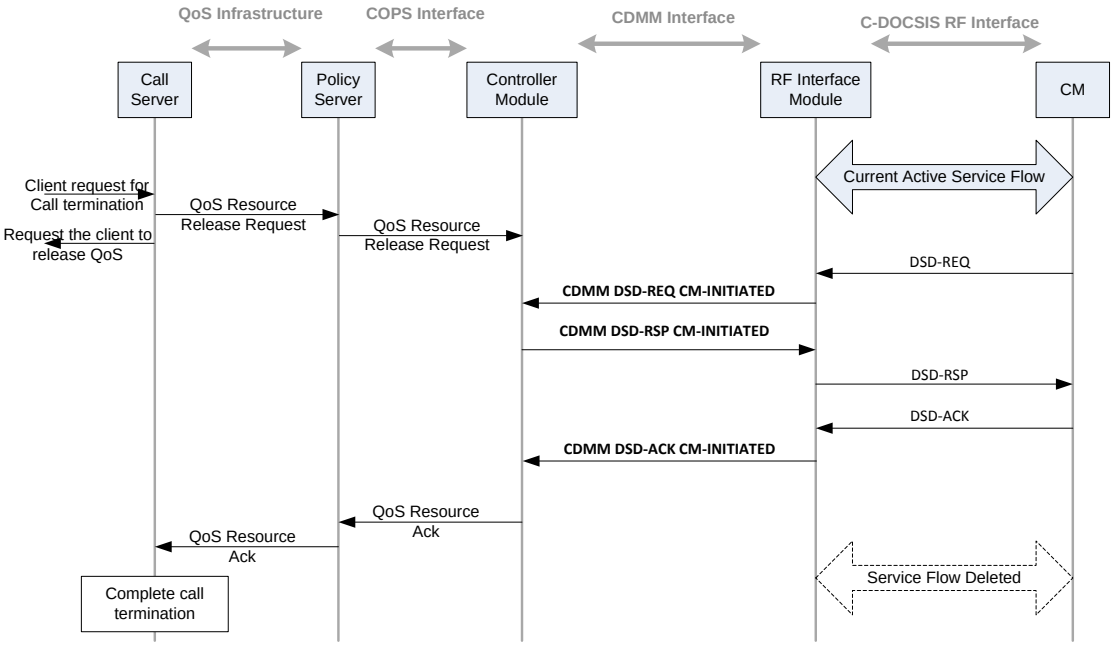

Figure I–5 - CM-Initiated DSD for Session Termination

I.5 Control Point Discovery Mechanism

Dynamic service operations described above require the Policy Server to establish COPS session (normally TCP-based) with the CMTS. However, when a multimedia session requests resource, the address information the Policy Server receives from the call server is the IP address of the multimedia client or the IP address of the CM (if the CM

is a NAT device). In order to set up a COPS session and start dynamic service operations, the Policy Server needs a mechanism to acquire the IP address and capability of the CMTS serving this client. This mechanism is called Control Point Discovery (CDP).

This specification recommends adoption of the CPD interface defined in [CPD]. This CPD interface uses Network Layer Signaling protocol (NLS) for message encapsulation, and defines corresponding payload fields for information exchange between the Policy Server and the CMTS.

CPD and other dynamic service interfaces are shown in Figure I–6.

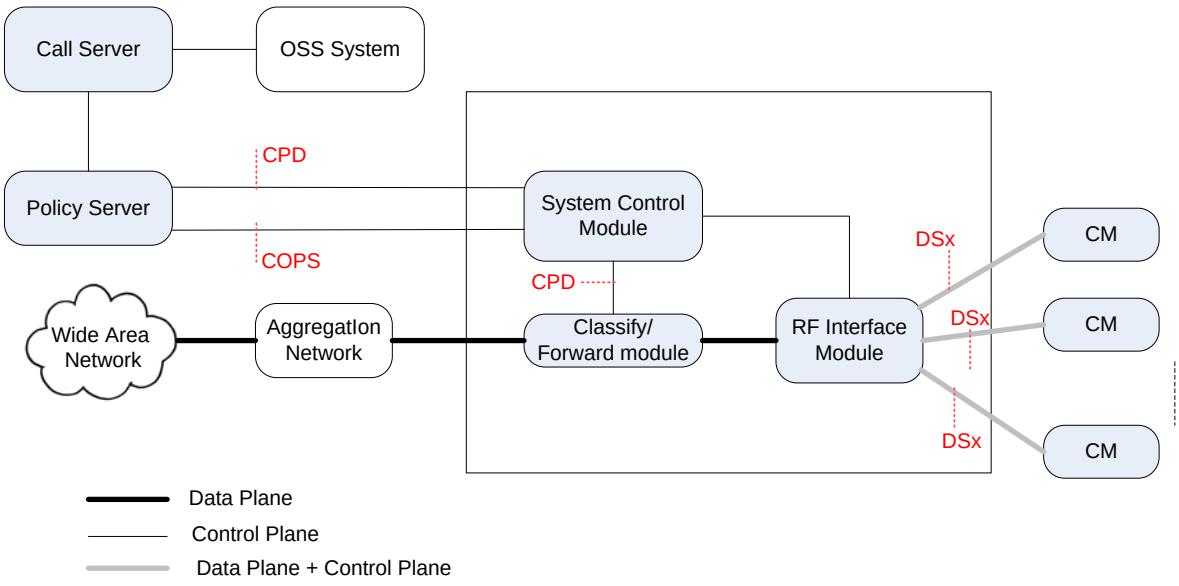

Figure I–6 - CPD and Other Dynamic Service Interfaces

The operation sequence of CPD is described as follows:

1. The Policy Server receives a request for QoS resource reservation, including IP address information of the client.
2. The Policy Server looks up the local address list of CMTSs. If not found, the Policy Server sends a CPD request message, with destination IP address being the IP address of the client, and the destination UDP port number being the port number registered for NLS (7549).
3. The CPD request message is routed to the CMTS serving the target client. A classification rule is provisioned on the Classify/Forward Module of this CMTS to capture the CPD request message and to forward it to the system control module.
4. The system control module parses the CPD request message, generates a CPD response message, including fields such as IP address, subnet mask and capability, and then sends the response message to the Policy Server.
5. The Policy Server receives the CPD response message from the system control module. Then the COPS session can be established according to information contained in the response message. The Policy Server can save the information associated with that CMTS for future queries when new resource requests are received.

For detailed definition of CPD, see [CPD].

Appendix II Acknowledgements

We would like to thank the team responsible for developing [GY/T266], which originally developed and defined the distributed CMTS architectures and concepts, and from which much of the material in this specification has been based.

On behalf of the cable industry and our member companies, CableLabs would like to thank the following individuals for their contributions to the development of this specification.

Organization	Contributor
SARFT	Zhifan (Steven) Sheng
Academy of Broadcasting Planning, SARFT	Yanlong Qin, Lili Sun, Zhongzhao Li, Jiasheng Yang, Peijiang Zhu
Beijing Gehua Catv Network Co., Ltd.	Jiangming Shi, Yue Dong
CableLabs	Karthik Sundaresan, Matthew Schmitt, Dan Rice
Radio, Film & TV Design and Research Institute	Shihua Wan
Topway Video Communication Co., Ltd.	Jiangshan (Johnson) Xu, Shijie Ouyang, Bei Xu
Wasu Digital TV Media Group Co., Ltd.	Zhifeng Zhao, Wei Zhang
Broadcom Corporation	Niki Pantelias, Jeffrey Zhang, Tom Kolze, Victor Hou, Gordon Li
Cisco	John Chapman, Xuan Wang
Huawei Technologies Co., Ltd.	Guangsheng Wu, Chenghu Shen
Sumavision Technologies Co. Ltd.	Yanming Ren, Yanjun Deng, Jigang Ru
ZTE Corporation	Chang Sun, Peng Zhang

Appendix III Revision History (Informative)

III.1 Engineering Change for CM-SP-CDOCSIS-I02-150305.

The following Engineering Change was incorporated into CM-SP-CDOCSIS-I02-150305.

ECN Identifier	Accepted Date	Title of EC	Author
CDOCSIS-14.1216-2	11/19/2014	CDOCSIS OSSI Updates and Fixes, Remote PHY reference	Sundelin, Andrew