

# ETSI TR 101 546 V1.1.1 (2011-10)



Technical Report

**Access, Terminals, Transmission and Multiplexing (ATTM);  
Integrated Broadband Cable and Television Networks;  
Converged Cable Access Platform Architecture**

---

**Reference**

DTR/ATTM-003015

---

**Keywords**access, broadband, cable, data, IP, IPcable,  
modem**ETSI**

---

650 Route des Lucioles  
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C  
Association à but non lucratif enregistrée à la  
Sous-Préfecture de Grasse (06) N° 7803/88

---

**Important notice**

Individual copies of the present document can be downloaded from:

<http://www.etsi.org>

The present document may be made available in more than one electronic version or in print. In any case of existing or perceived difference in contents between such versions, the reference version is the Portable Document Format (PDF). In case of dispute, the reference shall be the printing on ETSI printers of the PDF version kept on a specific network drive within ETSI Secretariat.

Users of the present document should be aware that the document may be subject to revision or change of status. Information on the current status of this and other ETSI documents is available at

<http://portal.etsi.org/tb/status/status.asp>

If you find errors in the present document, please send your comment to one of the following services:

[http://portal.etsi.org/chaicor/ETSI\\_support.asp](http://portal.etsi.org/chaicor/ETSI_support.asp)

---

**Copyright Notification**

No part may be reproduced except as authorized by written permission.  
The copyright and the foregoing restriction extend to reproduction in all media.

© European Telecommunications Standards Institute 2011.  
All rights reserved.

**DECT™**, **PLUGTESTS™**, **UMTS™** and the ETSI logo are Trade Marks of ETSI registered for the benefit of its Members.  
**3GPP™** and **LTE™** are Trade Marks of ETSI registered for the benefit of its Members and  
of the 3GPP Organizational Partners.  
**GSM®** and the GSM logo are Trade Marks registered and owned by the GSM Association.

# Contents

Intellectual Property Rights .....	6
Foreword.....	6
1 Scope .....	7
2 References .....	7
2.1 Normative references .....	7
2.2 Informative references.....	7
3 Definitions and abbreviations.....	9
3.1 Definitions.....	9
3.2 Abbreviations .....	10
4 VOID.....	12
5 CCAP Architecture Goals, Benefits and Overview .....	12
5.1 Fundamental Goals of the CCAP .....	12
5.2 CCAP Benefits .....	13
5.2.1 Service Multiplexing Flexibilities.....	13
5.2.2 Bandwidth Capacity and Density Gains .....	14
5.2.3 High Reliability and Redundancy Capabilities.....	14
5.2.4 Configuration and Management Simplifications .....	14
5.2.5 Rack-Space and Power Reduction .....	14
5.2.6 RF Combining Simplifications .....	16
5.2.7 IP Router Integration .....	16
5.3 Supported Services in CCAP.....	16
5.3.1 Video EQAM Services .....	16
5.3.1.1 Broadcast Digital Video.....	17
5.3.1.2 Switched Digital Video .....	17
5.3.1.3 Video on Demand .....	17
5.3.2 DOCSIS Services.....	17
5.3.2.1 High-Speed Internet .....	18
5.3.2.2 IPCablecom VoIP .....	18
5.3.2.3 Transparent LAN Service .....	18
5.3.2.4 Next Generation Video Services .....	19
5.3.3 DOCSIS Provisioning of EPON .....	19
5.4 CCAP Architectures.....	19
5.4.1 Integrated CCAP Architecture.....	19
5.4.1.1 CCAP MPEG Video Headend Reference Architecture .....	19
5.4.1.2 CCAP Data Reference Architecture.....	21
5.4.1.3 Modular Headend Architecture Functionality.....	22
5.4.2 Modular CCAP Architecture .....	22
5.4.2.1 Modular CCAP Functional Architecture.....	22
5.4.2.2 Packet Shelf Functionality .....	23
5.4.2.3 Access Shelf Functionality.....	23
5.4.2.4 Modular CCAP Data/Video Architecture .....	23
5.4.2.5 Downstream-Only Access Shelf .....	24
6 Summary of DOCSIS Specifications and Applicability .....	24
6.1 DOCSIS 3.0 Specifications .....	24
6.1.1 MAC and Upper Layer Protocols Interface Specification v3.0 .....	24
6.1.2 Physical Layer Specification v3.0.....	24
6.1.3 DOCSIS Security Specification v3.0.....	25
6.2 CCAP Specifications.....	25
6.2.1 CCAP Operations Support System Interface .....	25
6.2.1.1 SNMP Requirements and Reporting Requirements .....	25
6.2.1.2 CCAP Object Model .....	25
6.2.2 Packet Shelf to Access Shelf Interface Specification .....	25
6.3 Modular Headend Architecture Specifications.....	26

6.3.1	Edge Resource Management Interface Specification .....	26
6.3.2	DOCSIS Timing Interface Specification .....	26
6.3.3	Video Stream Interface Specification .....	26
6.4	Downstream RF Interface Specification.....	26
6.5	DOCSIS Set-Top Gateway Specification.....	27
6.6	Business Services over DOCSIS Specifications.....	27
6.6.1	Layer 2 VPN Specification .....	27
6.6.2	TDM Emulation Interface Specification.....	27
6.7	DOCSIS Provisioning of EPON Specifications .....	27
6.7.1	DOCSIS Provisioning of EPON Architecture Specification .....	27
6.7.2	DOCSIS Provisioning of EPON MEF Specification .....	27
6.7.3	DOCSIS Provisioning of EPON MAC and Upper Layer Protocols Specification .....	27
6.7.4	DOCSIS Provisioning of EPON Operations Administration and Maintenance Specification.....	27
6.7.5	DOCSIS Provisioning of EPON Operations Support System Interface Specification .....	27
6.7.6	DOCSIS Provisioning of EPON Physical Layer Specification .....	28
6.7.7	DOCSIS Provisioning of EPON Security Specification.....	28
6.8	Summary of DOCSIS Specification Applicability .....	28
7	CCAP Features and Capabilities .....	28
7.1	Service Multiplexing Capabilities .....	28
7.1.1	CCAP Service Groups .....	28
7.1.1.1	Broadcast Service Groups .....	28
7.1.1.2	Switched Digital Video Narrowcast Service Groups .....	29
7.1.1.3	VOD Narrowcast Service Groups .....	29
7.1.1.4	DOCSIS Narrowcast Service Groups.....	29
7.2	Optional Content Protection.....	29
7.2.1	Network Decryption .....	30
7.2.2	Access Encryption .....	30
7.3	QAM Replication .....	30
7.4	Spectrum Surveillance.....	31
7.5	CCAP Configuration Management .....	31
7.5.1	YANG Data Modelling Language and XML Background .....	31
7.5.2	Configuration Object Model.....	32
7.5.3	Configuration Data Model.....	32
7.5.4	CCAP Configuration File Processing .....	32
7.5.5	CCAP NETCONF-Based Configuration .....	32
7.6	PON Configuration: DOCSIS Provisioning of EPON .....	32
7.6.1	The DOCSIS and DPoE Networks .....	33
7.6.2	DPoE Provisioning and Management.....	34
7.6.3	Provisioning and Management of OLT Devices.....	34
7.7	Protocol Support.....	34
7.7.1	IP Versions.....	34
7.7.2	VPN.....	34
7.7.2.1	MPLS .....	35
7.7.2.2	Multicast VPN (MVPN) .....	35
7.7.3	Routing .....	35
7.7.4	Multicast .....	35
7.7.5	Modular CCAP: Packet to Access Shelf Interface (PASI) Protocols .....	36
7.7.5.1	PASI Management Plane .....	36
7.7.5.2	PASI Control Plane .....	37
7.7.5.3	PASI Data Plane.....	37
8	CCAP Implementations.....	38
8.1	CCAP Interface Options.....	38
8.1.1	Hybrid-Fibre Coax Interfaces .....	38
8.1.1.1	Downstream RF Interfaces.....	38
8.1.1.2	Upstream RF Interfaces.....	38
8.1.2	Ethernet Passive Optical Network (EPON) Interfaces.....	39
8.1.2.1	Split Ratios and Customers Served .....	39
8.1.2.2	EPON Redundancy .....	39
8.1.2.3	EPON Connectors .....	39
8.1.3	Network Side Interface .....	39

8.2	Platform Implementation Options .....	40
8.2.1	I-CCAP Chassis Sizing .....	40
8.2.2	M-CCAP Chassis Sizing and Physical Locations .....	40
History	.....	44

---

## Intellectual Property Rights

IPRs essential or potentially essential to the present document may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (<http://ipr.etsi.org>).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

---

## Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

---

# 1 Scope

The present document is intended to provide an introduction to the Converged Cable Access Platform (CCAP) architecture. The CCAP architecture has been specified in an integrated and a modular implementation. The present document describes both the integrated and modular architectures and discusses the various specifications that contain normative requirements pertaining to the CCAP. In addition, the present document describes the architectural entities and interfaces that make up the integrated and modular implementations, as well as the protocols they support. For the modular implementation, the present document provides an overview of the operation of Packet Shelf and Access Shelf devices, as well as the interface between them.

---

# 2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at <http://docbox.etsi.org/Reference>.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

## 2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

## 2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] ETSI EN 302 878-3: "Access, Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems; Part 3: Downstream Radio Frequency Interface; DOCSIS 3.0".
- [i.2] DOCSIS Set-top Gateway (DSG) Interface Specification: "CM-SP-DSG", Cable Television Laboratories, Inc.
- [i.3] DOCSIS Timing Interface Specification: "CM-SP-DTI", Cable Television Laboratories, Inc.
- [i.4] Edge QAM Video Stream Interface Specification: "CM-SP-EQAM-VSI", Cable Television Laboratories, Inc.
- [i.5] DOCSIS Edge Resource Manager Interface: "CM-SP-ERMI", Cable Television Laboratories, Inc.
- [i.6] IEEE Standard for Information technology: "Telecommunications and information exchange between systems-Local and metropolitan area networks-Specific requirements-Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment: Media Access Control (MAC) Parameters, Physical Layers, and Management Parameters for 10 Gbs Operation".
- [i.7] IEEE Std 802.3ba-2010: "IEEE Standard for Information Technology Specific Requirements - Part 3: 40Gb/s and 100Gb/s Ethernet".
- [i.8] Business Services over DOCSIS: "Layer 2 Virtual Private Networks", CM-SP-L2VPN, Cable Television Laboratories, Inc.

- [i.9] ETSI EN 302 878-4: "Access, Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems; Part 4: MAC and Upper Layer Protocols; DOCSIS 3.0".
- [i.10] Operations Support System Interface Specification: "CM-SP-OSSIV3.0", Cable Television Laboratories, Inc.
- [i.11] ETSI EN 302 878-2: "Access, Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems; Part 2: Physical Layer; DOCSIS 3.0".
- [i.12] IETF RFC 2328/STD0054: "OSPF Version 2", April 1998.
- [i.13] IETF RFC 2453/STD0056: "RIP Version 2", November 1998.
- [i.14] IETF RFC 3209 RSVP-TE: "Extensions to RSVP for LSP Tunnels", December 2001.
- [i.15] IETF RFC 3376: "Internet Group Management Protocol Version 3", October 2002.
- [i.16] IETF RFC 4023: "Encapsulating MPLS in IP or Generic Routing Encapsulation (GRE)", March 2005.
- [i.17] IETF RFC 4364: "BGP/MPLS IP Virtual Private Networks (VPNs)", February 2006.
- [i.18] IETF RFC 5420: "Encoding of Attributes for MPLS LSP Establishment Using Resource Reservation Protocol-Traffic Engineering (RSVP-TE)", February 2009.
- [i.19] IETF RFC 4448: "Encapsulation Methods for Transport of Ethernet over MPLS Networks", April 2006.
- [i.20] IETF RFC 4601: "Protocol Independent Multicast - Sparse Mode (PIM-SM): Protocol Specification (Revised)", August 2006.
- [i.21] IETF RFC 4664: "Framework for Layer 2 Virtual Private Networks (L2VPNs)", September 2006.
- [i.22] IETF RFC 4724: "Graceful Restart Mechanism for BGP", January 2007.
- [i.23] IETF RFC 4761: "Virtual Private LAN Service (VPLS) Using BGP for Auto-Discovery and Signalling", January 2007.
- [i.24] IETF RFC 4874: "Exclude Routes - Extension to Resource Reservation Protocol-Traffic Engineering (RSVP-TE)", April 2007.
- [i.25] IETF RFC 5036: "LDP Specification", October 2007.
- [i.26] IETF RFC 5303: "Three-Way Handshake for IS-IS Point-to-Point Adjacencies", October 2008.
- [i.27] IETF RFC 5709: "OSPFv2 HMAC-SHA Cryptographic Authentication", October 2009.
- [i.28] IETF RFC 5711: "Node Behavior upon Originating and Receiving Resource Reservation Protocol (RSVP) Path Error Messages", January 2010.
- [i.29] ETSI EN 302 878-5: "Access, Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems; Part 5: Security Services; DOCSIS 3.0".
- [i.30] TDM Emulation Interface Specification: "CM-SP-TEI-I06", Cable Television Laboratories, Inc.
- [i.31] IETF RFC 6020: "YANG - A Data Modelling Language for the Network Configuration Protocol (NETCONF)".
- [i.32] Data-Over-Cable Service Interface Specifications: "CCAP Operations Support System Interface Specification", CM-SP-CCAP-OSSI, Cable Television Laboratories, Inc.
- [i.33] DOCSIS Provisioning of EPON Architecture: "DPoE-SP-ARCHv1.0", Cable Television Laboratories, Inc.



- [i.34] DOCSIS Provisioning of EPON MEF Specification: "DPoE-SP-MEFv1.0", Cable Television Laboratories, Inc.
- [i.35] DOCSIS Provisioning of EPON MULPI Specification: "DPoE-SP-MULPIv1.0", Cable Television Laboratories, Inc.
- [i.36] DOCSIS Provisioning of EPON OAM Specification: "DPoE-SP-OAMv1.0", Cable Television Laboratories, Inc.
- [i.37] DOCSIS Provisioning of EPON OSSI Specification: "DPoE-SP-OSSIV1.0", Cable Television Laboratories, Inc.
- [i.38] DOCSIS Provisioning of EPON Physical Layer Specification: "DPoE-SP-PHYv1.0", Cable Television Laboratories, Inc.
- [i.39] DOCSIS Provisioning of EPON Security Specification: "DPoE-SP-SECv1.0", Cable Television Laboratories, Inc.
- [i.40] EQAM Architectural Overview Technical Report: "CM-TR-MHA", Cable Television Laboratories, Inc.
- [i.41] CCAP Packet Shelf to Access Shelf Interface Specification: "CM-SP-CCAP-PASI", Cable Television Laboratories, Inc.
- [i.42] IETF RFC 3810: "Multicast Listener Discovery Version 2 (MLDv2) for IPv6", June 2004.
- [i.43] IETF RFC 4741: "NETCONF Configuration Protocol", December 2006.
- [i.44] IETF RFC 4760: "Multiprotocol Extensions for BGP-4", January 2007.
- [i.45] IETF RFC 5120: "M-ISIS: Multi Topology (MT) Routing in Intermediate System to Intermediate Systems (IS-ISs)", February 2008.
- [i.46] 802.3ah-2004: "IEEE Standard for Information Technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Carrier Sense Multiple Access With Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment: Media Access Control Parameters, Physical Layers, and Management Parameters for Subscriber Access Networks".
- [i.47] 802.1Q-2003: "IEEE Standards for Local and Metropolitan Area Networks: Virtual Bridged Local Area Networks".
- [i.48] 802.3av-2009: "IEEE Standard for Information technology-- Telecommunications and information exchange between systems--Local and metropolitan area networks-- Specific requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment 1: Physical Layer Specifications and Management Parameters for 10 Gb/s Passive Optical Networks".

---

## 3 Definitions and abbreviations

### 3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

**Access Shelf (AS):** one of the two chassis that make up a Modular CCAP implementation. The Access Shelf is primarily responsible for MPEG processing and access functions (PHY, PON, etc.) normally associated with the CMTS and the Edge QAM

**Cable Modem Termination System (CMTS):** headend component that provides the operator network side termination for the DOCSIS link. A CMTS communicates with a number of Cable Modems to provide data services

**Converged Cable Access Platform (CCAP):** headend component that provides the functionality of a CMTS and an Edge QAM in a single architecture with greater QAM density and overall capacity

**Edge QAM (EQAM):** head-end or hub device that receives packets of digital video or data from the operator network. It re-packetizes the video or data into an MPEG transport stream and digitally modulates the transport stream onto a downstream RF carrier using QAM

**Ethernet Passive Optical Network (EPON):** point-to-multipoint, fibre to the premises network architecture in which unpowered optical splitters are used to enable a single optical fibre to serve multiple premises

**hybrid fibre-coax System:** broadband bidirectional shared-media transmission system using optical fibre trunks between the head-end and the fibre nodes, and coaxial cable distribution from the fibre nodes to the customer locations

**NETCONF:** IETF network management protocol that provides mechanisms to manipulate the configuration of a device. NETCONF executes YANG-based XML files containing configuration objects

**Packet Shelf (PS):** one of the two chassis that make up a Modular CCAP implementation. The Packet Shelf is responsible for the packet processing functions, such as subscriber management, service flow management, layer-3 routing and higher layer protocol manipulation, as well as Access Shelf command and control

**RF combiner:** headend equipment that accepts multiple input signals and delivers a single output that is equal in phase and amplitude

**service group:** set of channels for a given service (e.g. Video On Demand, High-Speed Internet) delivered via a number of fibre nodes to corresponding subscribers of that service to a single subscriber device

**YANG:** language used to model data for the NETCONF protocol. A YANG module defines a hierarchy of data which can be used for NETCONF-based operations, including configuration, state data, remote procedure calls (RPCs), and notifications

## 3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AES	Advanced Encryption Standard
ANCP	Access Node Control Protocol
AS	Access Shelf
ASM	Any-Source Multicast
AWGN	Additive White Gaussian Noise
BGP	Border Gateway Protocol
CA	Conditional Access
CATV	Cable Television
CBR	Constant Bit Rate
CCAP	Converged Cable Access Platform
CLI	Command-Line Interface
CM	Cable Modem
CMTS	Cable Modem Termination System
CPE	Customer Premises Equipment
CSA	Common Scrambling Algorithm
DES	Data Encryption Standard
DHCP	Dynamic Host Configuration Protocol
DLC	Downstream Line Card
DOCSIS	Data-Over-Cable Service Interface Specifications
DPIC	Downstream Physical Interface Card
DPoE	DOCSIS Provisioning of EPON (Ethernet Passive Optical Network)
DRFI	Downstream RF Interface
DSG	DOCSIS Set-top Gateway
DTI	DOCSIS Timing Interface
ECM	Encryption Control Message
ECMD	ECM Decoder
ECMG	ECM Generator
EoC	Ethernet over Coax
EPL	Ethernet Private Line

EPON	Ethernet Passive Optical Network
EQAM	Edge QAM
ERM	Edge Resource Manager
ERMI	Edge Resource Manager Interface
EVPL	Ethernet Virtual Private Line
EXP	Experimental
FFT	Fast Fourier Transform
Gbps	Gigabits per second
GigE	Gigabit Ethernet
GRE	Generic Routing Encapsulation
HFC	Hybrid Fibre/Coaxial
HSI	High-Speed Internet
I-CCAP	Integrated CCAP
ID	Identifier
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IPDR	IP Detail Record
ISIS	Intermediate System to Intermediate System
IS-IS	Intermediate System To Intermediate System Protocol
L2VPN	Layer 2 Virtual Private Network
LAN	Local Area Network
LDP	Label Distribution Protocol
LSP	Label-Switched Path
MAC	Media Access Control
M-CCAP	Modular CCAP
M-CMTS	Modular CMTS
MCX	Micro Coaxial
MEF	Metro Ethernet Forum
MHA	Modular Headend Architecture
MHz	Megahertz
MIB	Management Information Base
MPEG	Moving Picture Experts Group
MPLS	Multiprotocol Label Switching
MPTS	Multi-Program Transport Stream
MT	Multi Topology
MULPI	MAC and Upper Layer Protocols Interface
MVPN	Multicast Virtual Private Network
NA	Not Applicable
NNI	Network to Network Interface
NSI	Network-Side Interface
OAM	Operations Administration and Maintenance
OLT	Optical Line Termination
ONU	Optical Network Unit
OOB	Out Of Band
OSPF	Open Shortest Path First protocol
OSS	Operations Support System
OSSI	Operations Support System Interface
OTT	Over-the-Top
P2MP	Point-to-Multipoint
PASI	Packet to Access Shelf Interface
PC	Physical Contact
PCR	Program Clock Reference
PE	Provider Edge
PE-CE	Provider-Edge - Customer-Edge
PEG	Public, Education, and Government channels
PHY	Physical Layer
PIC	Physical Interface Card
PIM-DM	Protocol Independent Multicast - Dense Mode
PIM-SM	Protocol Independent Multicast - Sparse Mode
PON	Passive Optical Network
PS	Packet Shelf

PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RFC	Request for Comments
RFoG	Radio Frequency over Glass
RIP	Routing Information Protocol
RSVP	Resource Reservation Protocol
RSVP-TE	RSVP - Traffic Engineering
SC	Subscriber Connector
SCTE	Society of Cable Telecommunications Engineers
SDV	Switched Digital Video
SIP	Session Initiation Protocol
SNMP	Simple Network Management Protocol
SPTS	Single Program Transport Stream
SRM	Session Resource Manager
SSM	Source-Specific Multicast
STB	Set-Top Box
TDM	Time-Division Multiplexing
TEI	TDM Emulation Interface
TLS	Transparent LAN Service
TTL	Time-To-Live
UCH	Universal Cable Holder
UDP	User Datagram Protocol
UML	Unified Modelling Language
VBR	Variable Bit Rate
VLAN	Virtual LAN
VOD	Video On Demand
VoIP	Voice over IP
VPLS	Virtual Private LAN Service
VPN	Virtual Private Network
VSI	Video Stream Interface
XML	Extensible Markup Language

---

## 4 VOID

---

## 5 CCAP Architecture Goals, Benefits and Overview

### 5.1 Fundamental Goals of the CCAP

The Converged Cable Access Platform (CCAP) is intended to provide a new equipment architecture option for manufacturers to achieve the Edge QAM and CMTS densities that cable operators require in order to address the costs and environmental challenges resulting from the success of narrowcast services. The CCAP leverages existing technologies, including DOCSIS 3.0, Modular Headend Architecture, and current HFC architectures; and also can include newer ones, such as Ethernet optics and EPON (Ethernet Passive Optical Network).

The CCAP provides an alternative approach to the implementation of converged video and data services described in the Modular Headend Architecture (MHA) Technical Report (i.e. Modular CMTS with Universal Edge QAM). Similar to MHA, the CCAP provides sharing of QAM channels for different narrowcast services, but adds the capability of sharing broadcast QAM channels.

The key functional goals for CCAP include:

- Flexible use of QAM channels for the various services offered by cable operators, enabling modification to the number of QAMs using MPEG transport stream-based services (e.g. for VOD, SDV, etc.) versus DOCSIS-based services (e.g. HSI, voice, video over IP, etc.) over time through a single configuration point.
- Individually configurable assignment of QAM channels to various service groups, such that it would be possible to have HSI/voice service groups, VOD service groups, and/or SDV service groups overlap in different ways without requiring that these service groups be identical.
- Efficient implementation of separate sets of QAM channels for narrowcast and broadcast applications, such that QAM channels for narrowcast services can be individually implemented for each RF port, and QAM channels used for broadcast services can be shared among the RF ports in each downstream line card (DLC).
- Simplification of the RF combiner network by providing all QAM channels for all digital services from a single RF port, only leaving certain legacy functions for RF combining.
- Option to add content scrambling - both standardized and proprietary (e.g. PowerKEY™, DigiCipher®, etc.) - without requiring special-purpose hardware, such that a CCAP from any vendor can optionally implement the appropriate scrambling mechanisms without increasing the complexity of the platform.
- A transport-agnostic network architecture allowing implementation of EPON and other access network technologies natively within the CCAP. The CCAP will be expected to support additional access technologies and higher capacity uplink interfaces in the future with pluggable or otherwise replaceable components, allowing upgrade to a new access technology via installation or replacement of access modules.
- Modularization of the software environment, allowing upgrades to be applied to specific services without impacting other services. This partitioning also helps to ensure that software issues in the implementation of a given service do not necessarily impact other partitioned services.
- Significant operational improvements, including environmental efficiencies (e.g. reduced space, power consumption, and heat dissipation), implementation of functions such as upstream health monitoring, continuous wave carriers for plant amplifier biasing, and many other operational enhancements.

The CCAP can be implemented as a single integrated chassis or implemented in a "modular" fashion, consisting of more than one device. Despite the multiple chassis approach, a modular CCAP (M-CCAP) is seen and managed as a single network entity by the operations support system (OSS). Multiple different modular architectures are possible and permitted, provided they appear and are managed as a single network entity. However, for the purposes of the present document, an M-CCAP is defined as an architecture that is composed of two types of devices:

- A single Packet Shelf (PS) that contains the packet processing functions, such as subscriber management, service flow management, layer-3 routing and higher layer protocol manipulation.
- One or more Access Shelves (AS) that contains the upstream and downstream PHY functions normally associated with the CMTS and the Edge QAM, and nearly all of the DOCSIS MAC.

## 5.2 CCAP Benefits

Whether implemented in an integrated chassis or in a modular manner, the CCAP provides the following operational benefits.

### 5.2.1 Service Multiplexing Flexibilities

The CCAP provides efficient implementation of Edge QAM (EQAM) blocks by implementing separate sets of QAM channels for narrowcast and broadcast applications. QAM channels for narrowcast services are individually implemented for each RF port, while QAM channels used for broadcast services are shared among all the RF ports in each downstream line card (DLC). The number of narrowcast and broadcast QAMs supported on each RF port is flexible.

The CCAP provides the ability to map narrowcast and broadcast QAMs in different combinations to specific downstream ports via configuration. The same narrowcast video QAM can be mapped to multiple downstream ports, allowing for overlap of SDV and VOD service groups. This allows an operator to create service groups on a decoupled, service-by-service basis and effectively deal with service group inequalities.

The CCAP can configure any QAM in a given CCAP RF port for DOCSIS or Edge QAM applications. This allows all QAMs for a given service group to be generated from a single RF port. By allowing the configuration of any QAM on any RF port for broadcast, SDV, VOD, or DOCSIS, the CCAP provides the ability to transition to next generation video services (via DOCSIS or a new access technology) as necessary.

## 5.2.2 Bandwidth Capacity and Density Gains

The CCAP is designed to greatly increase the capacity of a single edge device, delivering all narrowcast and broadcast services via the downstream RF ports deployed (15-20 downstream ports on a small chassis; 40-60 on a larger chassis). The CCAP is expected to support multiple 10, 40, and/or 100 GigE interfaces with the ability to support a downstream capacity of over 150 Gbps. On a typical downstream line card in a large CCAP chassis, this traffic will be utilized by up to 12 downstream RF ports. QAM channels are flexible across service types. Each downstream port is capable of supporting up to 158 QAM channels. For example, a port could have 64 narrowcast QAMs and 96 broadcast QAMs. Each upstream port is capable of supporting a minimum of 4 DOCSIS RF upstream channels, with 6 channels being a recommended implementation. Support for higher data rates is possible with implementation of newer access technologies, such as EPON via DPoE. The ratio of downstream to upstream ports is variable, with an expected ratio of 2 upstream ports for every downstream port.

## 5.2.3 High Reliability and Redundancy Capabilities

Given the scope of each RF port providing all services for a given service group, it is important that the operation be highly reliable. Therefore, a CCAP is expected to support redundancy for critical components; however, even in a non-redundant configuration, the CCAP should provide sufficient up time. This, coupled with management of service group size, allows the size of failure groups to be reduced.

The CCAP is designed with a "wire once" approach: physical interface cards (PICs) implement the upstream and downstream physical interfaces, allowing replacement of line cards without impact to the cabling. N+1 redundancy allows line card replacement without impacting services for longer than the failover time and without the need to re-wire upstream and downstream connections. This reduces mean time to recovery for the CCAP.

The CCAP is designed such that software upgrades can be performed against a specific functional module, allowing an upgrade to a specific service that does not impact other services on the CCAP. Previous versions of the software images are available in local storage, allowing simplified regression to the last software image in the case of recovering from a failed software upgrade.

## 5.2.4 Configuration and Management Simplifications

The CCAP will allow configuration of both CMTS and EQAM functions from the same configuration interface. CCAP configuration will move away from SNMP-based configuration and focus instead on the processing of XML configuration files that hold the configuration details for all services on the CCAP. The CCAP utilizes a common object model, which standardizes the configuration objects across vendor implementations, and therefore simplifies the management of device configuration. Local storage and versioning of configuration files aids rapid recovery of services when a primary component has failed and been replaced by an offline component. The CCAP is also expected to support traditional command-line interface (CLI) methods of configuration, as well as next-generation configuration protocols such as NETCONF ([i.43]).

Management of CMTS and EQAM functions are also consolidated on the CCAP. The CCAP implements all MIBs required in CCAP OSSI [i.32], which includes appropriate CableLabs, SCTE and IETF MIBs.

## 5.2.5 Rack-Space and Power Reduction

One of the key benefits of the CCAP is to achieve significant environmental efficiencies. To that end, figures 5-1 and 5-2 demonstrate an example of the space and power savings achieved by deployment of the CCAP in a typical system.

Figure 5-1 depicts a typical installation in a headend consisting of the various digital services, including broadcast, SDV, VOD, and HSI equipment, plus the corresponding combiner and lasers/receivers.

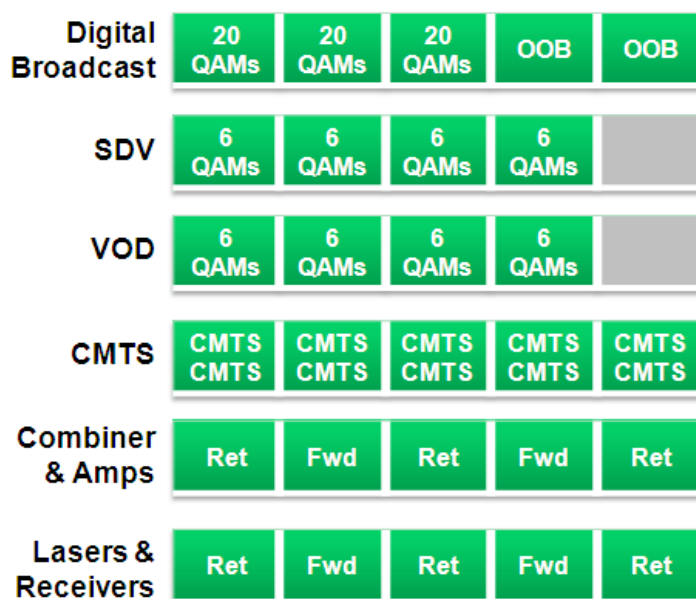


Figure 5-1: Typical Headend Space Usage

The example shown in figure 5-1 is intended to serve a typical population, combined in such a way as to result in 160 HSI service groups, and 120 VOD and matching SDV service groups.

Considering typical CMTS and Edge QAM equipment available today, this service group configuration would require about 10 CMTS chassis and about 4 racks for VOD and SDV, each containing 6 Edge QAM chassis configured for 64 QAM channels, each at a density of 4 QAM channels per RF port. The digital broadcast lineup is composed of 60 individual QAM channels, plus the corresponding out-of-band equipment.

Figure 5-2 depicts the analogous installation when considering the deployment of equivalent CCAP equipment in a medium-sized chassis.

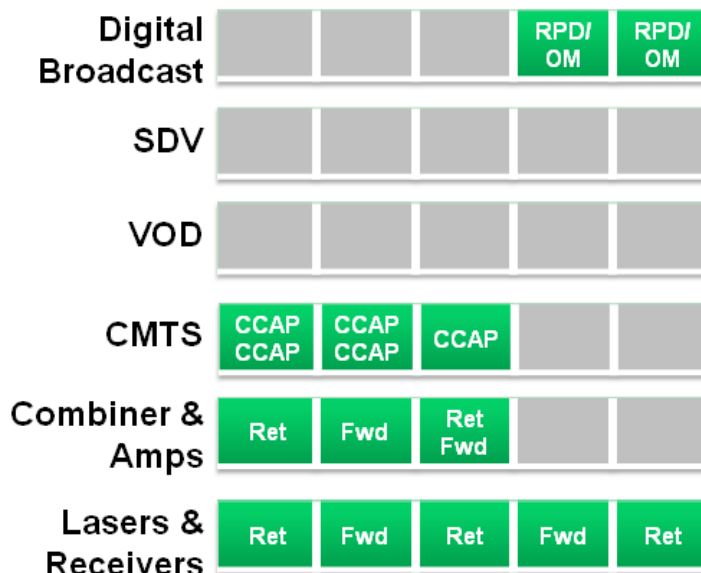


Figure 5-2: CCAP Deployment Space Usage

Figure 5-2 shows the following:

- Given that the CCAP chassis would have twice the density of a typical CMTS, only half the number of CCAP chassis are required (compared to CMTS chassis), resulting in equivalent space savings.

- Additionally, the CCAP chassis, in its basic implementation, includes all the necessary QAM channels for supporting the VOD and SDV services. Therefore, no additional equipment is needed to support these functions, resulting in significant additional space savings.
- Given that the CCAP also supports sufficient broadcast QAM channels, the space previously allocated to the broadcast equipment is no longer needed, further contributing to space savings.
- Finally, it is estimated that half of the space allocated to the combiner network would be saved, resulting in even further space savings.

With all this taken into account, as much as half of the space previously required is needed for deploying the CCAP. Moreover, given that the CCAP can serve twice as many narrowcast QAM channels as the previous architecture could, the depicted CCAP scenario actually results in even greater space savings, providing twice as much capacity in half the space.

In addition, a cursory analysis of the difference in power consumption, assuming typical power draw for existing equipment and the expected power consumption for the CCAP, yields an estimated power savings of greater than 50 %. And, this is taking into account the use of 32 QAM channels in the CCAP, or 2 times the capacity indicated in the original typical deployment.

With the decrease in equipment and power necessary to support this density of QAMs, the amount of heat generated by the equipment is also reduced, resulting in cooling savings in the headend.

## 5.2.6 RF Combining Simplifications

Deployment of the CCAP simplifies the RF combiner network by providing all QAM channels for all digital services from a single RF port, only leaving certain legacy functions for RF combining. Rather than having to rewire the physical plant to make service group changes, the QAM content of a downstream RF port can be changed via the CCAP configuration interface. Downstream of the CCAP, legacy out-of-band, analogue channels, and maintenance streams (balance, sweep) are the only things that need to be combined into the CCAP output.

## 5.2.7 IP Router Integration

A CCAP system will support IP routing and forwarding, including IP multicast proxies and forwarding, and IP service proxies from a CMTS, a DPoE System, and the hub router and switches that currently provide IP multicast functionality for video broadcast and SDV. As modular implementations are permitted, this functionality will not necessarily be supported in the device connected to the access network; however, the system as a whole will need to support this functionality in order to integrate into cable operator systems.

The CCAP operates as a single system for the purposes of IP forwarding; however, the QAM resources of the CCAP are also exposed to external VOD or SDV servers in order to allocate the QAM resource to MPTS video streams. As a result, the CCAP can operate as both a core when edge QAMs are controlled internally or, when implemented in a modular fashion, operate as an Edge QAM resource for the purposes of integration with VOD and SDV servers.

In the future MSOs will require MPEG-TS transport capability with a migration path to MPEG over IP (IP/UDP or IP/TCP). Such services will presumably be operated with IP over DOCSIS (and/or IP over EPON with DPoE). The CCAP will be required to support a wide range of IP applications during the expected lifetime of such a platform.

## 5.3 Supported Services in CCAP

This clause discusses the various services supported by the CCAP on an HFC system. Some of these services can also be supported by a CCAP for an EPON deployment.

### 5.3.1 Video EQAM Services

Video services supported by the CCAP include digital video services that are supported today by existing broadcast and narrowcast Edge QAMs (EQAMs). These services include digital video delivered as: 1) broadcast digital video; 2) switched digital video; and 3) video on demand. The CCAP is not intended to support modulation of analogue video. Analogue video signals are combined external to the CCAP with the output digital QAM signals of the CCAP prior to the input into the downstream fibre optic transmitter.



### 5.3.1.1 Broadcast Digital Video

Broadcast digital video services refer to the programming delivered in a channel lineup to subscribers in common, as opposed to just a particular subscriber or to a particular node. Sometimes, broadcast video services are referred to as linear broadcast services because of the time-linear nature of the broadcast, whereby the programming operates on a regular schedule that is not under the control of the viewers themselves (e.g. no native ability to pause, rewind, or fast-forward the program).

Broadcast digital video services are typically delivered to the hub site in "pre-packaged" multiplexes (a "broadcast lineup") that require minimal processing beyond local encryption, modulation, and upconversion.

The broadcast digital video services typically contain retransmission of over-the-air broadcast channels as well as programming supplied from various programmers delivered by satellite to a cable headend. Certain broadcast digital video services may also require local digital program insertion for advertisements targeted for particular ad zones, but the CCAP is not required to perform or support local ad insertion. Some broadcast lineups may require basic MPEG-2 "add/drop" type multiplexing to accommodate local public, education, and government (PEG) channels. For PEG channels, the CCAP is required to multiplex one or more SPTSs into an existing MPTS (Multi-Program Transport Stream) and perform MPEG table management (e.g. Program Association Table, Program Map Table).

Although digital music services delivered over a cable television (CATV) system are principally audio services, they are also included here as a broadcast digital video service, since the programming usually includes accompanying still pictures or video in the background along with descriptions of the musical track and artist.

### 5.3.1.2 Switched Digital Video

Switched digital video (SDV) is classified as a narrowcast video service, as opposed to a broadcast service. Although the SDV content is delivered in common to multiple subscribers, the target subscribers are only those of a particular SDV service group that corresponds to the SDV QAM channels delivered to one or more fibre nodes. SDV transmits channel programs to only those service groups where there is a subscriber viewing the channel. Bi-directional data transmission is a key element to the support of SDV since STBs that are SDV-capable will indicate that they are tuned to, or are tuning to, a particular channel.

With an SDV service, the system delivers to viewers programs that operate on a regular schedule and are not under the control of viewers. Thus, in that sense, SDV is a linear video service.

Broadcast video services and SDV services can coexist on the channel lineup transmitted on a given node. Programming considerations, analysis of viewership of particular programs, and available downstream frequency channels feed into decisions about which particular programs to include on downstream QAMs delivering SDV.

### 5.3.1.3 Video on Demand

A video on demand (VOD) service is defined as a video service delivered to a specific subscriber, generally in response to a real-time request for pre-packaged MPEG content. Thus, VOD is a narrowcast video service. VOD requires interaction between the subscriber STB and the program control system across a bi-directional CATV system. In addition, VOD typically means that the user has the ability to make a video selection and have control over its playback (e.g. pause, rewind, fast forward). In this sense, VOD is not a linear video service.

## 5.3.2 DOCSIS Services

Services enabled by the CCAP and other equipment supporting the interfaces specified in the various DOCSIS specifications include:

- High-speed Internet (HSI)
- IPCablecom voice over IP (VoIP)
- Transparent LAN Service (TLS) over DOCSIS L2VPN
- Next generation video services delivered via DOCSIS

These services are discussed in the following clauses.

### 5.3.2.1 High-Speed Internet

Interfaces for cable modems (CMs) and cable modem termination systems (CMTSs) have been defined in the DOCSIS specifications. Multiple generations of DOCSIS specifications exist in support of high-speed Internet services. The DOCSIS 1.0 specifications provide basic broadband Internet connectivity for one or more devices in the home. Among other things, they include the ability to rate-limit (cap) a particular customer's data rate to a cable operator selected value. The DOCSIS 1.1 specifications provide improved operational flexibility, security, and quality-of-service (QoS) features that support high-quality digital voice, interactive gaming, and commercial service level agreements (SLAs). The DOCSIS 2.0 specifications include increased upstream reliability and throughput for symmetric services. The DOCSIS 3.0 specifications provide a number of enhancements, most notably channel bonding, support for IPv6, and support for next generation video services. Channel bonding provides cable operators with a flexible way to significantly increase speeds to customers, with compliant devices supporting up to at least 160 Mbps in the downstream and at least 120 Mbps in the upstream.

The CCAP platform fully incorporates the functionality of DOCSIS 3.0 CMTSs - which includes backward compatibility for all previous DOCSIS generations - but with a much higher density.

### 5.3.2.2 IPCablecom VoIP

The VoIP service discussed in this clause refers to VoIP as provided by equipment supporting the interfaces specified in various IPCablecom specifications. In this context, IPCablecom VoIP provides a voice service that has voice quality, call features, and reliability that is expected from a primary line telephony service. Therefore, so-called over-the-top (OTT) VoIP services are not included in this category and can be considered as one of many applications that can be delivered under an HSI service. In addition to containing all the functionality of IPCablecom 1.0, IPCablecom 1.5 extends the IPCablecom residential voice capability with capabilities such as fax and modem support, analogue trunking for PBXs, and Session Initiation Protocol (SIP) for session management within and among IPCablecom networks.

At a very high level, the IPCablecom 1.5 architecture contains three networks: the DOCSIS HFC Access Network, the Managed IP Network, and the PSTN. The CMTS provides connectivity between the DOCSIS HFC Access Network and the Managed IP Network. Both the Signalling Gateway and the Media Gateway provide connectivity between the Managed IP Network and the PSTN. In the CCAP architecture, the CCAP performs the CMTS functions that are involved in support of IPCablecom functionality today.

### 5.3.2.3 Transparent LAN Service

The Transparent LAN Service (TLS) discussed in this clause refers to the functionality defined in the DOCSIS L2VPN specification [i.8]. TLS is also sometimes referred to as a "Metro Ethernet" or "Carrier Ethernet" service, such as that specified by the Metro Ethernet Forum (MEF). TLS allows businesses to extend their Layer 2 Ethernet networks (LANs) across the connectivity cloud of a core network that could be by itself an Ethernet, IP, or MPLS (Multiprotocol Label Switching) network.

The DOCSIS L2VPN specification [i.8] defines functionality required for the CM and CMTS to support TLS. It defines the CM interface providing TLS service on the subscriber side, and the CMTS interfaces on the core network connection side as well as the DOCSIS RF interface. The required functions reuse a lot of existing DOCSIS functionality and provide some necessary extensions. The DOCSIS L2VPN specification defines support for both point-to-point Ethernet connections (E-LINE type of service in MEF terminology) and multipoint-to-multipoint Ethernet connections (E-LAN type of service in MEF). It also provides support for non-multiplexed services (EPL - Ethernet Private Line) as well as services multiplexed on one CM port (EVPL - Ethernet Virtual Private Line). It has a robust support for QoS enforcement/guarantees and security/encryption for this type of business services.

In the CCAP architecture, the CCAP performs the CMTS functions as defined by the L2VPN specification. In particular, it performs necessary per-L2VPN flow packet encapsulation on the NSI, QoS enforcement, downstream encryption and other functions.

#### 5.3.2.4 Next Generation Video Services

The CCAP is expected to support the managed delivery of IP video for next generation video services.

Managed IP video delivery has certain characteristics that can make the handling of that traffic by the CCAP less resource intensive. For example, the traffic flows have the following fundamental characteristics:

- **Large Packets:** IP video traffic consists predominantly of large packets on the order of 1300 bytes to 1500 bytes. In order to sustain a given data rate, the CCAP needs to forward fewer packets per second than it otherwise would if the traffic flow consisted of small packets.
- **Long Sessions:** video sessions are generally long-lasting in comparison to internet sessions. Long duration sessions have the effect of minimizing session and flow setup and teardown overhead in the CCAP. Typical session duration is expected to be greater than 10 minutes.
- **Lower number of sessions:** video sessions are generally high bitrate sessions in comparison to internet sessions. High bitrate sessions require a lower number of sessions per QAM. The typical number of video sessions per QAM is expected to be lower than 40.

These characteristics of video traffic flows might allow a CCAP to be more cost-effectively sized with respect to the performance capabilities of a system than a system that is sized for full DOCSIS traffic of various sized packets on all data QAMs.

#### 5.3.3 DOCSIS Provisioning of EPON

The CCAP is expected to support EPON interfaces for high speed Internet. To facilitate the interoperability of EPON with the CCAP, the CCAP will support the entire DOCSIS Provisioning of EPON (DPoE) suite of specifications. The DPoE system includes DOCSIS Provisioning functions and IP routing (forwarding and service) functions that are common with DOCSIS (RF) functions.

Services deployed over RF or EPON will vary over time. While it may be appropriate, for example, to support a specific service on one platform at one time, a change in bandwidth demands or other service delivery requirements could easily justify the move of a service from one platform to another. The CCAP needs to be flexible enough to support both DOCSIS (RF) and EPON-based services. The CCAP will not just support a fixed allocation of services to RF or EPON interfaces, but will instead provide a platform that could be configured as 100 % DOCSIS (RF), 100 % EPON, or any mix of access technologies, where that mix is only limited by the access technology installed, the platforms capability to support EPON slots, and the overall throughput capacity supported.

High-speed Internet, IPCablecom, TLS, and the next generation video services described in clause 5.3.2 can all be delivered via EPON.

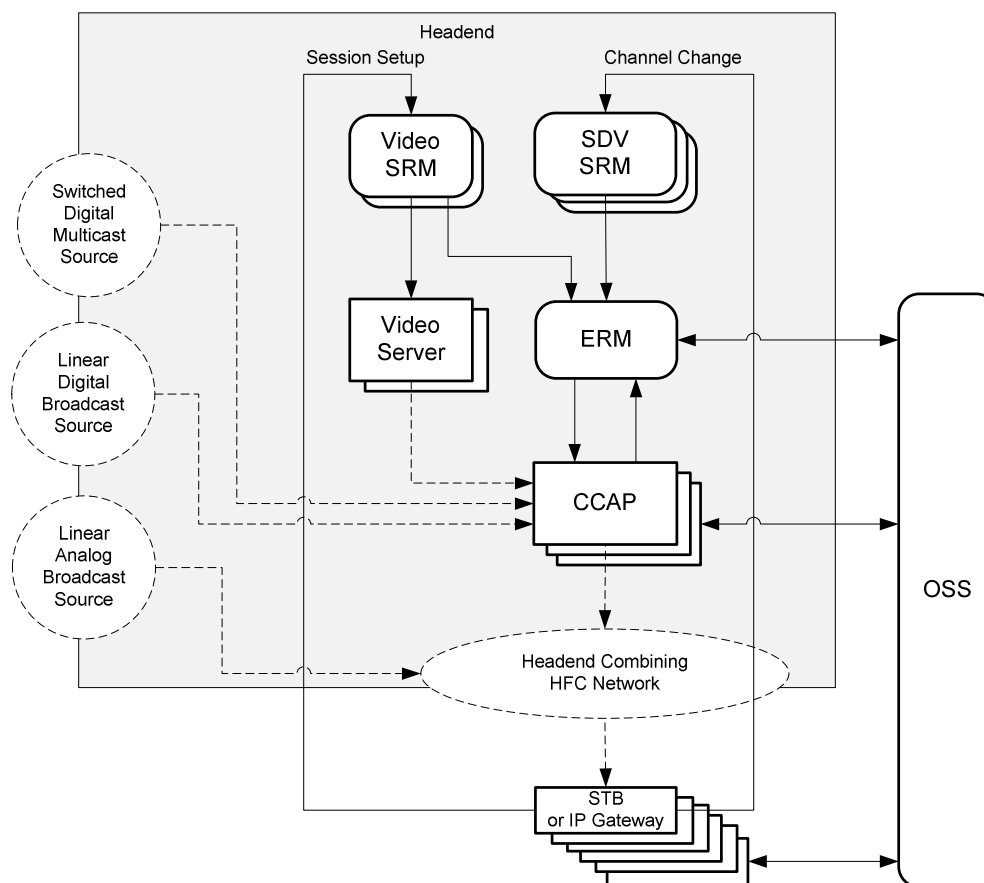
### 5.4 CCAP Architectures

#### 5.4.1 Integrated CCAP Architecture

Two reference architectures are provided in this clause: one showing the digital video delivery infrastructure, and the other showing the high-speed Internet infrastructure. The CCAP was designed to fully support both types of services simultaneously. A discussion of using the CCAP in an M-CMTS architecture is also discussed.

##### 5.4.1.1 CCAP MPEG Video Headend Reference Architecture

Cable headends acquire video from various sources to be provided to the subscriber via the access network. In figure 5-3, the dotted lines represent the video data while the remainder of the diagram represents control elements or flows within the MPEG video system.



**Figure 5-3: CCAP Video Headend Reference Architecture**

The CCAP has one or more ingress interfaces and multiple RF QAM outputs. The CCAP accepts input MPEG SPTSs or MPTSs transported via UDP/IP (multicast or unicast) over Ethernet, and multiplexes these input programs into an output MPTS that is then modulated and transmitted out one of the QAM RF outputs.

Digital video that is not broadcast continuously to service groups is controlled by the interaction of a service-specific client application on the STB, signalling to service-specific session resource managers (SRM) to request receipt of a video stream. When the STB client requests a stream, the SRM needs to acquire the necessary resources that allow the stream to be transported from source to destination. When the CCAP is first deployed, it is expected that VOD streams will be delivered as unicast, constant bit rate (CBR) SPTSs. The CCAP will be directed to route them to a particular QAM port and RF frequency, either via a UDP port mapping scheme, where the UDP port defines the RF port and frequency, or under the control of the Edge Resource Manager (ERM). In either case, the CCAP will be required to multiplex incoming SPTSs into MPTSs, and perform QAM modulation, up-conversion, and in some cases content scrambling. Variable bit rate (VBR) SPTSs may be supported in future releases.

Typical SDV architectures involve a centralized pre-processing of linear video streams into CBR SPTSs, a process known as "clamping". The SPTSs are then routed to a network encryption device that applies appropriate content security and multicasts the streams onto the network. An SDV SRM will have knowledge of the SPTS multicast groups that correspond to each service and will communicate this to the ERM. When a STB client sends a request to the network to view a particular service, the CCAP that is able to reach that STB client will be instructed by the ERM to join the multicast of that service and route it to a particular QAM. Therefore, the requirement on the CCAP is to respond to the ERM request and multiplex the encrypted SPTS into a transport stream with additional SPTSs and perform QAM modulation and upconversion.

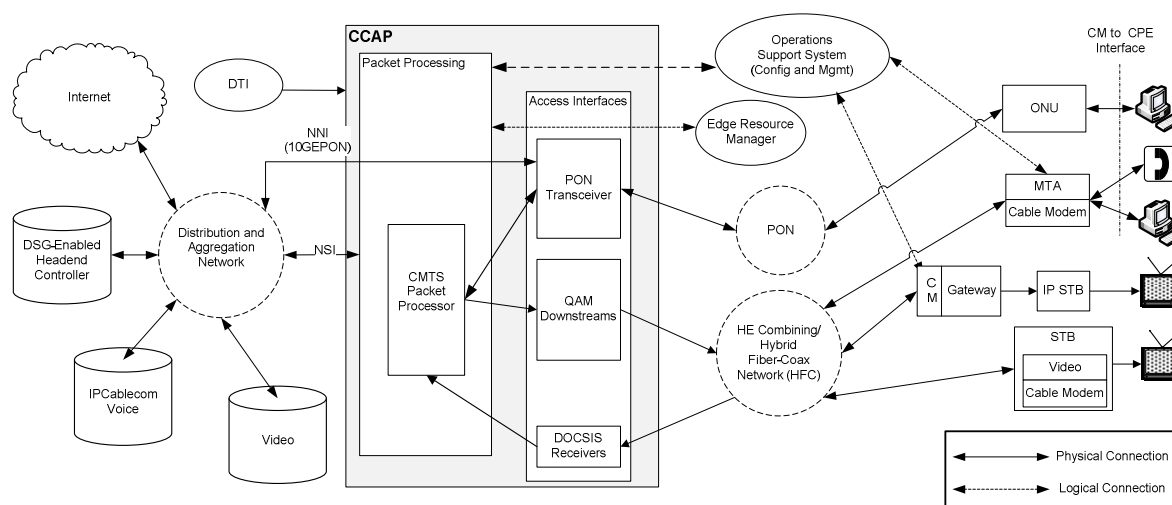
Linear digital broadcast video is routed to the CCAP in "pre-packaged" multiplexes (a "broadcast lineup") that require minimal processing beyond content scrambling, modulation, and upconversion. Each downstream line card on the CCAP will support at least a single broadcast lineup, sharing it among the service groups the line card serves. The CCAP can have multiple broadcast lineups per line card which are distributed across the service groups that the line card serves.

The ERM functional component is used to manage the use of transport bandwidth on the HFC network - the QAM channel and associated downstream frequency - out of the CCAP. The SRM uses the ERM to find a CCAP RF output having sufficient bandwidth and connectivity to the STB service group (serving area). In order to acquire the necessary RF/QAM bandwidth and CCAP resources needed to transport the stream to the service group, the SRM requests an ERM component function to allocate the bandwidth to the session manager. The ERM component provisions the CCAP to prepare it to receive the stream and direct it to the appropriate RF output using the allocated MPEG program number. The ERM can be either a controller interface outside of the CCAP or can be implemented internally to the CCAP.

The STB receives the QAM channel by tuning to the proper frequency, and can decode a single MPEG program from the MPTS. The STB is also responsible for providing the decoded A/V stream to the subscriber output device (i.e. monitor or TV) for presentation.

### 5.4.1.2 CCAP Data Reference Architecture

The CCAP performs all DOCSIS functions in the way that a traditional CMTS platform does. In addition, PON can be deployed on the CCAP to manage commercial HSI traffic. The following diagram, figure 5-4, illustrates how HSI streams flow through the CCAP and the network to DOCSIS and PON devices and back.



**Figure 5-4: CCAP Data Reference Architecture**

The CCAP receives Internet content, video, IPCablecom voice data, and DSG [i.2] data through the network side interface (NSI) from a distribution and aggregation network, via one or more physical interfaces. Individual NNI (Network to Network Interface) may be provided for HSI business services using a 10G EPON interface.

The CCAP has many of the functions of a traditional provider edge (PE) router. Since the CCAP supports multiple protocols, it also cannot be purely IP. In particular, the growth of Ethernet services (provided directly to customers) and use of Ethernet for managing logical IP networks (IP-VPNs), whether in-house or for customers, necessitates the usage of pseudo-wire transports over MPLS.

The CCAP performs all of the MAC-layer functionality and all the initialization and operational DOCSIS-related processes. The MAC-layer functionality includes all signalling functions, downstream bandwidth scheduling, and DOCSIS framing. The CCAP creates the DOCSIS QAMs for the service groups the CCAP serves, and these QAMs are modulated and output as either downstream QAMs on the downstream line cards in the CCAP, or QPSK on the downstream PON interfaces.

The CCAP will deliver data and voice per the DOCSIS 3.0 and IPCablecom 1.5 or IPCablecom Multimedia documents.

The ERM functions in a similar way to the MPEG video session setup: to acquire the necessary RF/QAM bandwidth and the CCAP resources to transport the stream to the service group.

The outputs of the CCAP are combined with legacy OOB data (and possibly legacy analogue video) in the headend combining network and are distributed through the HFC network or PON network, where they are received by the following devices:

- MTA/CM: Provides IPCablecom voice services and DOCSIS HSI for telephony and personal computing applications.

- ONU: Terminates the PON traffic for business services applications.
- Gateway: Receives video via MPEG Transport and/or IP protocol for distribution within the home.
- Set-top Boxes: native QAM video and command and control data (either through DOCSIS or legacy out-of-band).

Upstream DOCSIS HSI and IPCablecom voice traffic travel through the HFC or EPON and are received by either QAM upstream receivers or PON transceivers.

A DTI Server may be used to provide a common clock reference to synchronize to other TDM clock domains.

### 5.4.1.3 Modular Headend Architecture Functionality

To assist with the transition from traditional EQAM and CMTS devices to the converged implementation of the CCAP, a CCAP can also function as a universal edge QAM. This allows the CCAP to conform to the architecture defined in [i.40], allowing existing CMTS infrastructure to be leveraged while transitioning in CCAP devices. This approach will be essential during the transition from current CMTS/EQAM deployments to the deployment of the CCAP.

It is anticipated that devices implemented this way would be capable of operating in either in Universal EQAM or CCAP mode and changing mode could require a software change.

## 5.4.2 Modular CCAP Architecture

This clause presents two architectural views of the Modular CCAP (M-CCAP). The first is a functional architecture that describes the physical separation of the M-CCAP components and the responsibilities of each. The second presents an architectural view of the M-CCAP in the headend, showing the flow of data and video, as well as interaction with other headend devices.

### 5.4.2.1 Modular CCAP Functional Architecture

An M-CCAP is the result of the decomposition of an Integrated CCAP (I-CCAP), whereby packet processing is segregated logically and physically from the real-time critical, access-specific processing. The M-CCAP is implemented as two separate "shelves":

- A Packet Shelf
- An Access Shelf

The Packet Shelf is responsible for interfacing with Operational Support Systems on behalf of Access Shelves. Additionally the Packet Shelf is responsible for packet processing, service flows, and fine-grained quality of service. The Access Shelf insulates the Packet Shelf from access-specific technology such as HFC, EPON, or Wireless. In the case of HFC the DOCSIS MAC is contained in the Access Shelf. An HFC-based Access Shelf will also perform functions found in a Universal Edge QAM.

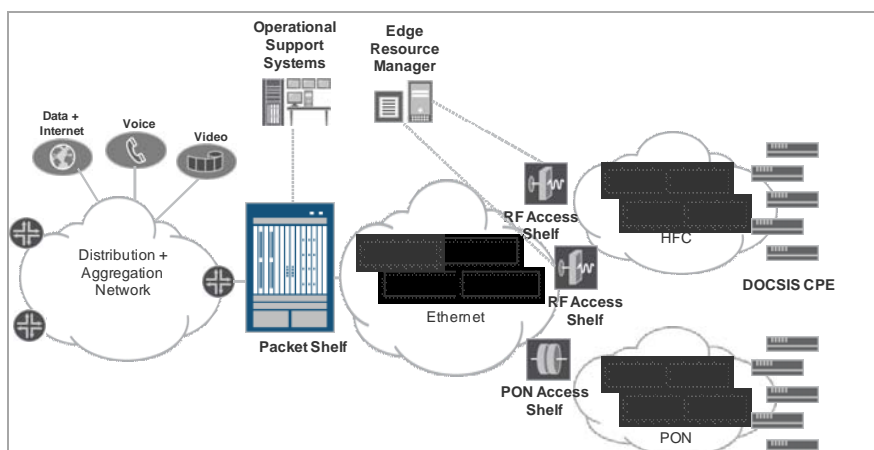


Figure 5-5: Modular Implementation

### 5.4.2.2 Packet Shelf Functionality

The Packet Shelf has common functions that are self-contained without regard to the type of Access Shelf connected to it. These common functions include, but are not limited to:

- Terminate the DOCSIS OSSI
- Provide an SNMP manager for querying the Packet Shelf and any subtended Access Shelves
- Provide a configuration interface for the Packet Shelf and any subtended Access Shelves
- Manage IP subscribers and CPE devices
- Support L2 and L3 VPNs, along with various IP-based and MPLS-based routing protocols
- Support L2VPN packet encapsulation and forwarding
- Provide common Packet to Access Shelf Interface (PASI) management, control and data planes
- IP/MPLS QoS, shaping and scheduling
- IPCablecom and IPCablecom Multimedia Support
- Cable broadband intercept and/or IPCablecom electronic surveillance functions
- Provide deep packet inspection functionality

### 5.4.2.3 Access Shelf Functionality

Since each Access Shelf type is access-specific, there is very little that is common across Access Shelves. Access Shelves can be access-technology-specific, only supporting one access medium such as HFC; or they can be hybrid, supporting more than a single access method, such as HFC and EPON. The following is a list of common functions found on every Access Shelf type:

- Terminating common PASI management, control and data planes
- Providing access to SNMP MIBs for attributes under the control of the Access Shelf
- Processing Access Shelf configuration objects in response to a configuration request from the Packet Shelf
- Generating Syslog messages/SNMP traps either through the Packet Shelf or to the operator's OSS

The other functions found on Access Shelves are access-specific. For example, an HFC Access Shelf will contain the DOCSIS MAC, MPEG processing, QAM processing, and DOCSIS upstream receiver functionality including QAM demodulation. In addition, the HFC Access Shelf will perform the following non-exhaustive list of functions:

- Cable modem ranging
- Modulation and demodulation
- DOCSIS timing
- Upstream bandwidth allocations and scheduling
- Framing and sequencing of downstream data
- Bonded channel scheduling

### 5.4.2.4 Modular CCAP Data/Video Architecture

The flow of data traffic and video traffic in the M-CCAP is very similar to the flow for the I-CCAP, the difference being the physical separation of the Packet Shelf and its subtended Access Shelves. Multicast and unicast streams enter the Packet Shelf via an NSI interface using the same protocols as are used in the integrated instance. These streams are then routed via a Route/Switch Engine within the Packet Shelf to the appropriate Access Shelf via the PASI Adapter Interface.

The Access Shelf receives these streams via its own PASI Adapter Interface, implemented as an NSI or NNI where they are processed and possibly replicated on the downstream line card (DLC) and directed to the appropriate downstream port (RF or EPON) for transmission across the access network.

The ERM and OSS interact with both the Packet Shelf and the Access Shelf, performing the same functions as they do for the integrated CCAP.

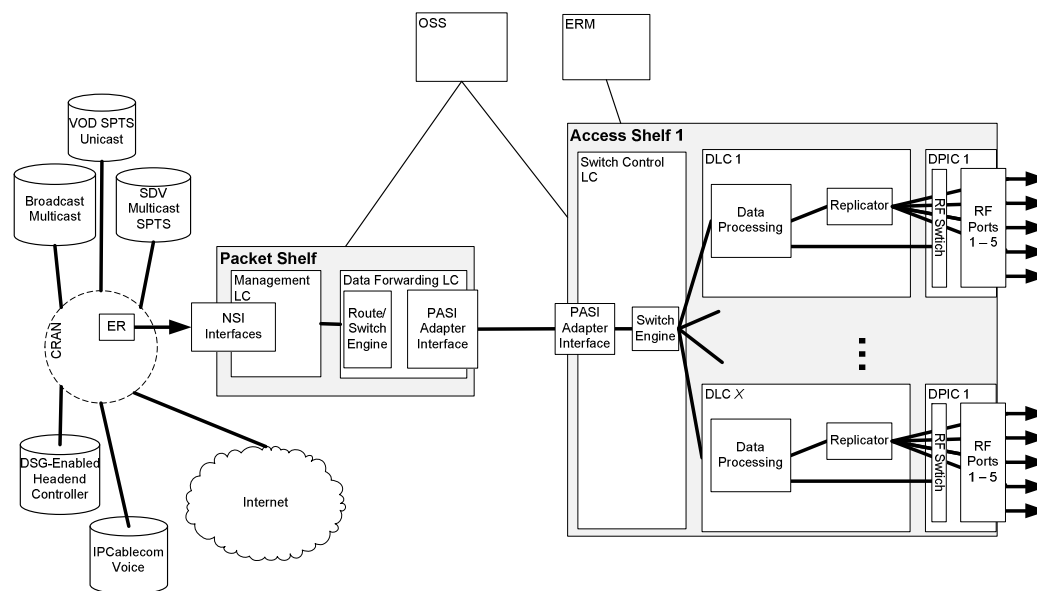


Figure 5-6: Video and Data Flow in the M-CCAP

#### 5.4.2.5 Downstream-Only Access Shelf

The AS can also be configured as a downstream-only edge QAM, in the architecture defined in [i.40]. This approach will be essential during the transition from current CMTS/EQAM deployments to the deployment of the CCAP.

## 6 Summary of DOCSIS Specifications and Applicability

### 6.1 DOCSIS 3.0 Specifications

The following clauses describe which DOCSIS 3.0 specifications are required for the CCAP, and the extent to which they apply.

#### 6.1.1 MAC and Upper Layer Protocols Interface Specification v3.0

The MAC and Upper Layer Protocols specification [i.9] defines the MAC layer protocols of DOCSIS 3.0 as well as the requirements for upper layer protocols (e.g. IP, DHCP, etc.). The CCAP is required to meet all CMTS requirements specified therein.

#### 6.1.2 Physical Layer Specification v3.0

The Physical Layer specification [i.11] defines the upstream physical layer requirements for hybrid fibre-coax systems that the CCAP needs to support. The CCAP is required to meet all of the requirements specified therein. In addition, the CCAP is also designed to be compatible with the European market. For a European CCAP, adherence to Annex B of [i.11] is required.



### 6.1.3 DOCSIS Security Specification v3.0

The Security Services specification [i.29] defines security services for DOCSIS communications, providing the operator with the ability to secure the provisioning process of cable modems (CM) and protect cable modem users by encrypting traffic flows between the CM and the cable modem termination system; in this case, the CCAP. The CCAP is required to meet all CMTS requirements specified therein.

## 6.2 CCAP Specifications

### 6.2.1 CCAP Operations Support System Interface

The CCAP OSSI [i.32] specification defines new configuration interfaces based on a standardized, converged object model, supporting both EQAM and CMTS functions. This specification introduces and standardizes YANG-based configuration and NETCONF as a protocol to support the configuration and management of the CCAP. This specification augments the configuration and management requirements specified in [i.10].

#### 6.2.1.1 SNMP Requirements and Reporting Requirements

The SNMP requirements of the CCAP are based upon the requirements specified in OSSI3.0 [i.10], but the CCAP does not implement all SNMP requirements specified therein. The CCAP is required to support SNMP v1 and v2, as well as at least 10 SNMP community strings with controlled access via access lists. The CCAP primarily diverges from OSSI3.0 [i.10] in its configuration methods. The CCAP is not required to implement SNMP as a configuration protocol; instead, the CCAP is configured through the processing of XML-based configuration files, the structure of which is defined in YANG instance modules.

The CCAP needs to support all standard event reporting mechanisms defined in clause 8 of the [i.10] specification. The CCAP is required to meet all IP Detail Record (IPDR) requirements specified in the [i.10] specification. The CCAP is also required to support all IPDR service definitions defined in the [i.10] specification.

#### 6.2.1.2 CCAP Object Model

The [i.32] specification implements object models for configuration, fault management, and performance management. These object models build upon models established in [i.10].

The specification supports the use of YANG, allowing access to these object models via NETCONF [i.31].

The CCAP implements a configuration object model based on existing DOCSIS 3.0 and DPoE configuration objects, extending them as needed to meet the advanced features of this platform.

All read-only MIB objects in the [i.10] specification are implemented for fault and performance monitoring, but the read-write and read-create MIB objects are not mandatory for the CCAP. The non-mandatory status of SNMP for configuration allows these write/create MIB objects to be excluded.

### 6.2.2 Packet Shelf to Access Shelf Interface Specification

A Modular CCAP (M-CCAP) supports the decomposition of an Integrated CCAP (I-CCAP), whereby packet processing is segregated logically and physically from the real-time critical, access-specific processing. The intention of this functional segregation is to independently leverage advances in routing and access technologies while also allowing for maximum flexibility and scalability in operator deployments of next generation access elements.

The Packet Shelf to Access Shelf Interface [i.41] specification defines the interface between the Packet Shelf and its sub-tending Access Shelves. The Packet to Access Shelf interface allows an M-CCAP to appear to be an I-CCAP platform from an operational and a functional perspective.

## 6.3 Modular Headend Architecture Specifications

### 6.3.1 Edge Resource Management Interface Specification

The Edge Resource Management Interface [i.5] specification defines interfaces that are used by EQAMs, ERMs, and M-CMTS Cores. While the CCAP does not require that all of [i.5] be supported, because the CCAP will interface with ERMs to dynamically control video and possibly DOCSIS QAMs, the following interfaces specified in [i.5] are required:

- Registration interface to the ERM (ERMI-1)
- Control interface to the ERM (ERMI-2)

In addition to these interfaces, the CCAP is also required to implement switched digital video (SDV) as defined in the [i.5] specification.

### 6.3.2 DOCSIS Timing Interface Specification

The DOCSIS Timing Interface [i.3] specification defines the timing interfaces required for the DOCSIS M-CMTS architecture. While the CCAP needs to support stratum 3 clock accuracies, it is not required to implement the timing interface as specified in the [i.3] specification, although [i.3] is an acceptable implementation. If a DOCSIS timing interface is not implemented, then the external timing interface is required to support a method to lock itself to the internal DOCSIS clock to ensure traceability of the clock to the TDM hierarchy.

### 6.3.3 Video Stream Interface Specification

The Video Stream Interface [i.4] specification defines the data plane requirements for receiving, processing, and transmitting MPEG transport streams in EQAMs. The CCAP implements all requirements in the [i.4] specification, with the following exceptions:

- Clause 9 - Encryption and Encryption Interface: The CCAP may be implemented with its own content protection mechanisms, described in further detail in clause 7.2, Optional Content Protection of the present document. In this case clause 9 is not required. The optional CCAP Scrambler is required to support payload input and payload output, as defined in [i.4].
- Clause 12 - Input and Output monitoring: The CCAP implements robust MPEG transport stream monitoring.

## 6.4 Downstream RF Interface Specification

The Downstream RF Interface specification [i.1] defines the downstream radio frequency interface for EQAMs and CMTS; as such, the requirements specified in [i.1] are required for the CCAP. While all DRFI [i.1] requirements need to be met by the CCAP, the CCAP does diverge from DRFI [i.1] in the following areas:

- Frequency accuracy: The CCAP requires a frequency accuracy of equal to or better than 5 ppm, 10 year aging over time and temperature.
- Port-to-port isolation: The CCAP requires a minimum port-to-port isolation of  $\geq 70$  dB from 50 MHz to 550 MHz and  $\geq 65$  dB from 550 MHz to 1 002 MHz.
- Frequency shift: The CCAP requires:
  - Carriers not sweep across bands.
  - Ports be muted when changing frequency.
  - Port output cannot be restored until the RF output is at the correct frequency and is stable.
- Output level adjustment: DRFI [i.1] contains general language regarding how the system should behave while changing output levels, which is required for the CCAP.

## 6.5 DOCSIS Set-Top Gateway Specification

The DOCSIS Set-Top Gateway specification [i.2] defines an interface and associated protocol that introduces additional requirements on a DOCSIS CMTS and DOCSIS CMs to support the configuration and transport of a class of service known as "Out-Of-Band (OOB) messaging" between a set-top controller (or application servers) and the customer premises equipment (CPE). The CCAP is required to meet all CMTS requirements in [i.2].

## 6.6 Business Services over DOCSIS Specifications

### 6.6.1 Layer 2 VPN Specification

The Layer 2 VPN specification [i.8] describes requirements for both CMTSs and CMs in order to implement a DOCSIS Layer-2 Virtual Private Network. The L2VPN feature allows cable operators to offer a Layer 2 Transparent LAN Service (TLS) to commercial enterprises. The CCAP is required to meet all CMTS L2VPN requirements and implement all relevant read-only L2VPN MIB objects. The CCAP is not required to implement L2VPN read-write and read-create MIB objects.

### 6.6.2 TDM Emulation Interface Specification

The TEI [i.30] specification defines a method for cable operators to deliver T1, E1 and NxDS0 emulation services that meet or exceed the quality requirement of applications that use such services. Implementation of TDM emulation is preferred for the CCAP, but no [i.30] specification requirements are mandatory.

## 6.7 DOCSIS Provisioning of EPON Specifications

A CCAP supporting EPON applications will be expected to implement the entire suite of DPoE specifications defined in the following clauses.

### 6.7.1 DOCSIS Provisioning of EPON Architecture Specification

The [i.33] specification describes the architecture required for DPoE Networks.

### 6.7.2 DOCSIS Provisioning of EPON MEF Specification

The [i.34] specification describes the provisioning and operations required to support Metro Ethernet Forum (MEF) Ethernet Services in DPoE Networks, which use EPON as defined in 802.3ah [i.46] and 802.3av [i.48].

### 6.7.3 DOCSIS Provisioning of EPON MAC and Upper Layer Protocols Specification

The [i.35] specification defines the MAC and upper layer protocols for DPoE Networks. The MAC in DPoE Networks is EPON.

### 6.7.4 DOCSIS Provisioning of EPON Operations Administration and Maintenance Specification

The [i.36] specification defines the interface used for conveying management information between a DPoE System and DPoE ONU.

### 6.7.5 DOCSIS Provisioning of EPON Operations Support System Interface Specification

The [i.37] specification identifies requirements for the adaptation or additions to DOCSIS specifications that are required to support DPoE Networks related to the Operations Support System functional area.

## 6.7.6 DOCSIS Provisioning of EPON Physical Layer Specification

The [i.38] specification identifies requirements for the EPON PHY for the adaptation or additions to DOCSIS specifications that are required to support DOCSIS Provisioning of EPON.

## 6.7.7 DOCSIS Provisioning of EPON Security Specification

The [i.39] specification identifies recommendations for the adaptation or additions to DOCSIS specifications that are required to support DOCSIS Provisioning of EPON (DPoE).

## 6.8 Summary of DOCSIS Specification Applicability

Table 6-1 summarizes the level of adherence the CCAP is required to have to DOCSIS specifications.

**Table 6-1: DOCSIS Specification Adherence**

Device	Specification												
	MULPI	PHY	SEC	CCAP OSSI	PASI	ERMI	DTI	VSI	DRFI	DSG	L2VPN	TEI	DPoE
I-CCAP	M	M	M	M	NA	P	O	P	M	M	M	O	M*
M-CCAP PS	M	NA	P	M	M	P	O	NA	NA	M	M	NA	NA
M-CCAP AS	M	M	P	M	M	NA	O	P	M	M	NA	O	M*
ERM	NA	NA	NA	NA	NA	M	NA	NA	NA	NA	NA	NA	NA

\* Required if EPON is implemented on the device  
M = Mandatory  
P = Partially Required  
O = Optional  
NA = Not Applicable

## 7 CCAP Features and Capabilities

### 7.1 Service Multiplexing Capabilities

#### 7.1.1 CCAP Service Groups

For the purposes of the CCAP, a service group is defined as a set of channels in a given service delivered via some number of fibre nodes to the corresponding subscribers of that service, provided by one or more CCAP ports. One of the concepts tied in with service groups is the reachability of certain signals from the CCAP to fibre nodes to the subscribers on those nodes, and likewise, the reachability of return path signals from fibre nodes to the CCAP. Thus, a service group is defined as a set of channels to or from a set of subscribers.

A downstream service group has traditionally been defined as a set of downstream channels carrying a particular service that reaches a specific set of optical nodes. The sizes of the service group for each service on the network, in terms of fibre nodes or actual subscribers, may be independent of each other. For the discussion below, it is assumed that the output of one port on the downstream line card (DLC) is associated to one fibre node. In addition, the number of channels provided for a particular service on each node differs for various service types available to subscribers.

The notion of a service group is important to understand some of the key functions of the CCAP. The following clauses provide an overview of the different types of service groups and how they relate to each other.

##### 7.1.1.1 Broadcast Service Groups

A broadcast service group consists of linear digital broadcast video channels corresponding to an advertising zone or a channel lineup with local or regional PEG channels. A broadcast service group typically spans more than one port on a DLC, possibly spans all ports on a DLC, and may even cross multiple DLCs.

### 7.1.1.2 Switched Digital Video Narrowcast Service Groups

An SDV service group consists of a number of downstream QAM carriers that are configured for video services for switched digital video applications. The SDV service group is a configured element of the CCAP and may span more than one RF port on a DLC.

### 7.1.1.3 VOD Narrowcast Service Groups

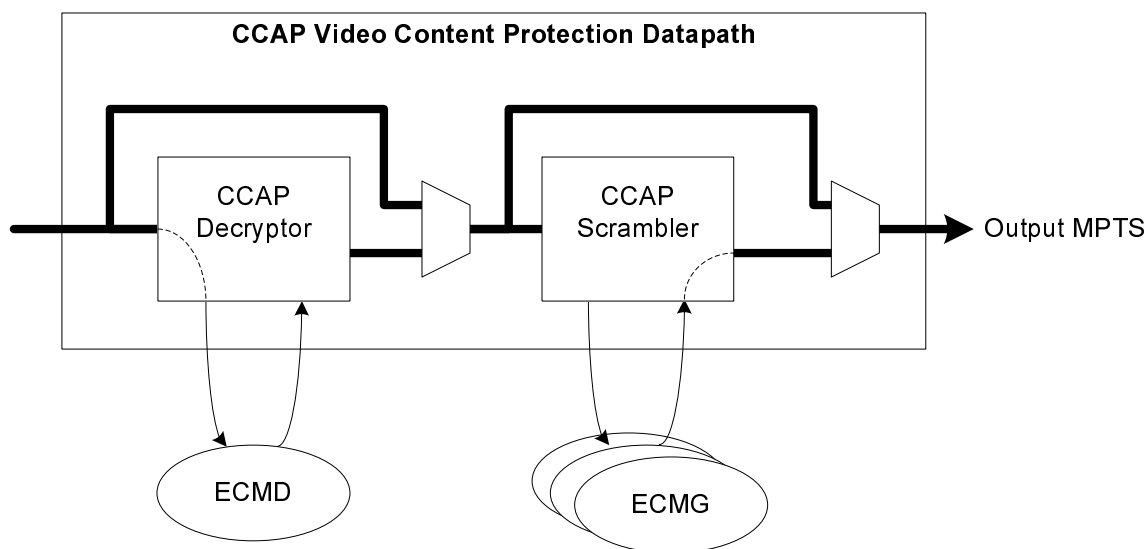
A VOD service group consists of a number of downstream QAM carriers that are configured for video services for video on demand. A VOD service group may be configured to be smaller than a DOCSIS service group, due to frequency re-use configurations and the number of QAMs needed for a specific serving area. The VOD service group may span more than one RF port on a DLC.

### 7.1.1.4 DOCSIS Narrowcast Service Groups

A DOCSIS downstream service group today is typically configured to be comprised of one to four optical nodes, depending on node size, service penetration, and data traffic load. There is some expectation (not necessarily a rule) that a DOCSIS service group would correspond to one port on a DLC.

## 7.2 Optional Content Protection

The CCAP provides an option to accept incoming transport streams that have had network encryption applied to keep them protected as they traverse the network of the cable operator, remove that network encryption, and then, based on the encryption mode specified for the content, apply the appropriate conditional access (CA) encryption for downstream transmission. The CCAP Decryptor and CCAP Scrambler are the two core optional functions of the CCAP, daisy-chained as shown in figure 7-1, to dynamically process a large portion of the input payload, according to the requirements of each content protection session.



**Figure 7-1: Optional CCAP Video Content Protection Overview**

The CCAP content protection data path is designed to support all of the decryption and content protection needs for the following existing and future video cable services:

- Video on demand
- Switched digital video
- Linear Digital Broadcast

The CCAP Decryptor and CCAP Scrambler functionally, when selected, reside on the downstream line card.

## 7.2.1 Network Decryption

The optional CCAP Decryptor component works in association with one external ECM decoder (ECMD) to remove the encryption layer used to secure the content distribution within the operator inner network. The control words and copy control information are retrieved from the incoming ECM to allow decrypting the associated payload, if required. The CCAP Decryptor supports 128-bit AES decryption.

## 7.2.2 Access Encryption

The CCAP Scrambler is a simple scrambling engine; the conditional access intelligence resides in the ECM Generator (ECMG). The CCAP Scrambler is under the control of one or more external ECMGs and applies the encryption layer required to secure the content distribution to the subscriber CPE devices, based on the ECMG-provided access criteria. In Simulcrypt operation, the Scrambler provides the same control word and access criteria to all ECMGs, which in return generate their matching ECMs. In non-Simulcrypt operation, the Scrambler receives both control words and ECMs from the selected ECMG, based on the provided access criteria.

The CCAP Scrambler supports both DigiCipher and PowerKEY conditional access systems, with support for the following encryption algorithms:

- DES (Data Encryption Standard)
- CSA (Common Scrambling Algorithm)
- 128-bit AES

## 7.3 QAM Replication

In order to simplify integration of the CCAP into existing systems, the CCAP is expected to implement a QAM replication feature. The purpose of this feature is to allow an operator to create logical service groups on a decoupled, service-by-service basis. This will provide the ability to replicate narrowcast video (SDV and VOD) QAMs across multiple ports on a given line card (not necessarily across all of the line cards in the chassis).

To effectively deal with service group inequalities, the CCAP will share a given set of SDV or VOD QAMs to other ports on the line card to form service groups with unique sets of HSI QAMs.

This is illustrated in figure 7-2; note that each DLC port has a unique HSI group of QAMs (not depicted).

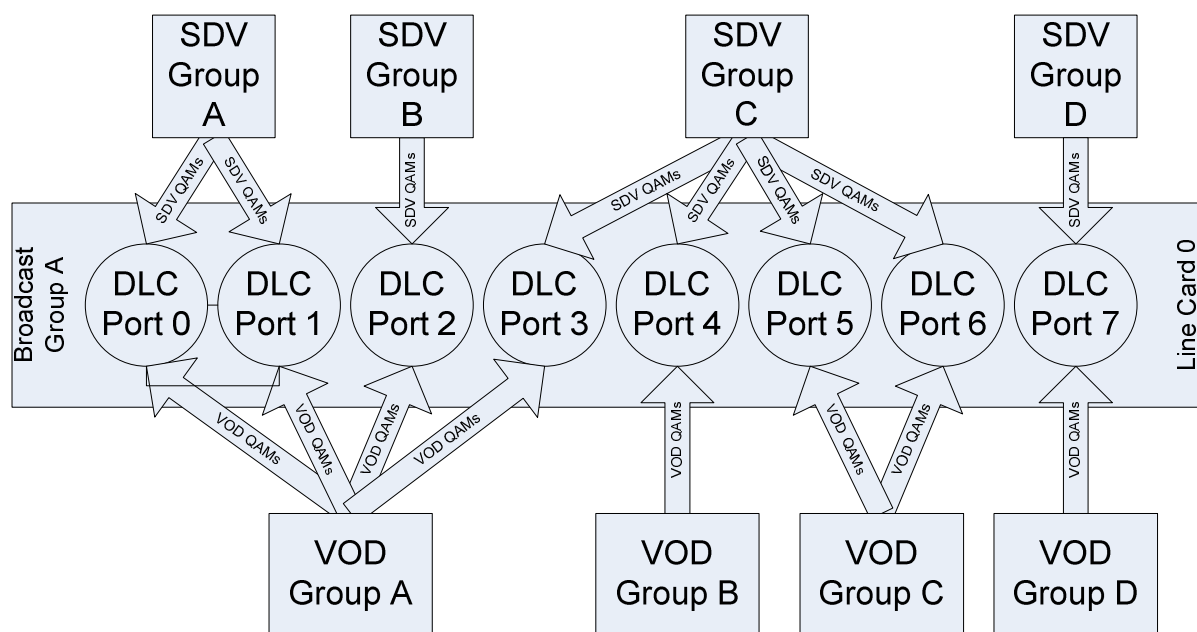


Figure 7-2: QAM Replication

NOTE: The SDV and VOD QAMs are not necessarily coupled, but can be combined in various SDV/VOD pairs. In this illustration, each service group has a unique set of HSI QAMs.

The CCAP will be capable of replicating the contents of all narrowcast QAMs configured for native MPEG transport stream video services (e.g. VOD or SDV), and those configured for DOCSIS services, to a minimum of 3 other QAMs operating at the same frequency on other ports on the same DLC. The replication can be done to any ports on the same DLC and to any ports on different DLCs.

## 7.4 Spectrum Surveillance

Due to the nature of the CCAP system and its targeted services, the CCAP is placed at a critical location within the cable operator's network. As the primary bridge between the back-office network and the HFC plant, the CCAP is responsible for transmitting and receiving all of the signals on the HFC plant for MPEG-TS SDV, MPEG-TS VOD, MPEG-TS Broadcast, DOCSIS High-Speed Internet, DOCSIS VoIP, and next generation video services. Many of these services require a fully-operational DOCSIS connection in the HFC return path for both data transport and for signalling/messaging transport.

To ensure the quality of the upstream, the CCAP is expected to be capable of monitoring the upstream return path to help identify:

- any return path RF issues that might negatively impact the performance of DOCSIS upstream channels, or
- proprietary signalling/messaging signals propagating in the upstream direction.

This upstream surveillance monitoring will provide the cable operator with up-to-date information on the RF quality of all of the upstream channels being used, and the entire upstream spectrum that is currently unused (in case the cable operator decides to utilize that spectrum for new upstream channels in the future). This upstream surveillance data will provide spectral information in the form of Fast Fourier Transform (FFT) outputs that could be used to quantify the magnitude of the Additive White Gaussian Noise (AWGN) on the upstream HFC plant, as well as the magnitude of ingress noise and impulse (burst) noise that might be present on the upstream HFC plant.

The CCAP will permit the cable operator to monitor the upstream spectrum without interrupting the transmission of DOCSIS data that is being simultaneously transmitted in the upstream direction. In addition, the CCAP will permit the cable operator to periodically schedule "quiet times" in the DOCSIS upstream channels to permit the RF noise to be successfully measured within the spectrum of each DOCSIS upstream channel. To ensure ease of use, the cable operator will be allowed to enable or disable this CCAP Spectrum Surveillance feature using simple configuration commands.

## 7.5 CCAP Configuration Management

The CCAP combines the functionality of an Edge QAM with a CMTS into a single platform designed to reduce operational costs and provide network flexibility. In order to provide operators the simplest path to deployment of CCAP with existing OSS systems, the goal for configuration and management of the CCAP is to treat the configuration of these very distinct platforms in a consolidated fashion.

This clause will provide an overview of the various aspects of configuring a CCAP chassis including background on the choice of object modelling language chosen and a discussion of the various object models and their constructs.

### 7.5.1 YANG Data Modelling Language and XML Background

The configuration of a CCAP chassis can be accomplished using a variety of methods such as via a command-line interface, through file-based processing, or methods such as NETCONF or Web services. Underlying these configuration methods is a common configuration object model which defines the parameters that are to be configured. For the purposes of the CCAP, the configuration object modelling language is UML and the configuration data modelling language used is YANG.

YANG is a data modelling language for the NETCONF network configuration protocol that has been developed within the IETF to allow for modelling of configuration data, network element state and network events (see [i.31]). For purposes of the integrated CCAP, only the configuration data modelling portion of YANG is utilized. The option of using NETCONF to configure the CCAP is a new feature of the CCAP. The Modular CCAP Packet Shelf will use NETCONF protocol for configuring its subtended Access Shelves.

A CCAP configuration XML schema - derived from the CCAP configuration YANG data model is the basis for the creation of the XML file which will be used to configure the CCAP. The CCAP will parse the entire XML configuration file and process the configuration objects that are present in the file. Internal processing of configuration objects specified in the CCAP configuration file is vendor-specific.

## 7.5.2 Configuration Object Model

A CCAP Configuration Object Model has been developed in UML to define the elements (objects) and their parameters (attributes) that will need to be represented in the YANG configuration data model and eventually, the configuration XML schema. The object model also defines the associations between objects.

One example of a CCAP object is the Downstream RF Port. The Downstream RF Port has its own attributes such as number (1...N where N is the number of ports on a line card), Administrative State (the status of the port), RF Mute and Channel Power. The Downstream RF Port is also defined to be associated with a particular Downstream Line Card object and a set of Downstream Channel objects; these associations define the location of the Downstream RF Port in the chassis and the particulars of the QAM channels that will be carried on the Downstream RF Port.

## 7.5.3 Configuration Data Model

The CCAP YANG configuration data model is created from a direct translation of the CCAP configuration UML object model into a set of YANG modules. The YANG data model is constructed in a tree format using modules and sub-modules. The CCAP YANG modules can be used by a YANG translation tool to generate the XML schema used for the XML configuration file. Alternatively, the CCAP can validate the XML configuration file directly against the set of YANG modules via NETCONF or other methods.

## 7.5.4 CCAP Configuration File Processing

The CCAP is configured via the execution of an XML configuration file that is transferred to the file system on the I-CCAP (or on the Packet Shelf in the M-CCAP). The CCAP parses the entire XML configuration file and processes the configuration objects represented in the file as a sequence of individual element operations. Individual element operations can succeed or fail; the CCAP will log unsuccessful operations.

Before a configuration file is applied to the CCAP, the CCAP performs several checks against the file, such as verifying that the configuration file is well-formed XML and that it validates against its schema. If the configuration file does not pass these checks, the CCAP will reject the file. The CCAP can also reject individual objects within the configuration file. In all rejection cases, the CCAP will log the rejection as an error.

The CCAP supports partial configuration, allowing the CCAP to not process objects that it either does not understand or that have invalid parameters, while continuing to process the objects that have no issues.

## 7.5.5 CCAP NETCONF-Based Configuration

The CCAP may also be configured via NETCONF as specified in [1.43]. The CCAP uses standard NETCONF edit-config commands to execute XML-based configuration parameters. The XML configuration data can contain explicit "merge", "replace", or "delete" operation values at various nodes within the configuration tree provided. In this manner, a NETCONF command may contain merge operations for one branch of the tree, replace operations for another portion, and delete operations for yet another branch. The CCAP supports partial configuration, allowing the CCAP to not process objects that it either does not understand or that have invalid parameters, while continuing to process the objects that have no issues.

## 7.6 PON Configuration: DOCSIS Provisioning of EPON

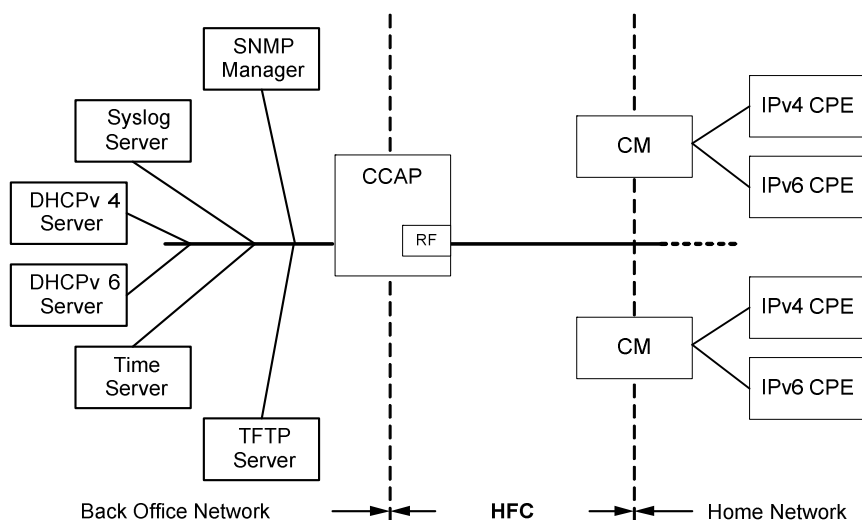
Cable operators have recognized the value of including alternative access technologies into their network topology. This has included exploration and deployment of various wireless and passive optical solutions. The common characteristic for all of these alternative access technologies is that they have uncommon OSS models. Specifically, they do not look nor feel like a DOCSIS-oriented system to the operator that is responsible for deploying and managing services provided by this new technology. As such, there is value in mediating the interaction between these new access technologies and existing back-office tools, processes, and operator expectations.



DOCSIS Provisioning of EPON (DPoE) specifications provide a service overlay of the DOCSIS and CMTS management framework on an IEEE 802.3ah [i.46]/av [i.48] EPON network. DPoE systems rely on the EPON MAC and PHY and the upper-layer DOCSIS protocols. The DOCSIS MAC and PHY do not apply.

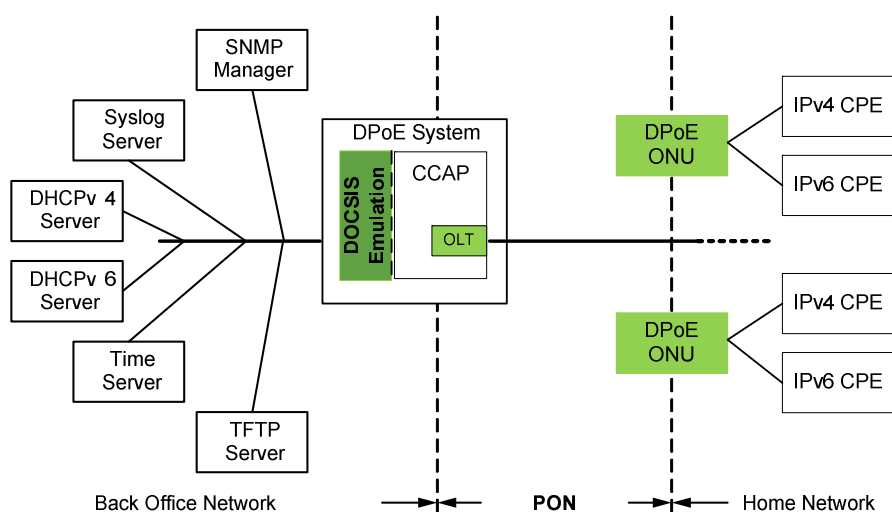
### 7.6.1 The DOCSIS and DPoE Networks

The following diagram summarizes the primary systems and elements involved in a typical HFC-based DOCSIS network. For brevity, only a sample of the back-office systems used to provision, manage, authorize, and control the network are included.



**Figure 7-3: DOCSIS 3.0 HFC Network Using CCAP**

The DPoE specifications define a system that is analogous to a CMTS. The DPoE System need not be a single device, but instead could be a collection of devices that includes an Optical Line Termination (OLT), router, and DOCSIS emulation system. Collectively, these separate devices would be referred to as the DPoE System. The DPoE System provides the logical interfaces and protocol translations necessary to integrate EPON devices into the DOCSIS OSSI framework. This permits operators to take advantage of standard EPON functionality while retaining their investment in back office operations and systems, leaving CPE unchanged.



**Figure 7-4: DPoE Network using CCAP**

## 7.6.2 DPoE Provisioning and Management

Interfaces and systems for managing DPoE devices may be provided through a DOCSIS Emulation module either running on the CCAP itself or running on an external server. Requirements for these interfaces are specified by the [i.37] specification to provide Provisioning and Management support for the network. As shown in figure 7-5, requirements for the CMTS and CM MIBs are provided via the DPoE system by proxying for the OLT components on the CCAP line cards and the remote ONU devices.

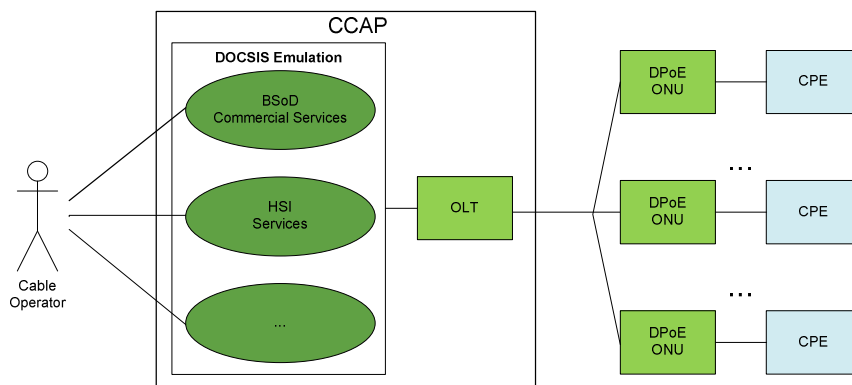


Figure 7-5: Operator Interfaces to EPON Access Network

## 7.6.3 Provisioning and Management of OLT Devices

As CCAP is providing the functionality of the DPoE System, the OLT and associated PON interfaces are managed in a similar fashion to DOCSIS RF interfaces. Logical DOCSIS constructs, such as MAC domains, are implemented on top of the physical EPON interfaces. Relevant CMTS MIBs and DOCSIS CLI operations are mapped to their EPON equivalents to maintain the look-and-feel and, more importantly, the functionality expected of a DOCSIS RF interface.

## 7.7 Protocol Support

This clause provides an overview of protocol support by the CCAP with respect to IP version, virtual private networks, routing, and multicast.

### 7.7.1 IP Versions

The CCAP supports IPv4 and IPv6 for both unicast and multicast traffic. The CCAP has the ability to forward traffic to both IPv4 and IPv6 devices.

### 7.7.2 VPN

The system will need to support VPN in order to support low cost layer 2 only VPN services provided over DOCSIS and expand offerings to high-touch managed L3 VPNs. The CCAP is expected to support the following VPN-related RFCs:

- VPLS using BGP for auto-discovery and signalling, as specified in [i.23]
- BGP/MPLS IP VPNs, as specified in [i.17]
- The framework for L2VPNs, as specified in [i.21]
- LDP (Label Distribution Protocol), as specified in [i.25]

- Extensions to RSVP for LSP tunnels, as specified in [i.14]
- Exclude routes extension to RSVP, as specified in [i.24]
- Node behaviour upon originating and receiving RSVP path error messages, as specified in [i.28]

### 7.7.2.1 MPLS

The system is expected to support MPLS label switching services in order to integrate into existing and planned commercial services platforms. Major applications of MPLS are telecommunications traffic engineering and MPLS VPN. In the context of MPLS VPNs, the CCAP is expected to support the following MPLS RFCs:

- Encapsulation MPLS in IP or Generic Routing Encapsulation (GRE), as specified in [i.16]
- Encapsulation methods for transport of Ethernet over MPLS networks, as specified in [i.19]
- Encoding of attributes for MPLS LSP establishment, as specified in [i.18]

### 7.7.2.2 Multicast VPN (MVPN)

Multicast Virtual Private Network (MVPN) is a technology to deploy multicast service in an existing VPN or as part of a transport infrastructure. Multicast data is transmitted between private networks over a VPN infrastructure by encapsulating the original multicast packets.

The CCAP is expected to support the following MVPN-related functionality:

- Intra-AS Multicast VPN (MVPN) membership discovery via BGP MCAST-VPN address family
- BGP C-multicast route exchange when the provider-edge - customer-edge (PE-CE) protocol is PIM-SM (SSM), PIM-SM (ASM), PIM-DM or IGMP
- IP/GRE based inclusive Provider tunnels (P-tunnels) signalled by PIM-SM (ASM)
- IP/GRE-based inclusive P-tunnels signalled by PIM-SM (SSM)
- MPLS inclusive P-tunnels signalled by RSVP-TE P2MP LSPs
- MPLS selective P-tunnels signalled by RSVP-TE P2MP LSPs

### 7.7.3 Routing

The CCAP is expected to support the following routing protocols:

- RIPv2 on the access side as specified in [i.13]
- IS-IS, as specified in [i.26]
- Multi-Topology support for IS-IS, as specified in [i.45]
- OSPFv2 as specified in [i.12] and [i.27]
- BGPv4, as specified in [i.22]
- Multiprotocol Extensions for BGP-4, as specified in [i.44]

### 7.7.4 Multicast

The CCAP is expected to support Protocol Independent Multicast-Sparse Mode (PIM-SM) with SSM extensions, as specified in [i.20]. In addition, the CCAP has the ability to join multiple IP multicast groups with PIM-SM.

For IPv4 on the access interfaces (DOCSIS, PON, etc.), the CCAP supports Internet Group Management Protocol version 3 (IGMPv3) with SSM extensions [i.15] and also IGMPv2. For IPv6 on the access interfaces, the CCAP supports Multicast Listener Discovery version 2 protocol as specified in [i.42]. When the CCAP receives a multicast join request on an access interface for a specific multicast source and group, the CCAP uses the PIM-SM protocol to join that multicast flow, if needed. The CCAP can allow support of IGMPv2, IGMPv3, and MLDv2 joins from the same access interface.

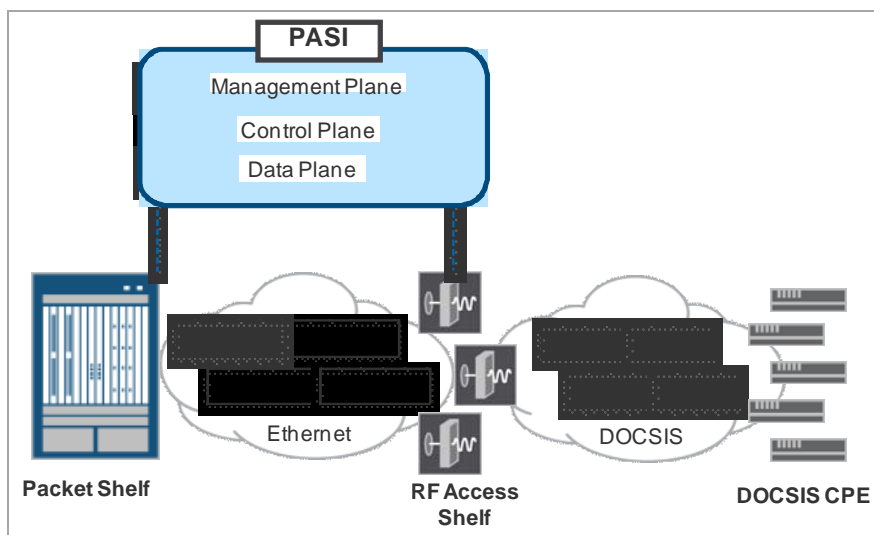
The CCAP is expected to support joining at least 4096 multicast groups.

### 7.7.5 Modular CCAP: Packet to Access Shelf Interface (PASI) Protocols

In a Modular CCAP, the Packet Shelf and the Access Shelf interact through the Packet to Access Shelf Interface (PASI), specified in [i.41]. PASI has three different planes, as shown in figure 7-6:

- Management plane conveying management information between the shelves
- Control plane signalling for information between the shelves
- Data plane encapsulation method to transport packets between shelves

Each plane has a specific purpose and uses a particular protocol(s). Protocols were chosen to re-use industry standard protocols and to avoid creating any new protocols that would be PASI-specific and would need to be standardized.



**Figure 7-6: PASI Planes**

These planes and their protocols are discussed in the following clauses.

#### 7.7.5.1 PASI Management Plane

Currently, the PASI Management plane is defined to use the NETCONF protocol for management requests. When SNMP queries are sent to Packet Shelf for particular attributes that are found on its subtended Access Shelves, the Packet Shelf will use NETCONF to forward the query to the appropriate Access Shelves. Each Access Shelf will send the results of these queries back to the Packet Shelf via NETCONF; the Packet Shelf is responsible for aggregating the results of the queries on behalf of all of its subtended Access Shelves. The Packet Shelf will then respond to the SNMP request from the operational support system with all of this information.

In the case of configuration requests, the Packet Shelf will take configuration requests that are specific to an Access Shelf and proxy them to the Access Shelf via the NETCONF protocol. The Access Shelf will respond to Packet Shelf via NETCONF, and then the Packet Shelf will respond back to the requesting operational support system.

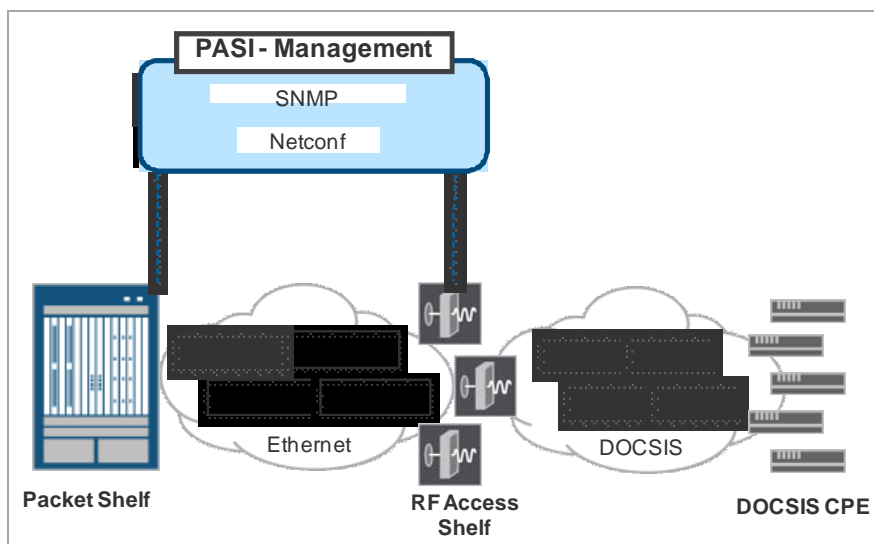


Figure 7-7: PASI Management Plane

### 7.7.5.2 PASI Control Plane

The PASI Control Plane uses the Access Node Control Protocol (ANCP) protocol. This protocol is a real time protocol used to communicate information between the PS and the AS. For example, when a modem ranges, the PS needs to be notified of this event. The AS will notify the PS via ANCP by encoding its information in Type Length Value attributes (TLVs). The AS will also communicate changes in RF plant performance and bonding configuration via ANCP in order to adjust the scheduling and QOS capabilities on the PS.

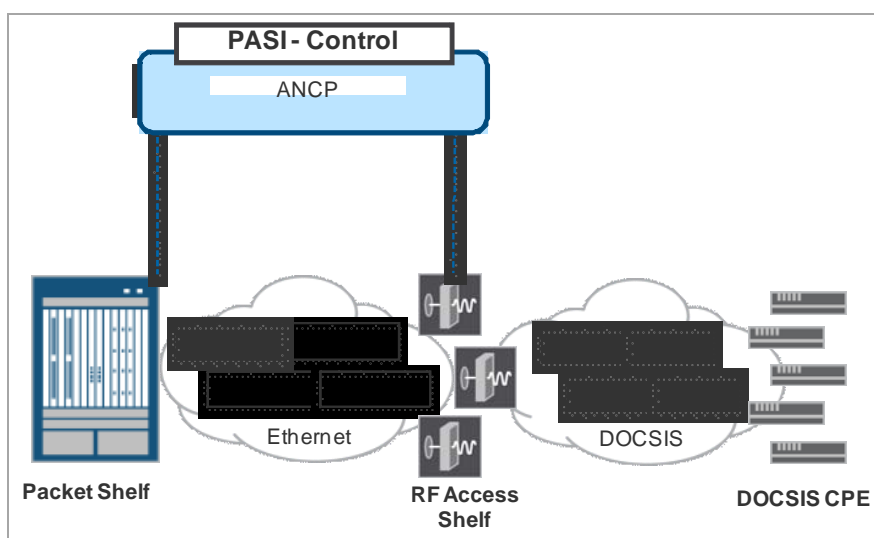


Figure 7-8: PASI Control Plane

### 7.7.5.3 PASI Data Plane

The PASI Data Plane protocols used for fast-path communication between PS and AS can be broken down into two separate types.

First is for packet steering to allow packets to be directed from the PS to the AS and back. The M-CCAP will use a basic Ethernet Frame with an IEEE 802.1Q [i.47] VLAN tag. This is used when the PS and AS are not directly connected and there are intermediate network nodes that need to forward the packet to the appropriate AS or PS. This selection was made to take advantage of Metro Ethernet deployments and the ubiquity of Ethernet in networks today.

The second aspect of the PASI Data Plane is encoding of Service Flow ID into a packet that will reuse the MPLS standard. The M-CCAP will not modify how the EXP, S bit, or TTL fields of the MPLS packet are used for PASI; these fields will continue to be used in a standard way. With PASI, the PS will add a two-label MPLS header to the packets along with Ethernet header with VLAN and the AS will remove both (the two MPLS labels and Ethernet header with VLAN) before forwarding it into the HFC/DOCSIS network. The AS, when transmitting upstream traffic toward the PS, adds the two MPLS labels and Ethernet header with VLAN. The PS will remove these before transmitting it upstream toward IP/MPLS aggregation network.

This particular solution was selected as to leverage existing forwarding capability on Edge routers and enable Access Shelves to take advantage of available industry silicon.

---

## 8 CCAP Implementations

The following clauses describe implementations that support current headend use cases. It is expected that the CCAP could evolve to support extended frequency ranges and other access network technologies, such as EoC, RFoG, and PON over Coax.

### 8.1 CCAP Interface Options

#### 8.1.1 Hybrid-Fibre Coax Interfaces

The CCAP is expected to implement upstream and downstream RF interfaces on separate downstream and upstream physical interface cards (PICs). This separation of PICs allows upstream and downstream capacity to be changed independently. The CCAP could be implemented with a combined PIC, a card that has both upstream and downstream interfaces although this is not expected to be a typical configuration.

##### 8.1.1.1 Downstream RF Interfaces

The CCAP is expected to support a downstream RF interface ratio of one downstream RF port per downstream service group. A large Integrated CCAP is expected to support a minimum of 40 to 60 downstream ports, and a small Integrated CCAP is expected to support a minimum of 16 to 20 downstream ports. Downstream physical interface cards (DPICs) are expected to support a minimum of 8 downstream RF ports per card.

Each downstream RF port supports the following edge-to-edge frequency ranges for North American devices:

- 54 MHz - 1002 MHz; or
- 108 MHz - 1002 MHz.

The North American channel width is specified as 6 MHz.

For European devices, each downstream RF port supports an edge-to-edge frequency range of 86 MHz - 1006 MHz, with a channel width of 8 MHz.

In addition, a single downstream RF port is expected to be capable of supporting up to 158 QAMs of any type. Each port will typically support 32 to 64 narrowcast QAMs and up to 96 broadcast QAMs.

The preferred implementation of a downstream RF interface is in the form of an F-connector, but ganged 75 Ohm MCX (Micro-Coaxial) interfaces in a universal cable holder (UCH) could also be implemented. All RF interfaces are expected to be located at the rear of the chassis.

##### 8.1.1.2 Upstream RF Interfaces

The CCAP is expected to support an upstream RF interface ratio of one upstream RF port per upstream service group. A large CCAP is expected to support at least 80 to 120 upstream ports (with 120 being the preferred minimum), and a small chassis is expected to support 32 to 40 upstream ports. Upstream physical interface cards (UPICs) are expected to support at least 16 upstream RF ports.

Each upstream RF port supports the following edge-to-edge frequency ranges for North American devices:

- 5 MHz - 42 MHz; or
- 5 MHz - 85 MHz.

For European devices, each upstream RF port supports an edge-to-edge frequency range of 5 MHz - 65 MHz, as specified in Annex B of [i.11].

Both European and North American devices support channel widths of 1,6 MHz, 3,2 MHz and 6,4 MHz. They are also expected to support between 4 to 6 DOCSIS RF upstream channels per RF port.

The preferred implementation of an upstream RF interface is in the form of ganged 75 Ohm MCX interfaces in a UCH, but an F-connector can also be implemented. All RF interfaces are expected to be located at the rear of the chassis.

## 8.1.2 Ethernet Passive Optical Network (EPON) Interfaces

Fibre access represents one method of offering higher bandwidth to subscribers. Increasing bandwidth may be required to meet the increasing data demands of business customers. EPON minimizes investment in the access infrastructure while delivering more bandwidth and greater service flexibility. It is the least costly method of constructing fibre to the subscriber and it has the service control and flexibility to offer any business or consumer service.

### 8.1.2.1 Split Ratios and Customers Served

The EPON split ratio for CCAP is expected to be 128:1. Each I-CCAP chassis is expected to support at least 16 active EPON interfaces, and 24 or more is preferable. Two RF service groups should be served by each EPON interface. This suggests a density of approximately 128 business customers per 1 000 residential customers.

In EPON networks distance and subscriber density are inversely correlated. For example, the CCAP is expected to support 128 business customers on a PON at a distance up to 5 km, up to 64 customers at 10 km, up to 32 customers at 20 km, 16 customers at 30 km, 8 customers at 40 km, and up to 4 customers at a distance of 50 km.

### 8.1.2.2 EPON Redundancy

The CCAP chassis can optionally support N+1 EPON redundancy. Other redundant configurations are possible as well. High availability and reliability are critical to enterprise business services and will be an important option when diversely routed fibre is available to the subscriber.

### 8.1.2.3 EPON Connectors

EPON line cards should support SFP-type connectors. This form factor allows for maximum flexibility for wavelength and port selection. SC/PC is also an option.

## 8.1.3 Network Side Interface

The CCAP receives any data to be transmitted downstream (e.g. Internet content, IP video, IPCablecom voice data, and DSG data) through the Network Side Interface (NSI), which would consist of at least 160 Gbps of data on one or more physical interfaces in order to support a fully loaded large chassis (at least 80 Gbps for a small chassis). The I-CCAP will be expected to implement multiple, redundant NSIs on the Switch Routing line card; the Packet Shelf will be expected to implement them on the Management line card. These interfaces should be deployed with standards-based pluggable optics. While initially deploying 10 GbE interfaces, CCAP deployments are expected to migrate to 100 GbE interfaces as the technology matures. 10 GbE interfaces should comply with [i.6] and 100 GbE interfaces should comply with [i.7]. Each NSI port should support untagged IEEE 802.3 Ethernet encapsulation. Individual Network-to-Network Interfaces (NNIs) may be provided for HSI business services using a 10G EPON interface.

## 8.2 Platform Implementation Options

As with the existing CMTS architectures, a CCAP device can be implemented in an integrated or modular manner. For the integrated CCAP (I-CCAP), all functions are implemented in a single chassis. In a modular CCAP, functions are divided between a Packet Shelf (PS) and an Access Shelf (AS), as follows:

- The PS implements packet-processing functions, such as subscriber management, service flow management, layer-3 routing and higher layer protocol manipulation, and other such functions.
- The AS implements all the upstream and downstream PHY functions normally associated with a CMTS and an Edge QAM, video program stream edge manipulation (e.g. multi-program transport stream creation, PCR restamping, etc.), and as much of the DOCSIS MAC as needed to support both upstream and downstream flows. A documented interface between the PS and the AS, specified as the Packet to Access Shelf Interface (PASI), is defined to enable interoperability between AS and PS vendors. EPON versions of the Access Shelf are also supported.

Details of the integrated and modular implementations are described in the following clauses.

### 8.2.1 I-CCAP Chassis Sizing

The integrated CCAP chassis may be deployed in a large chassis, designed to support a minimum of 40 downstream RF ports. The I-CCAP could also be implemented in a smaller chassis, supporting at least 16 downstream RF ports. The smaller implementation will provide great value to smaller hub sites in use by cable operators.

### 8.2.2 M-CCAP Chassis Sizing and Physical Locations

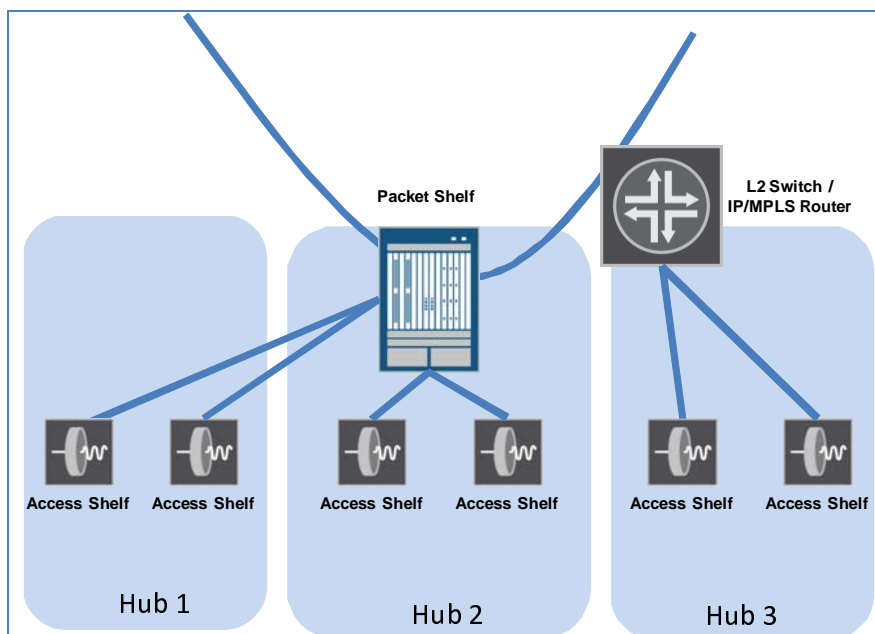
The Modular implementation of the CCAP is provided by two devices: a Packet Shelf (PS) and an Access Shelf (AS). The PS and AS are used together to provide the same functionality that is found in the I-CCAP implementation.

The Packet Shelf is designed to support a minimum of eight Access Shelves and 160 downstream service groups.

One implementation of the Access Shelf is designed to support a minimum of 40 downstream RF ports. The Access Shelf could also be implemented in a smaller chassis, supporting as few as 20 downstream RF ports, allowing efficient support for smaller headends and hub sites.

The Modular implementation also provides additional physical location flexibility for the shelves. The M-CCAP solution can be deployed in any location that makes sense for an Integrated CCAP. But there are some additional deployment options that Modular architecture enables. For example, the modular solution allows for the PS and AS to be positioned in the network in different physical locations and, therefore, in different parts of network.





**Figure 8-1: Access Shelf Deployments**

As shown in figure 8-1, the Access Shelves in Hub 1 are remote to the PS at Hub 2. They are interconnected via Point to Point fibre. In the Hub 2 case, the PS and AS are co-located. With Hub 3, the PS and AS are not in same location; they are connected across a Metro Ethernet aggregation network or IP/MPLS network. As illustrated, a modular architecture has a high degree of deployment flexibility.

---

## List of figures

Figure 5-1: Typical Headend Space Usage .....	15
Figure 5-2: CCAP Deployment Space Usage.....	15
Figure 5-3: CCAP Video Headend Reference Architecture .....	20
Figure 5-4: CCAP Data Reference Architecture .....	21
Figure 5-5: Modular Implementation .....	22
Figure 5-6: Video and Data Flow in the M-CCAP.....	24
Figure 7-1: Optional CCAP Video Content Protection Overview .....	29
Figure 7-2: QAM Replication .....	30
Figure 7-3: DOCSIS 3.0 HFC Network Using CCAP .....	33
Figure 7-4: DPoE Network using CCAP.....	33
Figure 7-5: Operator Interfaces to EPON Access Network.....	34
Figure 7-6: PASI Planes.....	36
Figure 7-7: PASI Management Plane.....	37
Figure 7-8: PASI Control Plane .....	37
Figure 8-1: Access Shelf Deployments .....	41

---

## List of tables

Table 6-1: DOCSIS Specification Adherence .....	28
---	----

---

## History

<b>Document history</b>		
V1.1.1	October 2011	Publication