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Data-Over-Cable Service Interface Specifications
Converged Cable Access Platform

Converged Cable Access Platform Architecture Technical Report

CM-TR-CCAP-V02-110614

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1 SCOPE

1.1 Introduction and Purpose

This Architectural Overview Technical Report 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. This document describes both the integrated and modular architectures and discusses the various CableLabs specifications that contain normative requirements pertaining to the CCAP. In addition, this 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, this document provides an overview of the operation of Packet Shelf and Access Shelf devices, as well as the interface between them.

2 INFORMATIVE REFERENCES

This technical report uses the following informative references. References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific. For a non-specific reference, the latest version applies.

[CCAP OSSI] Data-Over-Cable Service Interface Specifications CCAP Operations Support System Interface Specification, CM-SP-CCAP-OSSI, Cable Television Laboratories, Inc.

[DPoE ARCH] DOCSIS Provisioning of EPON Architecture, DPoE-SP-ARCHv1.0, Cable Television Laboratories, Inc.

[DPoE MEF] DOCSIS Provisioning of EPON MEF Specification, DPoE-SP-MEFv1.0, Cable Television Laboratories, Inc.

[DPoE MULPI] DOCSIS Provisioning of EPON MULPI Specification, DPoE-SP-MULPIv1.0, Cable Television Laboratories, Inc.

[DPoE OAM] DOCSIS Provisioning of EPON OAM Specification, DPoE-SP-OAMv1.0, Cable Television Laboratories, Inc.

[DPoE OSSI] DOCSIS Provisioning of EPON OSSI Specification, DPoE-SP-OSSIv1.0, Cable Television Laboratories, Inc.

[DPoE PHY] DOCSIS Provisioning of EPON Physical Layer Specification, DPoE-SP-PHYv1.0, Cable Television Laboratories, Inc.

[DPoE SEC] DOCSIS Provisioning of EPON Security Specification, DPoE-SP-SECv1.0, Cable Television Laboratories, Inc.

[DRFI] DOCSIS Downstream RF Interface Specification, CM-SP-DRFI, Cable Television Laboratories, Inc.

[DSG] DOCSIS Set-top Gateway (DSG) Interface Specification, CM-SP-DSG, Cable Television Laboratories, Inc.

[DTI] DOCSIS Timing Interface Specification, CM-SP-DTI, Cable Television Laboratories, Inc.

[EQAM VSI] Edge QAM Video Stream Interface Specification, CM-SP-EQAM-VSI, Cable Television Laboratories, Inc.

[ERMI] DOCSIS Edge Resource Manager Interface, CM-SP-ERMI, Cable Television Laboratories, Inc.

[IEEE 802.3ae] 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.

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[MHA TR] EQAM Architectural Overview Technical Report, CM-TR-MHA, Cable Television Laboratories, Inc.

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[RFC 2453] IETF RFC2453/STD0056 RIP Version 2, November 1998.

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[RFC 3376] IETF RFC3376, Internet Group Management Protocol, Version 3, October 2002.

[RFC 3810] IETF RFC3810, Multicast Listener Discovery Version 2 (MLDv2) for IPv6, June 2004.

[RFC 4023] IETF RFC4023, Encapsulating MPLS in IP or Generic Routing Encapsulation (GRE), March 2005.

[RFC 4364] IETF RFC4364, BGP/MPLS IP Virtual Private Networks (VPNs), February 2006.

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[RFC 4724] IETF RFC4724, Graceful Restart Mechanism for BGP, January 2007.

[RFC 4741] IETF RFC4741, NETCONF Configuration Protocol, December 2006.

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[RFC 4874] IETF RFC4874, Exclude Routes - Extension to Resource Reservation Protocol-Traffic Engineering (RSVP-TE), April 2007.

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[RFC 5120] IETF RFC5120, M-ISIS: Multi Topology (MT) Routing in Intermediate System to Intermediate Systems (IS-ISs), February 2008.

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[SEC] DOCSIS 3.0 Security Specification, CM-SP-SECv3.0, Cable Television Laboratories, Inc.

[TEI] TDM Emulation Interface Specification, CM-SP-TEI, Cable Television Laboratories, Inc.

2.1 Reference Acquisition

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

3 TERMS AND DEFINITIONS

This document uses the following terms:

Access Shelf	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	A 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	A 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	A 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	A point-to-multipoint, fiber to the premises network architecture in which unpowered optical splitters are used to enable a single optical fiber to serve multiple premises.
Hybrid Fiber-Coax System	A broadband bidirectional shared-media transmission system using optical fiber trunks between the head-end and the fiber nodes, and coaxial cable distribution from the fiber nodes to the customer locations.
NETCONF	An 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	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	A set of channels for a given service (e.g., Video On Demand, High-Speed Internet) delivered via a number of fiber nodes to corresponding subscribers of that service to a single subscriber device.
YANG	A 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.

4 ABBREVIATIONS AND ACRONYMS

This document uses the following abbreviations:

AES	Advanced Encryption Standard
ANCP	Access Node Control Protocol
APC	Angled Physical Contact
AS	Access Shelf
ASM	Any-Source Multicast
AWGN	Additive White Gaussian Noise
BGP	Border Gateway Protocol
BSoD	Business Services over DOCSIS
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
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
EPON	Ethernet Passive Optical Network
EQAM	Edge QAM
ERM	Edge Resource Manager
ERMI	Edge Resource Manager Interface
FFT	Fast Fourier Transform
Gbps	Gigabits per second
GigE	Gigabit Ethernet
GRE	Generic Routing Encapsulation
HSI	High-Speed Internet
I-CCAP	Integrated CCAP

IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
IPDR	IP Detail Record
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
MHz	Megahertz
MIB	Management Information Base
MPEG	Moving Picture Experts Group
MPLS	Multiprotocol Label Switching
MPTS	Multi-Program Transport Stream
MTA	Multimedia Terminal Adapter
MVPN	Multicast Virtual Private Network
NNI	Network to Network Interface
NSI	Network-Side Interface
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 Voice over IP
P2MP	Point-to-Multipoint Communication
PASI	Packet to Access Shelf Interface
PCMM	PacketCable Multimedia
PCR	Program Clock Reference
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
PPM	Parts per Million

PS	Packet Shelf
PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
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
TEI	TDM Emulation Interface
TLS	Transparent LAN Service
UCH	Universal Cable Holder
UML	Unified Modeling Language
VBR	Variable Bit Rate
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

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 MSOs 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 MSOs, 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 though 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 this 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 ([RFC 4741]).

Management of CMTS and EQAM functions are also consolidated on the CCAP. The CCAP implements all MIBs required in [CCAP OSSI], 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, Figure 5–1 and Figure 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.

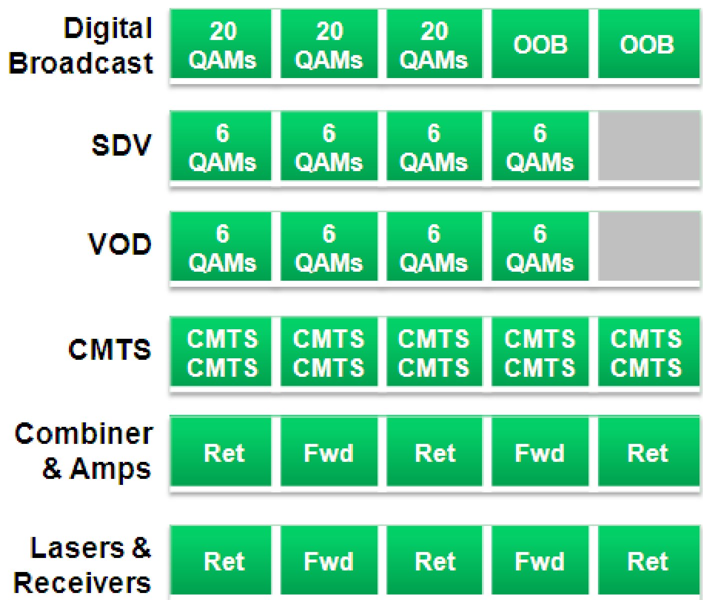

Figure 5–1 - Typical Headend Space Usage

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.

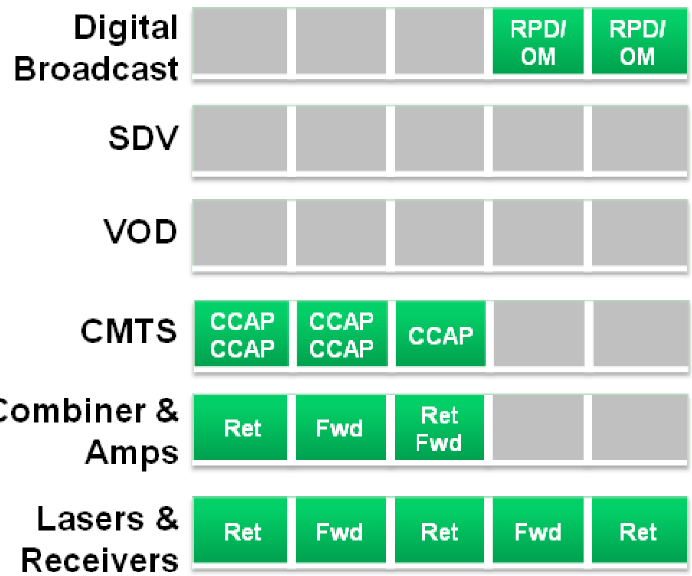

Figure 5–2 - CCAP Deployment Space Usage

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, analog 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 section 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 analog video. Analog video signals are combined external to the CCAP with the output digital QAM signals of the CCAP prior to the input into the downstream fiber 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 fiber 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)
- PacketCable 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 sections.

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 PacketCable VoIP

The VoIP service discussed in this section refers to VoIP as provided by equipment supporting the interfaces specified in various PacketCable specifications. In this context, PacketCable 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 PacketCable 1.0, PacketCable 1.5 extends the PacketCable residential voice capability with capabilities such as fax and modem support, analog trunking for PBXs, and Session Initiation Protocol (SIP) for session management within and among PacketCable networks.

At a very high level, the PacketCable 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 Signaling 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 PacketCable functionality today.

5.3.2.3 Transparent LAN Service

The Transparent LAN Service (TLS) discussed in this section refers to the functionality defined in the DOCSIS L2VPN specification. 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 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 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, PacketCable, TLS, and the next generation video services described in Section 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 section: 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.

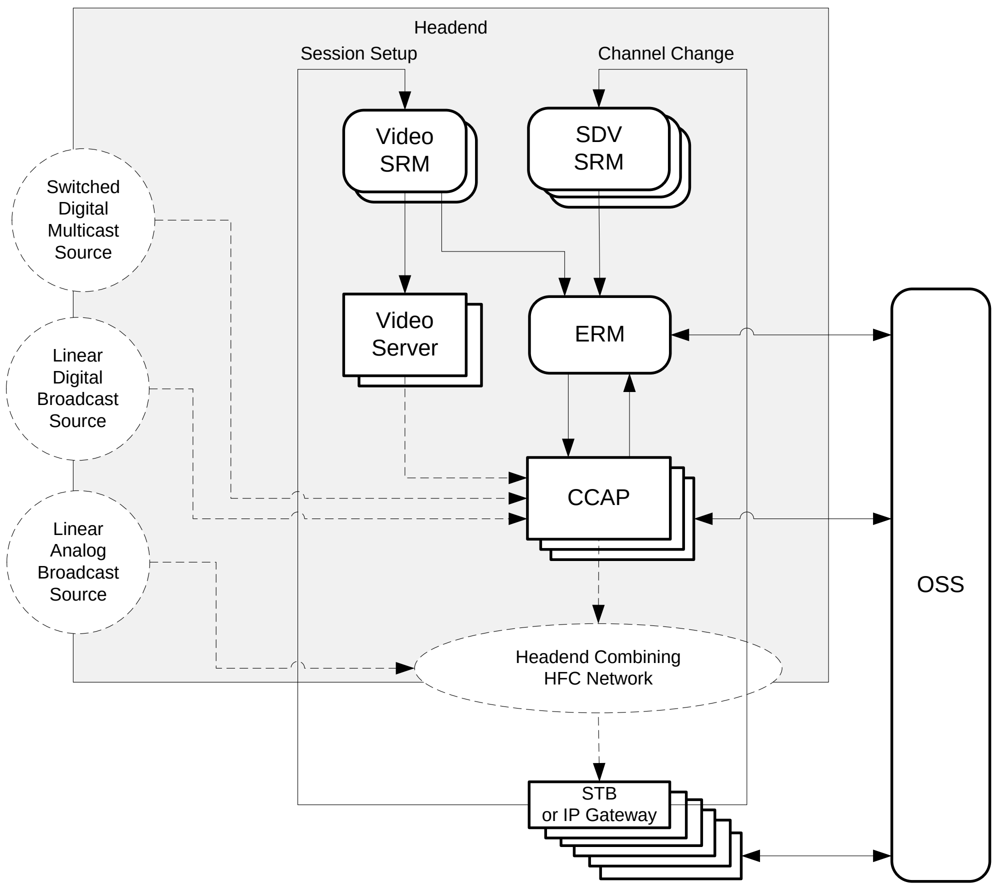

Figure 5–3 - CCAP Video Headend Reference Architecture

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, signaling to service-specific session resource managers (SRM) to request receipt of a video stream. When the STB client requests a stream, the SRM must 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.

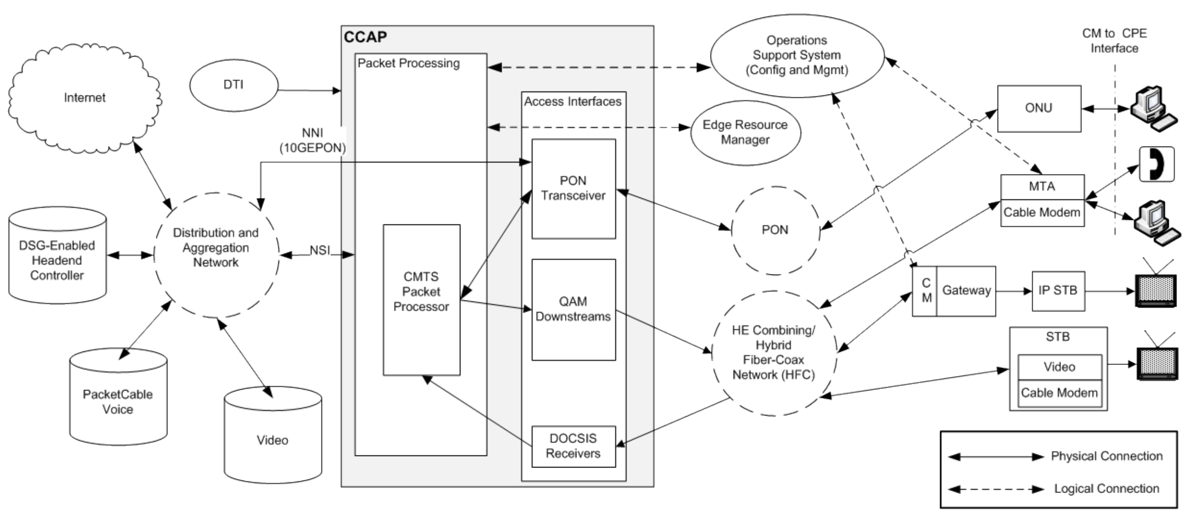

Figure 5–4 - CCAP Data Reference Architecture

The CCAP receives Internet content, video, PacketCable voice data, and [DSG] 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 signaling 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 PacketCable 1.5 or PacketCable Multimedia (PCMM) specifications.

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 analog 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 PacketCable 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 PacketCable 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 [MHA TR], 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 section 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.

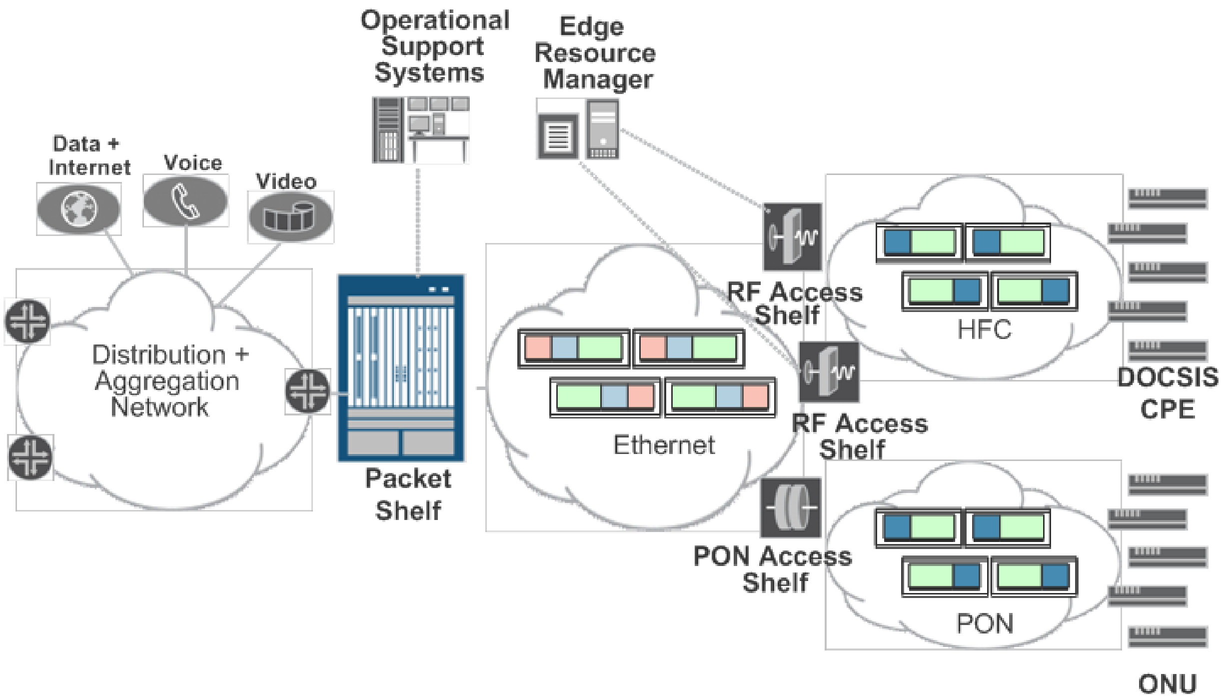

Figure 5–5 - Modular Implementation

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
- PacketCable and PCMM Support
- Cable broadband intercept and/or PacketCable 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.

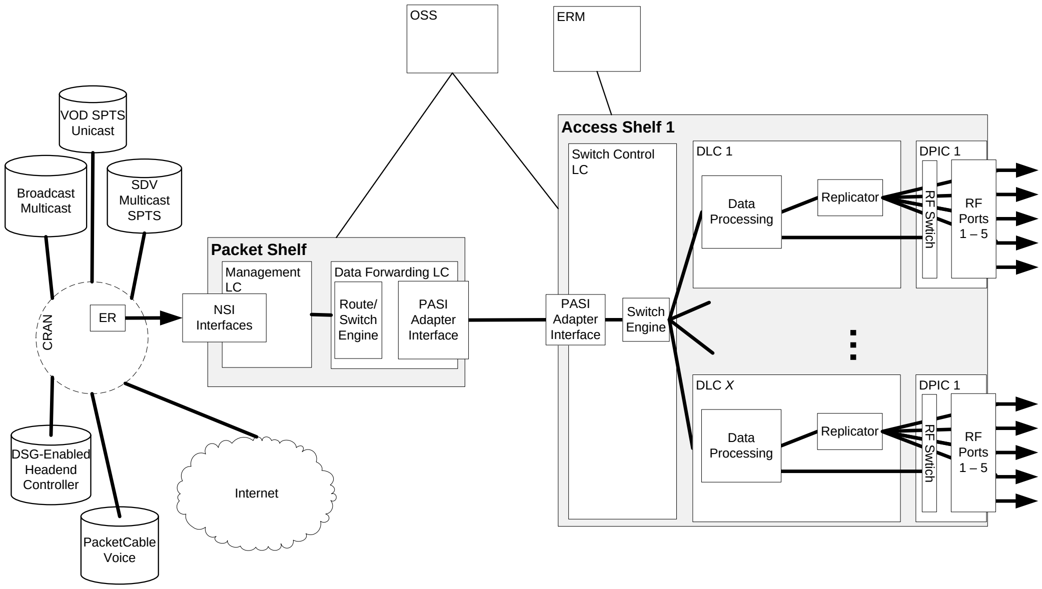

Figure 5–6 - Video and Data Flow in the M-CCAP

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 [MHA TR]. 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 sections 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 ([MULPI]) Specification v3.0

The [MULPI] specification 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 ([PHY]) Specification v3.0

The [PHY] specification defines the upstream physical layer requirements for hybrid fiber-coax systems that the CCAP must 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 [PHY] is required.

6.1.3 DOCSIS Security ([SEC]) Specification v3.0

The [SEC] specification 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 Specification

The [CCAP OSSI] 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 [OSSI].

6.2.1.1 SNMP Requirements and Reporting Requirements

The SNMP requirements of the CCAP are based upon the requirements specified in [OSSI], 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 the [OSSI] specification 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 must support all standard event reporting mechanisms defined in section 8 of the [OSSI] specification. The CCAP is required to meet all IP Detail Record (IPDR) requirements specified in the [OSSI] specification. The CCAP is also required to support all IPDR service definitions defined in the [OSSI] specification.

6.2.1.2 CCAP Object Model

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

The specification supports the use of YANG, allowing access to these object models via NETCONF [RFC 6020].

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 [OSSI] 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 ([PASI]) 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 [PASI] 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 ([ERMI]) Specification

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

6.3.2 DOCSIS Timing Interface ([DTI]) Specification

The [DTI] specification defines the timing interfaces required for the DOCSIS M-CMTS architecture. While the CCAP must support stratum 3 clock accuracies, it is not required to implement the timing interface as specified in the [DTI] specification, although [DTI] 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 ([EQAM VSI]) Specification

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

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

6.4 Downstream RF Interface ([DRFI]) Specification

The [DRFI] specification defines the downstream radio frequency interface for EQAMs and CMTS; as such, the requirements specified in [DRFI] are required for the CCAP. While all [DRFI] specification requirements must be met by the CCAP, the CCAP does diverge from the [DRFI] specification 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 ≥70 dB from 50 MHz to 550MHz and ≥65 dB from 550 MHz to 1002 MHz.
- Frequency shift: The CCAP requires:

- Carriers must not sweep across bands.
- Ports must 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: The [DRFI] specification 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 ([DSG]) Specification

The [DSG] specification 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 the [DSG] specification.

6.6 Business Services over DOCSIS Specifications

6.6.1 Layer 2 VPN ([L2VPN]) Specification

The [L2VPN] specification 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 ([TEI]) Specification

The [TEI] 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 [TEI] 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 sections.

6.7.1 DOCSIS Provisioning of EPON Architecture Specification

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

6.7.2 DOCSIS Provisioning of EPON MEF Specification

The [DPoE MEF] 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 and 802.3av.

6.7.3 DOCSIS Provisioning of EPON MAC and Upper Layer Protocols Specification

The [DPoE MULPI] 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 [DPoE OAM] 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 [DPoE OSSI] 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 [DPoE PHY] 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 [DPoE SEC] 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

The following table summarizes the level of adherence the CCAP must have to the DOCSIS specification.

Table 6–1 - DOCSIS Specification Adherence

	Specification												
Device	**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 fiber 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 fiber nodes to the subscribers on those nodes, and likewise, the reachability of return path signals from fiber 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 fiber 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 fiber 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 sections 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.

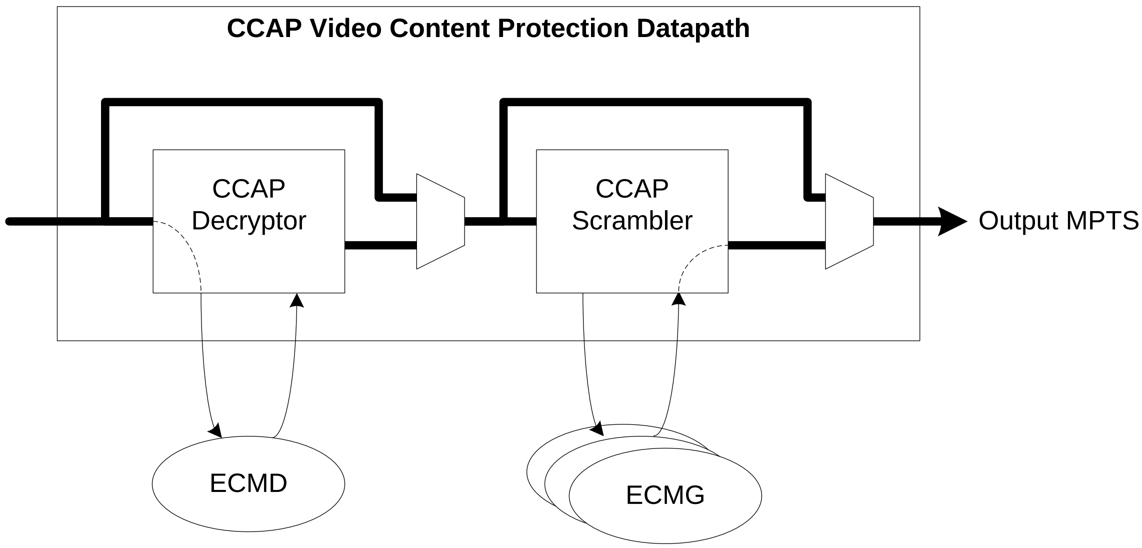

Figure 7–1 - Optional CCAP Video Content Protection Overview

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 the Figure 7–2; note that each DLC port has a unique HSI group of QAMs (not depicted).

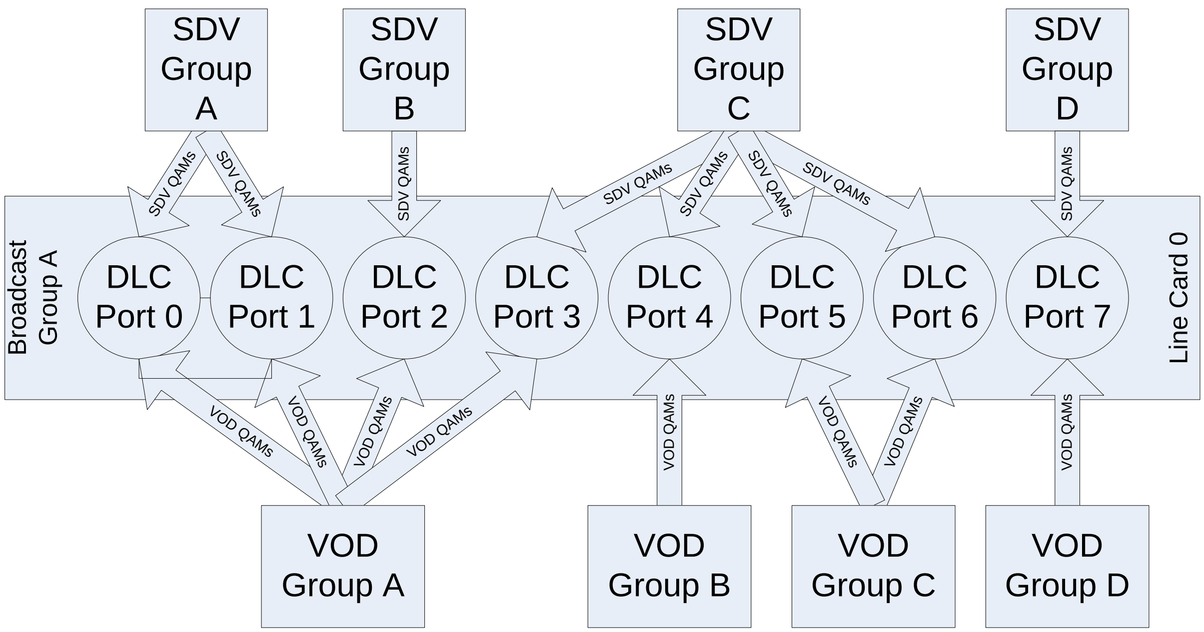

Figure 7–2 - QAM Replication

Note that 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 signaling/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 signaling/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 section will provide an overview of the various aspects of configuring a CCAP chassis including background on the choice of object modeling language chosen and a discussion of the various object models and their constructs.

7.5.1 YANG Data Modeling 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 modeling language is UML and the configuration data modeling language used is YANG.

YANG is a data modeling language for the NETCONF network configuration protocol that has been developed within the IETF to allow for modeling of configuration data, network element state and network events (see [RFC 6020]. For purposes of the integrated CCAP, only the configuration data modeling 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 and Management 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 [RFC 4741]. 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.

The DOCSIS Provisioning of EPON (DPoE) specifications provide a service overlay of the DOCSIS and CMTS management framework on an IEEE 802.3ah/av EPON network. DPoE systems rely on the EPON MAC and PHY and the upper-layer DOCSIS protocols defined by CableLabs. 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.

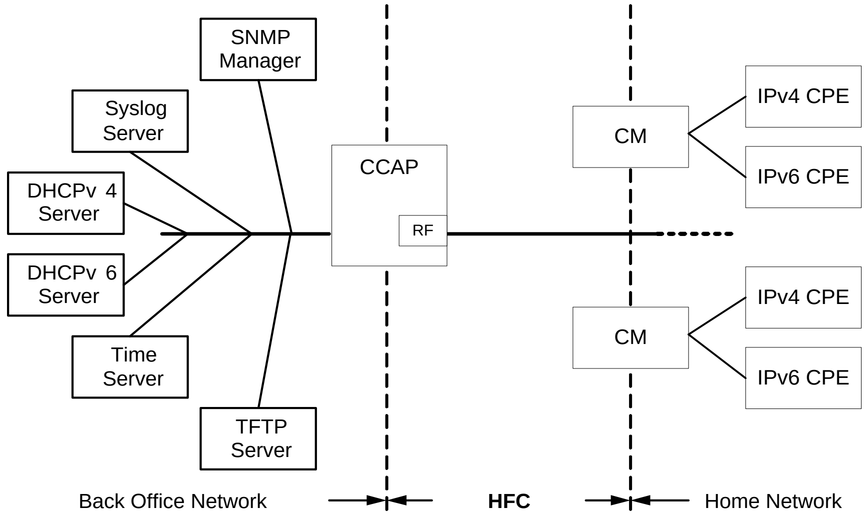

Figure 7–3 - DOCSIS 3.0 HFC Network Using CCAP

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.

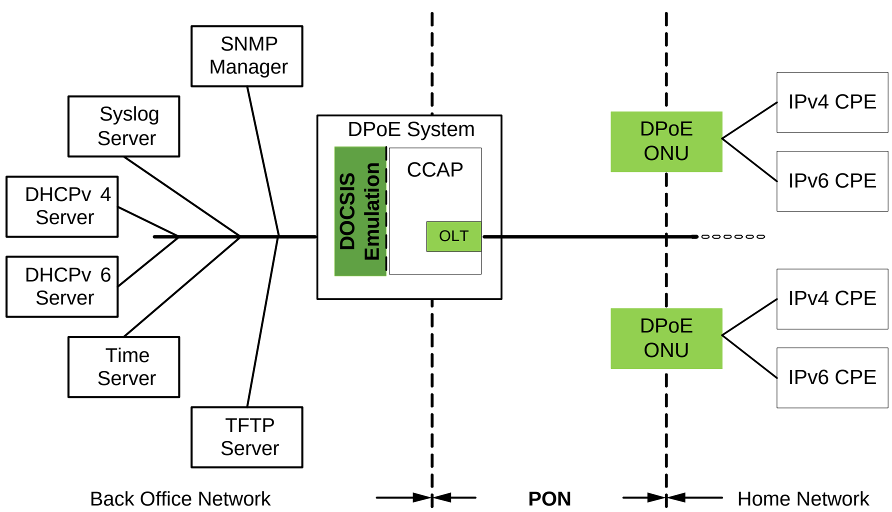

Figure 7–4 - DPoE Network using CCAP

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 [DPoE OSSI] 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.

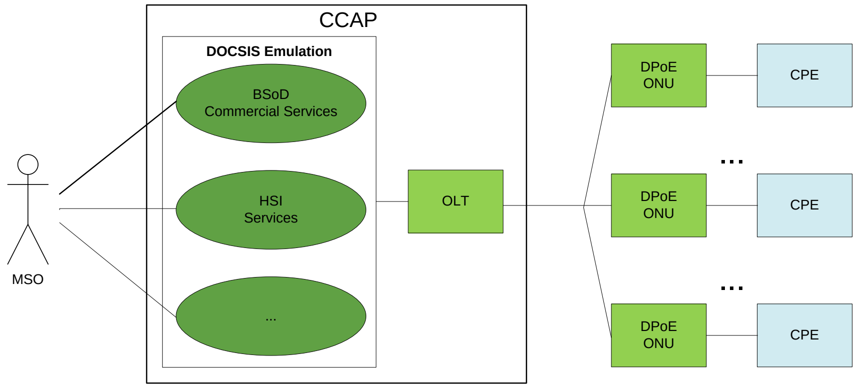

Figure 7–5 - Operator Interfaces to EPON Access Network

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 section 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 signaling, as specified in [RFC 4761]
- BGP/MPLS IP VPNs, as specified in [RFC 4364]
- The framework for L2VPNs, as specified in [RFC 4664]
- LDP (Label Distribution Protocol), as specified in [RFC 5036]
- Extensions to RSVP for LSP tunnels, as specified in [RFC 3209]
- Exclude routes extension to RSVP, as specified in [RFC 4874]
- Node behavior upon originating and receiving RSVP path error messages, as specified in [RFC 5711]

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 [RFC 4023]
- Encapsulation methods for transport of Ethernet over MPLS networks, as specified in [RFC 4448]
- Encoding of attributes for MPLS LSP establishment, as specified in [RFC 5420]

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) signaled by PIM-SM (ASM)
- IP/GRE-based inclusive P-tunnels signaled by PIM-SM (SSM)
- MPLS inclusive P-tunnels signaled by RSVP-TE P2MP LSPs
- MPLS selective P-tunnels signaled 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 [RFC 2453]
- IS-IS, as specified in [RFC 5303]
- Multi-Topology support for IS-IS, as specified in [RFC 5120]
- OSPFv2 as specified in [RFC 2328] and [RFC 5709]
- BGPv4, as specified in [RFC 4724]
- Multiprotocol Extensions for BGP-4, as specified in [RFC 4760]

7.7.4 Multicast

The CCAP is expected to support Protocol Independent Multicast-Sparse Mode (PIM-SM) with SSM extensions, as specified in [RFC 4601]. 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 [RFC 3376] and also IGMPv2. For IPv6 on the access interfaces, the CCAP supports Multicast Listener Discovery version 2 protocol as specified in [RFC 3810]. 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 [PASI]. PASI has three different planes, as shown in Figure 7–6:

- Management plane conveying management information between the shelves
- Control plane signaling 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.

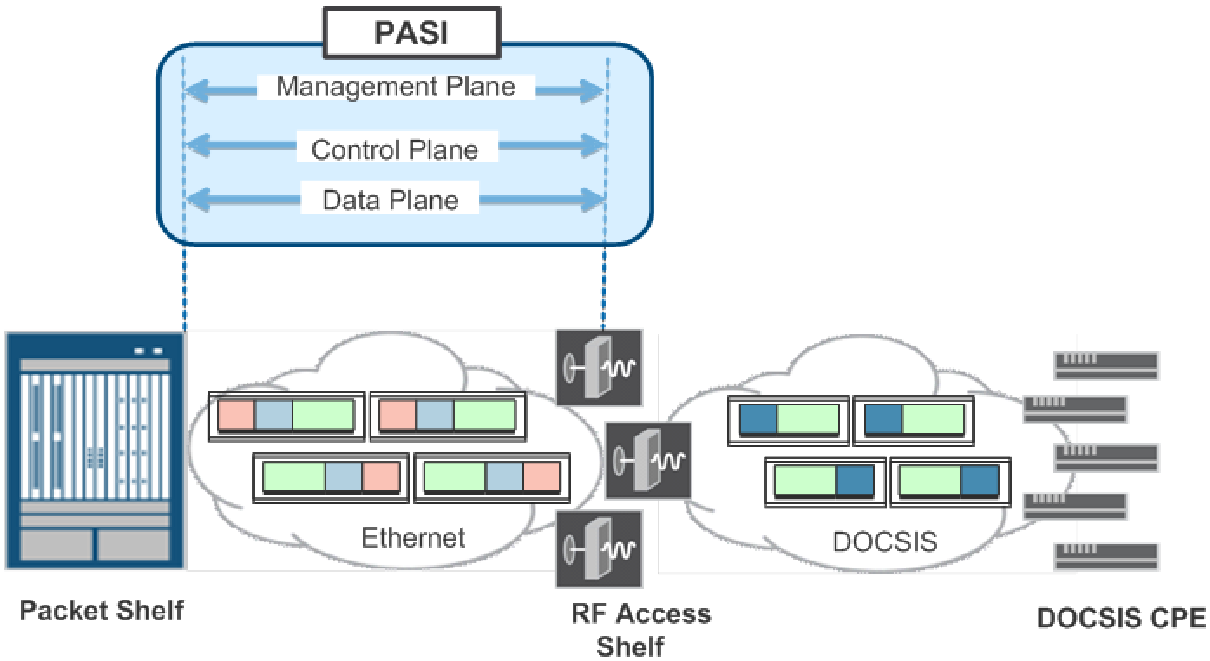

Figure 7–6 - PASI Planes

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

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.

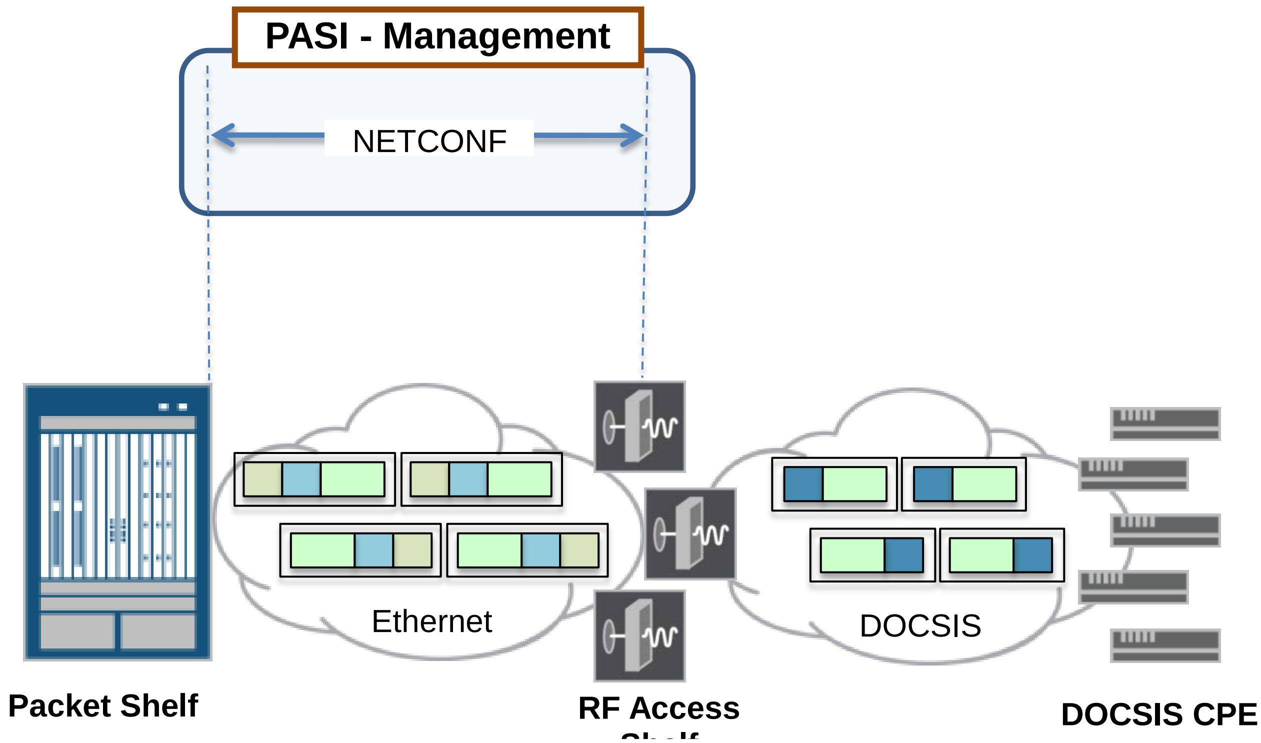

Figure 7–7 - PASI Management Plane

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.

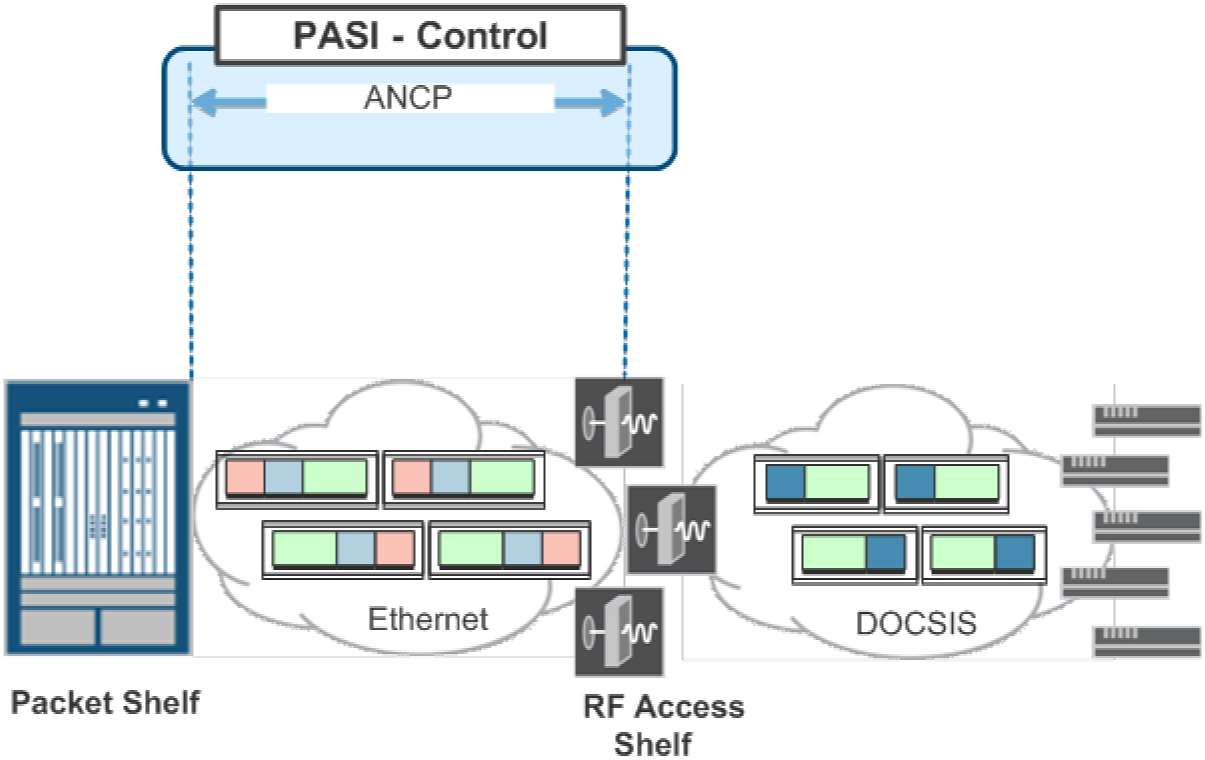

Figure 7–8 - PASI Control Plane

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 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 paragraphs 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-Fiber 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 – 60 downstream ports, and a small Integrated CCAP is expected to support a minimum of 16 – 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 – 1002 MHz or
- 108 – 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 – 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 – 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 – 120 upstream ports (with 120 being the preferred minimum), and a small chassis is expected to support 32 – 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 – 42 MHz or
- 5 – 85 MHz

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

Both European and North American devices support channel widths of 1.6, 3.2, and 6.4 MHz. They are also expected to support between 4 – 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

Fiber 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 fiber 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 1000 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 5km, up to 64 customers at 10km, up to 32 customers at 20km, 16 customers at 30km, 8 customers at 40km, and up to 4 customers at a distance of 50km.

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 fiber 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/PV 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, PacketCable 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 [IEEE 802.3ae] and 100 GbE interfaces should comply with [IEEE 802.3ba]. 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 sections.

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 MSOs.

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.

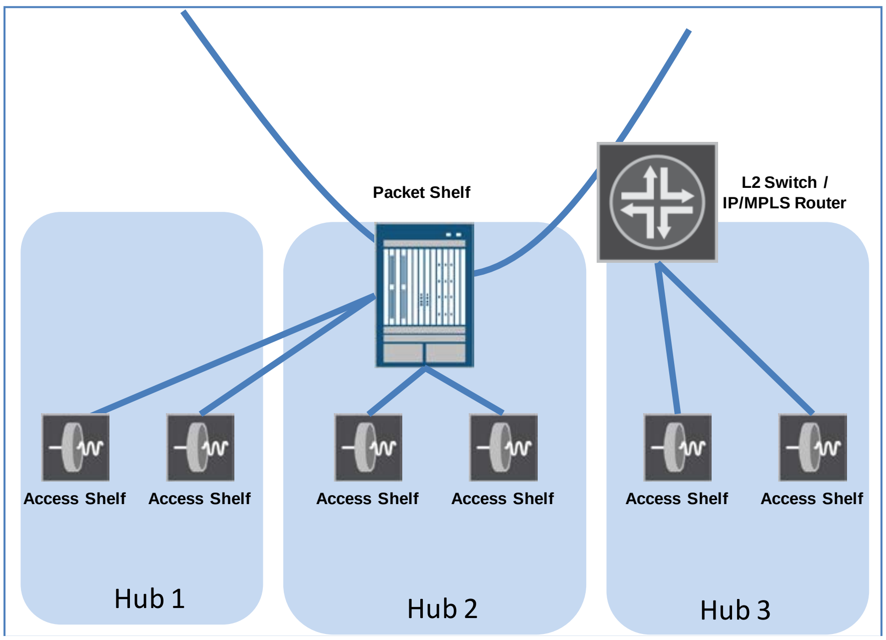

Figure 8–1 - Access Shelf Deployments

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 fiber. 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.

Appendix I Acknowledgments

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