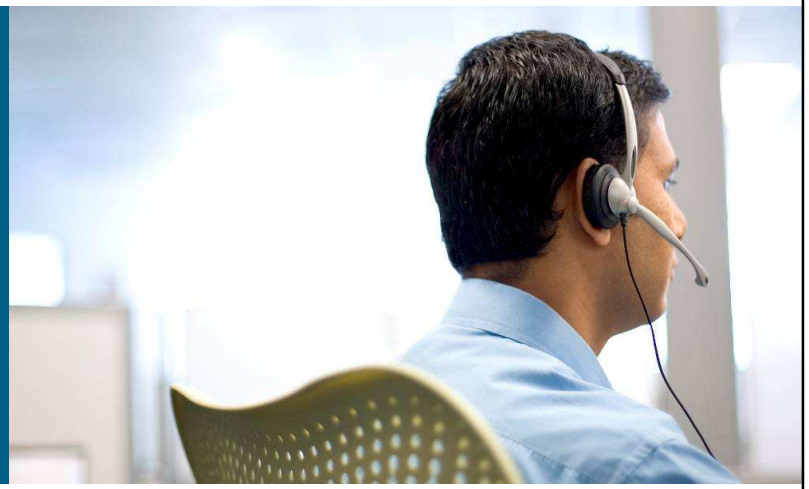
Introduction to DOCSIS 3.0



Speaker: Byju Pularikkal, Cisco Systems Inc.

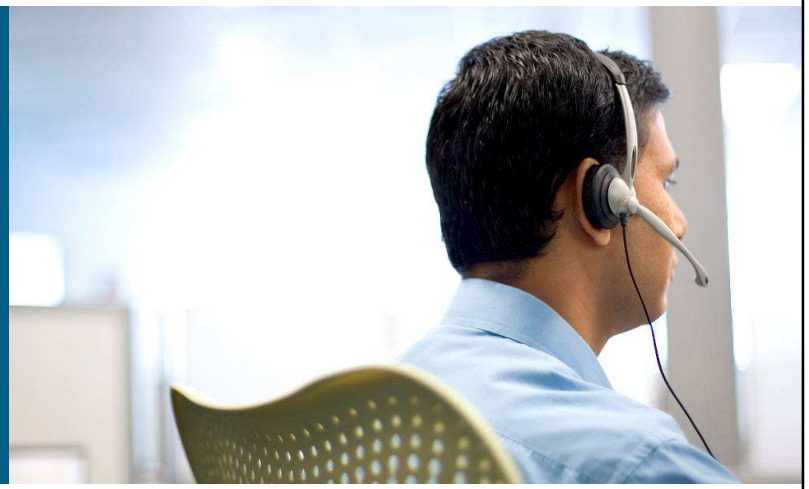
Acronyms/Abbreviations

- DOCSIS = Data-Over-Cable Service Interface Specification
- CMTS = Cable Modem Termination System
- DS = Downstream
- US = Upstream
- CM = Cable Modem
- M-CMTS = Modular CMTS
- PC = Primary Channel
- BG = Bonding Group
- QAM = Quadrature Amplitude Modulation
- TLV = Type Length Value
- BPI = Baseline Privacy Interface
- S-CDMA = Synchronous Code Division Multiple Access
- MLD = Multicast Listener Discovery
- SA = Security Association
- EAE = Early Authentication and Encryption
- MIC = Message Integrity Check
- MDD = MAC Domain Descriptor
- CIN = Converged Interconnect Network
- EQAM = Edge QAM
- OSSI = Operations Support System Interface
- QPSK = Quadrature Phase Shift Keying
- FN = Fiber node
- HFC = Hybrid Fiber Coaxial
- DTI = DOCSIS Timing Interface
- DEPI = Downstream External PHY Interface
- DRFI = Downstream Radio Frequency Interface
- IGMP = Internet Group Management Protocol
- ASM = Any Source Multicast
- SSM = Source Specific Multicast
- MMH = Multilinear Modular Hash
- OCSP = Online Certificate Status Protocol
- CRL = Certificate Revocation List
- ND = Network Discovery

Agenda

- Motivation for DOCSIS 3.0
- DOCSIS 2.0 overview
- Modular CMTS (M-CMTS) architecture
- DOCSIS 3.0 overview
  - Downstream channel bonding
  - Upstream channel bonding
  - Multicast
  - Physical layer technologies
  - Security
  - OSSI
- IPv6 in Cable

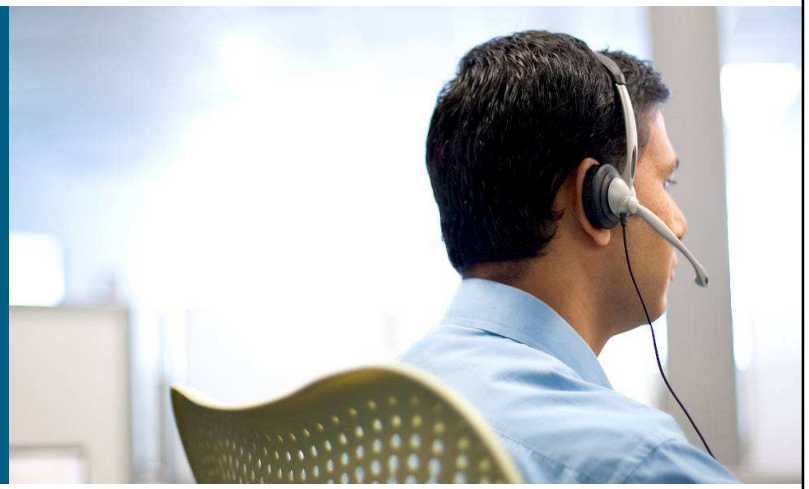
Motivation - Why DOCSIS 3.0?



DOCSIS 3.0 Business Objectives

- Allow more BW for DOCSIS 1.X & 2.0 CMs
- Limit/reduce more node splits
- Introduce new HSD service of 50 to 100 Mbps
- Allow migration of existing customers to higher tier and DOCSIS 3.0 capability
- To provide more robust data encryption
- Address the need for more IP address space through the support of IPv6
- Reduction of the overall cost of CMTS ports
  - Break DS/US dependence i.e. independent scalability of US and DS
  - Expected to reduced the cost of downstream port by more than 1/10

DOCSIS 2.0 Overview



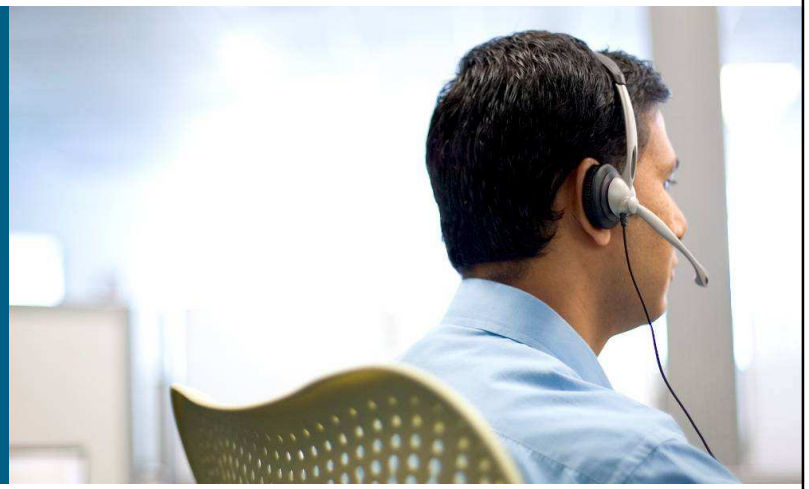
DOCSIS 2.0 Rates

- Downstream rates
  - 6 MHz channels in the United States, 8 MHz in Europe, 64 QAM or 256 QAM modulation
  - In the range of 26 Mbps / 38 Mbps (United States), higher for Europe.
- Upstream rates
  - 200Khz-6Mhz Channel Width, QPSK to 64QAM
  - In the range 320kbps to 30Mbps.
  - Per flow speed is limited by the request-grant latency. That typically limits the US rates to 1-3mbps (though it can be faster with special configurations)
- Typically, out of 131 channels on the DS, only one is used for DOCSIS, the rest are used for video (digital or analogue)

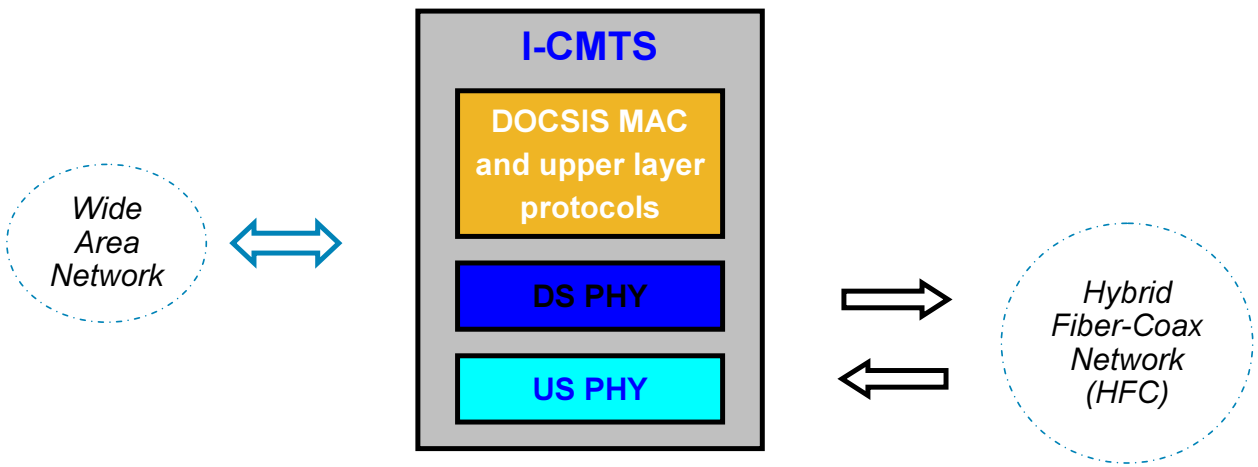
Feeds

- The distribution network is optical all the way to a specific neighborhood. A FN (fibernode) converts the optical signal to an electrical signal over coax.
- An FN typically serves 500 homes (HHP – house holds passed)
- A typical DOCSIS configuration:
  - Single downstream channel is split to 4 FN
  - This configuration serves typically 2000 homes passed by a DS.
  - Each FN has a single upstream frequency
  - About 800-1000 subscribers per downstream (not all homes have cable modems)

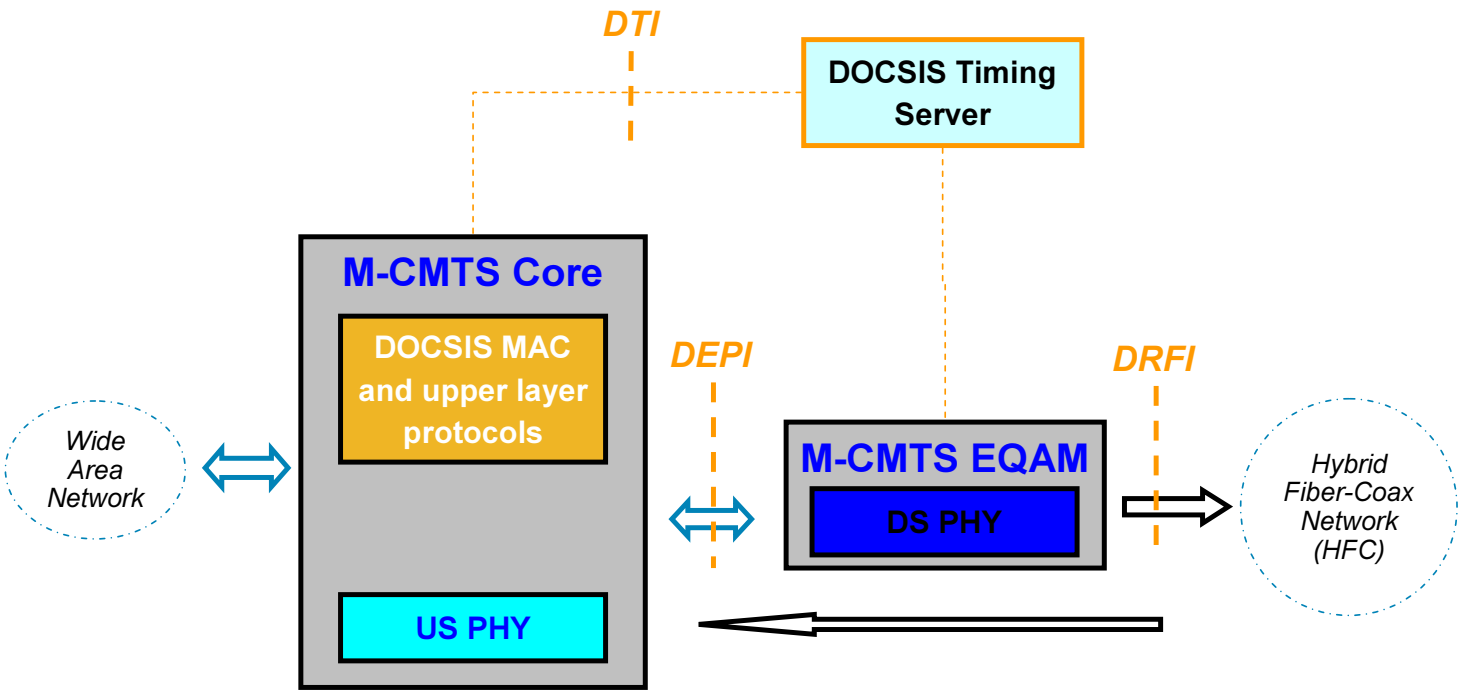
Modular CMTS



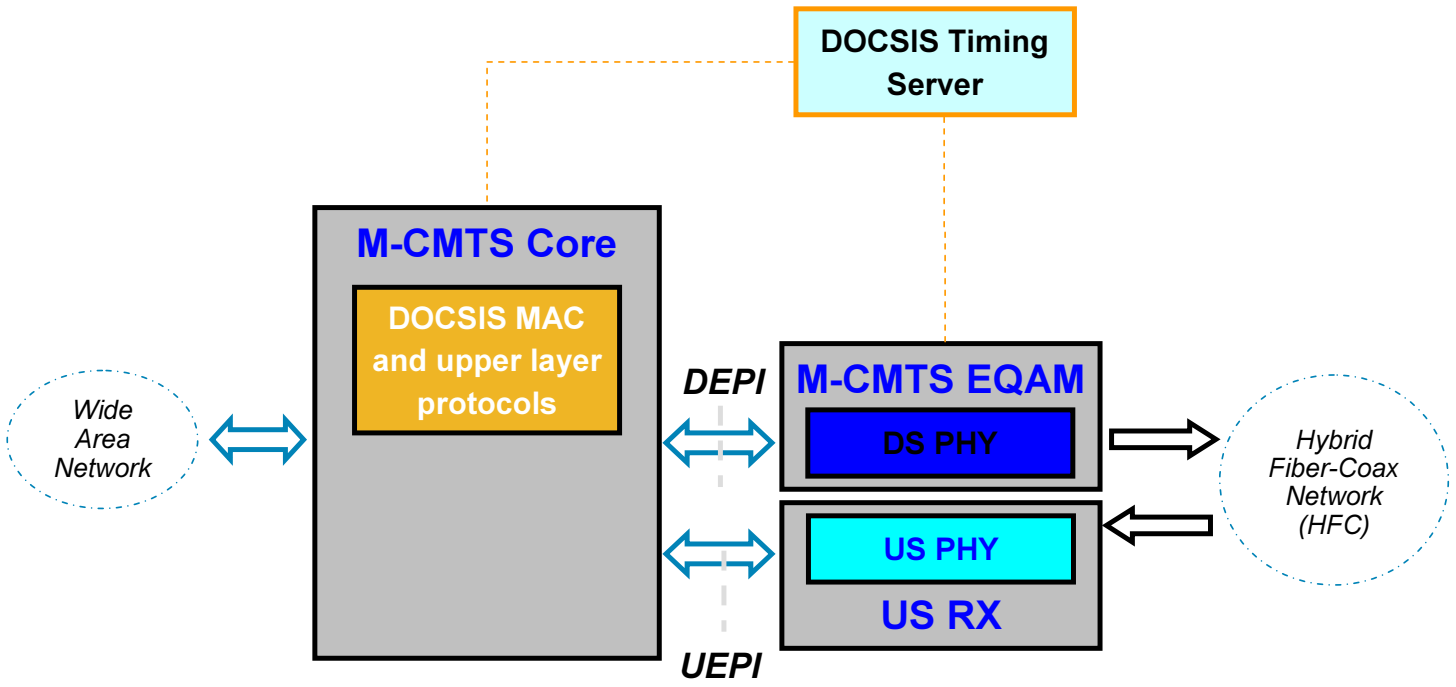
Integrated-CMTS Logical Functions



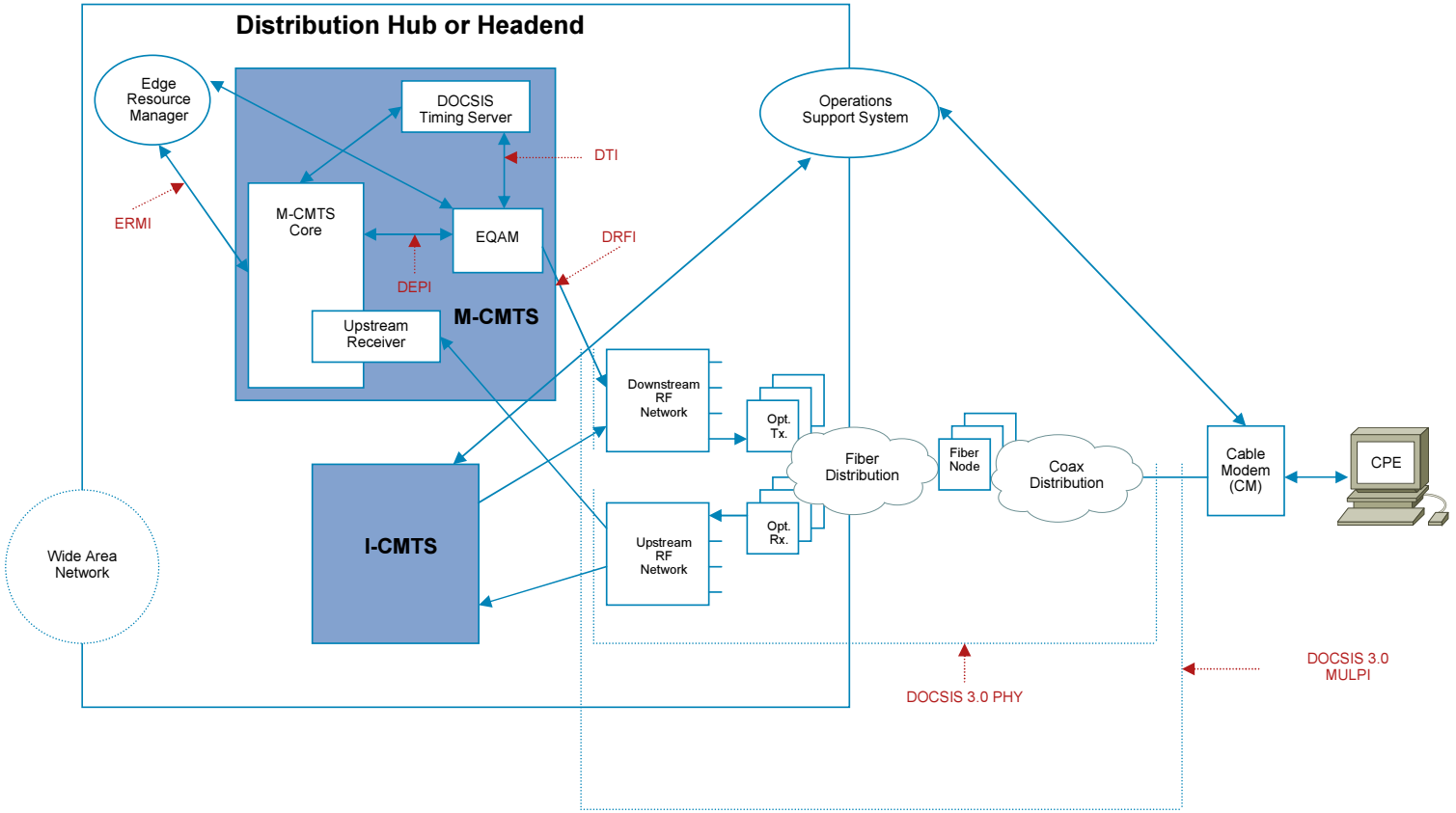
Modular-CMTS Phase 1



Modular-CMTS Phase 2



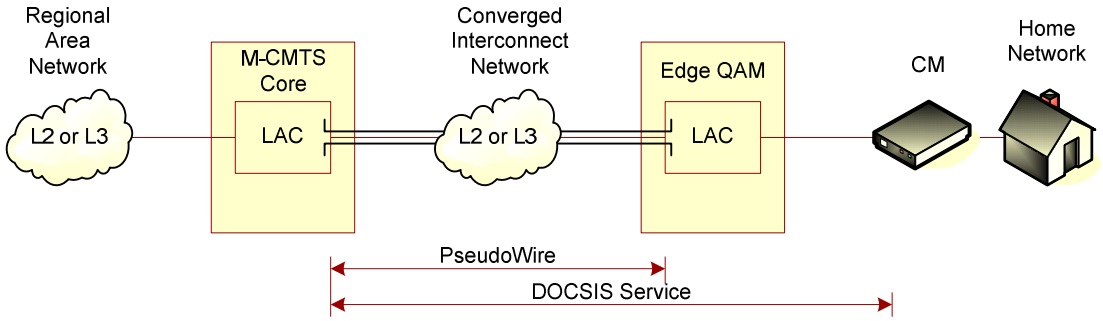
M-CMTS Components and Interfaces



M-CMTS Components

- **EQAM (Edge QAM Device):** System with multiple Gigabit Ethernet interfaces on the input side and multiple QAM modulators and upconverters on the output side
- **M-CMTS Core:** Contains the DS MAC and all the initialization & operational DOCSIS related software. In the future US receivers may be external to the M-CMTS core
- **DTI (DOCSIS Timing Interface) Server:** Provides a Common Frequency of 10.24 MHz and a DOCSIS time stamp to M-CMTS elements
- **ERM (Edge Resource Manager):** Manages the dynamic assignment of QAM channel resources to CMTS mac domains

DEPI Introduction



- **DEPI is an IP Tunnel, known as a pseudowire, that exists in the downstream direction between the DOCSIS MAC in the M-CMTS Core and the DOCSIS PHY that exists in the EQAM.**
- **The CIN (Converged Interconnect Network) may be a Layer 2 or Layer 3 network.**
- **The M-CMTS Core provides the DOCSIS MAC functionality, while the EQAM provides the DOCSIS PHY functionality.**
- **DEPI interfaces the MAC to the PHY**

DEPI Introduction: Contd..

- DEPI uses L2TPv3 (RFC 3931 Layer 2 Tunneling Protocol version 3) as the baseline protocol for the data path and control plane.
- DEPI uses two new pseudowire types:

  PSP (Packet Streaming Protocol) encapsulates a continuous stream of DOCSIS frames into a DEPI payload.

  MPT (MPEG Protocol Transport) encapsulates a group of 188 byte MPEG-TS packets into a DEPI payload.
- M-CMTS Core/EQAM must support MPT and/or PSP
- Signaling

  DEPI has one (or more) Control Connection between the M-CMTS Core and the EQAM for configuration.

  DEPI has one session for each QAM. There are one or more sessions per control connection.

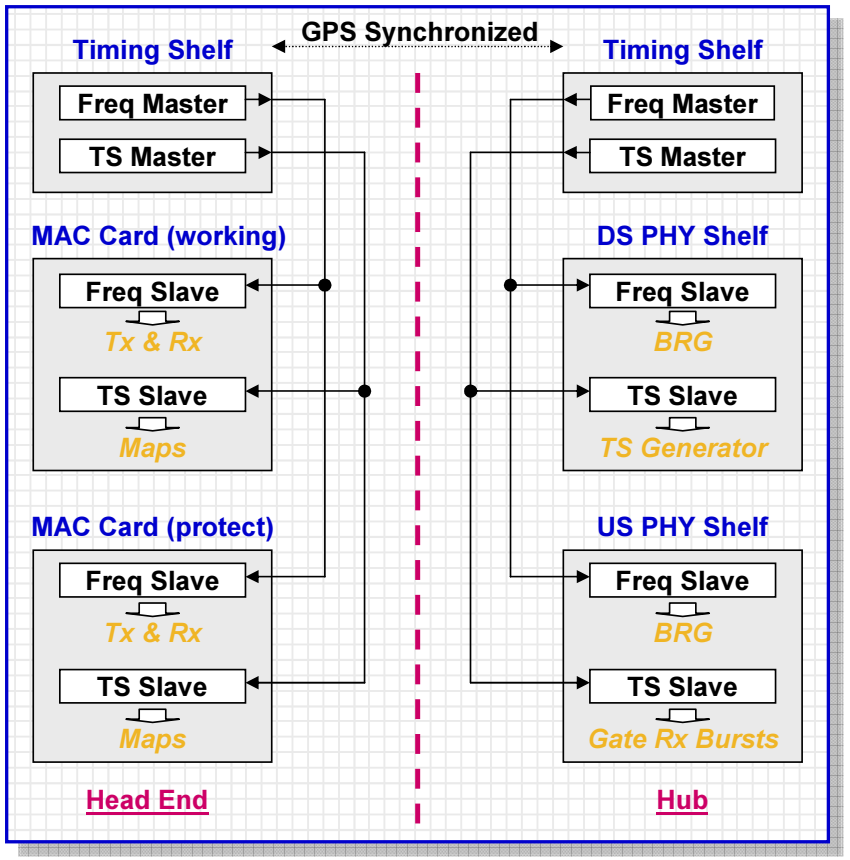
  DEPI has one or more flows per session for QoS. (Flows are a DEPI specific concept)

DTI: DOCSIS Timing Interface

- A DTI Server supplies a 10.24 MHz frequency plus a DOCSIS timestamp to MAC and PHY
- MAC and PHY contain DTI Clients.
- Two-way protocol. DTI Server cancels out cable and circuit delays.

  Everyone has the same timestamp.
- Interface is UTP RJ45 Ethernet-like.

Legend
BRG = Baud Rate Generator
TS = Timestamp



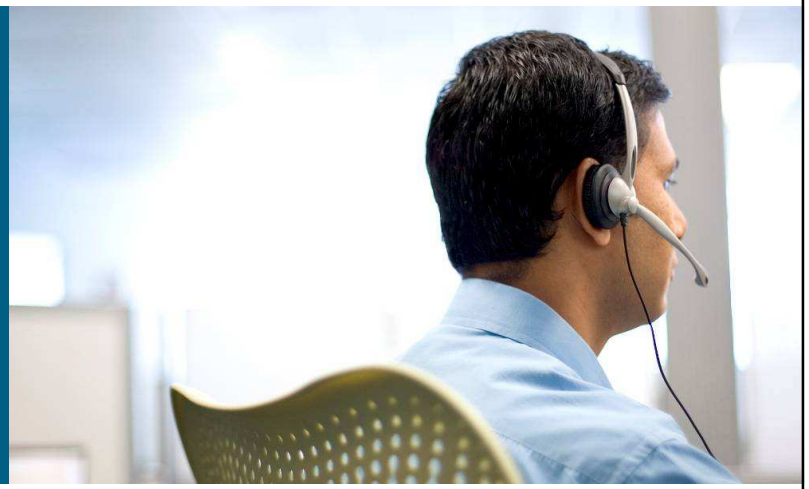
Edge Resource Manager (ERM)

- ERM Keeps a database of the EQAM resources which include location info and the EQAM channel properties
- Edge QAM uses a registration interface to advertise its QAM resources to ERM
- An ERM normally manage multiple EQAMs
- EQAMS use DRRP protocol to register a QAM channel to ERM
- DRRP :DOCSIS Resource Registration Protocol

Edge Resource Manager (Contd..)

- The M-CMTS core initiates a QAM resource transaction with the ERM when it requests or releases a QAM channel resource.
- Example: MAC domain is being created, for example, the M-CMTS core provides the ERM with details of the desired service group, bandwidth, and QAM channel capability.
- A service group is identified by a list of QAM channels and each QAM channel is assigned with an MPEG Transport Stream ID (TSID)

DOCSIS 3.0



DOCSIS 3.0 Introduction

- Series of Specifications that define the third generation of high speed data over cable systems
- Released during first week of August 2006
- DOCSIS 3.0 Addresses the following service goals

  increasing channel capacity,

  enhancing network security,

  expanding addressability of network elements, and

  deploying new service offerings

DOCSIS 3.0 Specifications

Core Specifications

Specification Title	Designation
DOCSIS 3.0 Physical Layer Interface Specification	CM-SP-PHYv3.0
DOCSIS 3.0 MAC and Upper Layer Protocols Interface Specification	CM-SP-MULPIv3.0
DOCSIS 3.0 Operations Support System Interface Specification	CM-SP-OSSIv3.0
DOCSIS 3.0 Security Specification	CM-SP-SECv3.0

DOCSIS 3.0 Related Specifications

Specification Title	Designation
Downstream Radio Frequency Interface Specification	CM-SP-DRFI
DOCSIS Timing Interface Specification	CM-SP-DTI
Downstream External PHY Interface Specification	CM-SP-DEPI
Edge Resource Manager Interface Specification	CM-SP-ERMI
M-CMTS Operations Support System Interface Specification	CM-SP-M-OSSI
eDOCSIS™ Specification	CM-SP-eDOCSIS
Cable Modem CPE Interface Specification	CM-SP-CMCI
Layer 2 Virtual Private Networks Specification	CM-SP-L2VPN
TDM Emulation Interfaces Specification	CM-SP-TEI
DOCSIS Set-Top Gateway Interface Specification	CM-SP-DSG

DOCSIS 3.0 Features

- Channel Bonding
  - Upstream Channel Bonding
  - Downstream Channel Bonding
- IP Multicast
  - Source Specific Multicast
  - QoS Support for Multicast
  - PHS for Multicast
  - QoS and Authorization
- IPv6
  - IPv6 Provisioning and Management of CMs
  - Alternative Provisioning Mode & Dual Stack Management Modes for CMs
  - IPv6 Connectivity for CPEs

DOCIS 3.0 Features: Contd..

- Security
  - Enhanced Traffic Encryption
  - Enhanced Provisioning Security
- Physical Layer
  - Upstream Frequency Range Extension
- MAC Layer
  - Topology and ambiguity resolution
  - MAC Initialization
  - DOCSIS Path Verify Network
- Management
  - CM Diagnostic Log
  - Enhanced Signal Quality Monitoring
  - Service Statistics Reporting

New D3.0 MAC Management Messages

MDD	MAC Domain Descriptor
B-INIT-RNG-REQ	Bonded Initial Ranging Request
DBC-REQ	Dynamic Bonding Change Request
DBC-RSP	Dynamic Bonding Change Response
DBC-ACK	Dynamic Bonding Change Acknowledge
DPV-REQ	DOCSIS Path Verify Request
DPV-RSP	DOCSIS Path Verify Response
CM-STATUS	Status Report
CM-CTRL	CM Control
REG-REQ-MP	Multipart Registration Request

New D3.0 Frames, Headers, & EHDRs

- Queue-depth Based Request Frame
- Upstream Segment Header
- Upstream Privacy EHDR with no piggyback request
- Upstream Privacy EHDR with piggyback queue-depth request
- Downstream Service EHDR
- DOCSIS Path Verify EHDR

MAC New Features

- **MDD: Mac Domain Descriptor**

  A MAC Management Message that defines plant topology and other parameters that are shared in a MAC domain and the CM needs to know about.

- **Plant Topology**

  In DOCSIS 3.0 it is mandatory that the plant topology (fiber nodes and how they are split/combined) is configured in the CMTS

- **Ambiguity Resolution**

  An efficient process for determining which FN a CM is physically connected to (or more precisely, which downstream service group its connected too) is possible thanks to the fact that plant topology is reflected in the MDD

MAC New Features: Contd..

- **Upstream/downstream bonding**

  Sending packets on multiple downstreams for increased downstream throughput. Packets may be sequenced per Service Flow to ensure no out of order delivery

- **DS Service EHDR – DSID and Sequence Number**

  Packets are marked with a DSID which is used as a sequencing index for unicast and as a filter (and sequencing index) for multicast

- **DBC-REQ/RSP/ACK: Dynamic Bonding Change**

  A new message “DBC” (dynamic bonding change) to handle changing of channel assignments and DSIDs. The DSx messages are not impacted. The DBC replaces DCC for DOCSIS 3.0. DCC is only used when moving a modem to a new MAC domain (and modem will always re-initialize in such a case).

MAC New Features: Contd…

- **CM-CTRL: CM Control**

  The CM control message is used to force various actions on the modem, such as reboot, or channel mute. It obsoletes the UP-DIS message

- **CM-STATUS: CM Status Report**

  In DOCSIS 3.0 we may still have a healthy connection to the CMTS even if some of the channel are in failure more. We can use this connection to inform the CMTS of the failures that it can not detect otherwise.

- **DPV-REQ/RSP: DOCSIS Path Verify**

  The DPV message is used to verify the state of a path (in terms of delay and packet loss samples) in the cable network, for example from the CMTS, over the CIN, the QAM and to the CM.

MAC New Features

- **DS Service EHDR – Priority Field**

  Packets are marked with a priority for prioritizing CMCI egress traffic – this is needed because the CM can not re-classify a packet to a flow

- **Application ID**

  Application ID added to the service flow definitions to help define CMTS policies such as admission control, channel assignments, bonded vs. non-bonded operation etc.

- **Bonding Group Attributes**

  Each bonding group has a list or attributes, for example, “high availability” or “low latency”. Each service flow is encoded with a certain set of attributes. This helps the CMTS in flows to bonding group assignment.

MAC New Features: Contd..

- **The CMTS controls error recovery**

  In many cases where a CM is in an intermediate, or incomplete state, it is the responsibility of the CMTS to recover the modem. The modem will not take action on its own.

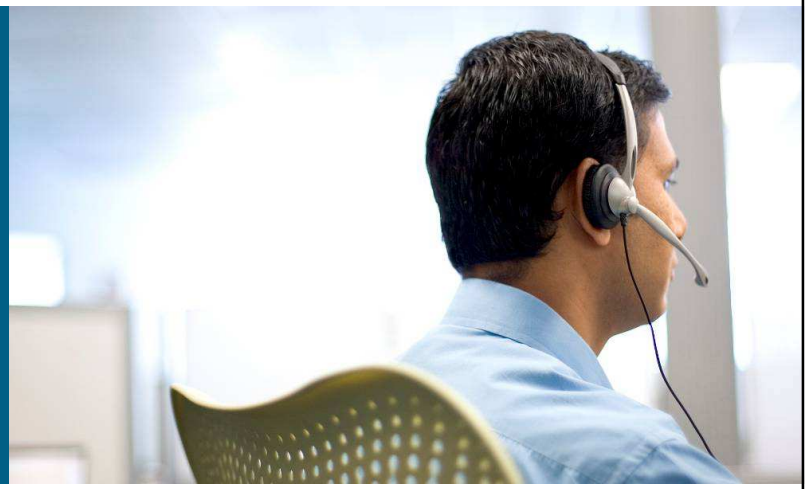
- **Multipart REG-REQ**

  Since the registration request can get fairly long it can be sent it in multiple parts.

- **Receive Channel Profile**

  The CM can send a set of limitations in its receive circuitry to the CMTS. The CMTS can use it for channel assignment to accommodate for these limitations.

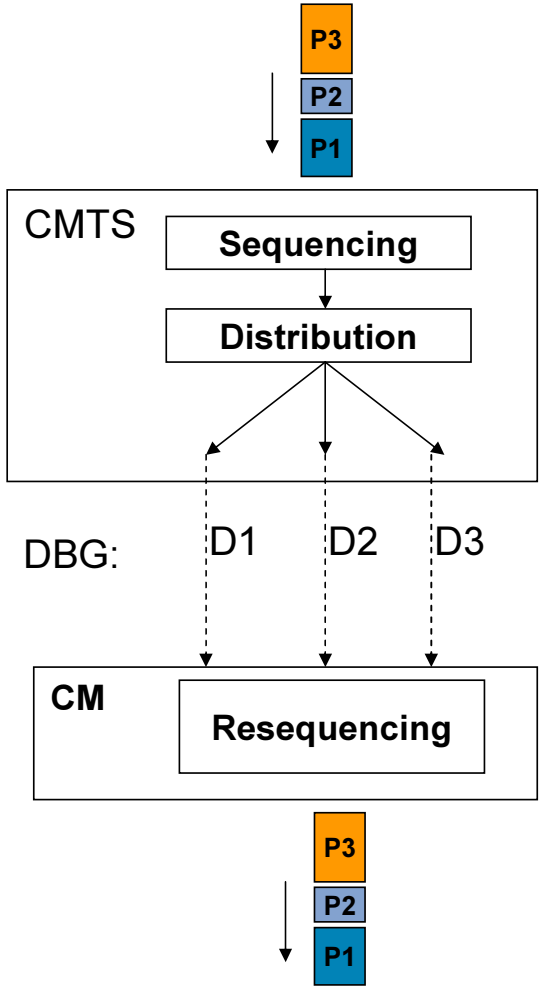
DOCSIS 3.0 DS Channel Bonding



What is downstream channel bonding ?

- **An MLPPP like technology**
- **Each packet is tagged with a sequence number and a re-sequencing index:**
  - The sequence number is used to place packets back in order
  - The re-sequencing index (DSID – downstream service ID) is used so that each flow, or group of flows, could be re-sequenced independently

DS Channel Bonding (Contd..)

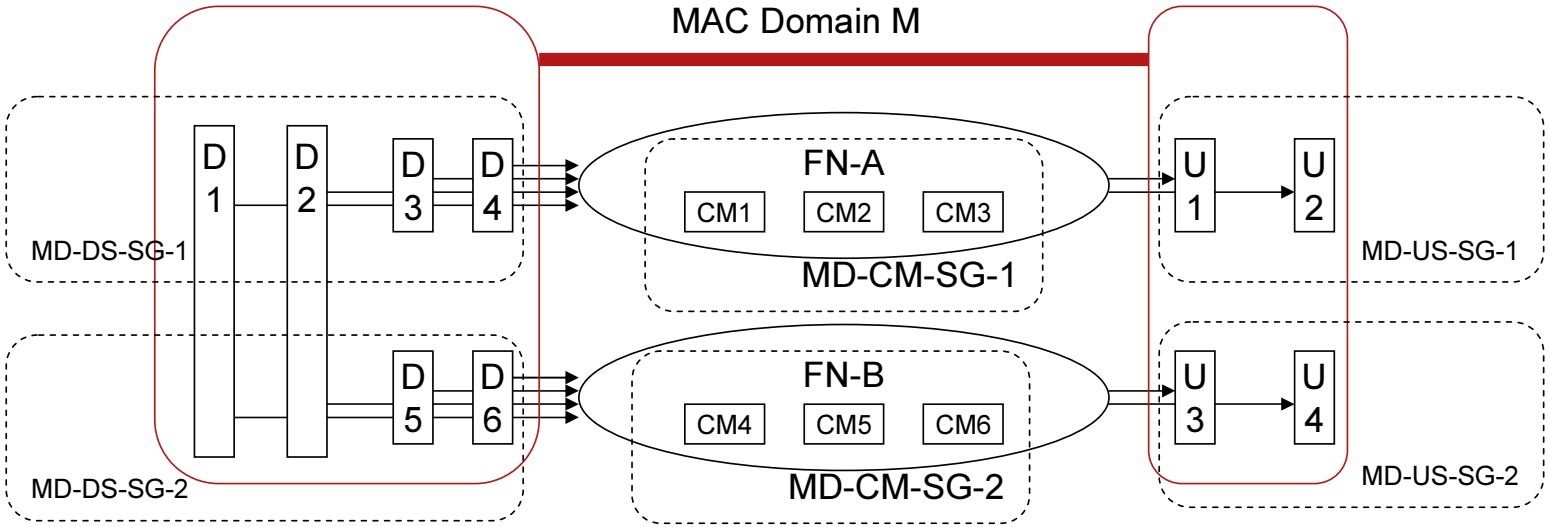


- With DOCSIS 3.0, the CMTS distributes a stream of downstream packets to a set of channels called a “Downstream Bonding Group” (DBG).
- The CMTS usually “sequences” bonded packets by marking them with a packet sequence number.
- Bonded packets may arrive at the CM out of sequence order.
- The CM “resequences” bonded packets and emits them in packet sequence order.

MAC Domain

- Defined as a CMTS subcomponent object responsible for all DOCSIS functions on a set of DS channels and US channels
- A MAC Domain
  - Contains atleast one DS channel and one US channel
  - Provides layer 2 data forwarding services between the CMTS forwarders and the set of CMs registered to that MAC domain (including channel bonding)
  - Implements all DOCSIS MAC management message exchanges with CMs across multiple US and DS channels using a common MAC address for the MAC domain
  - Implements load balancing of CMs and bandwidth among the channels of each DS service group associated with the MAC domain & among the channels of each US service group associated with the MAC domain

MAC Domain Service Groups

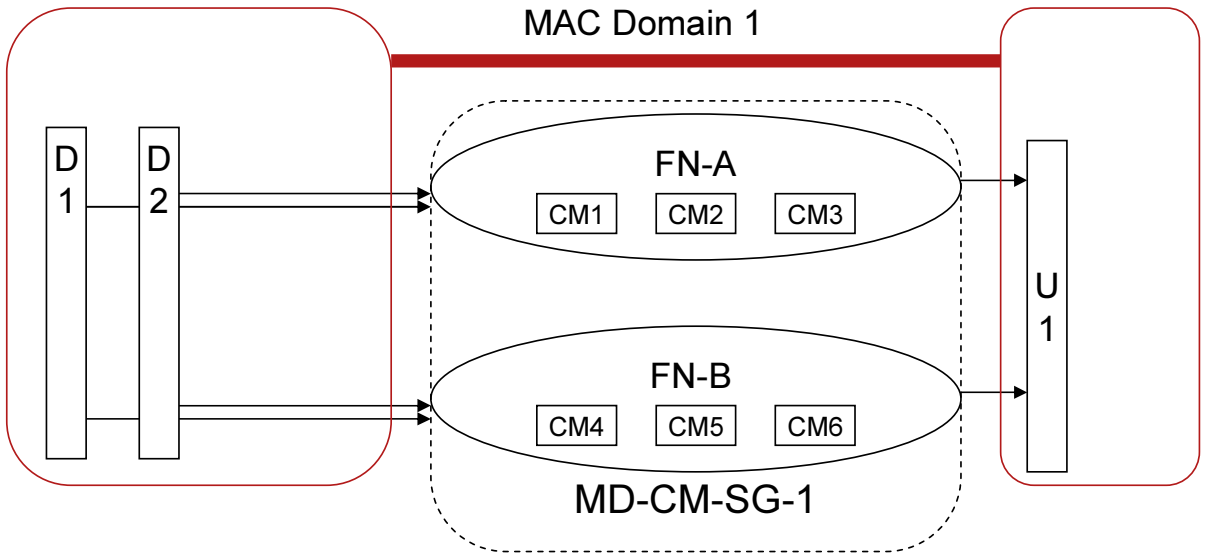


A MAC Domain Downstream Service Group (**MD-DS-SG**) is the set of downstream channels from a single MAC Domain that reach a single CM.
MD-DS-SG-1= D1/D2/D3/D4 MD-DS-SG-2 = D1/D2/D5/D6

A MAC Domain Upstream Service Group (**MD-US-SG**) is the set of upstream channels in a single MAC Domain reached by a single CM..
MD-US-SG-1 = U1/U2 MD-US-SG-2 = U3/U4

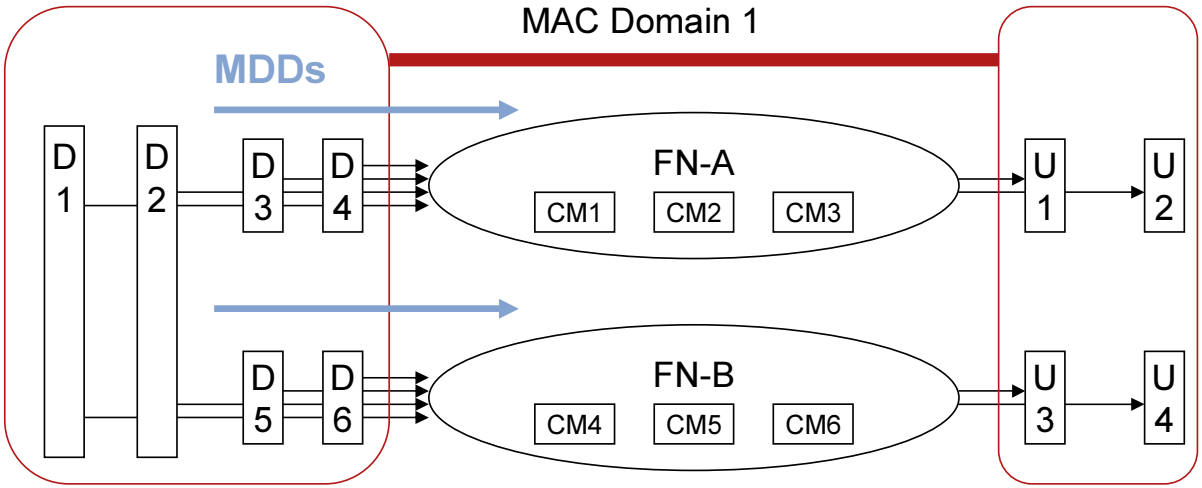
A "MAC Domain CM Service Group" (**MD-CM-SG**) is the full set of channels from a single MAC Domain reaching a single CM.
MD-CM-SG-1 = D1/D2/D3/D4/U1/U2 MD-CM-SG-2 = D1/D2/D5/D6/U3/U4

MD-CM-SGs and Fiber Nodes



Usually, each fiber node is served by a unique set of upstream channels, and each MD-CM-SG corresponds to a single fiber node.
When upstream signals from fiber nodes are combined and downstream channels are split to the same nodes, the same set of channels reaches multiple fiber nodes, and an MD-CM-SG corresponds to multiple fiber nodes.

MAC Domain Descriptor (MDD)

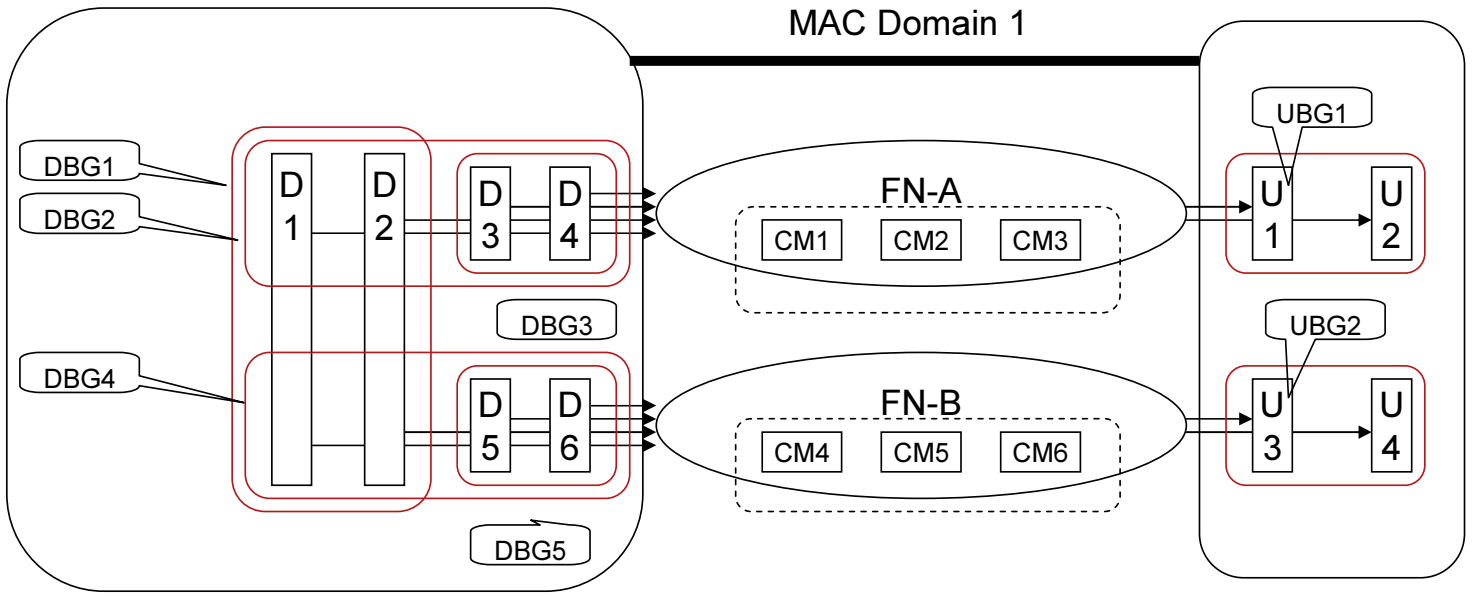


Each CMTS MAC Domain sends a MAC Domain Descriptor (MDD) on each of its downstream channels.

The MDD is used by CMs initializing (ranging and registering) on that MD.

The header of the MDD contains the Downstream Channel ID (DCID) assigned by the MD.

Bonding Groups

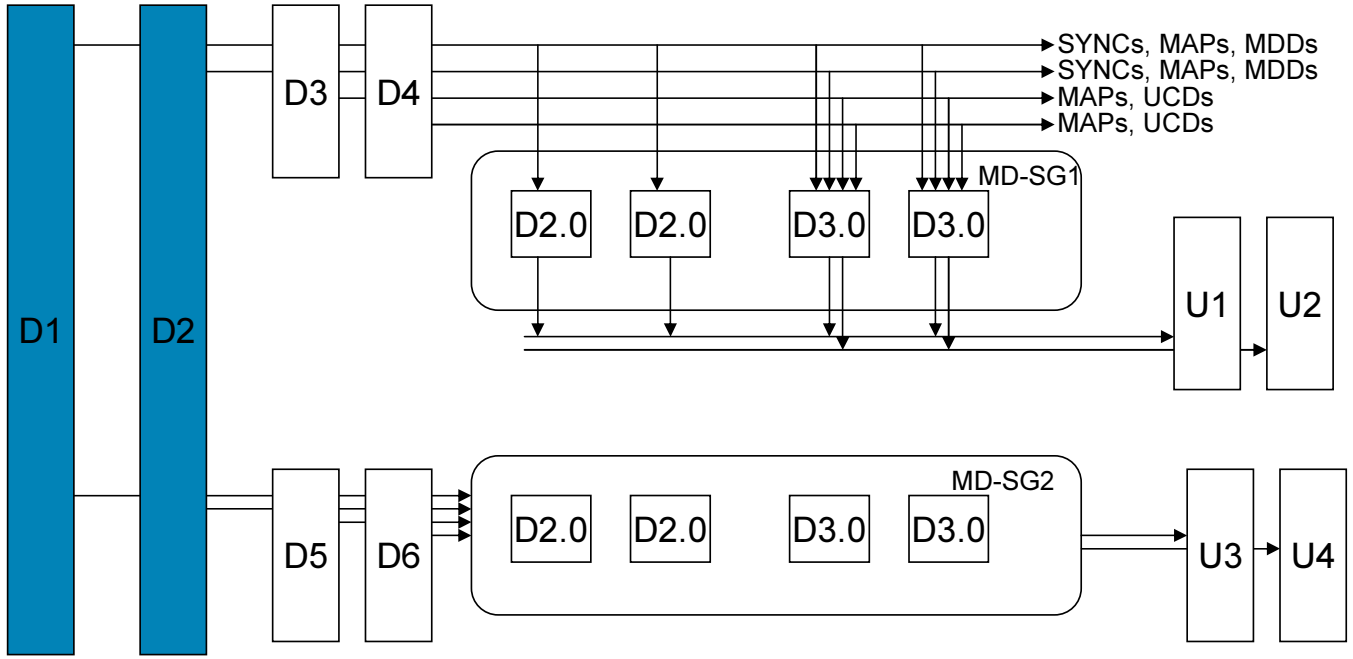


A downstream bonding group (DBG) is a set of channels on which the CMTS distributes a sequence of packets to a set of CMs;

An upstream bonding group (UBG) is the set of channels on which the CMTS schedules a sequence of upstream segments on a SID_cluster.

Primary Capable DS Channels

(All on MAC Domain 1)



Primary Channel of a CM is the DS channel on which it receives SYNCs.
Primary Capable Channel of a CMTS is a DS channel configured to send SYNCs.
D1 and D2 in this figure.

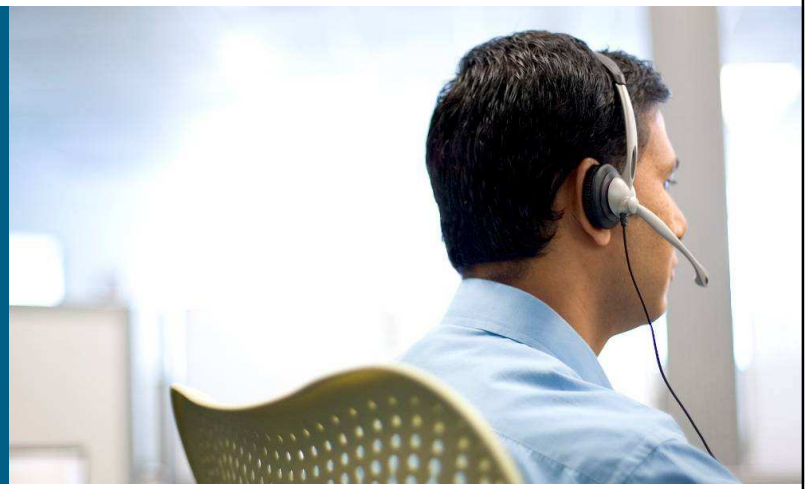
Downstream Service IDs

- At the CMTS, a DSID identifies a “stream of packets to a set of CMs”.
- At the CM, a “bonding” DSID identifies a resequencing context.
- Each bonding DSID identifies a different sequence of packet sequence numbers.
- A CM ignores packet sequence numbers for packets it does not forward.
- DSID per “stream”, not DSID per bonding group

DSID – many meanings for single field

- The DSID serves as:
  - A re-sequencing index
  - DSIDs can be used only on a specific set of QAMs
  - A tag to identify (and filter on) multicast flows
  - Associated with an interface mask on the CM for multicast replication
- How is the DSID related to service flows ?
  - Not directly related
  - Several service flows can map to one DSID
  - Several DSIDs can map to a single service flow
  - DSIDs and service flows are signaled independently, in other words, there is no messages that associated a service flow to a DSID

DOCSIS 3.0
US Channel Bonding



Upstream Channel Bonding

- Upstream bonding

  Designed so that a single flow can consume the available BW on multiple upstreams.

- Continuous Concatenation and Fragmentation (CCF)

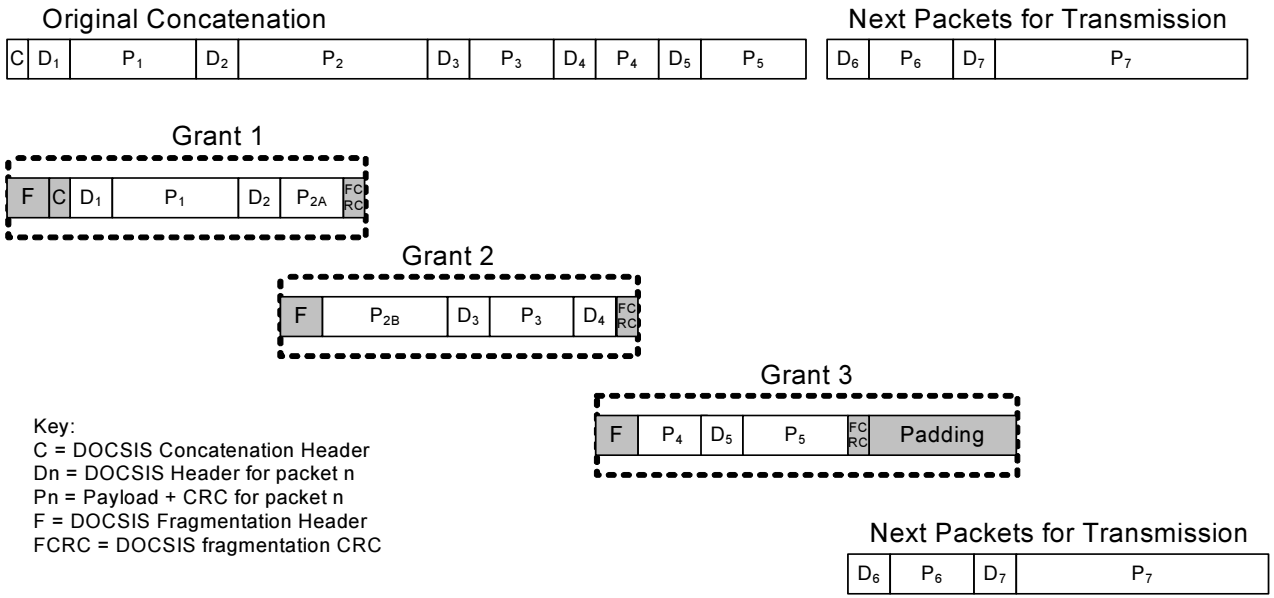
  An improved form of both concatenation and fragmentation that is needed for DOCSIS 3.0 operation.

- Multiple outstanding grants per SID, or multiple SIDs with a single outstanding request, or both

Granting Bandwidth in MTC Mode

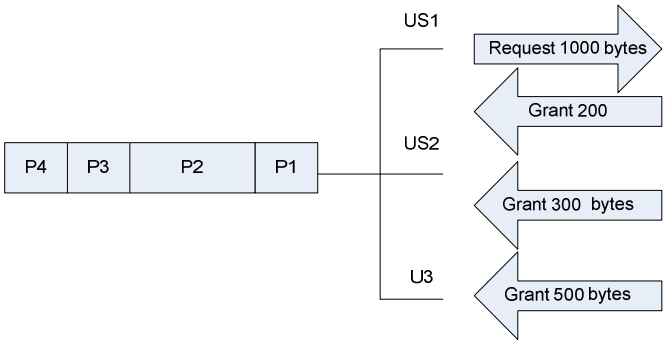
- CMTS scheduler allocates bandwidth on the individual channels based on the available bandwidth on all of the bonded US channels
- For a request transmitted on any individual channel bandwidth may be allocated on any combination of upstream channels within the bonding group associated with the requesting service flow
- In this manner CMTS performs real time load balancing across US channels

Pre-DOC3.0 Concatenation & Fragmentation



- Legacy DOCSIS encapsulates each fragment with a fragment header and fragment CRC adding 16 bytes to each fragment.
- Multiple packets can only be combined through concatenation.
- Fragments cannot be combined with other fragments or whole PDUs in a burst.
- Inefficient whenever packets are split across grants.

CCF – Continuous Concatenation Fragmentation



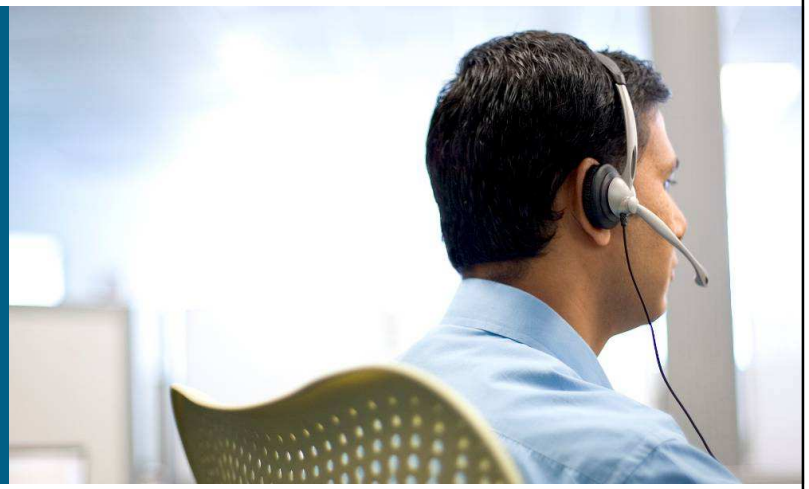
The CM has a buffer with a 1000 bytes to send. Its requests for 1000 on US1, the CM receives grants on US1, US2 and US3. The size of the grant may depend on the load on that channel

The CM does not send packets since the grant might not align with packet boundaries

Instead the CM sends "segments"

Each segment has a sequence number, and a pointer field so that individual packets Can be extracted (the pointer field is similar to the one used on the MPEG pointer In the DS

DOCSIS 3.0 - PHY



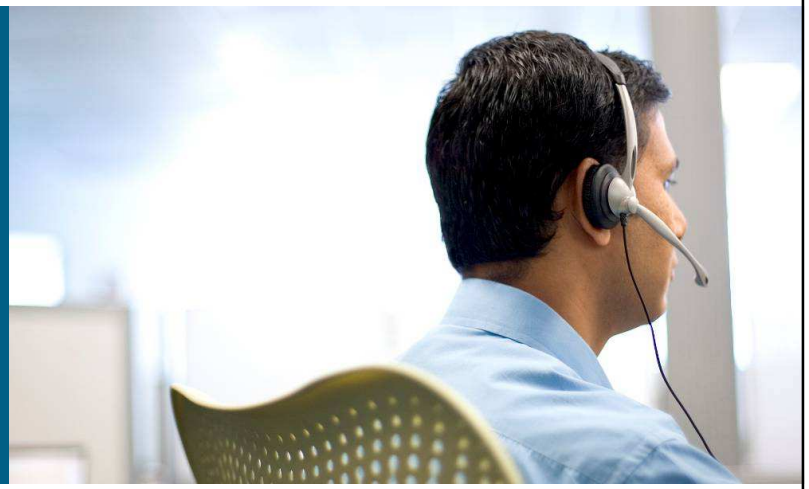
DOCSIS 3.0 PHY Enhancements

- Downstream bonding requiring the simultaneous demodulation of a minimum of 4 carriers in a minimum capture band of 60MHz.
- Upstream bonding requiring the simultaneous burst transmission of up to 4 carriers.
- Upstream frequency has been increased

  Options for either 65MHz or 85MHz.
- Lower symbol rates eliminated,

  Only 1.28ms/s 2.56ms/s and 5.12ms/s are used in DOCSIS 3.0.
- Normal downstream operating range increased from 860 MHz up to 1002 MHz

DOCSIS 3.0- Enhanced Multicast



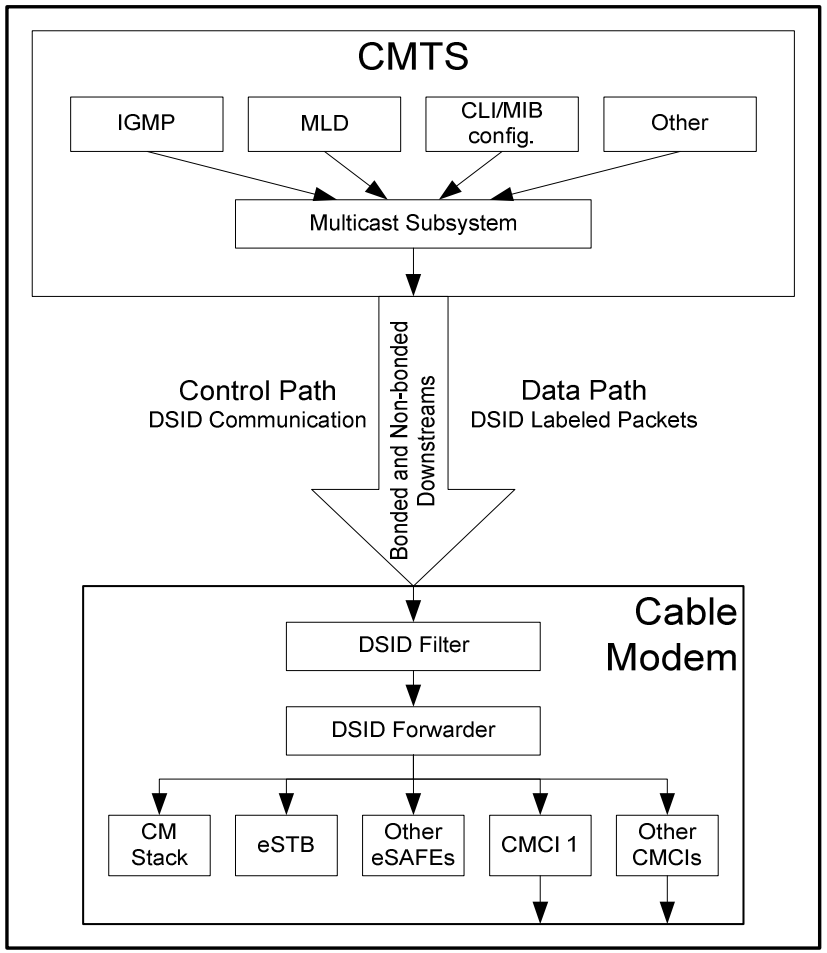
D3.0 Multicast - Goals

- Support for SSM and IGMPv3
- IPv6 multicast support (pre and post registration)
- Support for Multicast QoS
- Support for bonded multicast
- Support for non-IGMP based multicast
- Maintain backward compatibility with legacy DOCSIS devices
- Enable explicit tracking of multicast listeners

D3.0 Multicast - Architecture

- No IGMP snooping in the CM
- DSID label used to identify a replication of a multicast stream
- CMTS has complete control of multicast forwarding in the CM via *DBC* messaging
- Multicast filtering and replication within the CM
  - Based on DSIDs
  - GMAC promiscuous operation

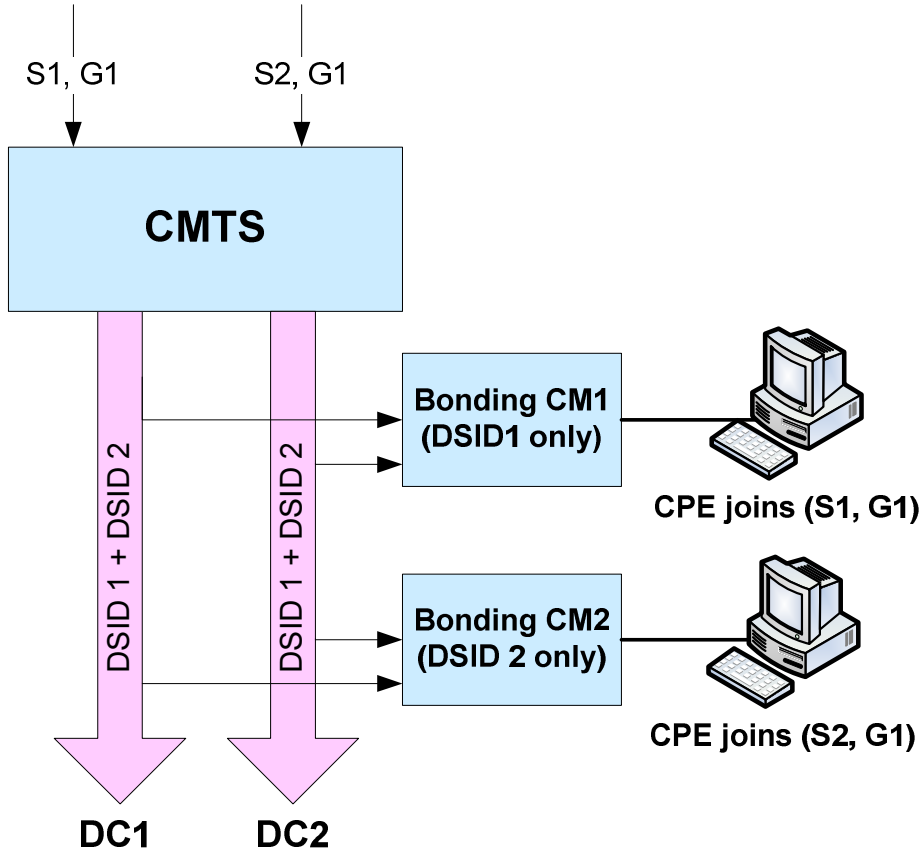
D3.0 Multicast - Architecture



Multicast DSID forwarding (MDF) support

- Identifies group of CMs receiving a multicast replication from the CMTS
- CMTS allocates unique DSID within a mac domain for each replication of each session to prevent duplicate packets to D3.0 CMs
- CM discards multicast packets with unknown DSID
- CM discards multicast packets without DSID label
- D3.0 CM supports GMAC promiscuous operation
- DSID used by CM to replicate to appropriate egress interface using signaled CMIM and/or CPE MAC list

Multicast DSID forwarding (MDF) support



D3.0 Dynamic multicast support

- CM provisioned in D3.0 mode does not snoop IGMP/MLD packets
- CMTS supports IGMPv3 and MLDv2
- CMTS sends periodic IGMPv2, IGMPv3, MLDv1 and MLDv2 general queries
- CMTS does not echo back membership reports
- CMTS can track membership explicitly
  - Per-CPE basis for IGMPv3/MLDv2
  - Per-CM basis for IGMPv2/MLDv1
- CMTS needs to ensure that the right version of IGMP/MLD general queries is forwarded through a CM

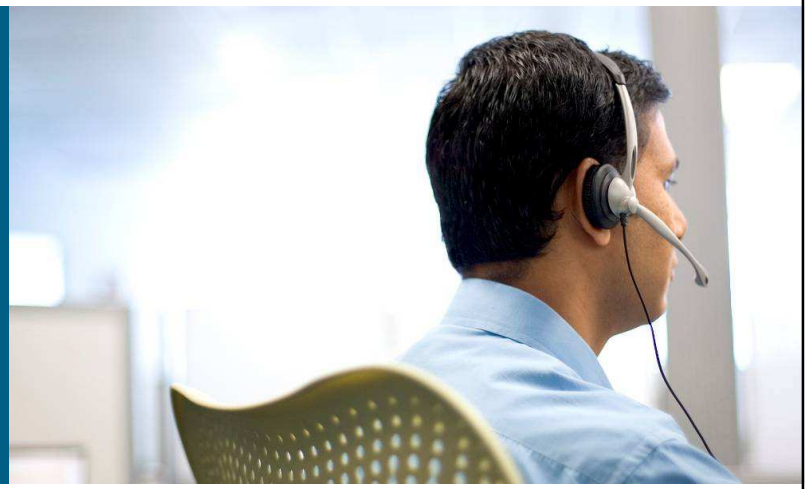
D3.0 Dynamic multicast support: Contd..

- When CMTS receives join request from a multicast client, it signals the DSID to the CM using DBC messaging with client MAC address and encryption info
- If CMTS receives join request from another multicast client behind that CM, it signals that client MAC address to the CM to control stream replication within the CM
- When CMTS receives a IGMPv2/MLDv1 leave message it checks for additional receivers behind the CM using a group-specific query directed to that CM
- If there are no receivers (IGMP query times out), it signals the CM to delete the DSID

D3.0 Static multicast support

- Useful for “always-on” service
- CMTS supports Static Multicast Session Encoding TLV in CM config file
  - Contains 1 group address
  - For SSM, 1 source address (not included for ASM)
  - CMIM to control multicast session replication with CM
- CMTS treats this TLV similar to an IGMP join
- CMTS includes corresponding DSID along with CMIM and encryption info in registration response
- Static multicast forwarding to a CM is unaffected by IGMP leaves or query timeouts

DOCSIS 3.0- Security



Security Objectives

- **Secure provisioning of CMs**
  - Unauthorized CMs can be prevented network access
- **Encrypt data traffic between the CM and CMTS**
  - Best effort IP data traffic
  - QoS enabled IP data traffic
  - Multicast group traffic

Early Authentication and Encryption (EAE)

- Provides enhanced security
- Authenticate CM after Ranging/before DHCP
  - Network admission control
  - Eliminate possibility of bypassing authentication by manipulating config file
- EAE Signaling: TLV 6 in MDD (MAC Domain Descriptor) Message
- Can be enabled on a per CM or per MAC domain basis
- Per CM traffic: encrypted using primary SA (security association)

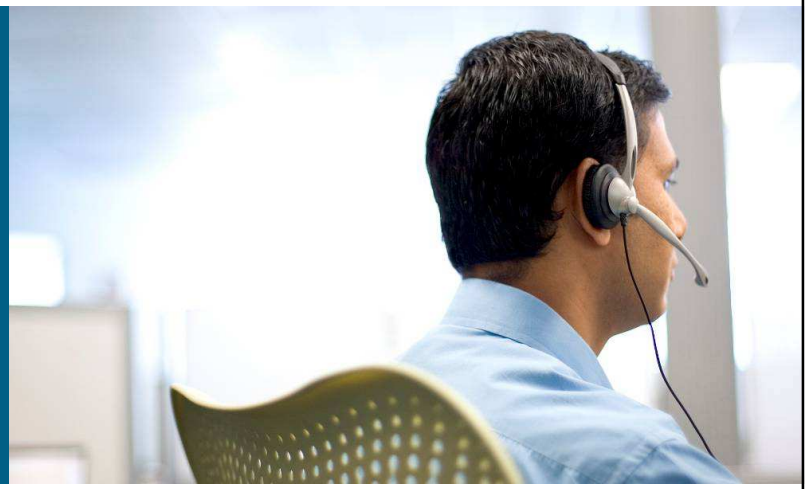
Enhanced Security – Secure Provisioning

- Authentication reuse:
  - Encrypt DHCP, TOD, TFTP, and REG-REQ
- CMTS TFTP Proxy
  - CMTS acts as a TFTP server to the CM and as TFTP client to the provisioning server
  - This allows config parameters enforcement since CMTS receives the config file first from the Provisioning Server
  - Config file authorization
  - TFTP options: CM MAC addr and IP addr
- DHCPv6 authentication: Lightweight protocol
- New MIC hash algorithm: MMH

Enhanced Security – Additional Features

- AES required on CM and CMTS for DOCSIS 3.0
  - DES is required for backwards compatibility
- Source-verify is now standardized
- ARP rate-limit
- Certificate Revocation: CRL + OCSP
- Enhanced software validation

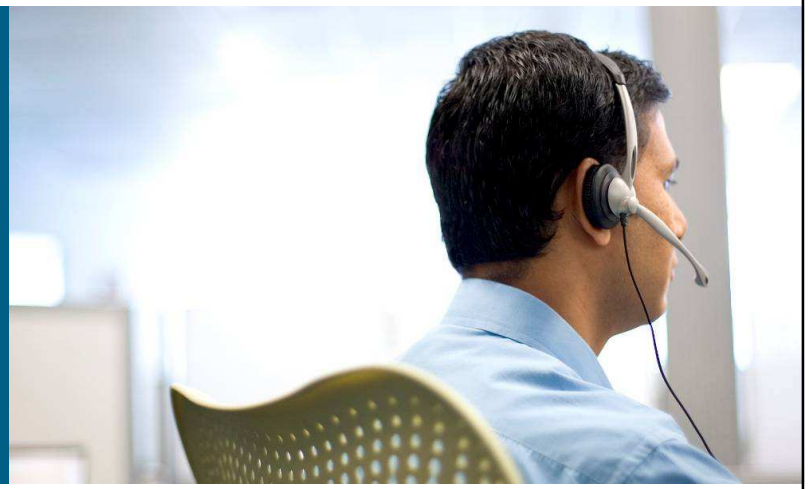
DOCSIS 3.0- OSSI



Network Management – Features

- IPDR service definitions
  - Fault management service specifications including diagnostic log
  - Configuration service specifications including CM topology
  - Accounting service specifications including optimized SAMIS
  - Performance service specifications including spectrum measurement
  - Security service specifications including CM status
- Diagnostic Log
  - Object descriptions are for fault management
  - Included in OSSI Annex G
- Enhanced Signal Quality Monitoring
  - Based on PHY requirements, object descriptions are for performance management
  - Included in OSSI Annex J

IPv6 in Cable Networks



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IPv6 More Than Just Addresses

- New address size and format
  - 128 bit vs. 32 bit addressing, 10B vs. 250M nodes
- Equitable global assignment
- Smarter packet
  - Simplified provisioning
    - Facilities for automatic configuration beyond DHCP
  - Built-in security
    - Mandated IPSec support
  - Improved mobility
    - Seamless handover between IP sub-networks
  - QoS via flow labels*
    - Even when the packet payload is encrypted
  - Support for Anycast and enhanced Multicast

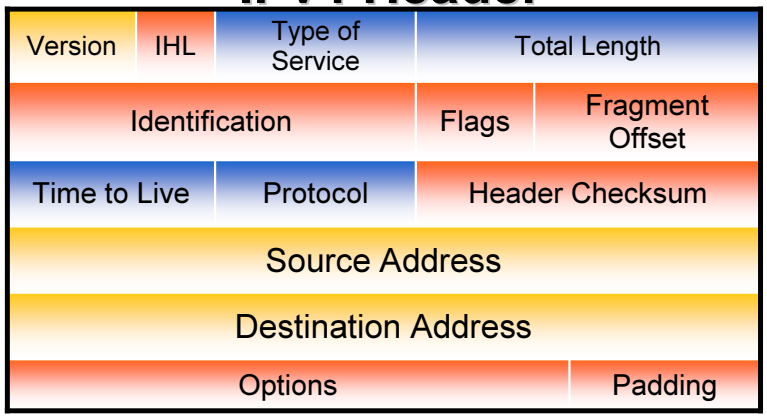
*** Not yet available from an implementation stand point**

Legacy IPv4 vs. IPv6 Comparisons

IP Service	IPv4 Solution	IPv6 Solution
Addressing Range	32-bit, Network Address Translation	128-bit, Multiple Scopes
Autoconfiguration	DHCP	Serverless Configuration, DHCP
Security	IPSec Optional	IPSec Mandated, works End-to-End
Mobility	Mobile IP	Mobile IP with Direct Routing
Quality-of-Service	DiffServ, IntServ	DiffServ, IntServ, Flow Labels
IP Multicast	IGMP/PIM/Multicast BGP	MLD/PIM/Multicast BGP,Scope Identifier
IP Anycast	--	Supported

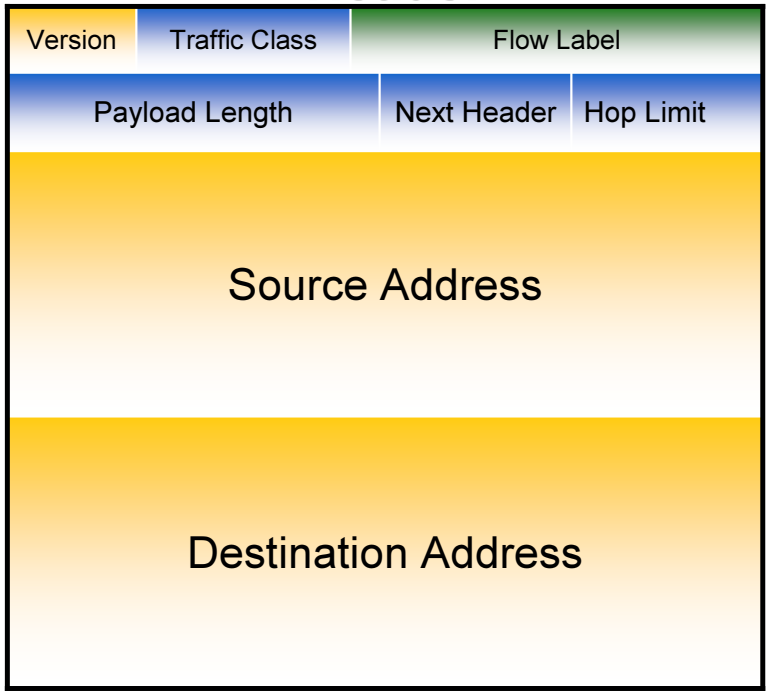
IPv4 & IPv6 Header Comparison

IPv4 Header



20 bytes (without options)

IPv6 Header



40 bytes

Legend

- field's name kept from IPv4 to IPv6
- fields not kept in IPv6
- Name & position changed in IPv6
- New field in IPv6

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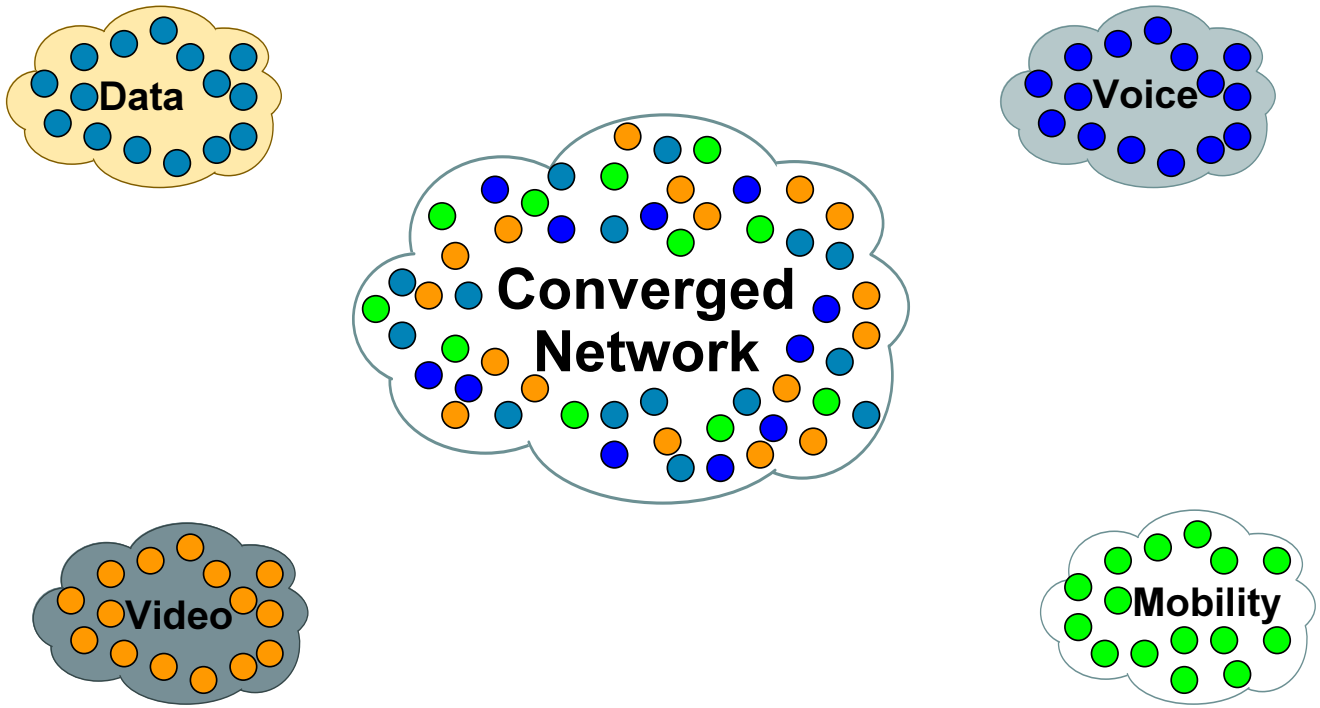
Why do Cable MSO's need IPv6 *now?*

- Convergence of multiple services over IP is driving the need for large scale addressing
  - MSO infrastructures
  - Home/SMB networks
- Industry consolidation has led to mergers of IP networks with overlapping addresses
  - Managing overlapping private address spaces is complex and expensive …
- Consumers demanding plug-&-play operation
  - Sling-boxes, IP cameras, PDAs, gateways, automobiles, media centers, IP phones, etc...
- Next generation applications require global transparency
  - Peer-to-peer connectivity without NAT
- Next generation services require access transparency
  - Seamless roaming across networks for fixed/mobile convergence

All IP Quad Play

Convergence of n IP networks calls for huge scale (nxIP) address space.



Industry Consolidation

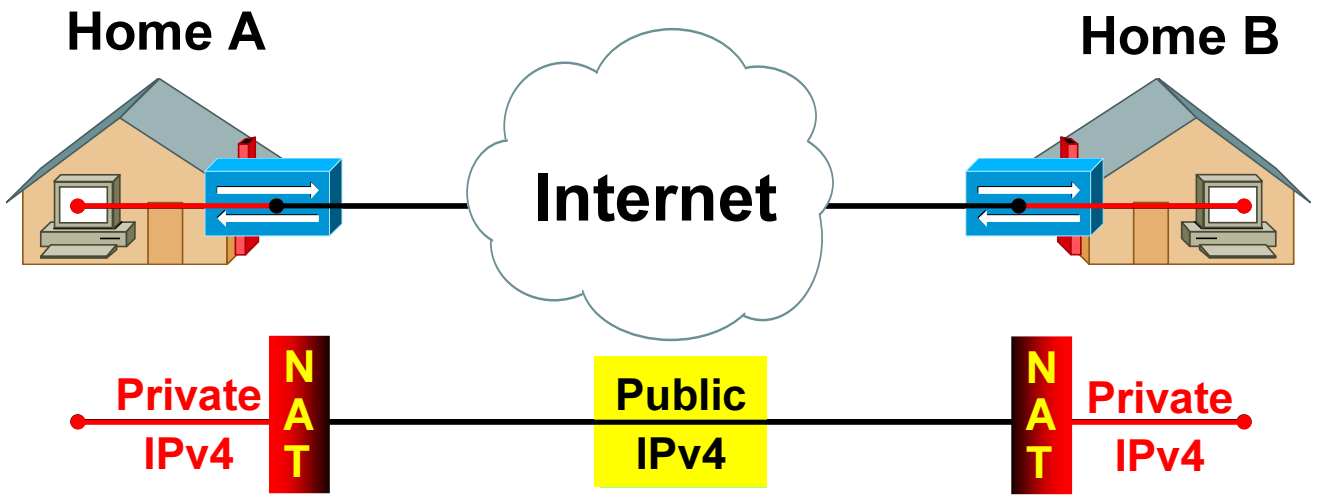
Merger of networks with over-lapping address space calls for large, non-overlapping address space.

Plug-n-Play Home Networking

Premises network(s), automatic config. beyond DHCP

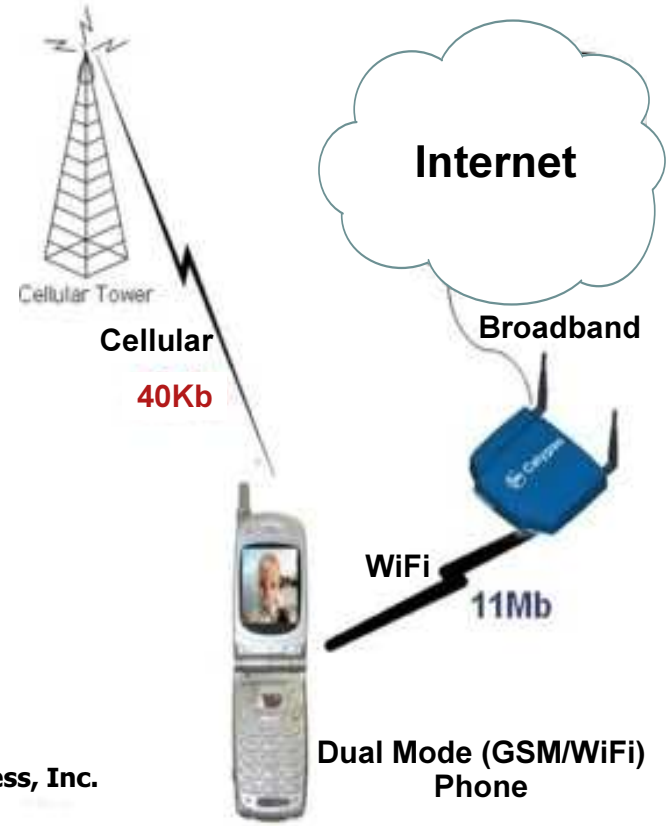
Global Transparency

IPv6 restores global transparency by getting rid of NAT.



Access Transparency

Mobile IPv6 improves mobility across access networks.



Sample Example : Calypso Wireless, Inc.

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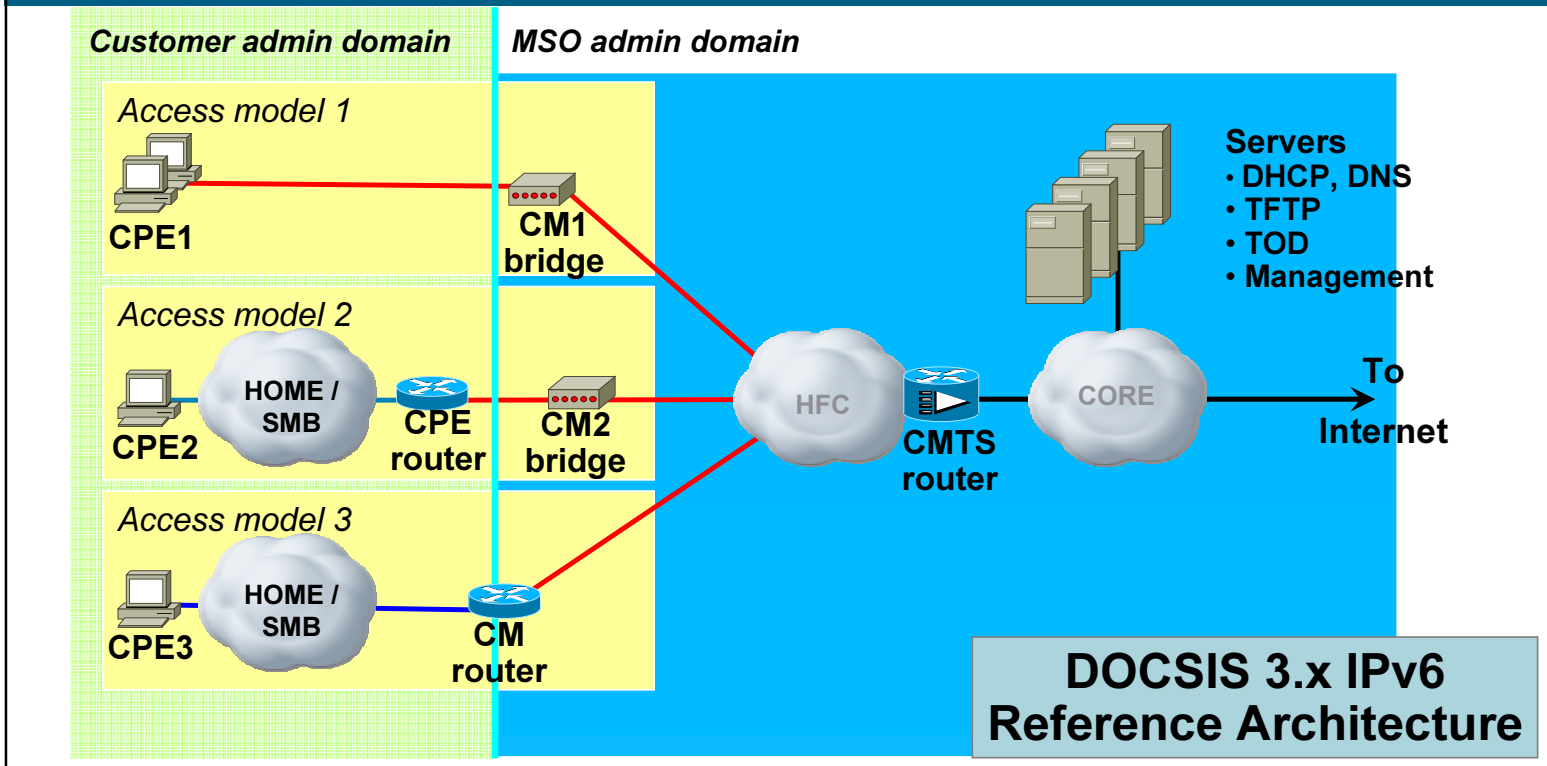
CableLabs IPv6 Decision and Approach

- CableLabs members put IPv6 in consideration for DOCSIS 3.0
  - IPv6 was amongst the top DOCSIS 3.0 feature candidates
- Result: DOCSIS 3.x MUST fully support IPv6
- Rationale
  - Increased address space for CM management
  - CPE services
- Proposed phases
  - Phase 1 –CM provisioning and management over IPv6; embedded IPv6 router
  - Phase 2 – Remaining IPv6 features for CPE services, for example IPv6 CPE provisioning and IPv6 service support

IPv6 Features in DOCSIS 3.0

- Customer will have premises network, not individual CPEs on HFC
  - "Lightweight router" function to be defined as eSAFE function
  - Customer will be assigned /48 prefix for sub-delegation within premises network
- CM can be provisioned and managed exclusively through IPv6
  - Relieves pressure on IPv4 address space
  - Customer can still receive IPv4 service (dual-stack network)
- HFC may have management prefix for CMs and managed CPEs, and service prefix for data service
- DHCPv6 used for address assignment to meet MSO requirement for IPv6 address control
- Fields, options and sub-options from DHCPv4 redefined as vendor-specific options in DHCPv6



Management prefix: 2001:DB8:FFFF:0::/64
Service prefix: 2001:DB8:FFFE:0::/64
Customer 2 prefix: 2001:DB8:2::/48
Customer 3 prefix: 2001:DB8:3::/48

HFC link; assigned 2001:DB8:FFFF:0::/64 (mgmt) and 2001:DB8:FFFE:0::/64 (service)
Customer 2 premises link; assigned 2001:DB8:2:1::/64
Customer 3 premises link; assigned 2001:DB8:3:1::/64

Routers span customer and MSO administrative domains

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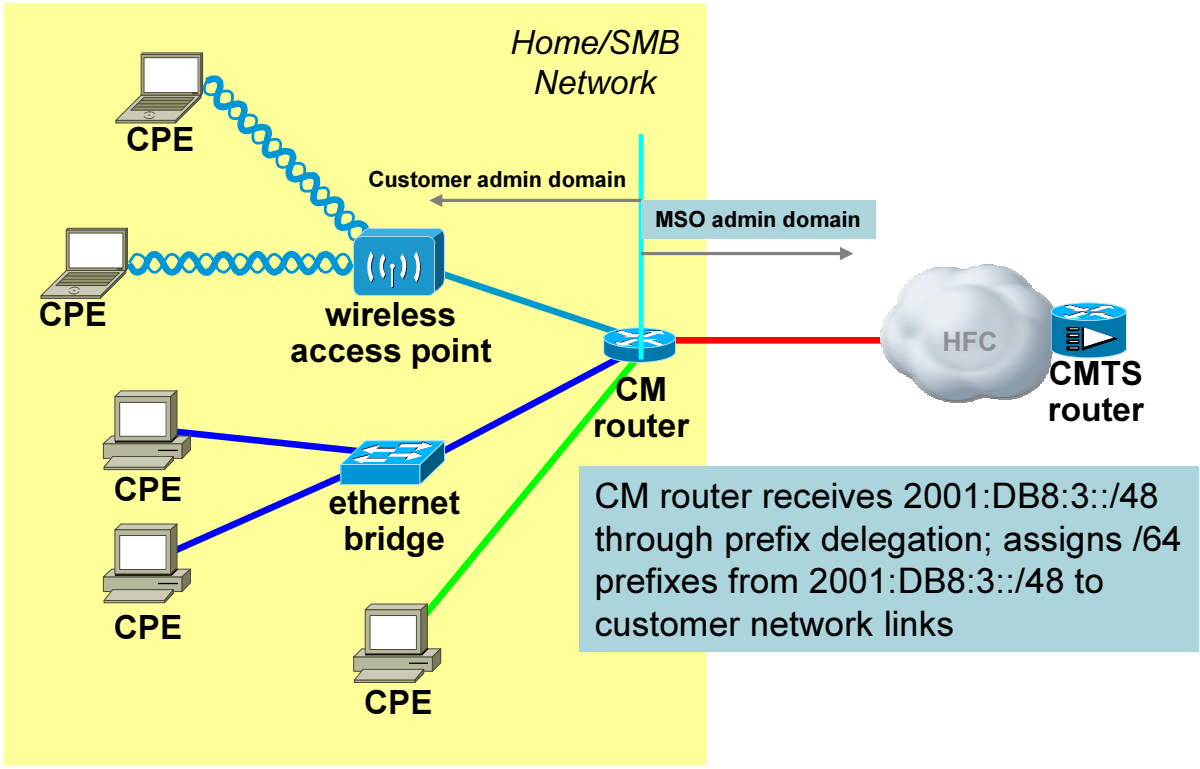
Access Model 3 – Zoom In View



CM router receives 2001:DB8:3::/48 through prefix delegation; assigns /64 prefixes from 2001:DB8:3::/48 to customer network links

HFC link; assigned 2001:DB8:FFFF:0::/64 (mgmt) and 2001:DB8:FFFE:0::/64 (service)

Customer 3 premises link 0; assigned 2001:DB8:3:0::/64

Customer 3 premises link 1; assigned 2001:DB8:3:1::/64

Customer 3 premises link 2; assigned 2001:DB8:3:2::/64

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Theory of Operations: DOCSIS 3.0

- CM can operate in either bridging or routing mode
- CM management stack can operate in
  - IPv4 only mode
  - IPv6 only mode
  - Dual mode
- CM instructed by the CMTS via an L2 message (MDD) as to what mode to use

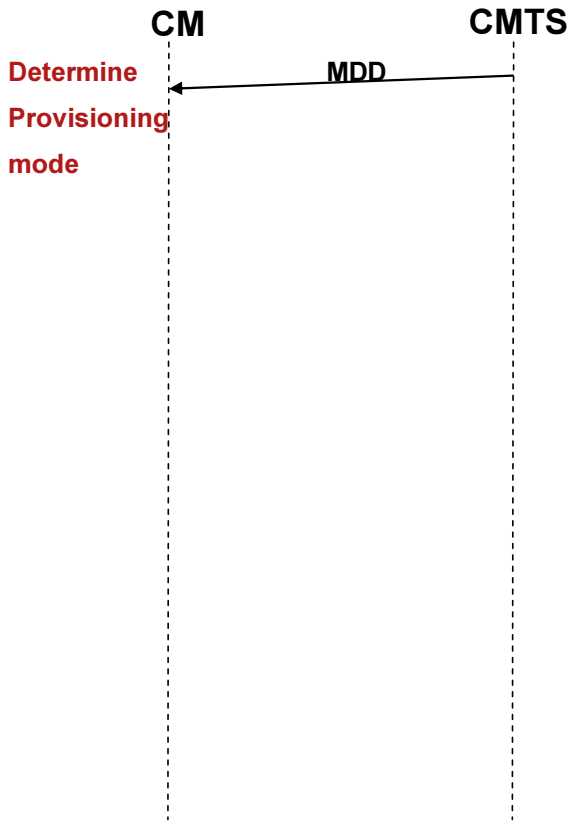
  If the CM does not receive any message from the CMTS it operates in DOCSIS 2.0 mode

CM provisioning

- Layer 2 provisioning
- Acquire IPv6 connectivity
- Obtain time of day
- Obtain configuration file
- Complete registration

CM provisioning: Layer 2

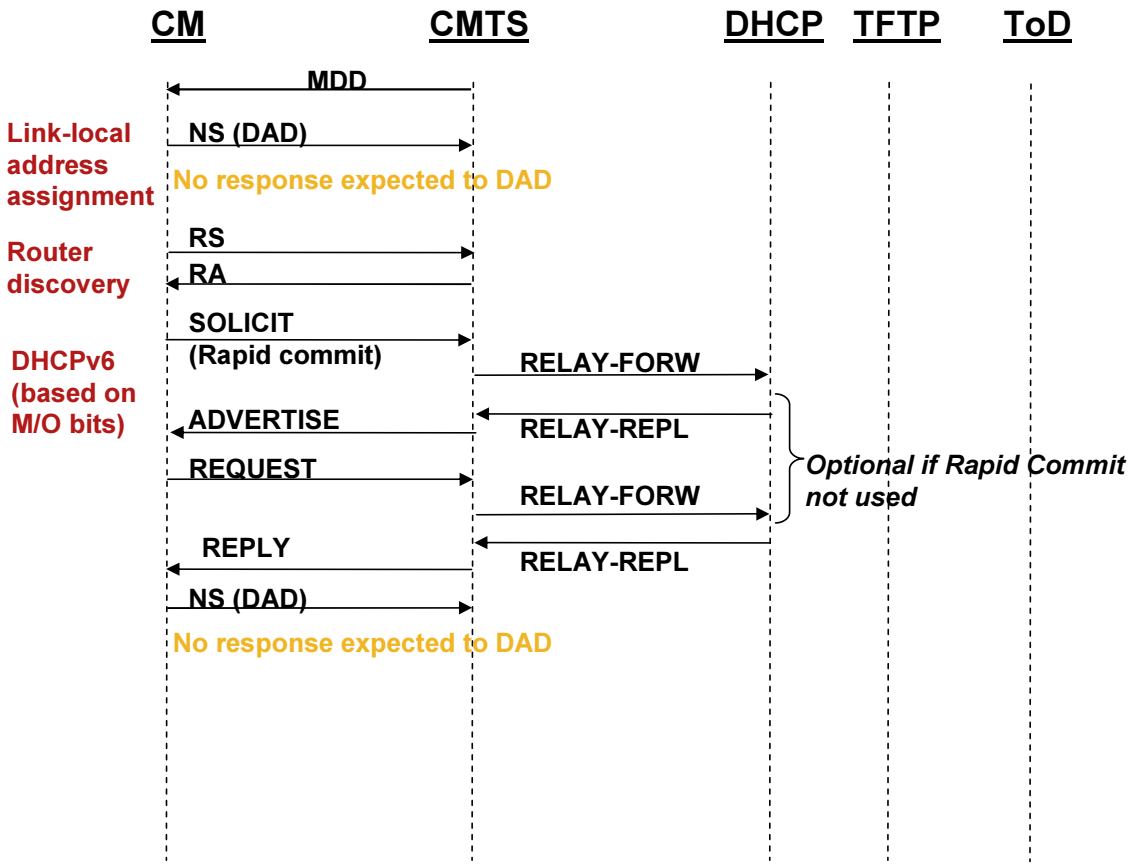
- CMTS sends an L2 message to the CM that controls
  - Use of IPv4 or IPv6 as the preferred mode for CM provisioning and management
  - Dual stack management
  - Alternate Provisioning Mode (APM): If preferred mode fails, restart provisioning in the alternate mode



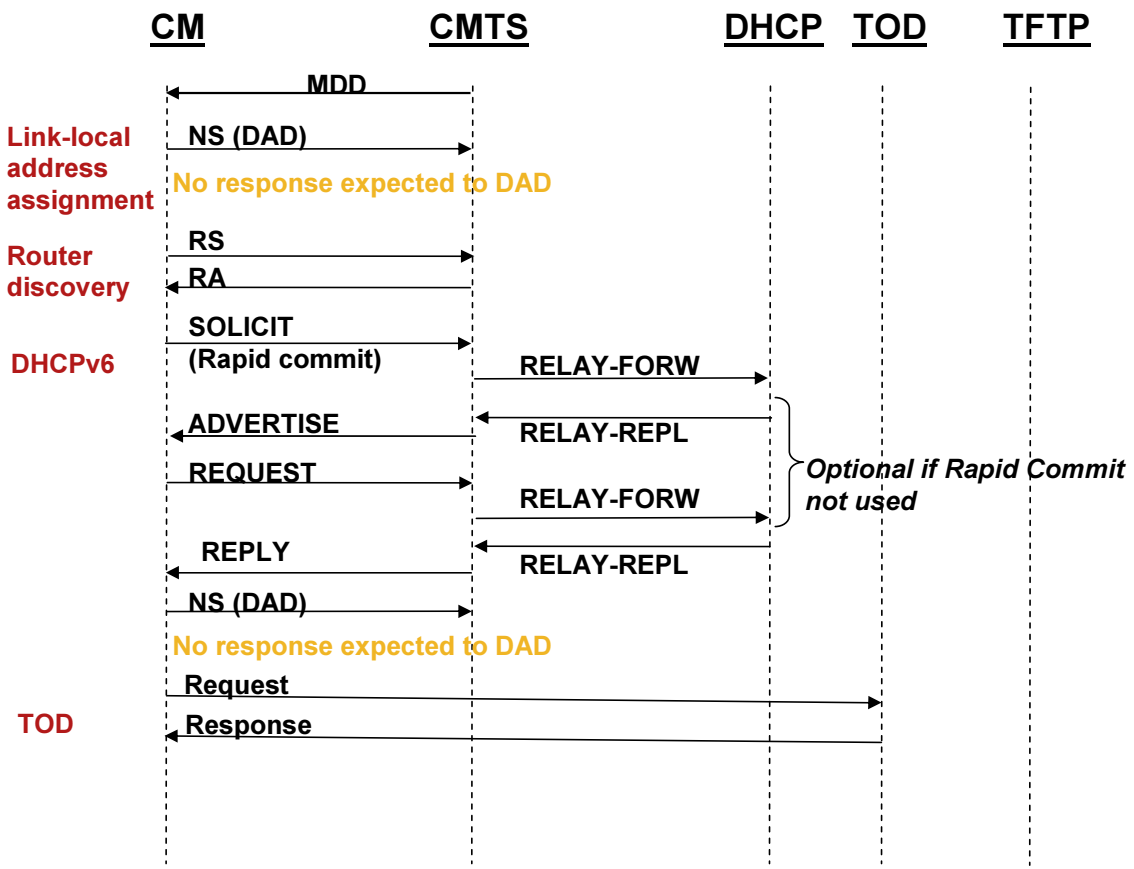
CM Provisioning: Acquire IP connectivity

- DHCPv6 used for address configuration
  - Stateless auto configuration NOT used
  - M and O bits set appropriately in RAs from the CMTS
- MSOs want to have the knowledge and want to control IP address assignments
- MSOs used to DHCP. Minimizes changes in operational models
- Dynamic DNS updates can be done at the DHCP servers (instead of relying on CPEs and CMs)

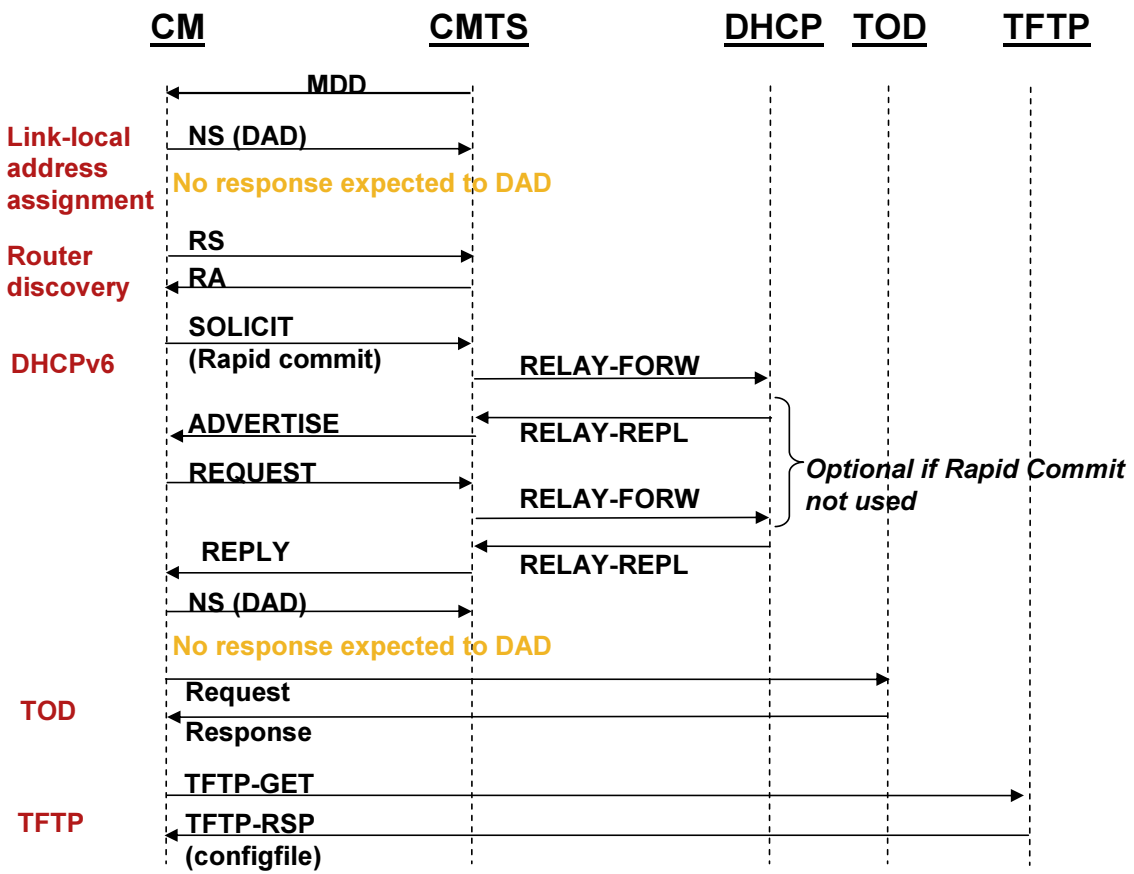
CM Provisioning: Acquire IP connectivity



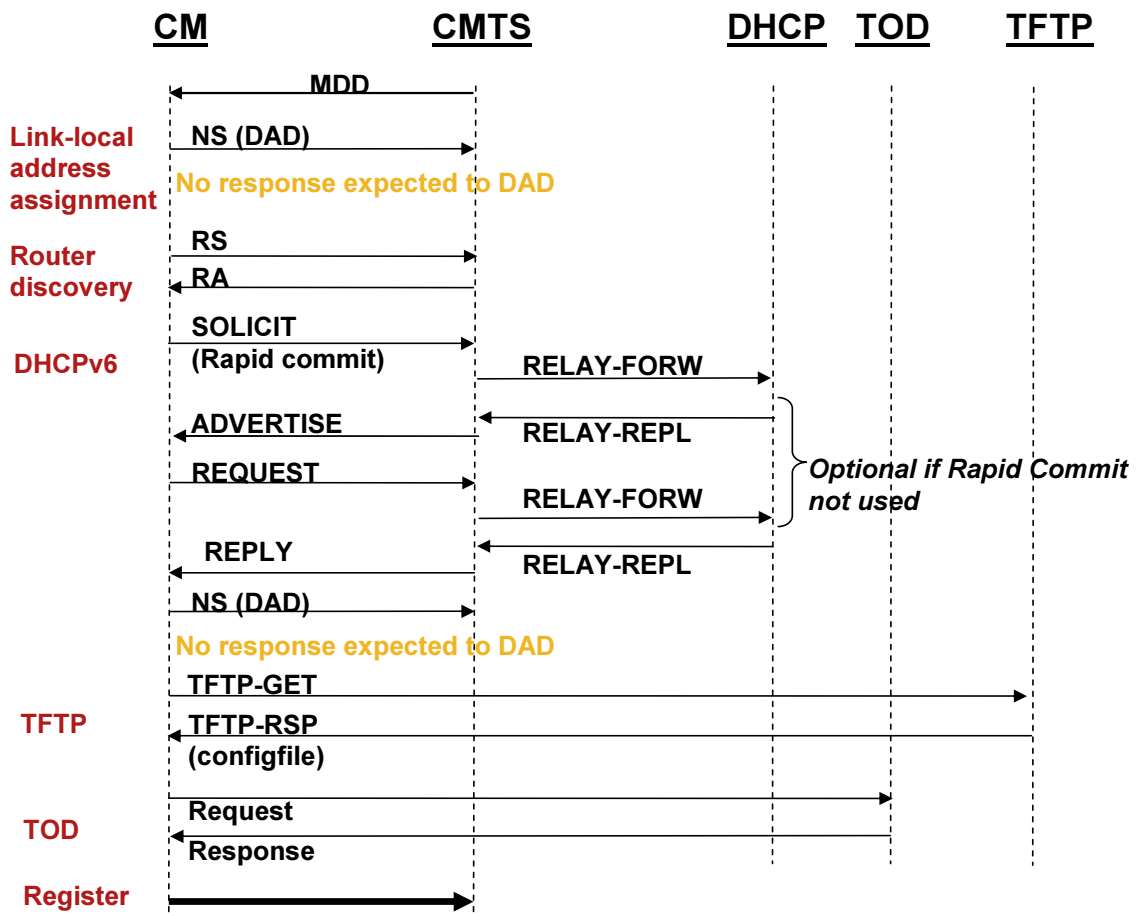
CM Provisioning: Obtain TOD



CM Provisioning: Obtain Configuration File



CM Provisioning: Complete Registration



Dual Stack Management

- CM directed to use dual stack management via MDD message
- After registering with either IPv4 or IPv6 address, the CM acquires the additional IP address type using DHCP
- Allows the MSOs to manage the CMs using SNMP carried over IPv4 or IPv6
  - Useful during the transition period

Alternate Provisioning Mode (APM)

- To improve provisioning reliability
- CM first uses primary provisioning protocol (IPv6 or IPv4) as specified by MDD message
- If primary provisioning mode fails, the CM tries to provision itself using the other protocol

  e.g., if primary mode is IPv6 and it fails, CM restarts provisioning in IPv4 mode (only if APM is configured)

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CMTS requirements for IPv6

- CMTS can be a bridge or a router
  - Provides IP connectivity between hosts attached to CMs and the core data network
- Acts as a relay agent for DHCPv6 messages
  - Inserts some options in the request. Receives some options in the response
- Participates in Neighbor Discovery (ND)
  - Forward ND packets from one host to other
  - Optionally implement an ND proxy service
- Generates RA messages towards the cable network (RF side)
- Multicast: ASM, SSM, Forwarding IPv6 control traffic (ND, RA etc.)
- Backward compatibility with CMs running previous versions of DOCSIS

CM (bridge) requirements for IPv6

- Address assignment through DHCPv6
- Support APM and dual stack mode
- Management via SNMP over IPv4 or IPv6 or dual stack IPv4 and IPv6
- Allow data IPv4 and IPv6 data forwarding from CPEs, regardless of how the CM is provisioned

Embedded IPv6 (CM) Router requirements

- Implement DHCPv6 client for acquiring IPv6 prefix (Prefix delegation)
- Support SLAAC for CPE hosts
- Implement DHCPv6 server to support PD or address assignments to CPE hosts
- Support ND and RS queries from home CPE devices
- Support propagation of config information (DNS servers etc.) to home CPE devices
- Support MLDv1 and MLDv2 for multicast

Q and A