Docsis 3.0 Workshop

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Objectives (1st Half of the Workshop)

- Understand the motivation for DOCSIS 3.0
- Understand the similarities/differences between DOCSIS specifications
- Understand the key features and concepts of DOCSIS 3.0
- Understand the CMTS models described in DOCSIS 3.0 specifications
- Understand DOCSIS 3.0 qualification and certification requirements
- Understand some possible network designs to deploy DOCSIS 3.0 services

Agenda

- **Why DOCSIS 3.0?**
- **DOCSIS Specification Comparison**
- **DOCSIS 3.0 Features and Concepts**
- **DOCSIS 3.0 Qualification and Certification**
- **DOCSIS 3.0 CMTS Models**
- **DOCSIS 3.0 Network design examples**
- **Q&A**

Why DOCSIS 3.0?

Why DOCSIS 3.0?

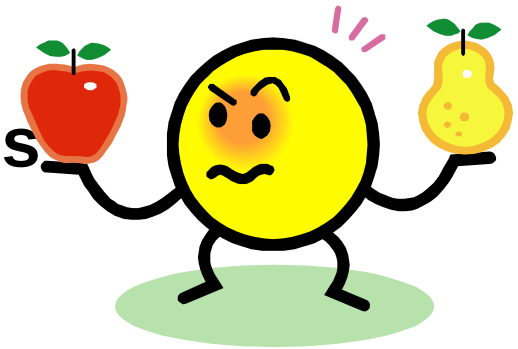
- **Increased competition from Telcos and other providers**
- **Facilitates additional service offerings**
- **Consumers want higher tier data offerings**
- **IP applications consuming more capacity**

Competition from Telcos

- **FiOS and U-verse expanding footprint across the country**
- **Broadband data offerings up to 50Mbps down and 20Mbps up**
- **Telcos Bundling services with broadband data offerings**
  - **Video; including High Definitior**
  - **Voice**

Additional Service Offerings

- **IP Video**
  - **More capacity to offer IP based video**
  - **IP Set Top Boxes**
  - **IP video to the PC**
- **Business Services**
  - **Small/Medium businesses**
  - **Ethernet over DOCSIS**
  - **Symmetrical speed offerings**



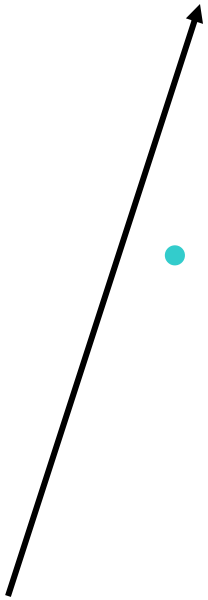
DOCSIS 1.x and 2.0 Limitations

- **Despite the improvements that have occurred as DOCSIS has evolved, maximum data rates to and from cable modems are pretty much topped out. Competition and the desire to provide new services are driving the need for even greater throughput in our DOCSIS networks.**
- **We're limited by the fact that the maximum raw data rate to or from cable modems is ultimately constrained by what a single 6 MHz wide channel can carry in the downstream, or what a single 6.4 MHz wide channel can carry in the upstream.**
- **Enter DOCSIS 3.0 and something called channel bonding**

Industry Objectives

DOCSIS 3.0

- **Goal:**
  - More aggregate speed
  - More per-CM speed
  - Enable New Services
- **Components:**
  - Channel Bonding
  - IPv6
  - Multicast



- Better stat muxing with bigger "pipe"
  - Offer >38.8 Mbps for single CM

M-CMTS

- **Goal:**
  - Increase Scalability
  - Reduce Cost
- **Components:**
  - Low Cost E-QAM
  - CMTS Core Processing

DOCSIS Specification Comparison

DOCSIS Specification Evolution

- **DOCSIS 1.0 (issued on March 1997)**

  High Speed Data service

- **DOCSIS 1.1 (issued on April 1999)**

  Classes of Service

  New scheduling to support voice and other real-time services

- **DOCSIS 2.0 (issued on Dec 2001)**

  More upstream capacity

  6.4 MHz channel width

  A-TDMA/S-CDMA supported

  Additional modulation formats – 8 QAM, 32 QAM, 64 QAM

DOCSIS Specification Evolution Cont.

- **DOCSIS 3.0 (issued on Aug 2006)**
  - **Channel Bonding**
  - **IPv6**
  - **Enhanced Multicast**
  - **Enhanced Security**

DOCSIS Specification Comparison

DOCSIS Channel Assumptions

Specification	DOCSIS 1.x	DOCSIS 2.0	DOCSIS 3.0
Downstream Freq. Range	50 – 860 MHz	50 – 860 MHz	50 – 1002 MHz
Downstream CNR	≥ 35 dB	≥ 35 dB	≥ 35 dB
Upstream Freq. Range	5 – 42 MHz	5 – 42 MHz	5 – 42 MHz or 5 – 85 MHz
Upstream CNR	≥ 25 dB	≥ 25 dB	≥ 25 dB

DOCSIS Modulation Formats and Rates

Specification	DOCSIS 1.x	DOCSIS 2.0	DOCSIS 3.0
Downstream – 6Mhz Channel	64 QAM (27Mbps) 256 QAM (38.8Mbps)	64 QAM (27Mbps) 256 QAM (38.8Mbps)	64 QAM (27Mbps) 256 QAM (38.8Mbps)
Upstream Formats	QPSK (2 bits/s) 16 QAM (4 bits/s)	QPSK (2 bits/s) 8 QAM (3 bits/s) 16 QAM (4 bits/s) 32 QAM (5 bits/s) 64 QAM (6 bits/s)	QPSK (2 bits/s) 8 QAM (3 bits/s) 16 QAM (4 bits/s) 32 QAM (5 bits/s) 64 QAM (6 bits/s)
Upstream Rates 200 kHz 400 kHz 800 kHz 1600 kHz 3200 kHz 6400 kHz	 160 ksym/sec 320 ksym/sec 640 ksym/sec 1280 ksym/sec 2560 ksym/sec -	 160 ksym/sec 320 ksym/sec 640 ksym/sec 1280 ksym/sec 2560 ksym/sec 5120 ksym/sec	 160 ksym/sec 320 ksym/sec 640 ksym/sec 1280 ksym/sec 2560 ksym/sec 5120 ksym/sec

DOCSIS 3.0 Features

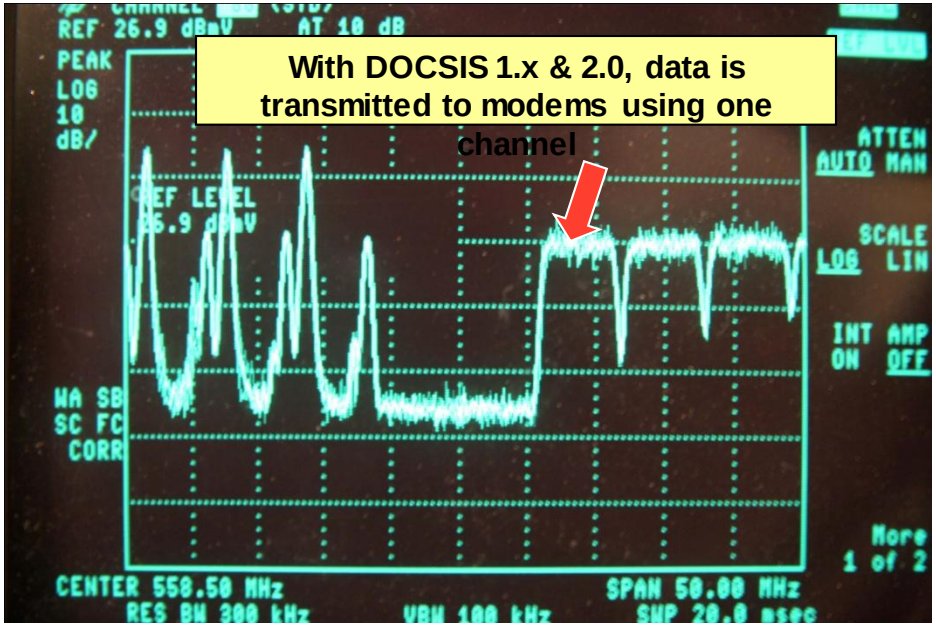
DOCSIS 3.0 Features

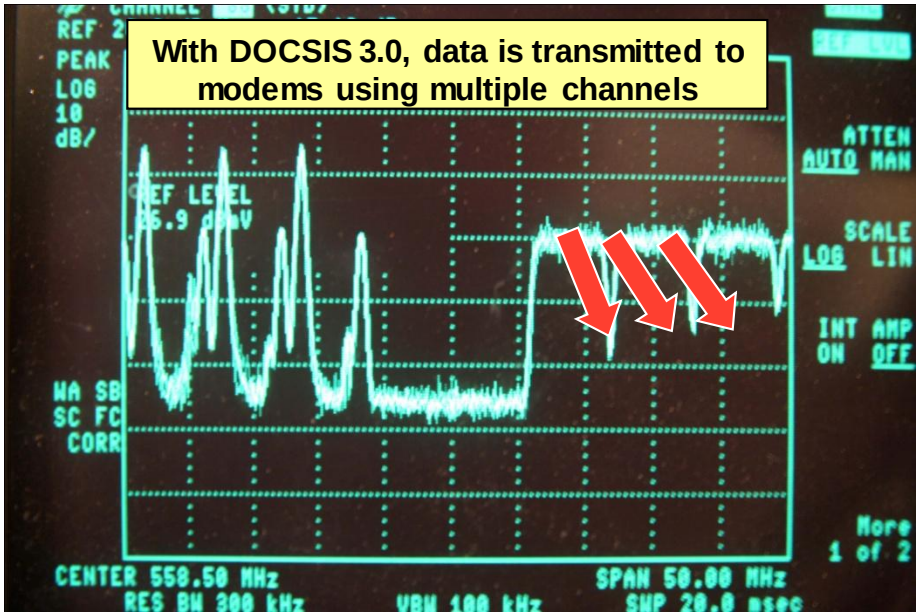
- **Channel Bonding**
  - Upstream Channel Bonding
  - Downstream Channel Bonding
- **MAC Layer**
  - Topology and ambiguity resolution
  - Latency and Skew measurements
  - CM Status and Control
- **Security**
  - Enhanced Traffic Encryption
  - Enhanced Provisioning Security
- **Network Management**
  - CM Diagnostic Log
  - Enhanced Signal Quality Monitoring
  - IPDR Service Statistics Reporting
  - Capacity Management
- **IPv6**
  - IPv6 Provisioning & Management of CMs
  - Alternative Provisioning Mode & Dual-stack Management Modes for CMs
  - IPv6 Connectivity for CPEs
- **IP Multicast**
  - Source Specific Multicast (SSM)
  - PHS, QoS, and Authorization
  - IGMPv3/MLDv2
- **Physical Layer**
  - Extended US/DS Freq Range
  - S-CDMA Active Code Selection
- **Business Services over DOCSIS**
  - Layer 2 Virtual Private Networks
  - Support for T1/E1 Emulation

Downstream Channel Bonding

Channel Bonding

- **In a nutshell, channel bonding means data is transmitted to or from CMs using multiple individual RF channels instead of just one channel**
- **Channels aren't physically bonded into a gigantic digitally modulated signal; bonding is logical**





Downstream Channel Bonding

- **Let's say you want to increase the downstream data rate between the CMTS and modems from today's single 6 MHz wide channel limit of 38.8 Mbps (post FEC data rate)**
- **If you were to spread your downstream data payload across four 6 MHz wide channels, the combined raw data rate using 256 QAM on each channel would be 38.8 Mbps x 4 = 155.2 Mbps.**
- **A DOCSIS 3.0 modem incorporates a special tuner capable of simultaneously receiving data from those four channels. To the modem, the four channels are the logical equivalent of one large bonded channel, even though we're using four physically separate channels.**

Downstream Channel Bonding

- **Want more? Bonding, say, 10 channels, will yield 38.8 Mbps x 10 = 388 Mbps, and bonding 24 channels works out to 24 x 38.8 Mbps = 931.2 Mbps, or just under 1 Gbps. Yikes!**
- **The same channel bonding concept is applicable to the upstream, giving us the ability to go far beyond DOCSIS 2.0's per-channel limit of 30.72 Mbps. How does 4 x 30.72 Mbps = 122.88 Mbps—or more—sound?**
- **But where do we get the extra spectrum to carry DOCSIS 3.0's bonded channels?**

Two Choices to get extra spectrum for D3.0 Services

- **Bandwidth optimization**

  Improve efficiency of existing spectrum usage *(channel grooming, MPEG4 compression, SDV, analog reclamation, Migrate to all digital,…)*

- **Bandwidth enhancement**

  Get a bigger pipeline (*Expand cable network's upper frequency limit to 1 GHz)*

Downstream Channel Bonding

- The CMTS must support Downstream bonding groups of 2 to 4 channels
- The CMTS may support Downstream bonding groups of more than 4 channels
- Channels do not need to be adjacent
  - 60 MHz window driven by Cable Modem
- Channels can be 64 QAM or 256 QAM
- Non-disruptive technology
  - Seamless migration from DOCSIS 1.x/2.0
  - M-CMTS and high density I-CMTS cards
  - E-QAMs

Upstream Channel Bonding

Upstream Channel Bonding

- The CMTS must support Upstream bonding groups of 2 to 4 channels
- The CMTS may support Upstream bonding groups of more than 4 channels
- Upstream Channels do not have to be the same:
  - Channel Width
  - Modulation format
- Multiple Transmit Channel mode
  - Enabled = Bonding
  - Disabled = DOCSIS 2.0

Upstream Channel Bonding

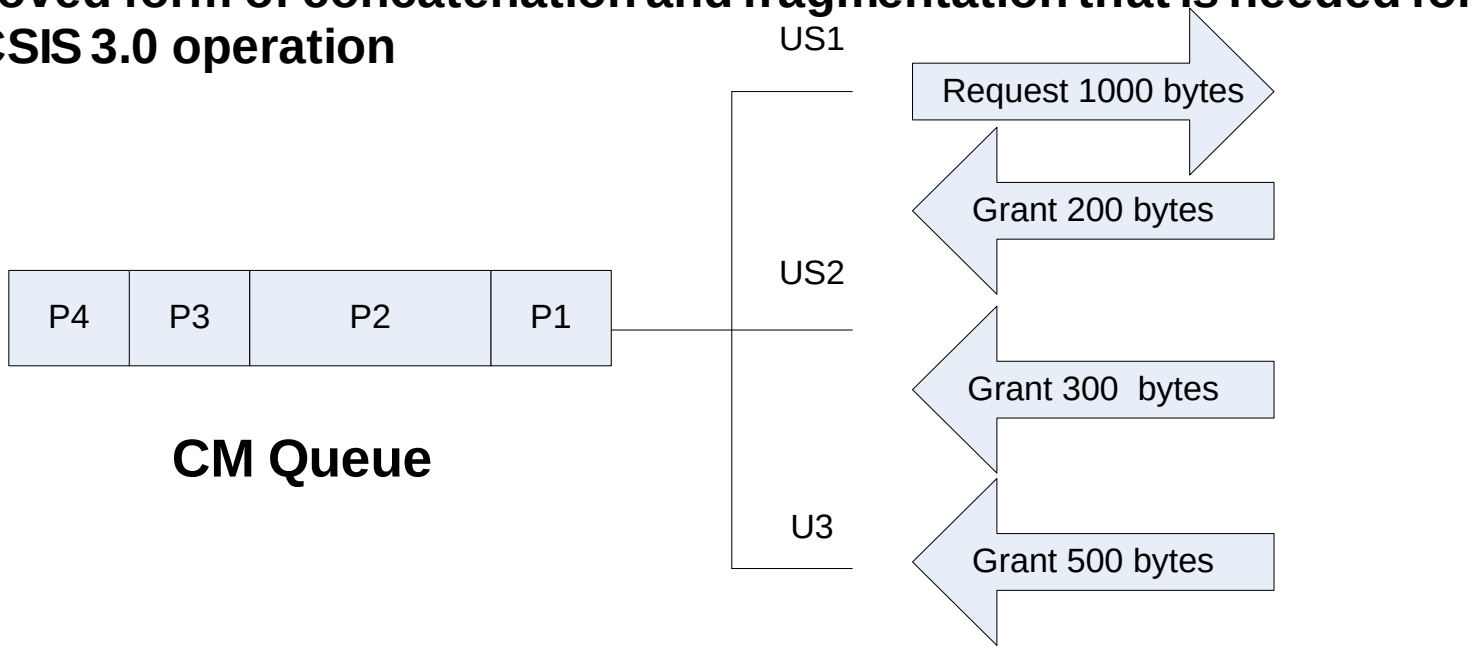
- **Upstream Request in Multiple Transmit Channel Mode**

  Cable Modem sends a request for grants based on queue depth

- **Requests made based on bytes, not minislots.**

- **Continuous Concatenation & Fragmentation (CCF)**

  Improved form of concatenation and fragmentation that is needed for DOCSIS 3.0 operation



Channel Bonding - General

- **Channel Bonding is IP packet based**
- **The CMTS assigns service flows to individual Downstream or Upstream channels or Bonding Groups**
- **The assignment can be dynamic or static**
- **The CMTS can support bonded and non-bonded service flows simultaneously**
- **With bonded service flows, a sequencing mechanism ensures packets are ordered correctly**

Bonded power levels

- **Changes were made to Tx power levels**
- **May cause issues in Upstream direction as Tx power level by CM will be lower that in DOCSIS 1.x/2.0**
- **Power Per Channel**

  Maximum power per channel depends on the amount of channels on one RF port

Number of Channels	Max Power / Channel
1	60
2	56
3	54
4	52

Additional Docsis 3.0 MAC Layer Concepts

DOCSIS 3.0 Concepts

- **Primary Capable Channel**
  - **SYNC and MDD messages**
  - **MAP and UCD messages for at least one upstream in the Service Group that Downstream reaches**
- **MAC Domain Descriptor Message**
  - **Sent on Primary Capable Channels**
  - **Describes the MAC Domain to DOCSIS 3.0 Cable Modems**
  - **Contains Active Channel Lists**

Channel Group Domain and Fiber Node definitions

- **A CGD “Channel Group Domain is a MAC DOMAIN that contains multiple “primary capable channels”**
- **A “M x N Domain represents the total “primary and secondary” channels within the DOMAIN**
- **The Fiber-node describes the plant topology, the set of upstream and downstream channels that can be seen by a group of bonding capable modems only.**

DOCSIS 3.0 MDD (MAC Domain Descriptor)

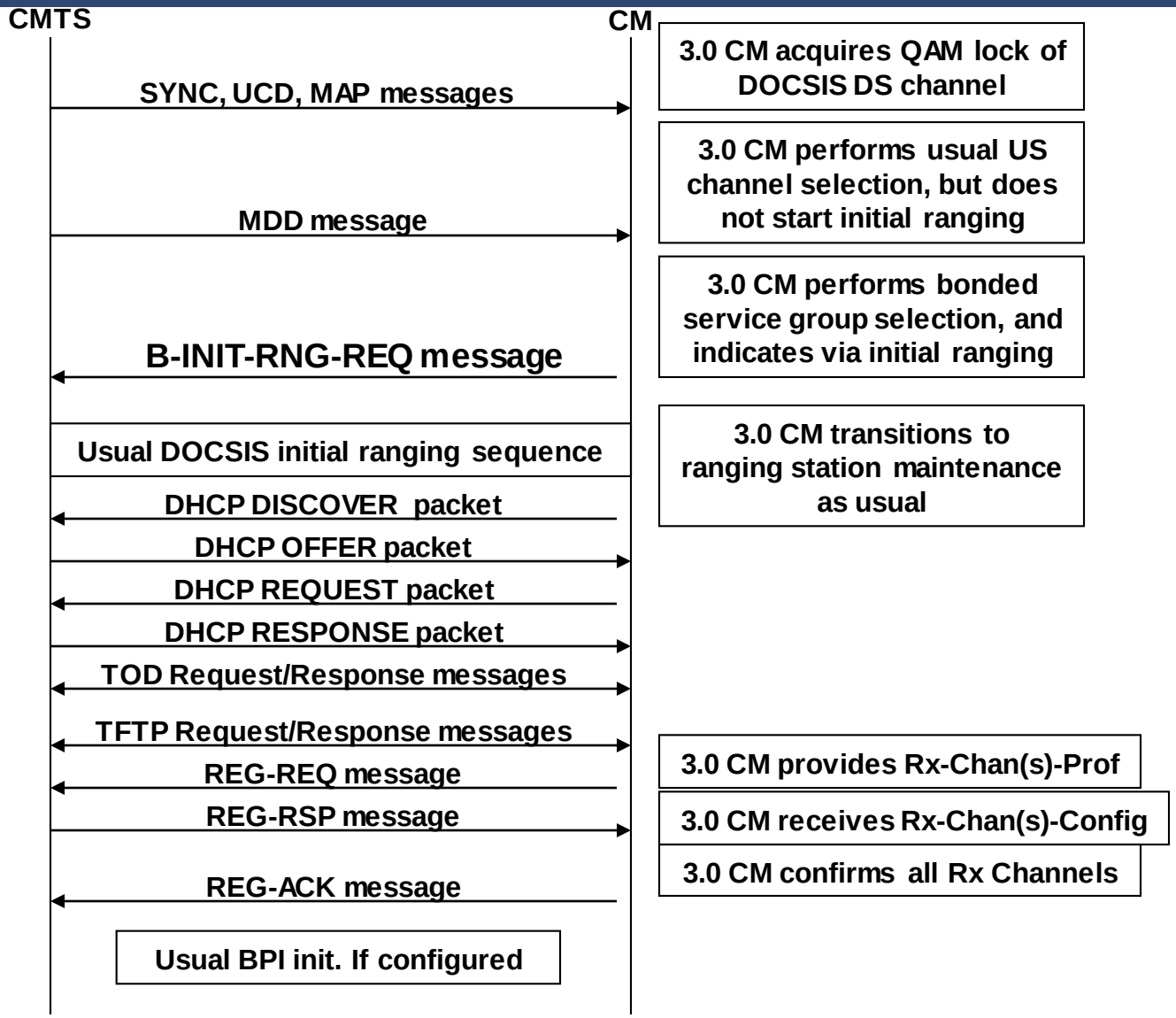
```
Nov  1 21:02:08 MET: Cable5/0/1 MDD datagramsize 127, msg len
    125, ehdr type_or_len 107, tlv_size 97 max_pak_size 1518
Nov  1 21:02:08 MET: MDD MESSAGE
Nov  1 21:02:08 MET:   FRAME HEADER
Nov  1 21:02:08 MET:     FC                          - 0xC2 ==
Nov  1 21:02:08 MET:     MAC_PARM                    - 0x00
Nov  1 21:02:08 MET:     LEN                         - 0x7D
Nov  1 21:02:08 MET:   MAC MANAGEMENT MESSAGE HEADER
Nov  1 21:02:08 MET: DA                        - 01E0.2F00.0001
Nov  1 21:02:08 MET: SA                        - 0005.00E4.998F
Nov  1 21:02:08 MET:     msg LEN                     - 6B
Nov  1 21:02:08 MET:     DSAP                        - 0
Nov  1 21:02:08 MET:     SSAP                        - 0
Nov  1 21:02:08 MET:     control                     - 03
Nov  1 21:02:08 MET:     version                     - 04
Nov  1 21:02:08 MET:     type                        - 21
Nov  1 21:02:08 MET:     dcid                        - 26 ==
Nov  1 21:02:08 MET:     MDD TLV, Total TLV size - 97
```

```
Nov  1 21:02:08 MET:MDD TLV
Nov  1 21:02:08 MET:Downstream Active Channel List
Nov  1 21:02:08 MET:Channel ID:              24
Nov  1 21:02:08 MET:Frequency:               453000000Hz
Nov  1 21:02:08 MET:Modulation Order/Annex:256 QAM/AnnexB
Nov  1 21:02:08 MET:Primary Capable:      Primary-Capable
Nov  1 21:02:08 MET:Downstream Active Channel List
Nov  1 21:02:08 MET:Channel ID:              25
Nov  1 21:02:08 MET:Frequency:               461000000Hz
Nov  1 21:02:08 MET:Modulation Order/Annex:256 QAM/AnnexB
Nov  1 21:02:08 MET:Primary Capable: Not Primary-Capable
                :
                :

Nov  1 21:02:08 MET:       MAC Domain Downstream Service
    Group
Nov  1 21:02:08 MET:         MD-DS-SG ID:            2
Nov  1 21:02:08 MET:         Channel IDs:            24
Nov  1 21:02:08 MET:                                 25
Nov  1 21:02:08 MET:                                 26
Nov  1 21:02:08 MET:                                 27

Nov  1 21:02:08 MET:Downstream Ambiguity Resolution Frequency List
Nov  1 21:02:08 MET:Frequencies:           453000000Hz
Nov  1 21:02:08 MET:                       461000000Hz
Nov  1 21:02:08 MET:                       469000000Hz
Nov  1 21:02:08 MET:                       477000000Hz
```

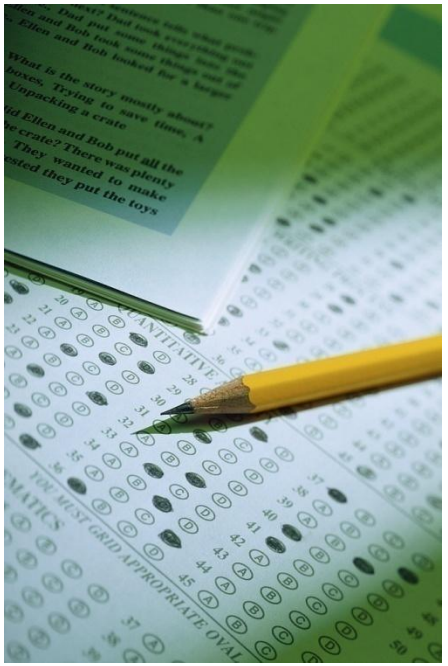
DOCSIS 3.0 Registration



DOCSIS 3.0 Qualification

DOCSIS 3.0 Qualification Levels

- **Bronze**
  - **Downstream Channel Bonding**
  - **IPv4 / IPv6 Cable Modem Manageability**
- **Silver**
  - **Bronze**
  - **Advanced Encryption System**
  - **Upstream Channel Bonding**
  - **Multicast**
- **Gold**
  - **Full DOCSIS 3.0 Compliance**



DOCSIS 3.0 Qualification Guidelines

- **CMTS can be submitted for Silver or Full qualification**
- **CM can only be submitted for Full certification**
- **Results for CertWave 79 are the latest posted**
- **The list of qualified products can be found at:**

http://www.cablelabs.com/certqual/lists/

DOCSIS 3.0 CMTS Models

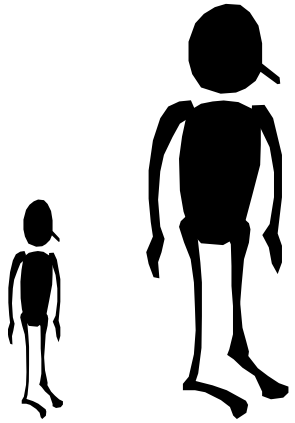
DOCSIS 3.0 CMTS Models

- **The DOCSIS Specification outlines two CMTS Models**
- **Recall the CMTS is the Network Element which forwards traffic from the Network Side Interface (NSI) to the RF Interface (RFI)**
- **Integrated CMTS**

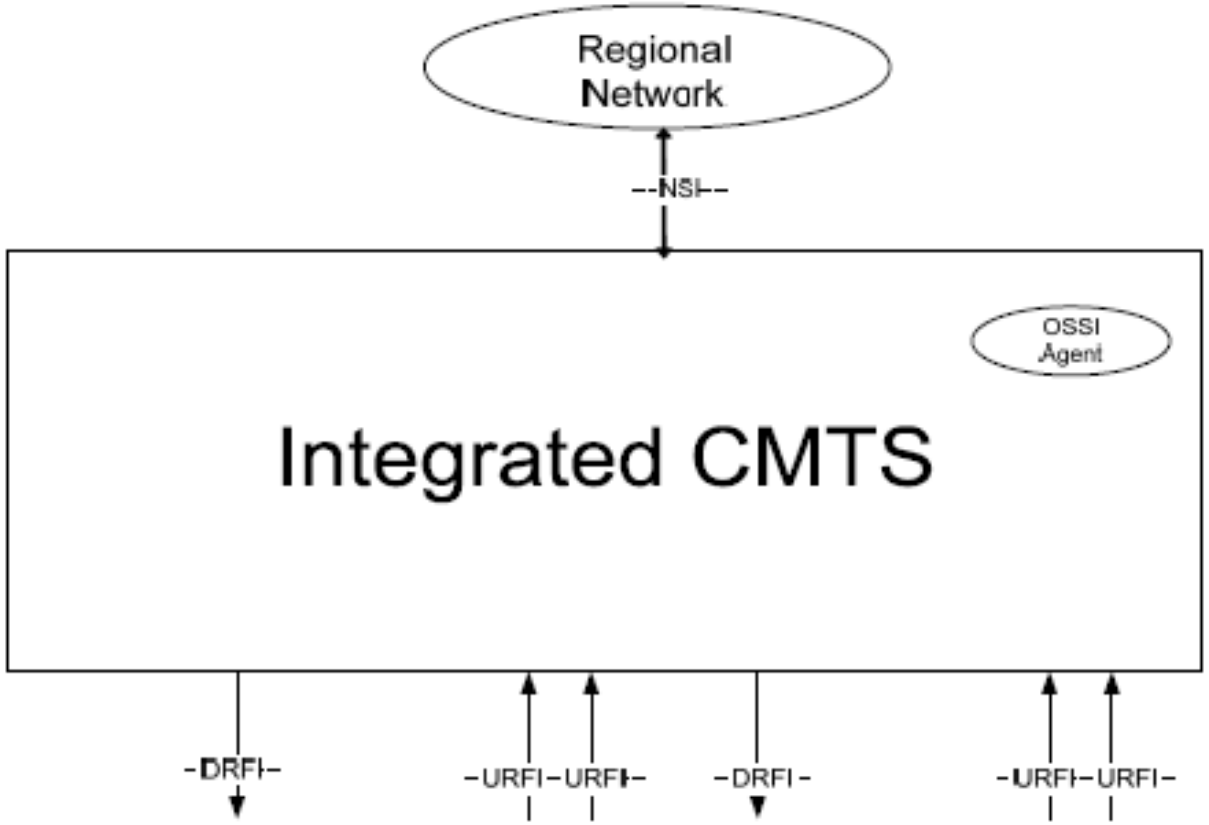
  Downstream and Upstream Interfaces implemented in single entity
- **Modular CMTS (M-CMTS)**

  DOCSIS Timing Interface Server

  Converged Internetwork (CIN)



Integrated CMTS Model



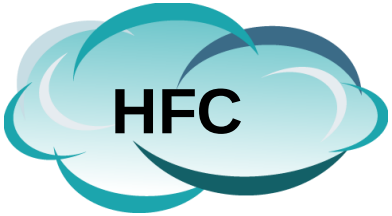
Integrated CMTS

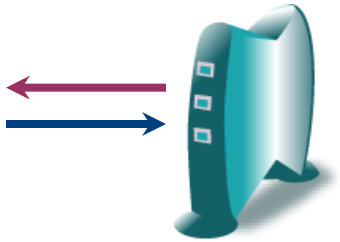
High Density Linecards

I-CMTS

DOCSIS 1.x/2.0 US

DOCSIS 1.x/2.0 DS





DOCSIS 1.x/2.0 CMs

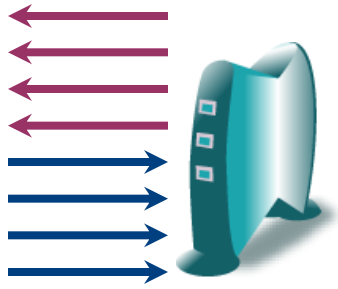
Integrated CMTS with DOCSIS 3.0

High Density Linecards

I-CMTS

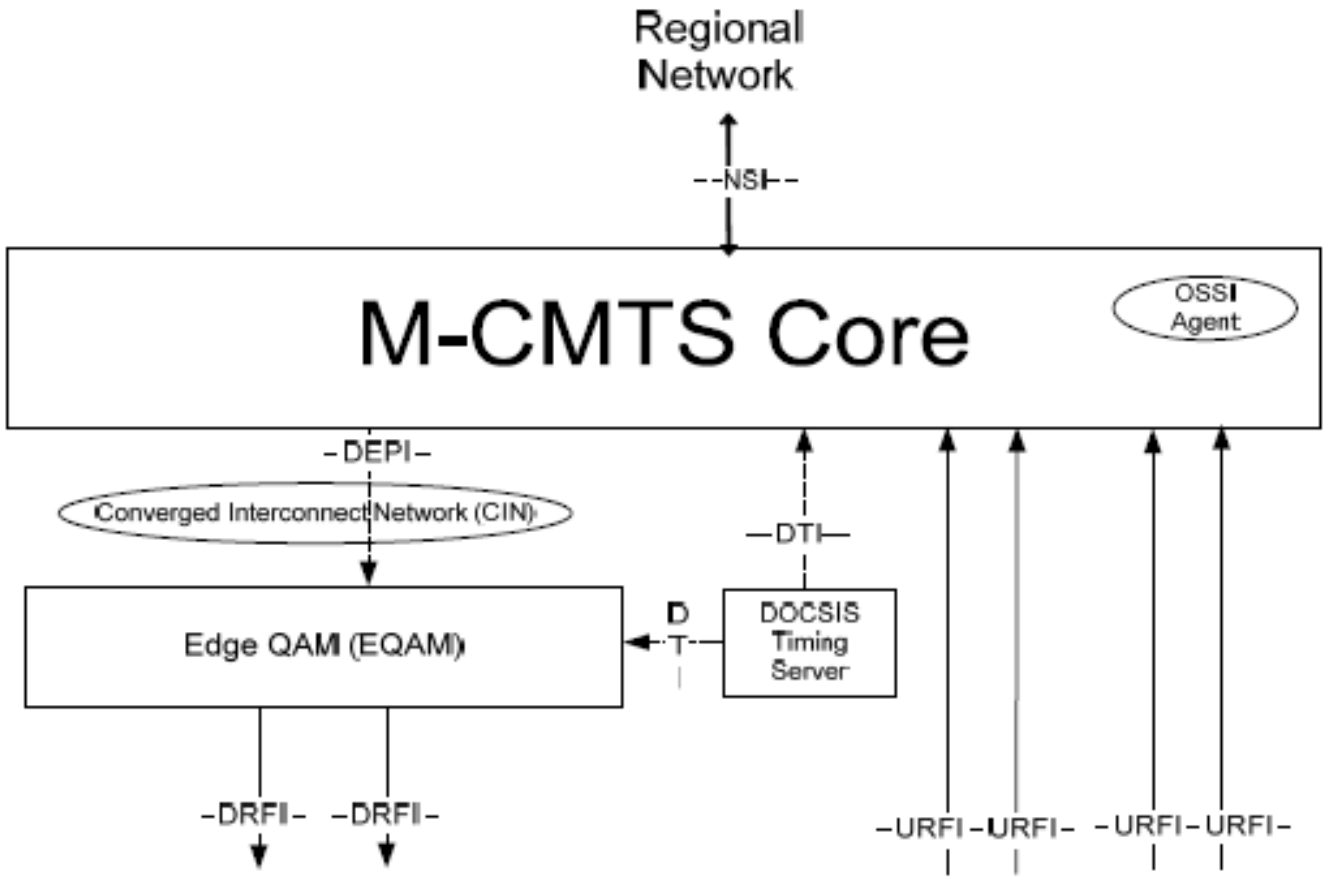
DOCSIS 3.0 Bonded US

DOCSIS 3.0 Bonded DS

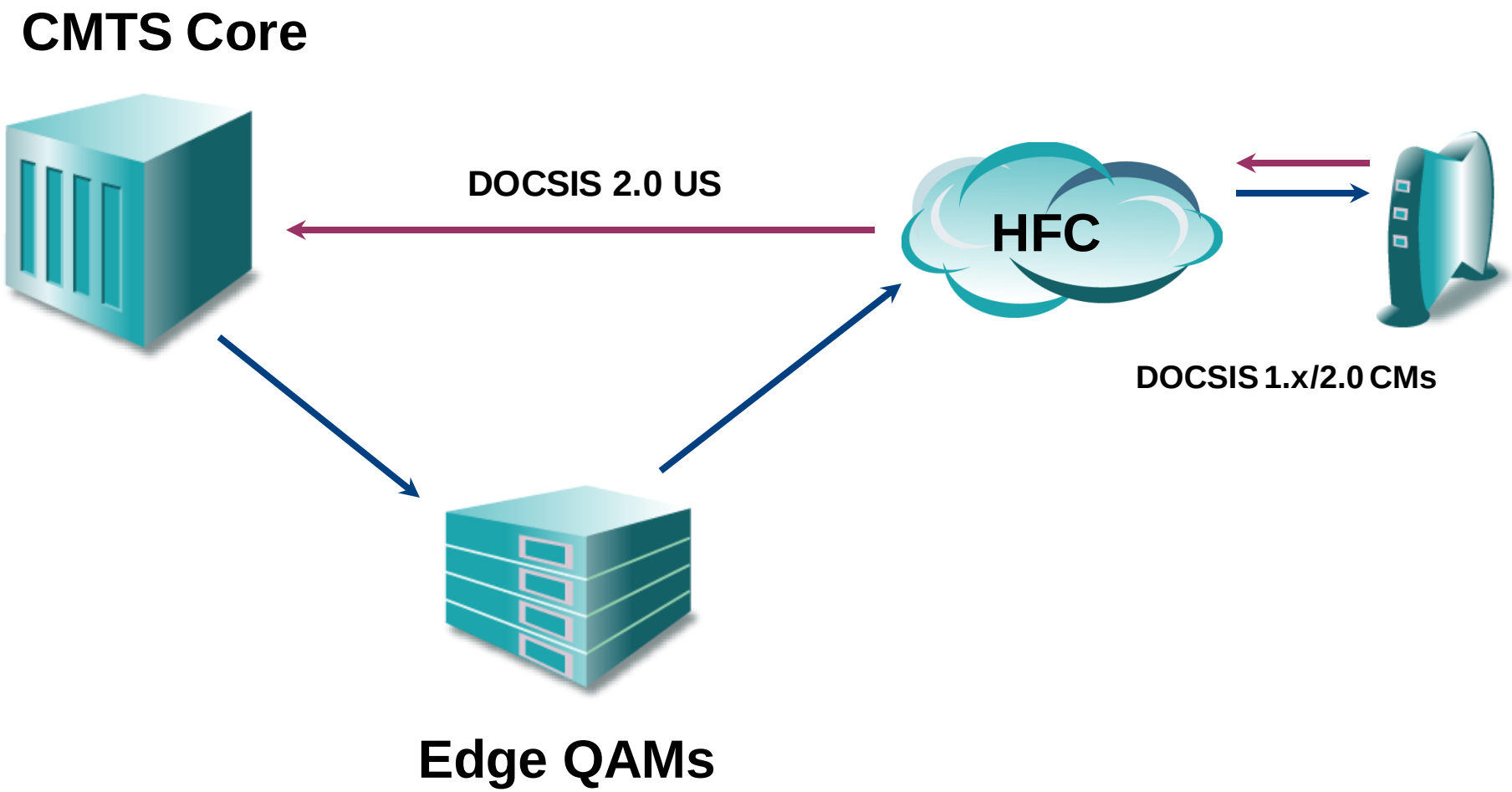


Supports DS Bonding and Existing DOCSIS 1.x/2.0 CMs

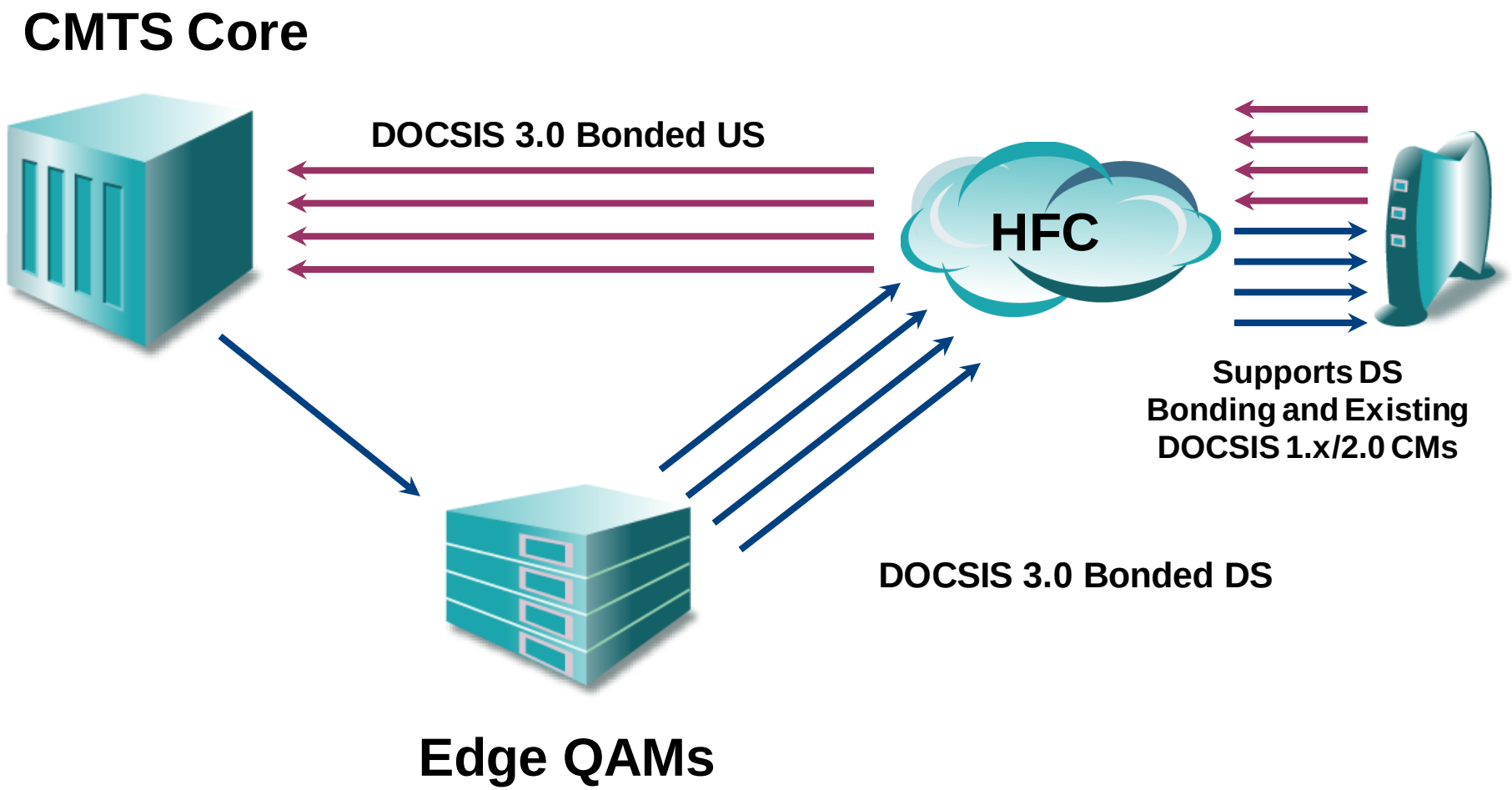
Modular CMTS Model



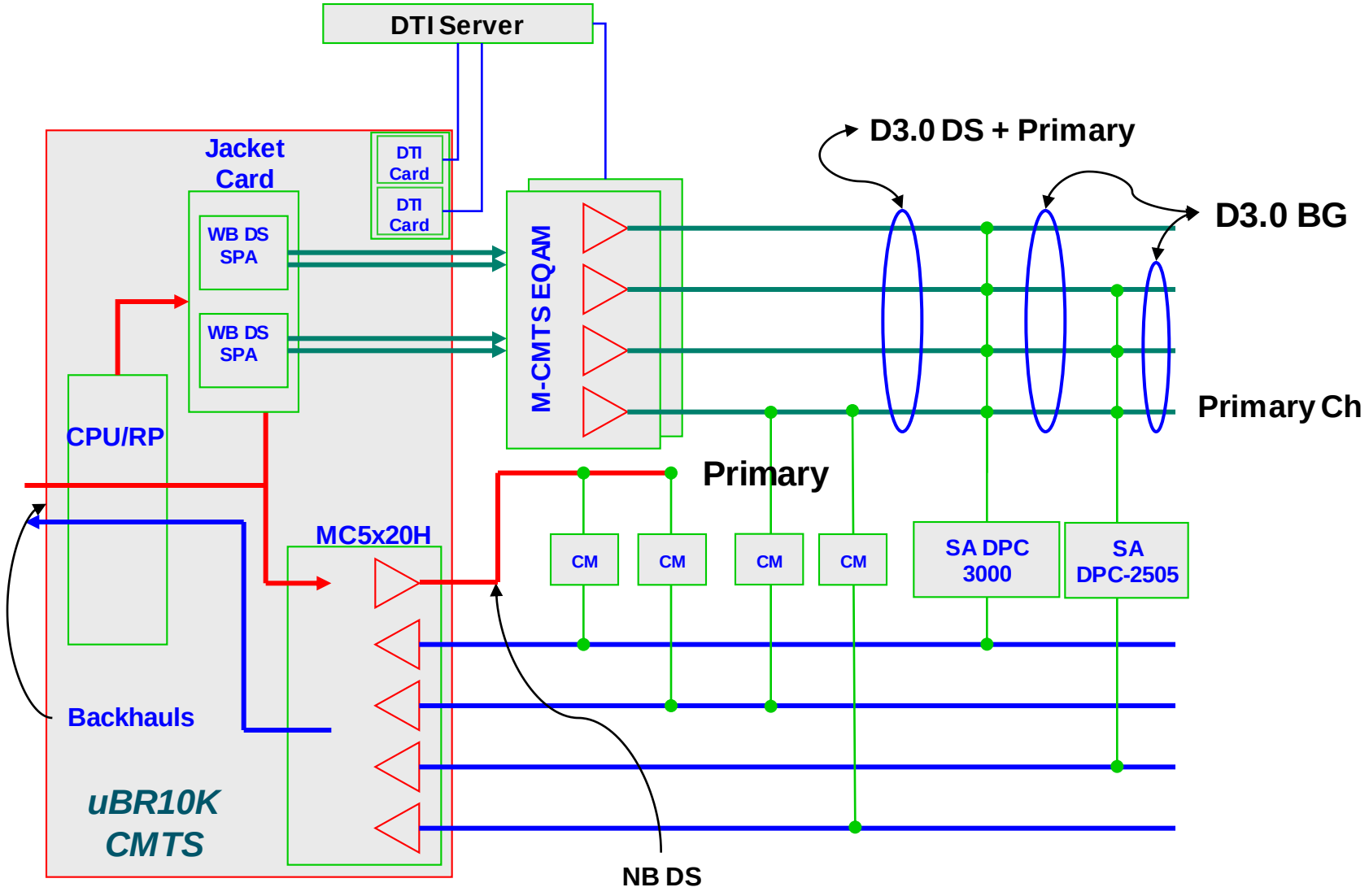
Modular CMTS



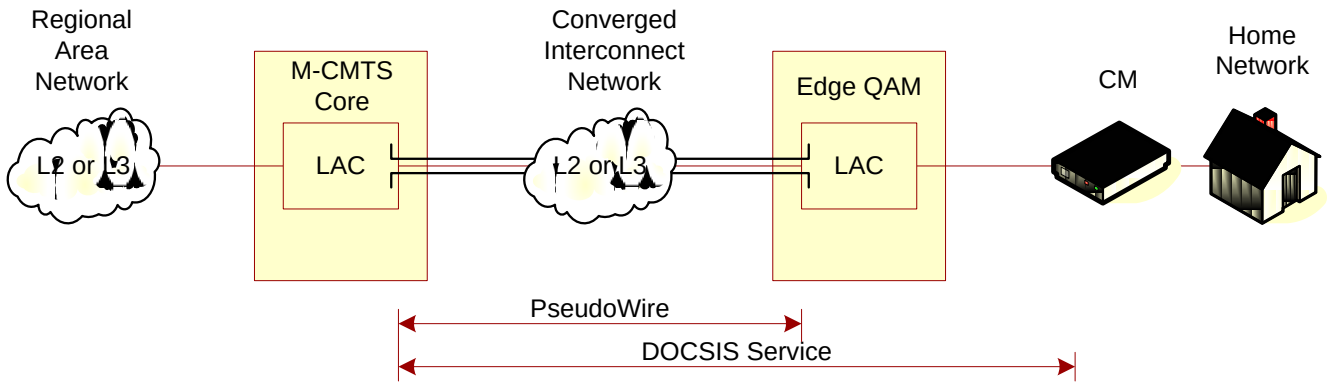
Modular CMTS with DOCSIS 3.0



DOCSIS 3.0 M-CMTS System



DEPI Intro



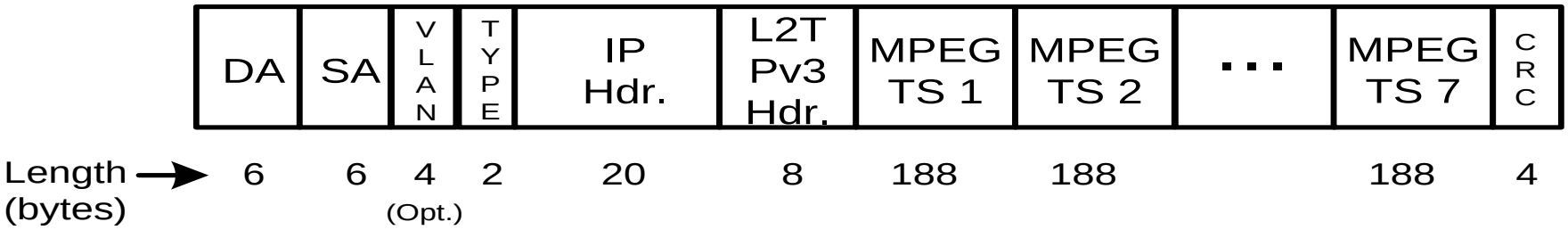
- **DEPI is an IP Tunnel, known as a pseudowire, that exists in the downstream direction between the DOCSIS MAC in the M-CMTS Core and the DOCSIS PHY that exists in the EQAM.**
- **The CIN (Converged Interconnect Network) may be a Layer 2 or Layer 3 network.**
- **The M-CMTS Core provides the DOCSIS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

Encapsulation of DOCSIS MPEG-TS

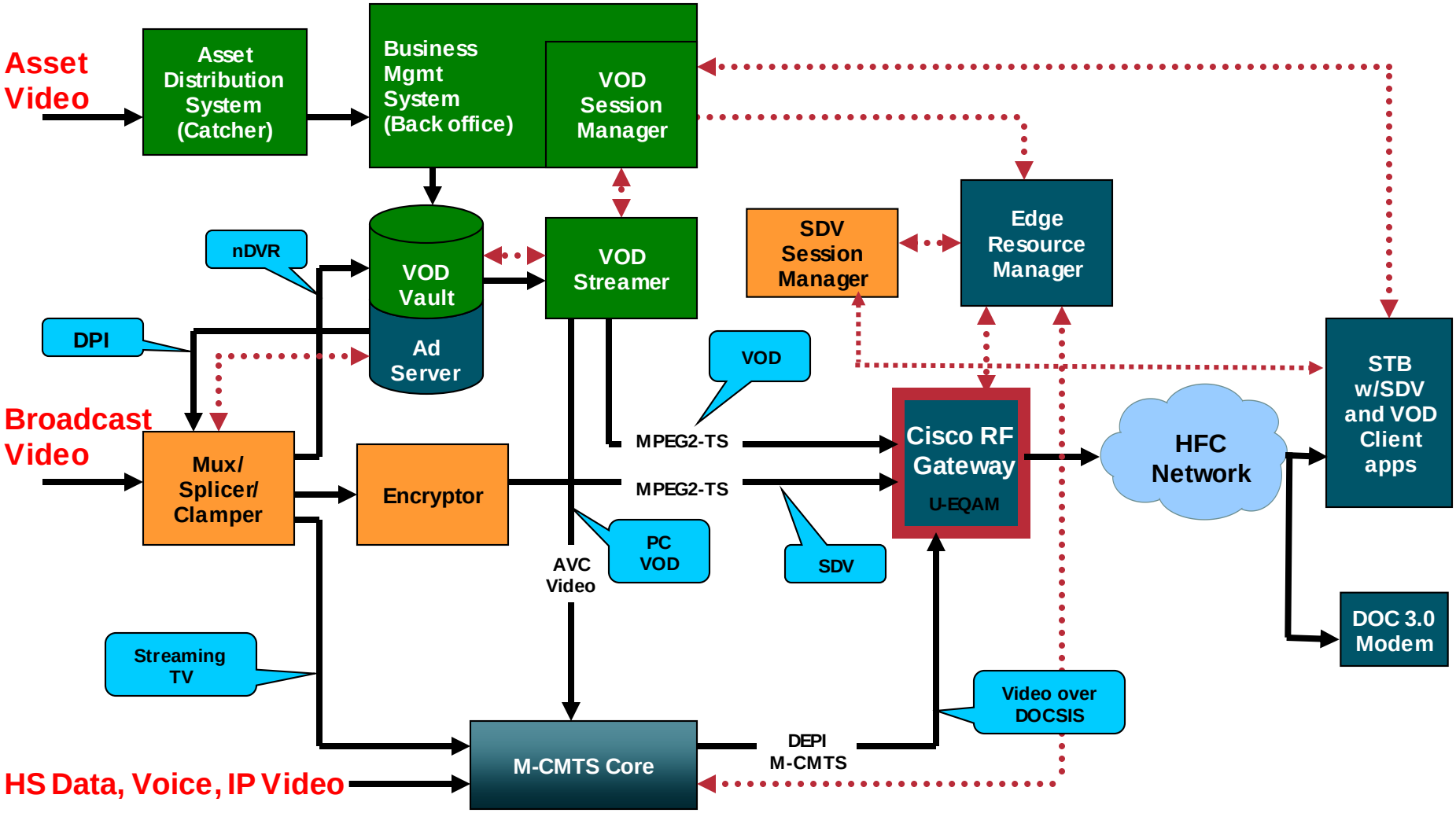
- **Seven (7) – 188 Bytes MPEG-TS packets are encapsulated**
- **Ethernet, IP, and L2TPv3 Headers added**

46 or 50 bytes (50 bytes w/ VLAN tag)

- **Ethernet Frames sent to GigE MAC for transmission to the external QAM box.**
- **188 bytes/MPEG-TS pkt * *7_MPEG_Pkts_Per_Frame* + 46 or 50 bytes of Header/CRC (50 with VLAN tag)**
- **For example, an Ethernet frame without a VLAN tag and with seven MPEG-TS packets would be 1362 Bytes long.**



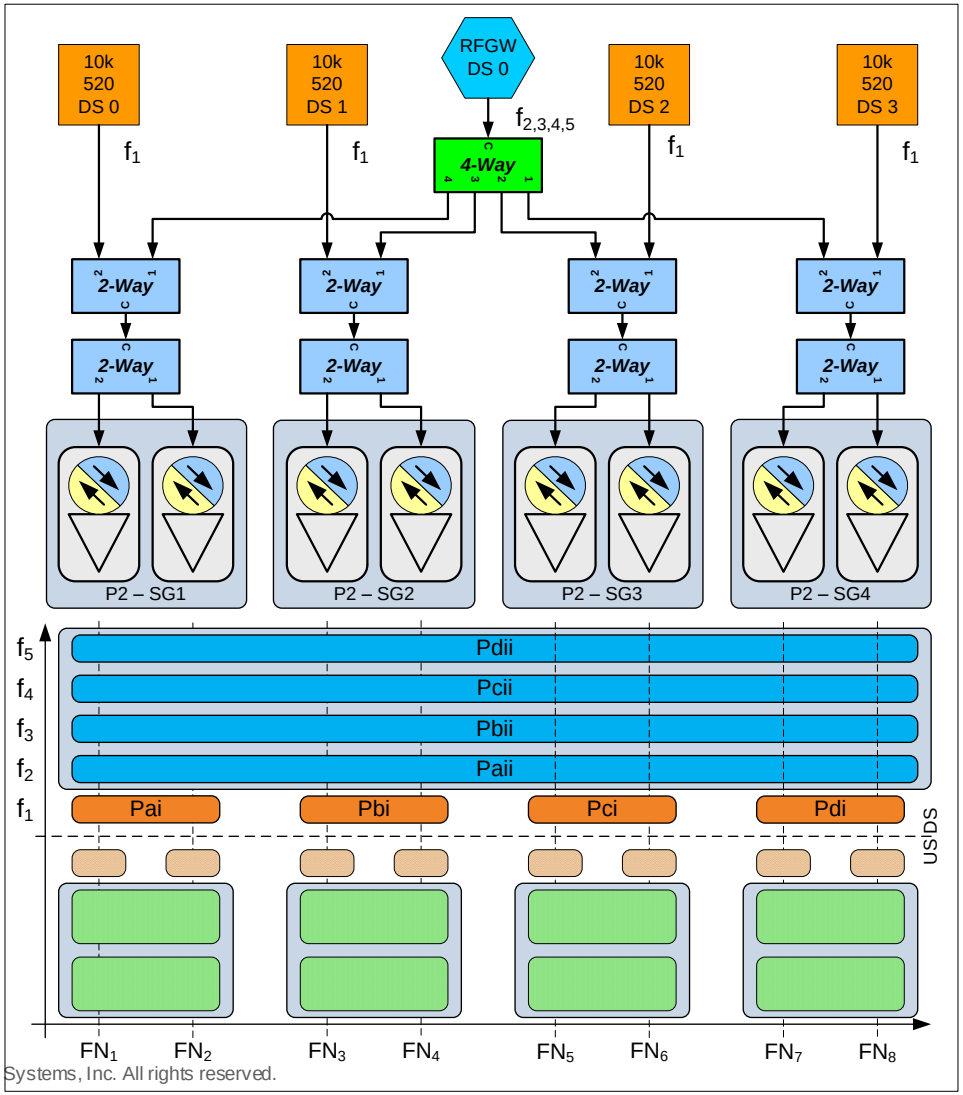
Cisco RF Gateway Family: U-EQAM Solutions for SDV, VOD, M-CMTS, DOCSIS 3.0 and VDOC



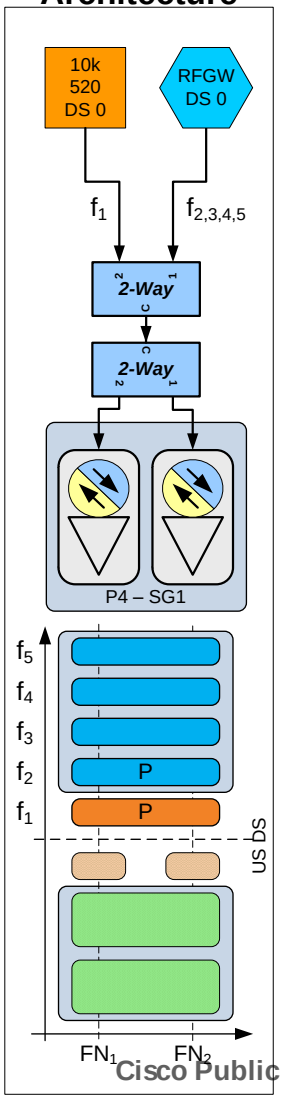
D3.0 Network Design Examples

D3.0 Overlay & Narrowcast Architectures

DOCSIS 3.0 Overlay Architecture



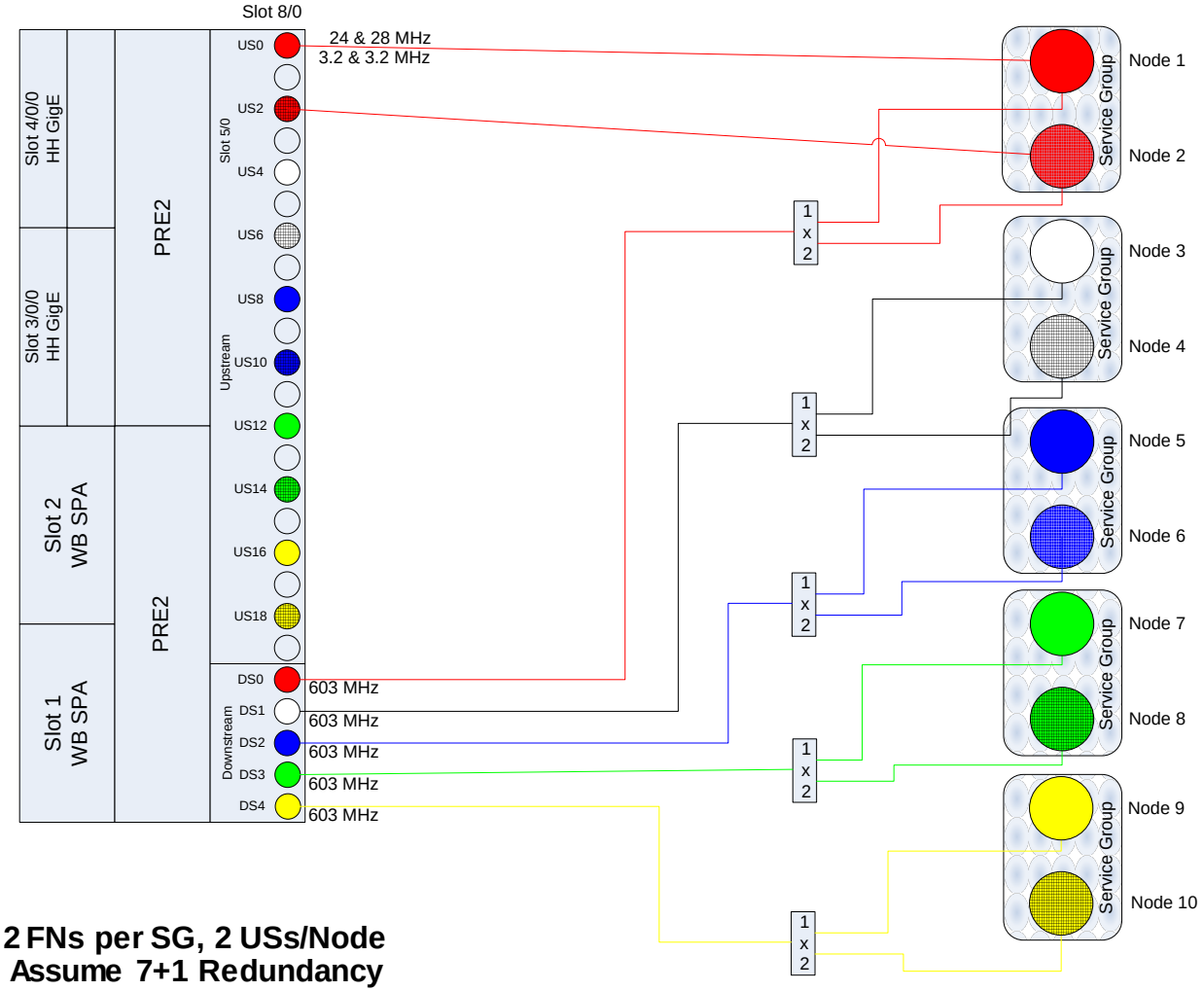
DOCSIS 3.0 Narrowcast Architecture



Customer Requirements

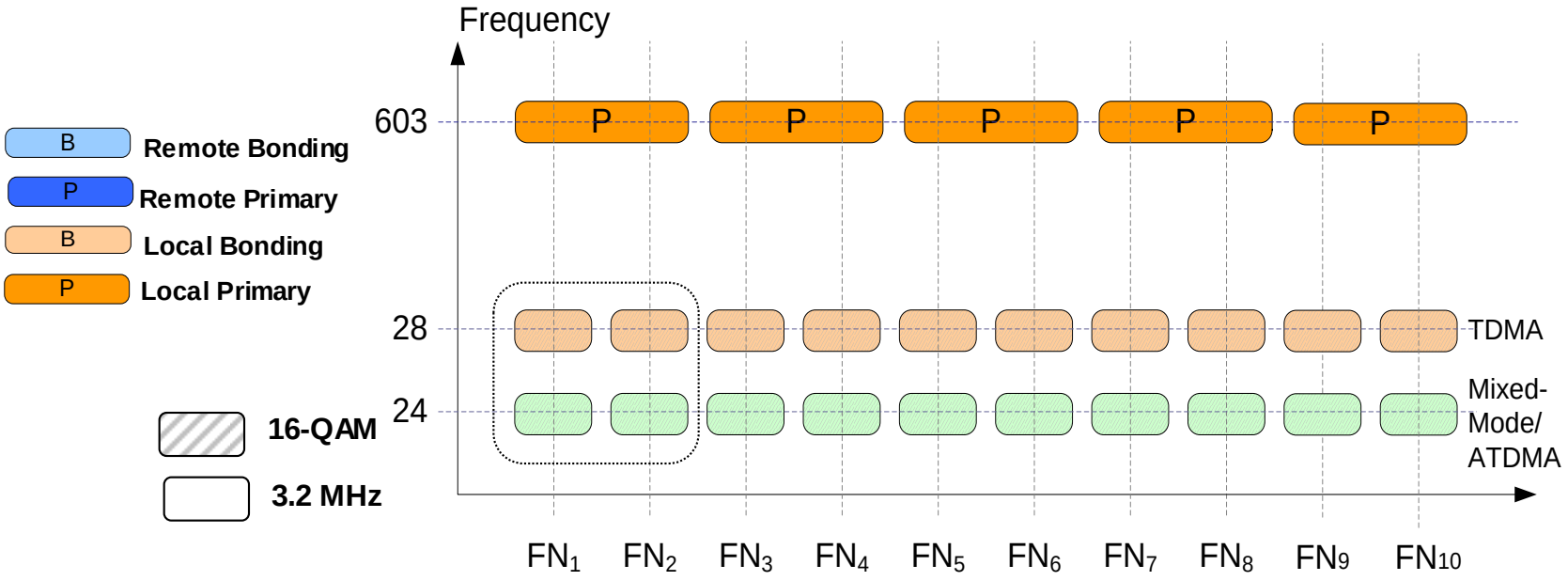
- **Customer had an existing DOCSIS 2.0 solution in place today and would like to migrate to a higher speed service.**
- **The initial plan was to deploy up to 50Mbps and then up to possibly 100Mbps. USCB was also to be included in the plan but not initially implemented**

Example Initial Configuration



2 FNs per SG, 2 USs/Node
Assume 7+1 Redundancy
HHP and penetration depends on service/tier mix

Example Initial Configuration (using MC5x20)



- **5, 1x4 MAC domains with 256-QAM DS & 3.2 MHz, 16-QAM US**
- **2 fiber node service groups (SG) with US load balance**
- **7+1 linecard redundancy**
- **70 US nodes covered by 10K chassis (35 SGs)**

Example Service Templates

- **Option 1: 50 Mbps bonded service**
- **Option 2: 100 Mbps bonded service**
- **Option 3: 100 Mbps DS and 50 Mbps US bonded service**

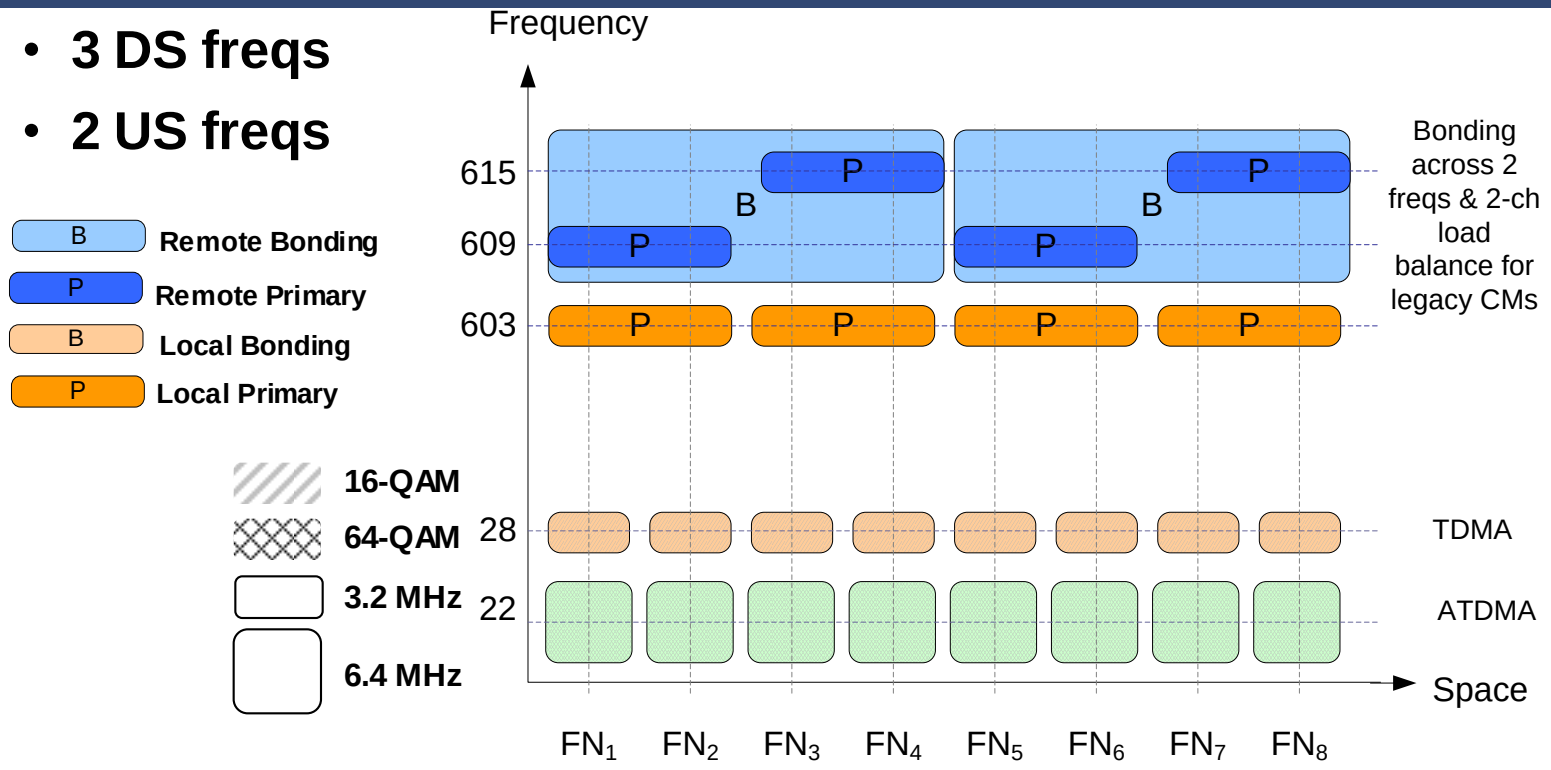
Option 1: 50 Mbps DS Service

- **50 Mbps high-end tier will require 3 DS carriers**
- **Provides one MC520 DS and a maximum of 4 DS carriers from the RFGW**
- **Maximum flexibility that allows high peak bonded rate while allowing load balancing of D1.x/D2.0 CMs**
- **Minimal wiring requirements**

  Enables future DS growth with no wiring change
- **Reduces node splits and de-combines**

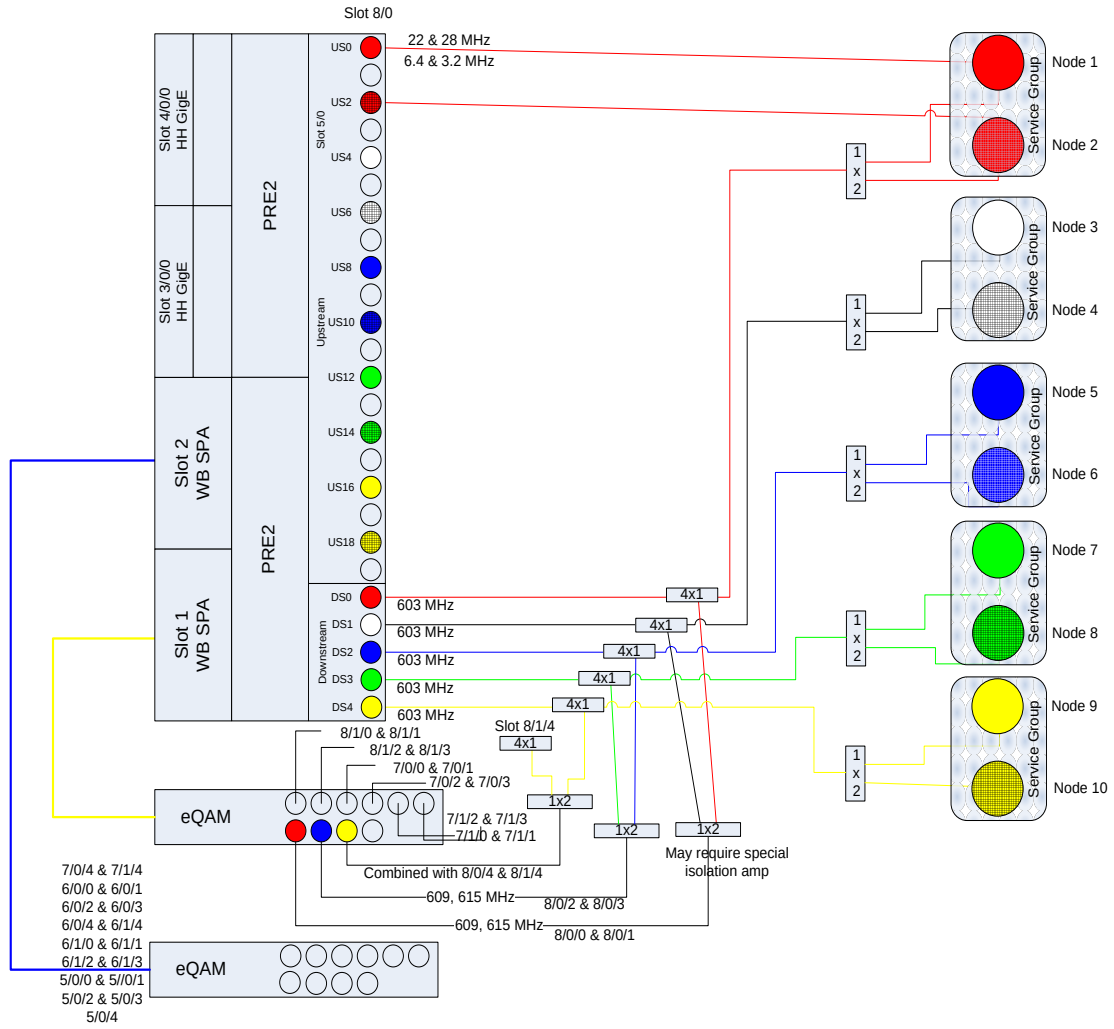
Option 1: 50 Mbps Service Tier

- **3 DS freqs**
- **2 US freqs**



- **4, 2x4 MAC domains with 256-QAM DS w/ ATDMA & TDMA USs**
- **E-qam overlays 2 SGs, also 5th DS from 2 linecards**

Option 1: 50 Mbps Service



Cisco Products

- **UBR10012 CMTS w/ PRE2**
- **"Rembrandt", 12.3(23) IOS software**
- **5x20H linecards**
- **Saratoga SIP with 2 SPAs**
- **RFGW-1 EQAM**
  - **2 chassis**
  - **5 modules each**
- **DPC3000 cable modem**

Resources (Per SG)

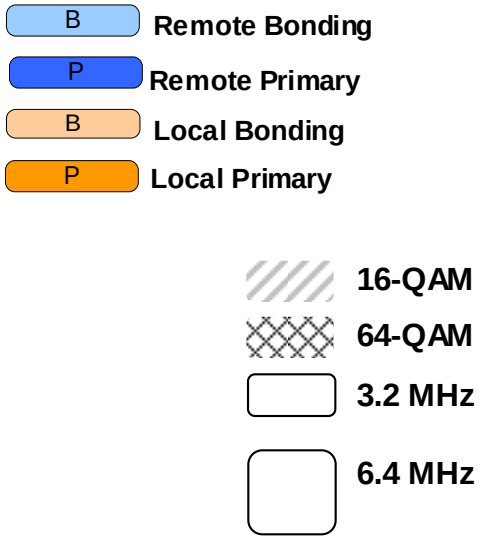
- **3 DS frequencies**
  - **1 I-DS**
  - **2 M-DS**
- **2 US frequencies**

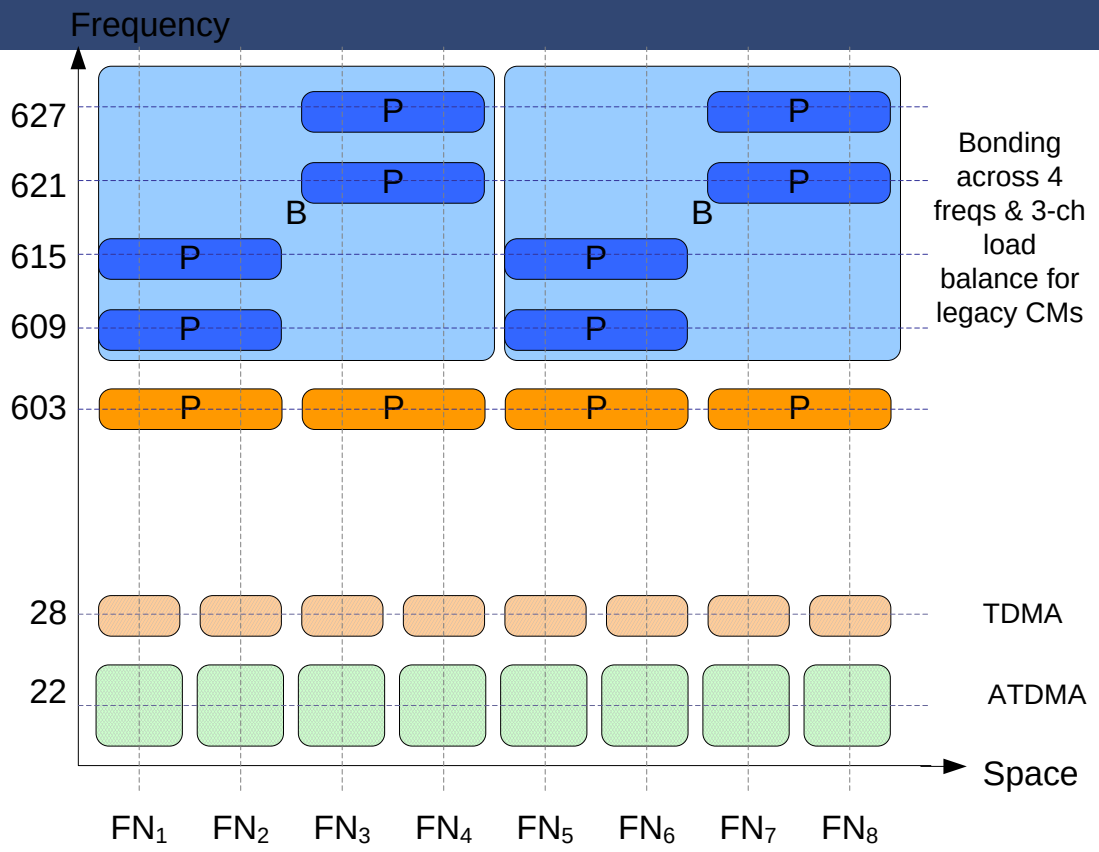
Option 2: 100 Mbps Service

- Enables 100 Mbps service with 4 DS carriers
- No wiring change – enable 2 additional chs on EQAM
- Provides one MC520 DS and a maximum of 4 DS carriers from the RFGW
  - Maximum bonded speed of 160 Mbps without wiring change
- Maximum flexibility that allows high peak bonded rate of 120 Mbps while allowing load balancing of D1.x/D2.0 CMs
- Minimal wiring requirements
  - Enables future DS growth with no wiring change
- Reduces node splits and de-combines

Option 2: 100 Mbps Service

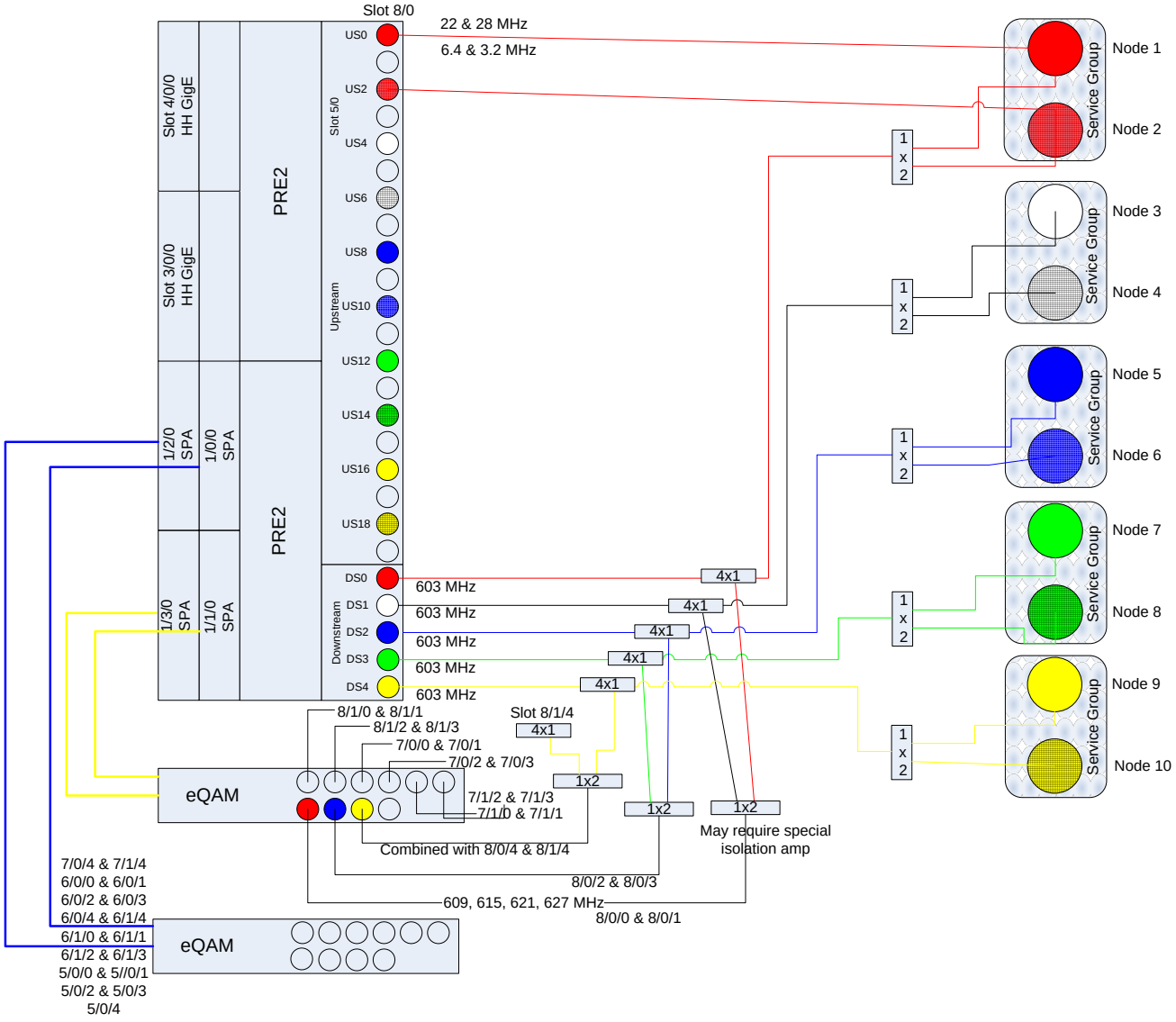
- **5 DS freqs**
- **2 US freqs**





- **4, 3x4 MAC domains with ATDMA & TDMA USs**

Option 2: 100 Mbps Service Tier



Cisco Products

UBR10012 CMTS w/ PRE2

“ ”, 12.2SCA IOS

5x20H linecards

SIP with 4 SPAs

RFGW-1 EQAM

2 chassis

5 modules each

DPC/EPC 3000 CM

DPC/EPC 3002 eMTA

Resources (Per SG)

5 DS frequencies

1 I-DS

4 M-DS

(3 Primary)

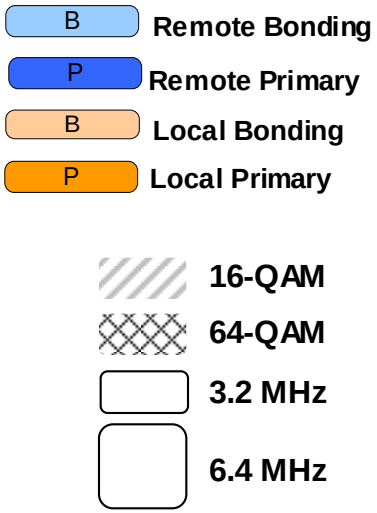
2 US frequencies

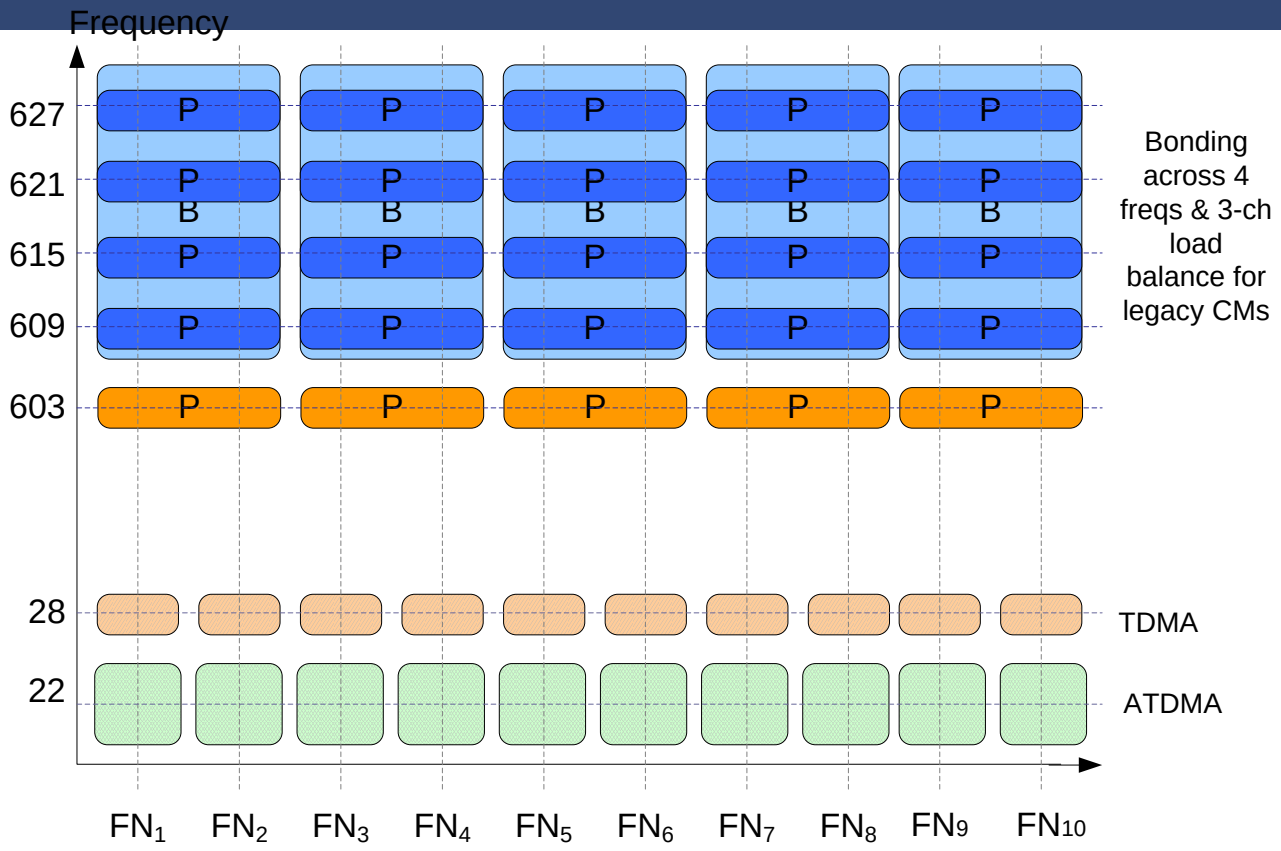
Option 3: 100 Mbps DS & 50+ Mbps US Service

- **Extends 100 Mbps service with 4 DS carriers**
- **Enables 50+Mbps bonded US service with US carriers**
- **Minimizes wiring change**

Option 3: 100+ Mbps Tier & Channel US Bonding (Step 1)

- **5 DS freqs**
- **2 US freqs**

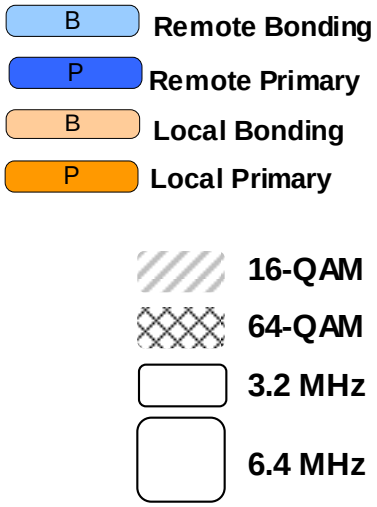


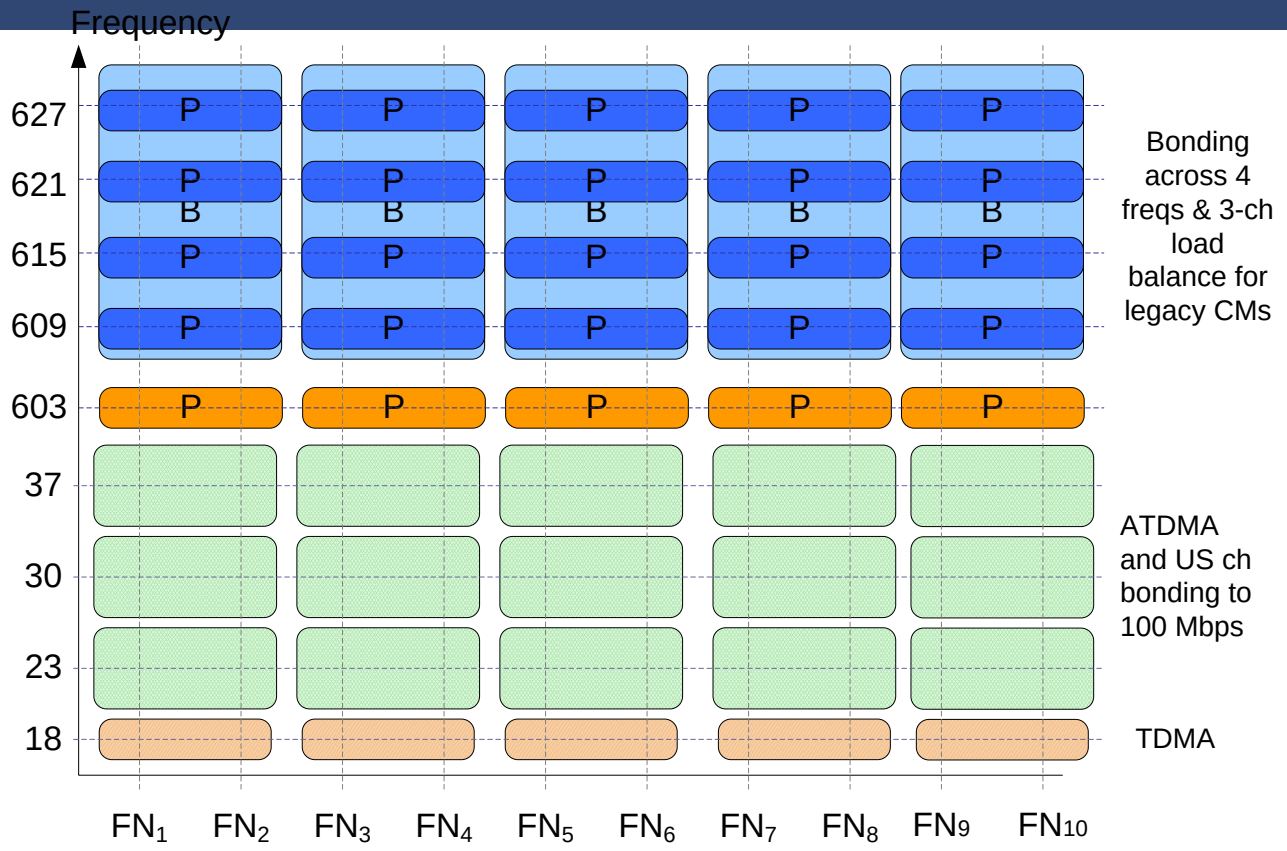


- **5, 5x4 MAC domains with ATDMA & TDMA USs**

Option 3: 100+ Mbps Tier & Channel US Bonding (Step 2)

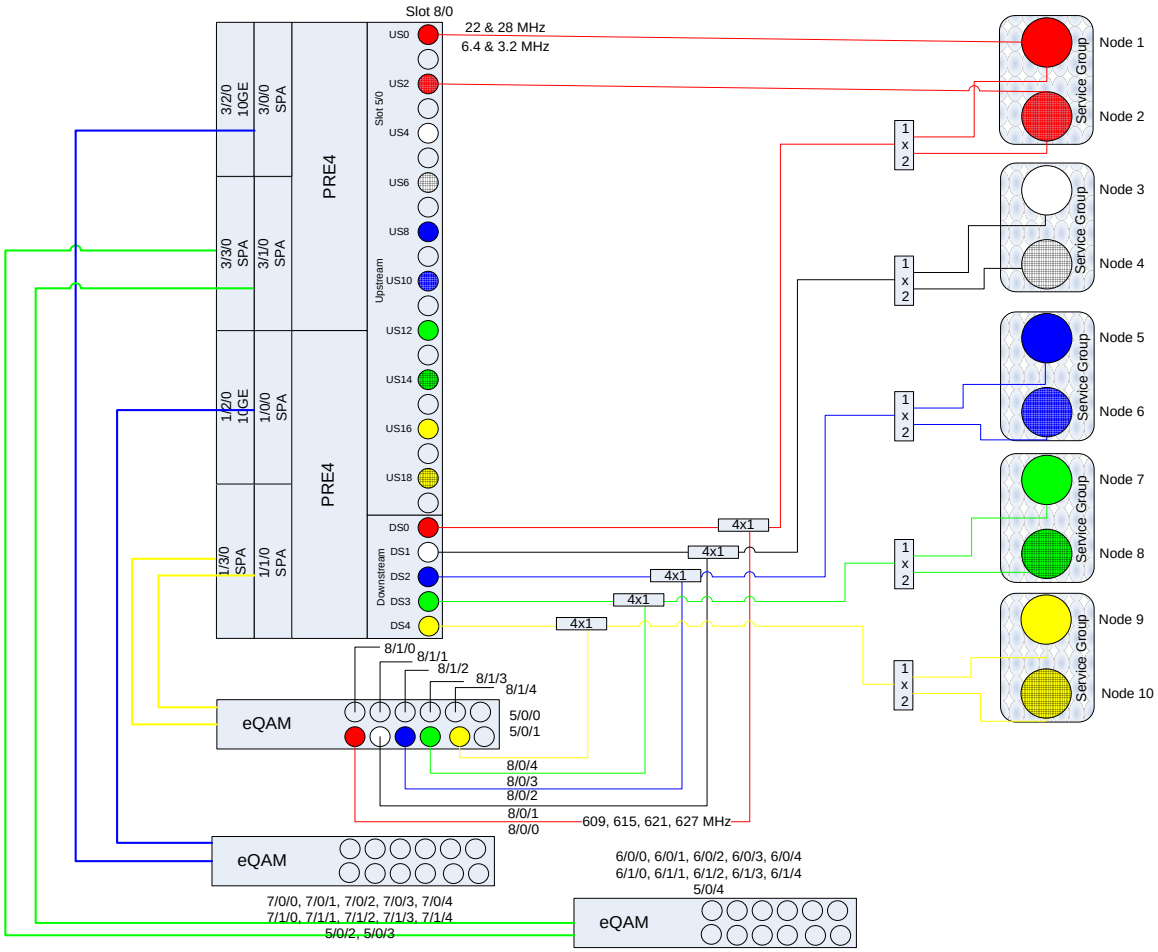
- **5 DS freqs**
- **4 US freqs**





- **5, 5x4 MAC domains with ATDMA & TDMA USs**
  - **Enable US channel Bonding across 2 FN**

Option 3: 100 Mbps Tier & 2 Channel US Bonding



Cisco Products

UBR10012 CMTS w/ "Amazon", 12.2SCA IOS

Spumoni SIP with 6 SPAs

5x20H linecards

RFGW-1 EQAM

- **3 chassis**
- **6 modules each**

DPC/EPC 3000 CM

DPC/EPC 3002 eMTA

Resources (Per SG)

5 DS frequencies

- **1 I-DS**
- **4 M-DS**
- **(5 Primary)**

2 US frequencies

References

DOCSIS Specifications

DOCSIS Specifications

- **DOCSIS 1.0 (http://www.scte.org)**

  ANSI/SCTE 22-1 2007

- **DOCSIS 1.1 (http://www.cablemodem.com)**

  SP-RFIv1.1 – Radio Frequency Interface v1.1

- **DOCSIS 2.0 (http://www.cablemodem.com)**

  SP-RFIv2.0 – Radio Frequency Interface v2.0

- **DOCSIS 3.0 (http://www.cablemodem.com)**

  SP-PHYv3.0 – Physical Layer

  SP-DRFI – Downstream RF Interface

  SP-MULPIv3.0 – MAC and Upper Layer Protocols Interface

DOCSIS Specifications Cont.

- **DOCSIS 3.0**

  SP-SECv3.0 – Security Specification

DOCSIS 3.0 IPV6

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Agenda

- IPv6 Drivers in Broadband Access Networks
- Structure of IPv6 Protocol
- Deploying IPv6 in Cable Networks
- IPv6 CM Initialization Steps in Detail

IPv6 Drivers

- **IPv4 address constraints are becoming a burden on network operations**
  - **Network scaled to use IPv4 in the last 20 years**
  - **IPv4 address exhaustion**
  - **All IP quad play** (Data, Video, Voice. Mobility)
  - **Industry consolidation**
- **Build infrastructure for future services**
  - **Global transparency**
  - **Plug and play home networking**
  - **Access transparency**

IPv6 Drivers

- **Convergence of multiple services over IP is driving the need for large scale addressing**
  - **MSO infrastructure**
  - **Home/SMB networks**
- **IP is being embedded in devices that are no longer "computers" limited to IT environment**
  - **Sling-boxes, IP cameras, PDAs, gateways, automobiles, media centers, IP phones, etc.**
- **Home Networking combined with "always on" technologies (e.g. Broadband Cable, DSL)**
  - **Consumers demanding plug-and-play operation.**
  - **Consumer space is migrating toward a one-subnet-per-home model (instead of a shared subnet across multiple homes)**

Agenda

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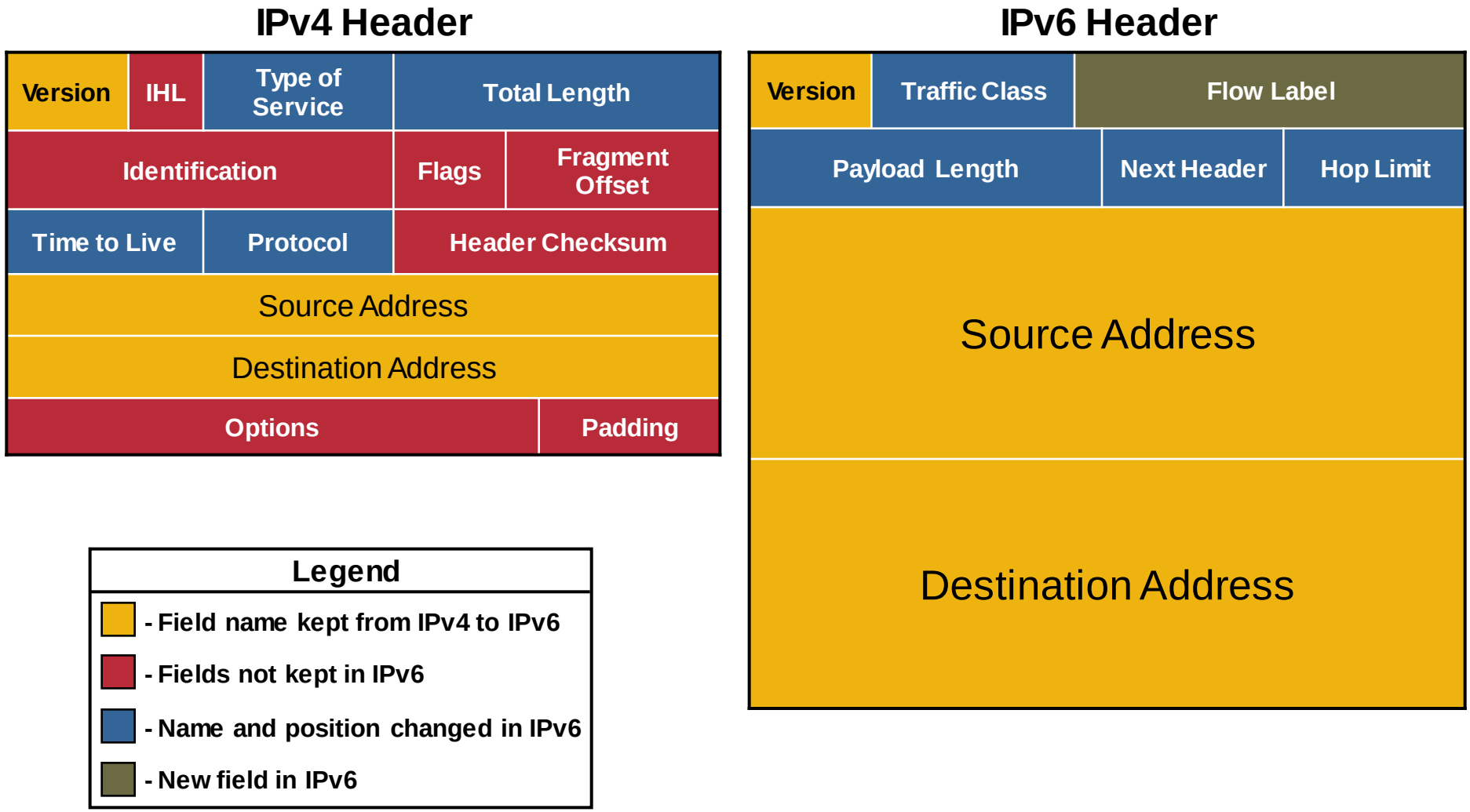
IPv4 and IPv6 Header Comparison



IPv6 Addressing

IPv4 32-bits

IPv6 128-bits

2^{32} = 4,294,967,296

2^{128} = 340,282,366,920,938,463,463,374,607,431,768,211,456

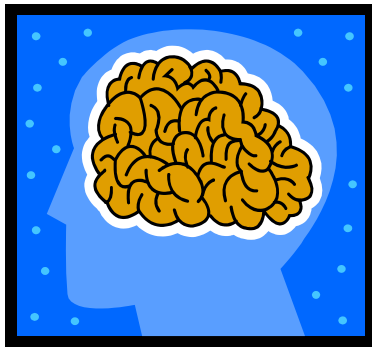
$2^{128} = 2^{32} * 2^{96}$

2^{96} = 79,228,162,514,264,337,593,543,950,336 times the number of possible IPv4 Addresses (79 trillion trillion)

IPv6 Addressing

World's population is approximately 6.5 billion

$$\frac{2^{128}}{6.5 \text{ Billion}} = 52 \text{ Trillion Trillion IPv6 addresses per person}$$



Typical brain has ~100 billion brain cells (your count may vary)

$$\frac{52 \text{ Trillion Trillion}}{100 \text{ Billion}} = 523 \text{ Quadrillion (523 thousand trillion) IPv6 addresses for every human brain cell on the planet!}$$

Agenda

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Cablelabs IPv6 Decision and Approach

- **CableLabs members put IPv6 in consideration for DOCSIS 3.0**
  - **IPv6 support was amongst the top DOCSIS 3.0 feature candidates**
- **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 eROUTER 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)**

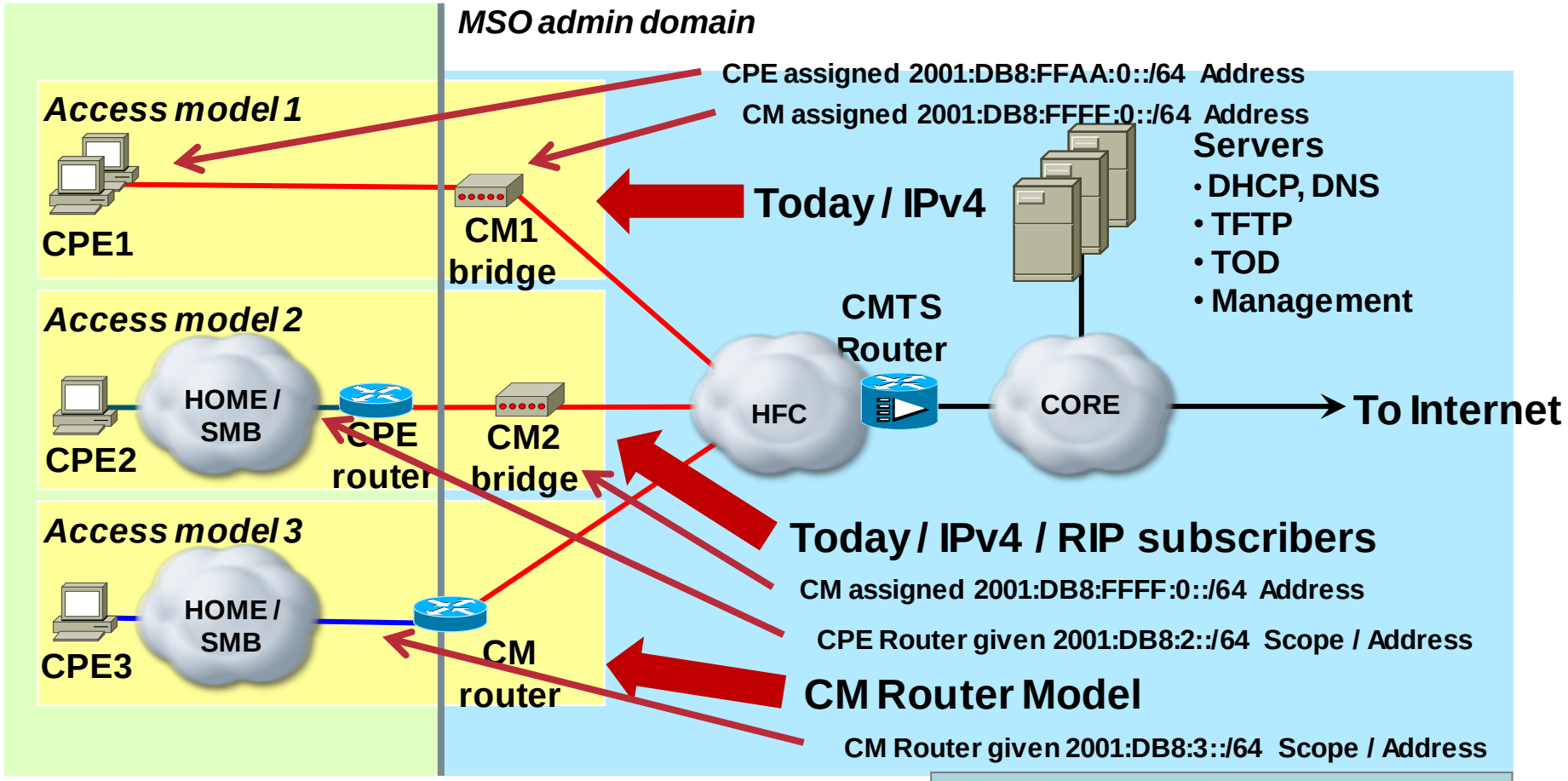
IPv6 Features in DOCSIS 3.0

- 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

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

DOCSIS IPv6 Customer Network Model

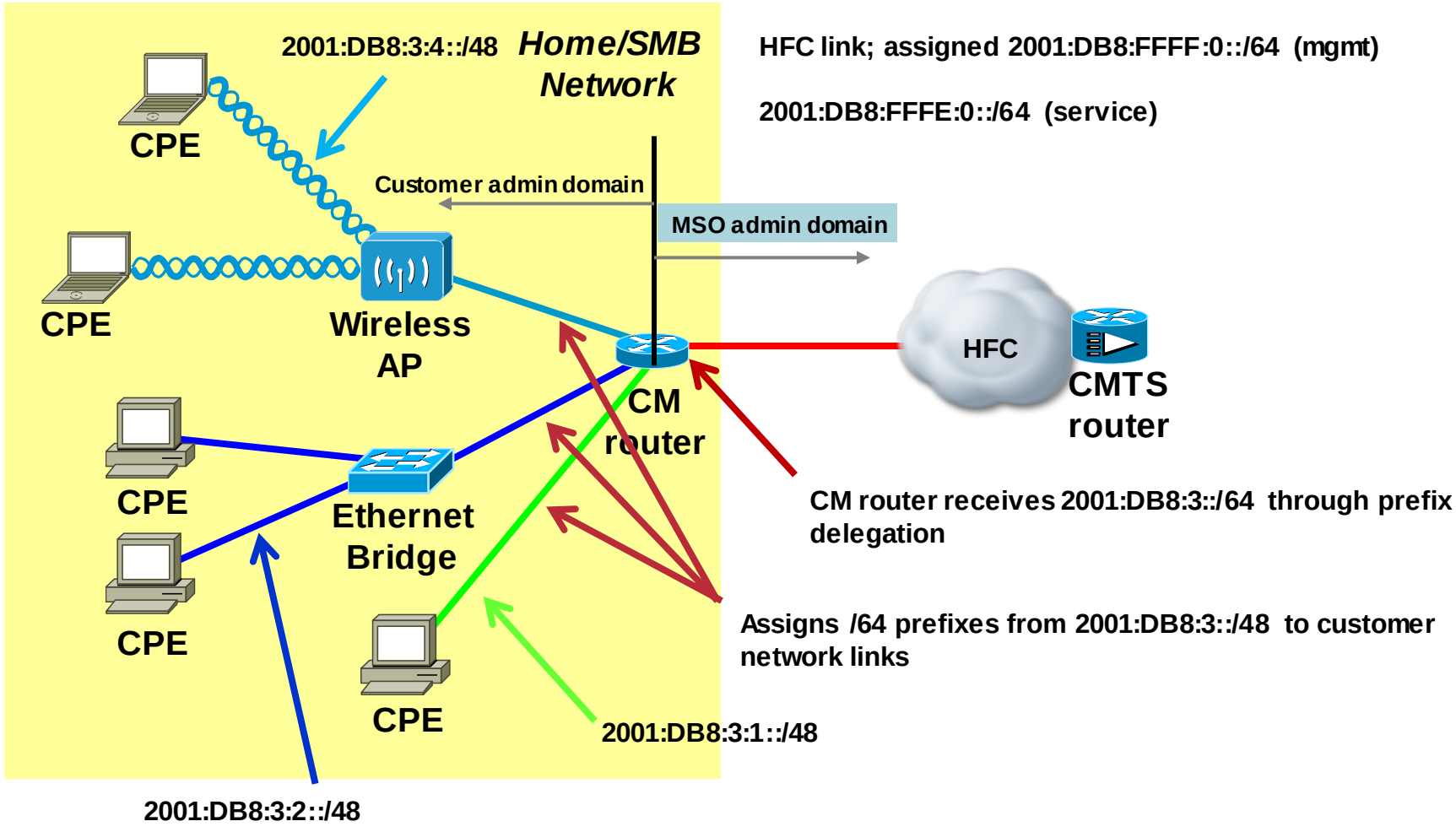


Management prefix:	2001:DB8:FFFF:0::/64
Service prefix:	2001:DB8:FFAA:0::/64
Customer 2 prefix:	2001:DB8:2::/48
Customer 3 prefix:	2001:DB8:3::/48

DOCSIS 3.x IPv6 Reference Architecture

DOCSIS IPv6 Customer Network Model

DOCSIS 3.x IPv6 Reference Architecture



Agenda

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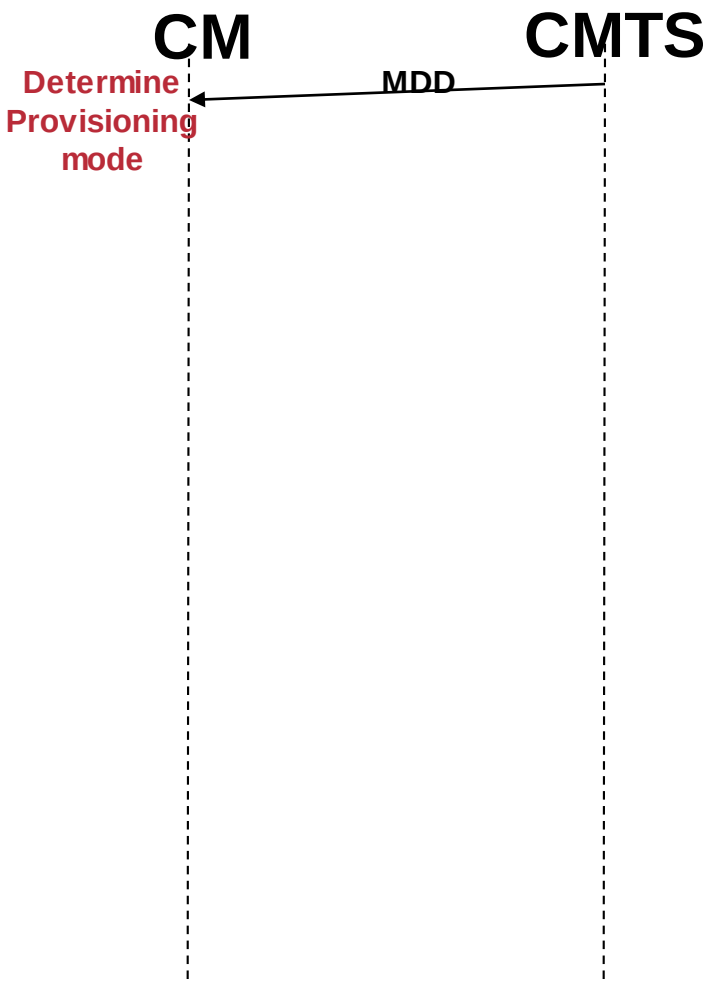
- IPv6 CM Initialization Steps in Detail

CM provisioning: Layer 2

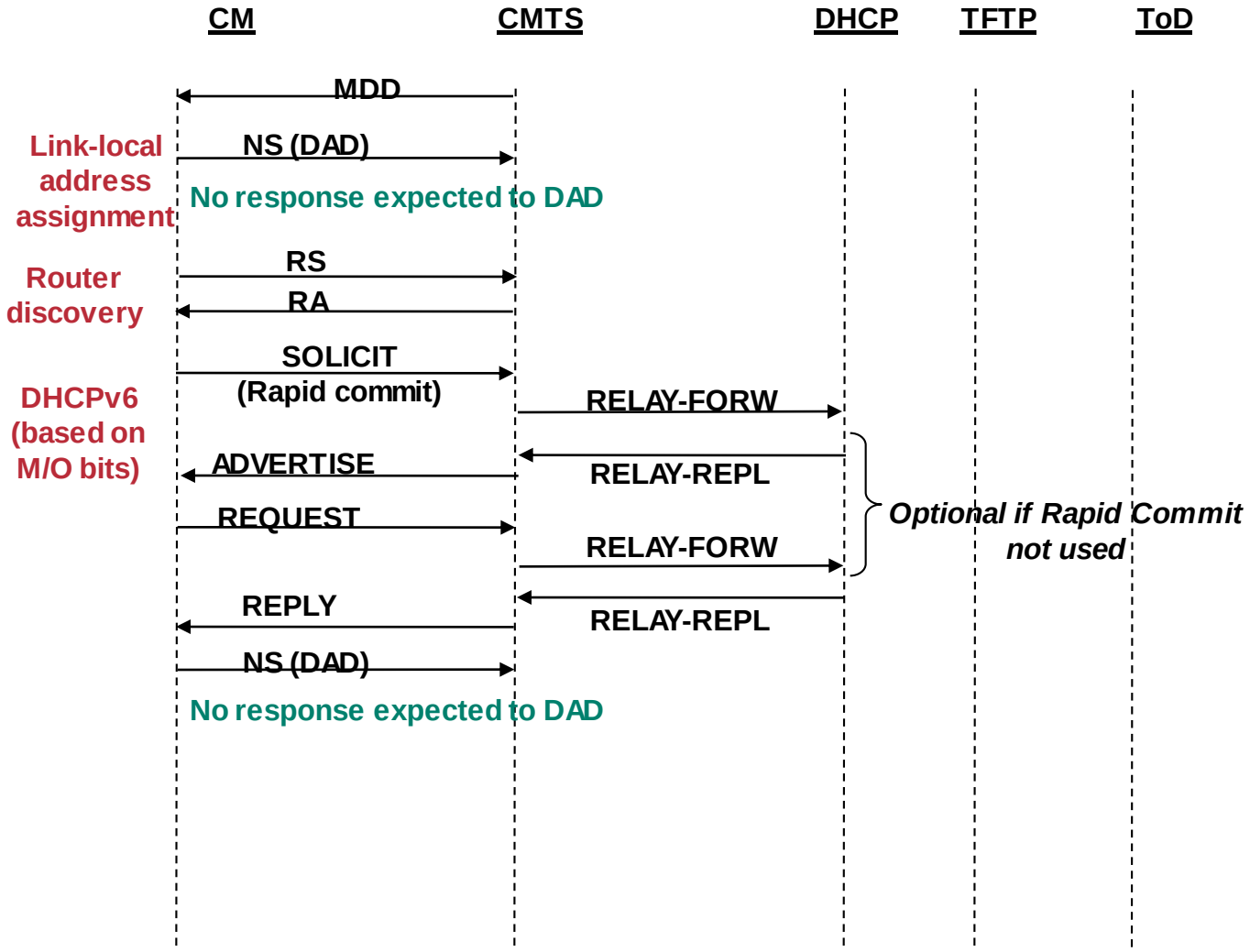
- **CMTS sends an L2 message to the CM that controls**
  - **Use of IPv4 or IPv6 as the preferred mode for CM provisioning and management**
  - **Dual stack management**
  - **Alternate Provisioning Mode (APM): If preferred mode fails, restart provisioning in the alternate mode**



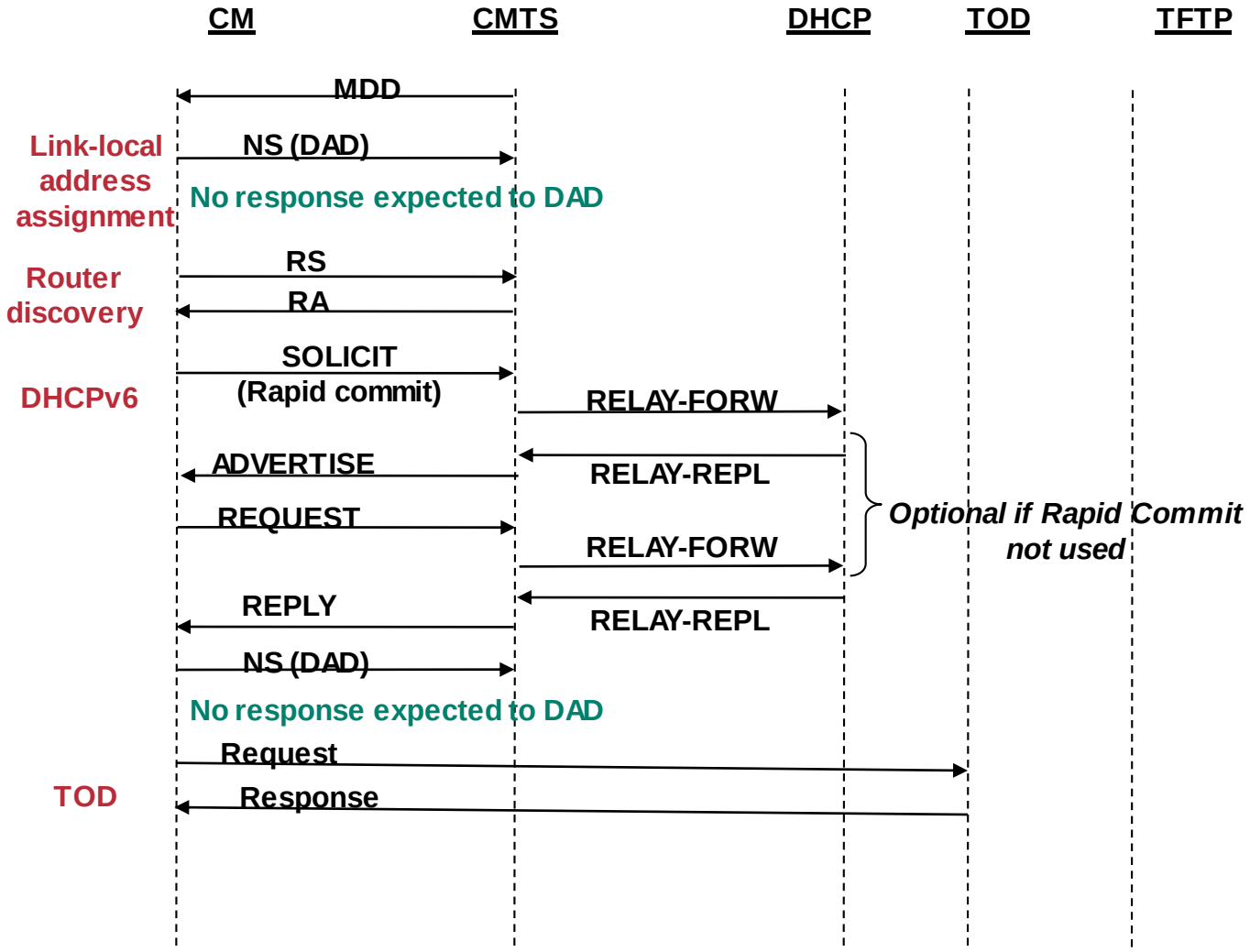
CM Provisioning: Acquire IP connectivity

- **DHCPv6 used for address configuration**
  - **Stateless auto configuration NOT used**
- **MSOs want to have the knowledge and want to control IP address assignments**
- **MSOs used to DHCP. Minimizes changes in operational models**

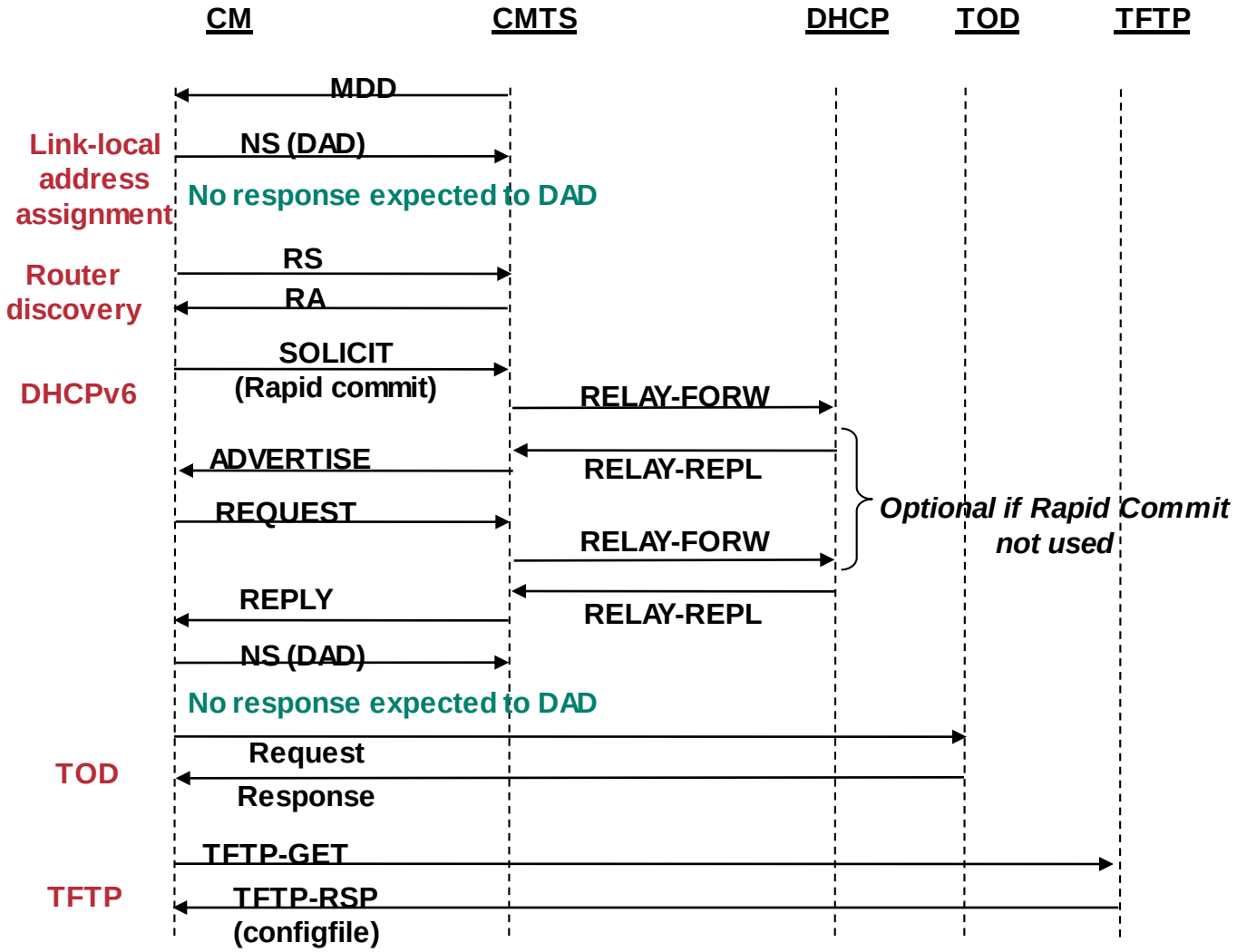
CM Provisioning: Acquire IP connectivity



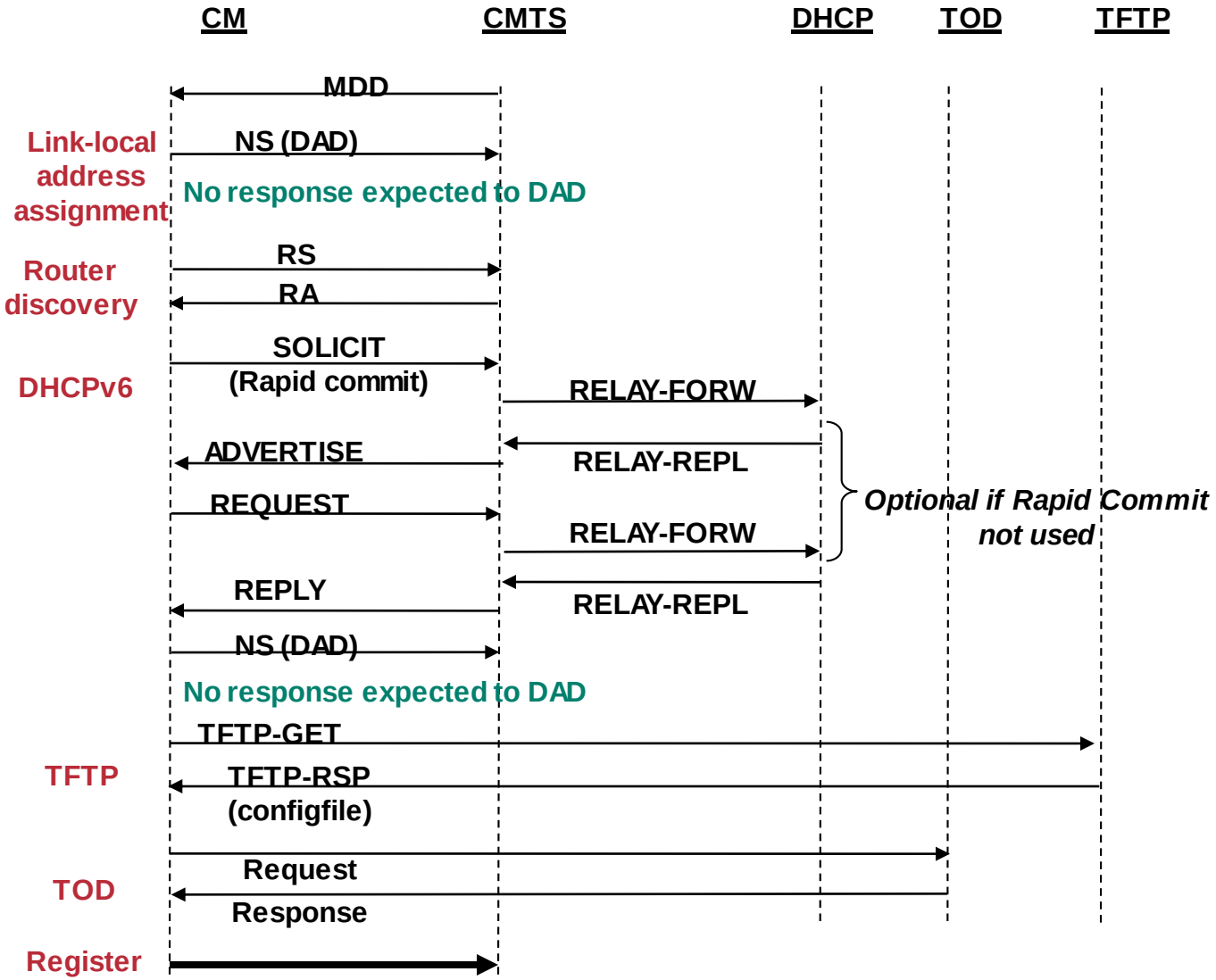
CM Provisioning: Obtain TOD



CM Provisioning: Obtain Configuration File



CM Provisioning: Complete Registration



Questions?

DOCSIS 3.0 Multicast

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Agenda

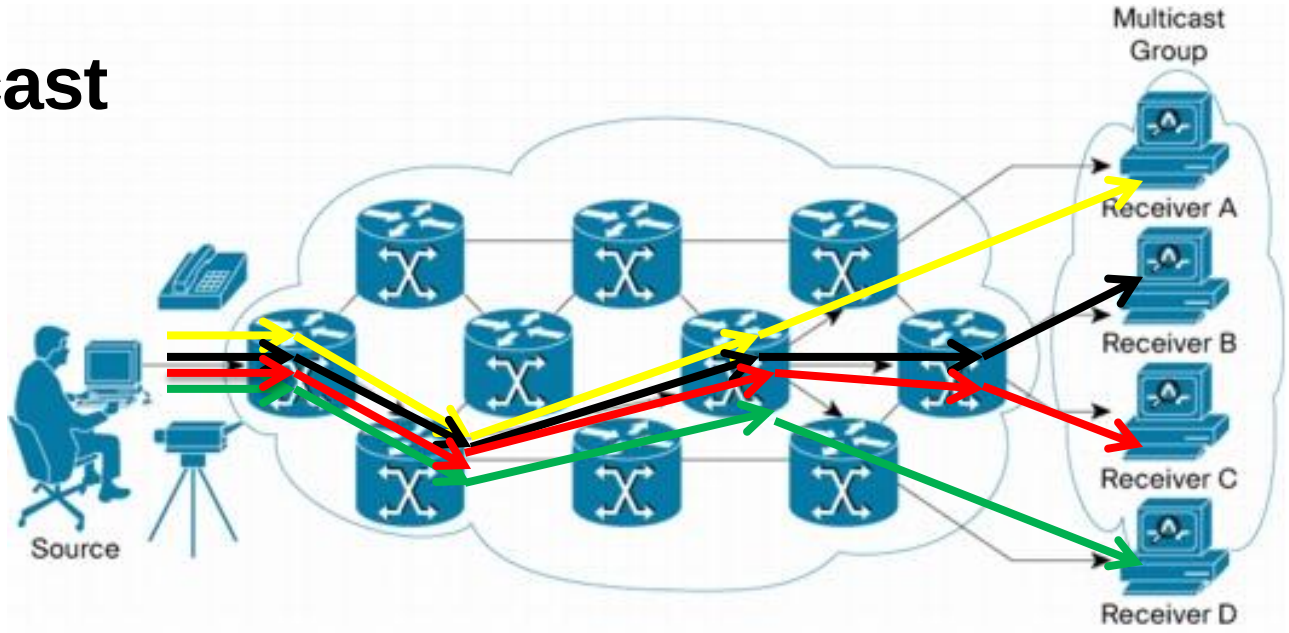
- IP Multicast Primer
- Multicast in Earlier DOCSIS Versions
- Multicast in DOCSIS 3.0

IP Multicast Motivation

- ***Distributed Applications*: Makes multipoint applications possible**
- ***Enhanced Efficiency*: Controls network traffic and reduces load on servers**
- ***Optimized Performance*: Eliminates traffic redundancy**

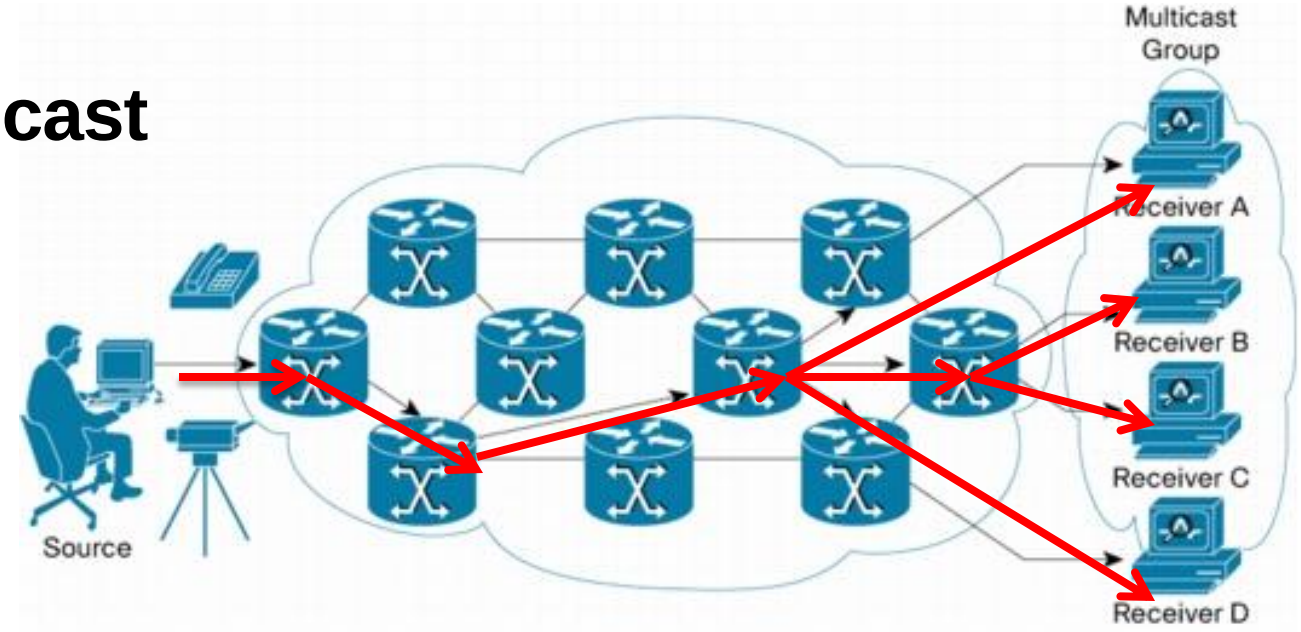
IP Multicast Operation

Unicast



IP Multicast Operation

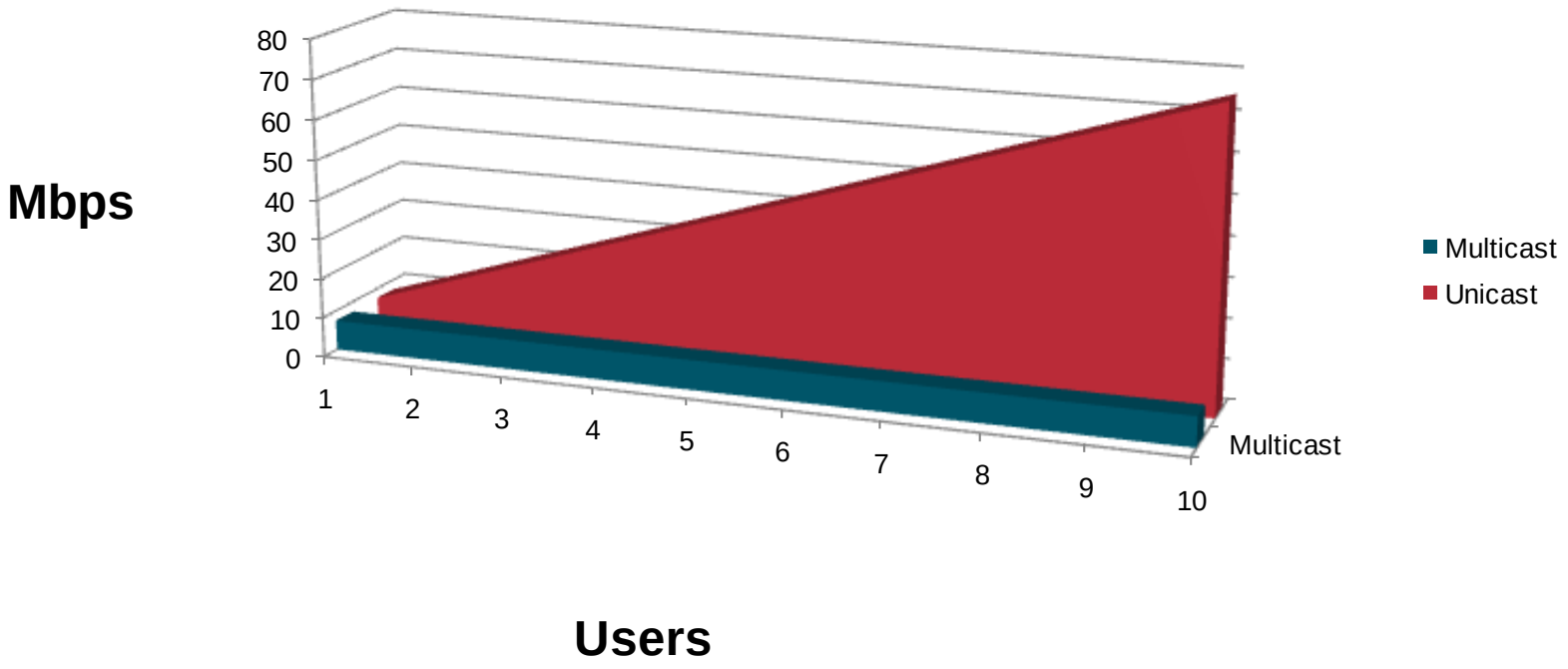
Multicast



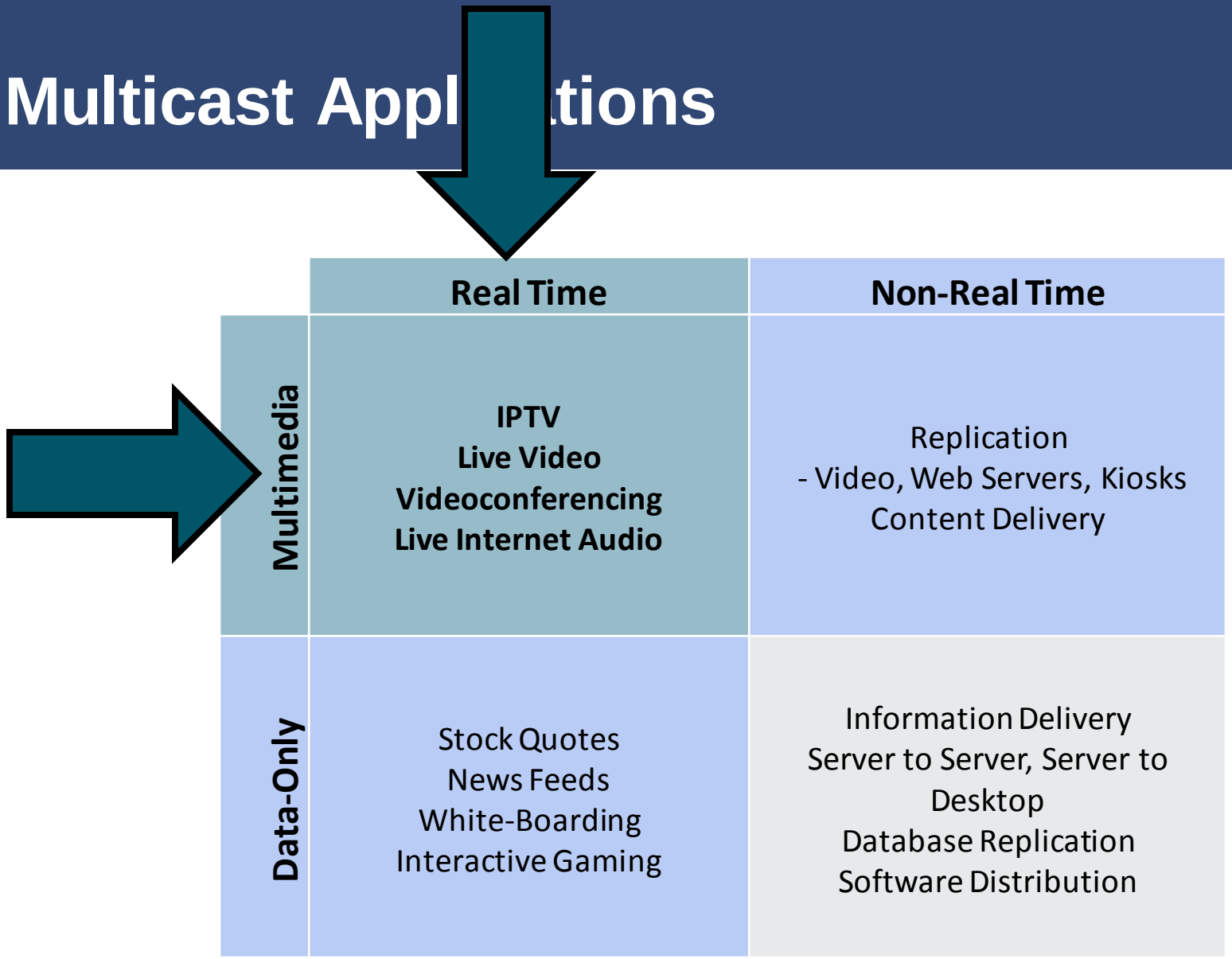
IP Multicast Motivation

Example: Video Streaming

Video over DOCSIS (VDOC) MPEG-4 Stream of 1020p Video
Assuming average of 7.5Mbps



Multicast Appl tions



	Real Time	Non-Real Time
Multimedia	**IPTV** **Live Video** **Videoconferencing** **Live Internet Audio**	Replication - Video, Web Servers, Kiosks Content Delivery
Data-Only	Stock Quotes News Feeds White-Boarding Interactive Gaming	Information Delivery Server to Server, Server to Desktop Database Replication Software Distribution

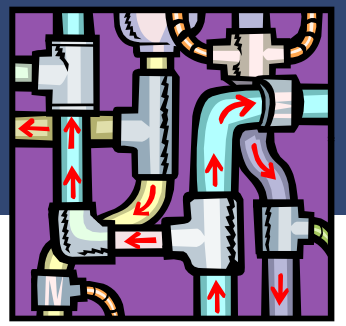
Multicast Applications

- **Streaming Audio and Video Content**
  - **ASM Content to STB and Cable Subscribers**
- **IP Video (Video over DOCSIS)**
  - **Allows static SSM Multicast media content on bonded channels**
  - **Eastern Europe & American**

Multicast Applications

- **Set-Top-Box Programming**
  - **Conditional access (CA) and system information (SI)**
  - **Out of Band method to communicate with STBs (e.g. DSG – DOCSIS STB Gateway)**
- **Multicast VPN Services**
  - **Business Services utilizing L2VPNs have customer requests to carry Multicast traffic**
  - **Examples: Video conferencing, NetMeeting, Finance-specific application**

Multicast and Unicast in MSOs



XoD, nPVR

Linear Video
Niche Programming

HSD

VoIP

VoD

On Demand

Personal
Channels

Linear TV

Broadcast/
Edge
QAMs

Router

PacketCable

CMTS
Packet Shelf

M-CMTS

Cable
Modem

IP STB

Cable
Modem

IP STB

Cable
Modem

IP STB

Cable
Modem

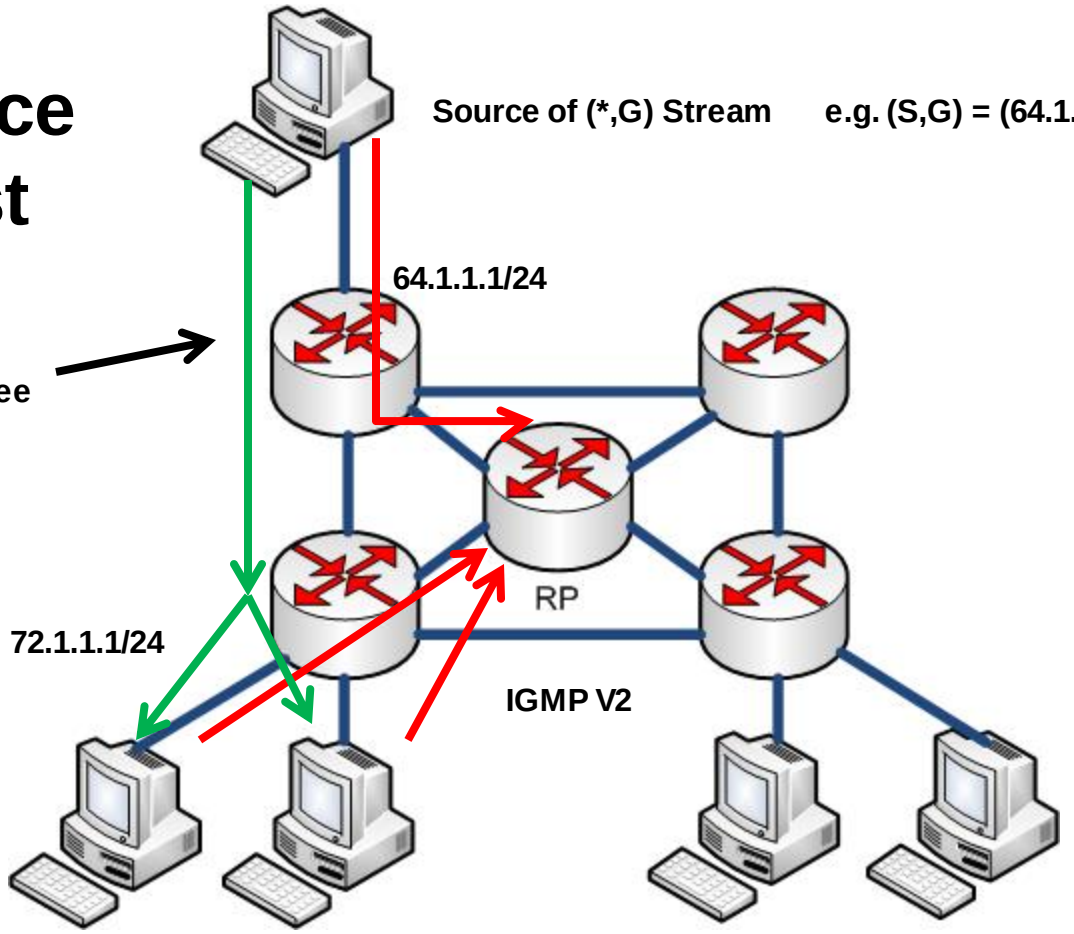
IP STB

IP Multicast: SSM vs ASM

- **ASM service model (RFC1112) (any source multicast)**
  - Sources send traffic to a host-group G
  - Receivers join a host-group (*,G) and receive traffic from **all sources** sending to G
  - Receivers do not need to know who the sources are
- **SSM service model (RFC 4607) (source specific multicast)**
  - Sources send traffic to a host-group G
  - Receivers subscribe to (S,G) channel(s) and receive traffic from specific sources sending to G
  - Receiver need to know the sources in advance

IP Multicast: SSM vs ASM

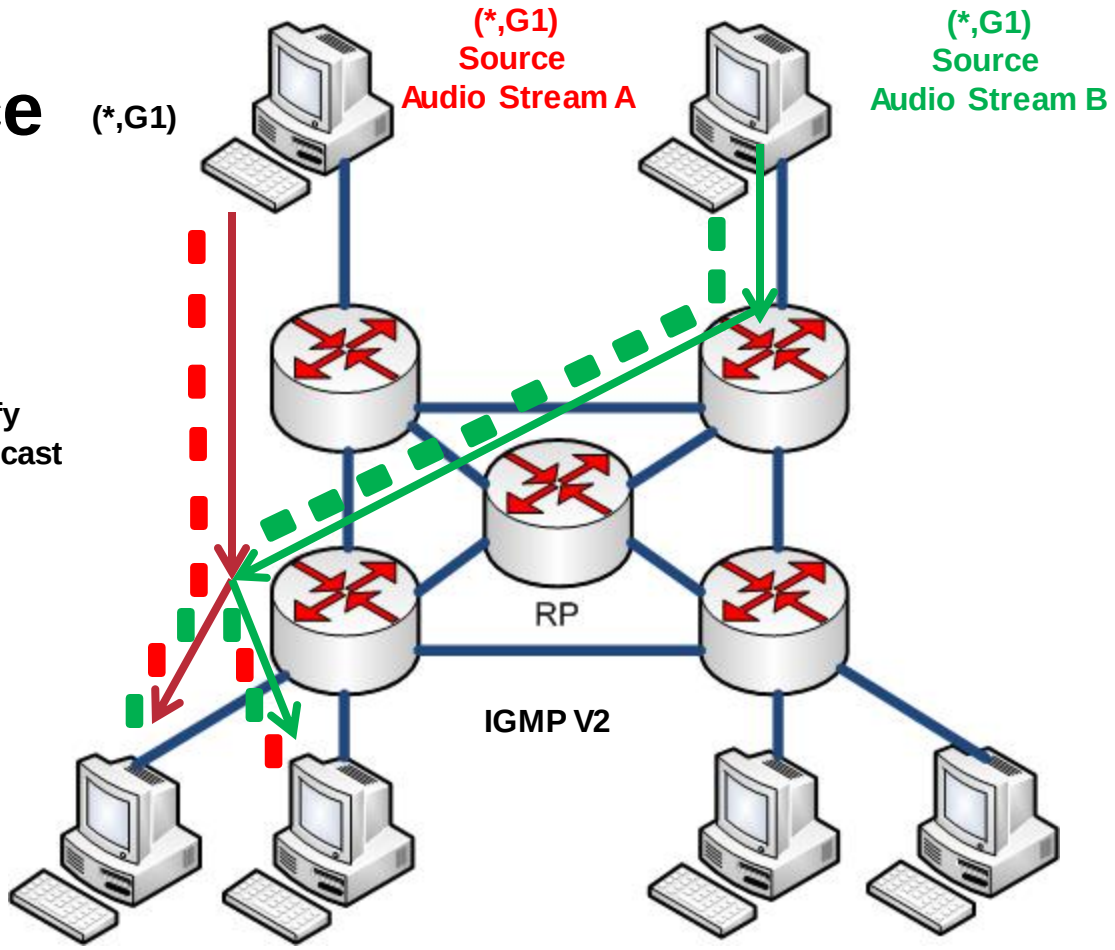
Any Source Multicast



IP Multicast: SSM vs ASM

Any Source Multicast

(*,G1)



Receiver cannot specify the source of the multicast

Collisions may occur

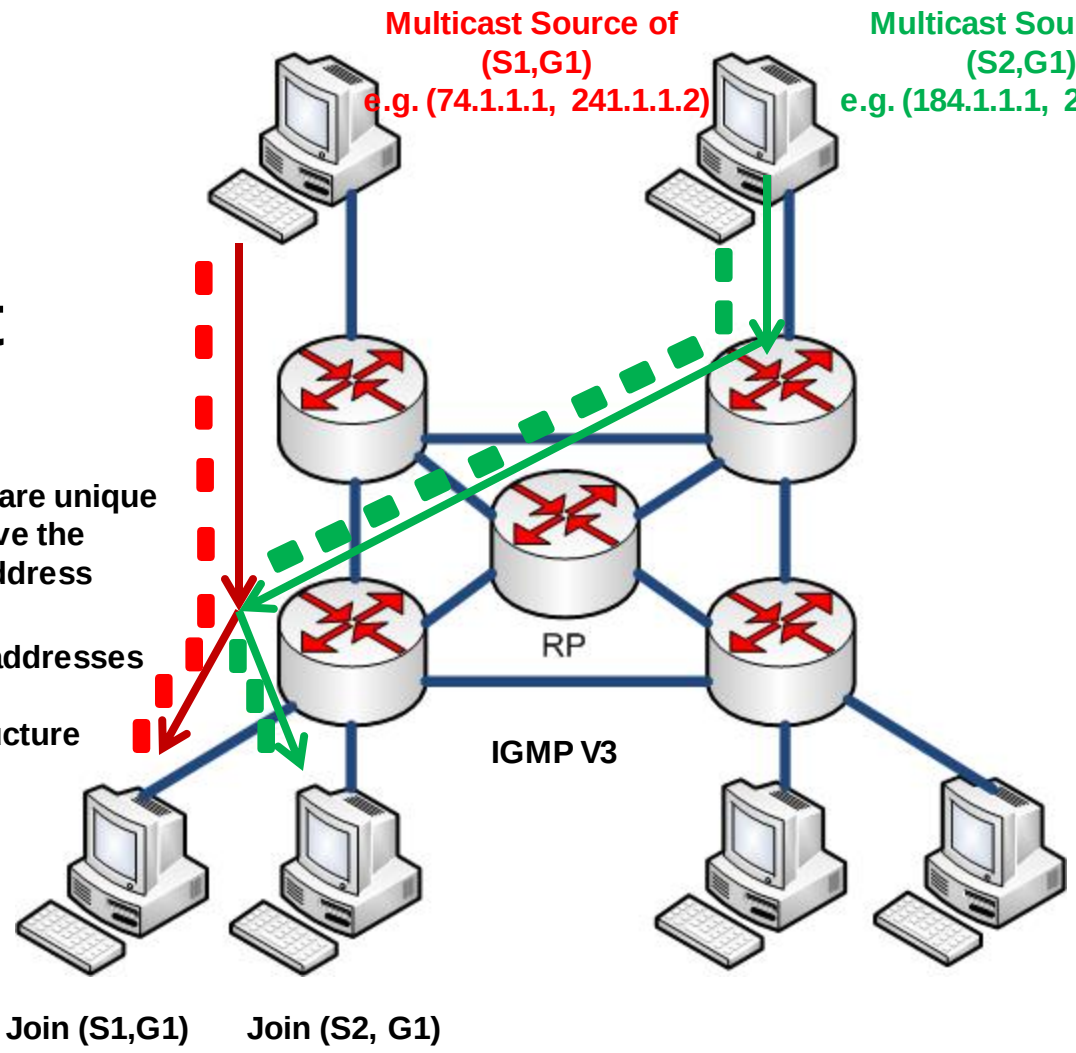
I want to listen to A Join (*,G1) Join (*,G1) I want to listen to B

IP Multicast: SSM vs ASM

Source Specific Multicast

Multicast Streams (S1,G1) and (S2, G1) are unique even though they have the same G1 Multicast Address

Well Known source addresses does not require Shared Tree Infrastructure (e.g. MSDP and RP)



IP Multicast: IGMP Protocol

- **Defines mechanism for a host to report its multicast group membership to adjacent routers**
- **IGMPv1**

  Hosts send IGMP Report to join an ASM group

  Router send periodic queries to ensure ASM group has active listeners

  Hosts respond to queries and support *report suppression*
- **IGMPv2**

  Adds explicit *leave mechanism*
- **IGMPv3**

  Adds Include/Exclude Source Lists

  No Report Suppression to allow explicit tracking and better "channel" change behavior

Agenda

- **IP Multicast primer**
- **Multicast in earlier DOCSIS versions**
- **Multicast in DOCSIS 3.0**

Multicast Support in DOCSIS 1.0

- **DOCSIS 1.0 does not standardize the support for dynamic multicast**
- **DOCSIS 1.0 CM forwards all multicast traffic, by default**
- **Multicast forwarding through the CM can be controlled statically by setting packet filters**

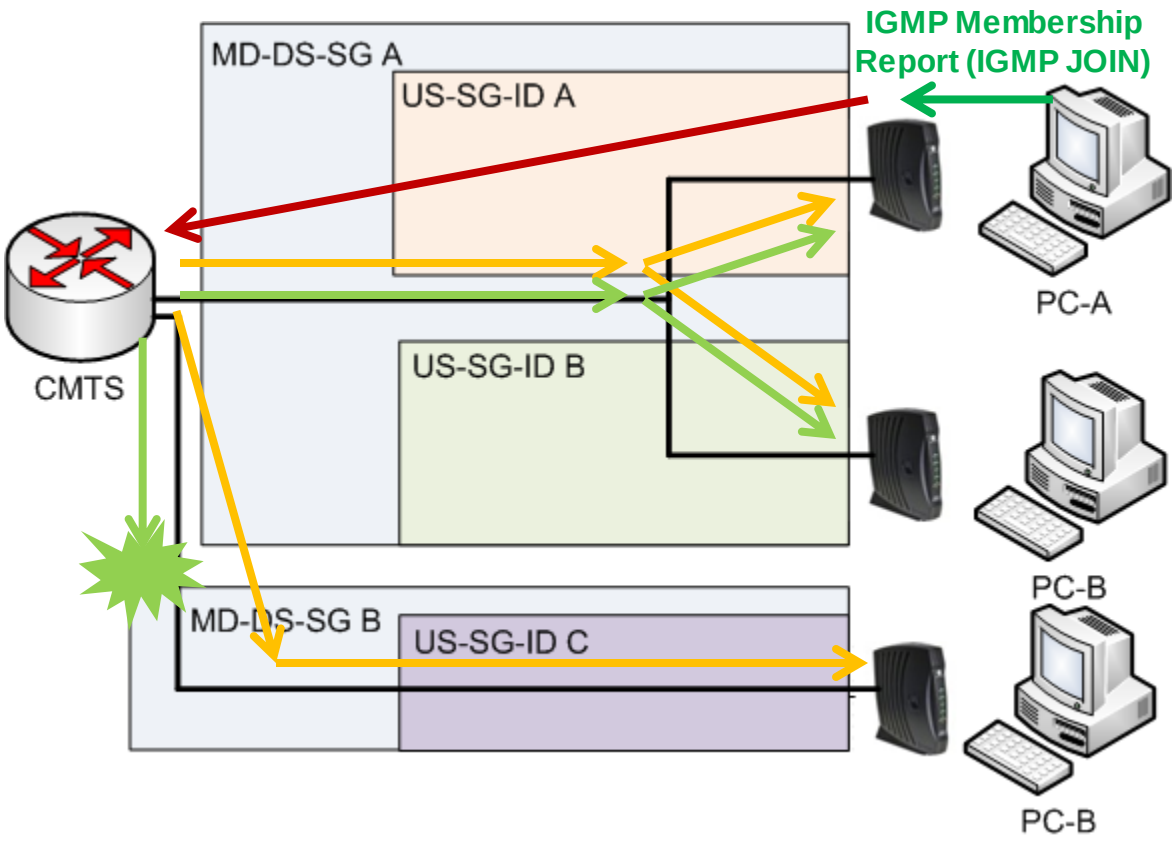
Multicast Support in D1.1/2.0

- **Provides Dynamic Access to ASM multicast**
  - **Ability to dynamically learn which streams should be forwarded to the cable network**
- **Conservation of bandwidth**
  - **Conservation of HFC Downstream and Upstream**
  - **Conservation of CPE LAN bandwidth**
- **Authorized access and management**
  - **Ability to provide Cable operator control of multicast**
  - **Session access on a per subscriber basis**

Multicast support in D1.1/2.0

- CM and CMTS snooping of IGMPv2
- Packet Classification Rules (LLC Filters and IP Filters)
- Baseline Privacy for multicast streams based on snooped joins
- CMTS required to Echo IGMP membership reports to the downstream (this is how the CM knows its joined an IGMP group)

Multicast Support in D1.1/2.0



1. PC-A Sends IGMP Membership Report (by CPE Interface)
2. CM snoops the Membership Report and forwards it. CM immediately forwards any Multicast Group traffic received on RF interface to the CPE
3. CMTS receives Membership Report and echoes it back on the downstream (All DS if it is the first)
4. If not already streaming, the multicast stream starts on that Downstream group (note CMTS may choose to send multicast traffic only on those Downstreams with multicast hosts)

Drawbacks in D1.1/2.0

- **Protocol-aware implementation (e.g. IGMP snooping) makes CM more complex and less extensible**
  - **No support for IGMPv3 and SSM**
  - **Only IGMP protocol supported (e.g. no IPv6 MLDv1/v2)**
  - **No support for routed networks on CPE side**
  - **Rudimentary support for static multicast**

Drawbacks in D1.1/2.0

- **No support for Multicast QoS (no explicit service flow created for multicast stream)**
- **IGMP echo requirement rules out explicit tracking of multicast listeners**
- **No Support for multicast PHS (Packet Header Suppression)**
- **Rudimentary support for multicast authorization**
- **No join acknowledgement**

Agenda

- **IP Multicast primer**
- **Multicast in earlier DOCSIS versions**
- **Multicast in DOCSIS 3.0**

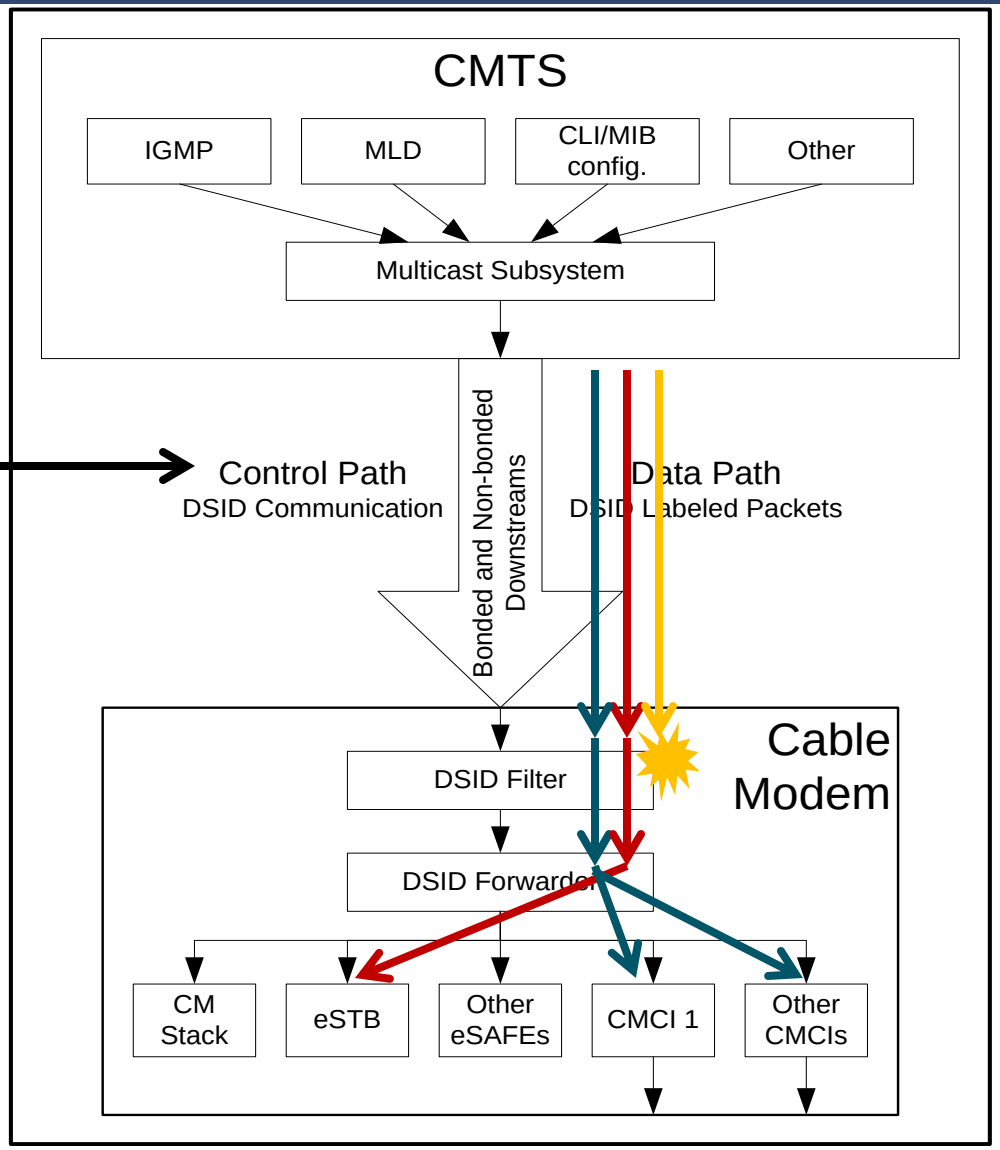
D3.0 Multicast - Goals

- Support for SSM and IGMPv3
- IPv6 multicast support (pre and post registration)
- Support for Multicast QoS
- Support 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

Control Path Established with:

1) **MDD Messages**
2) **REG-RSP during CM Registration**
3) **DBC-REQ Messages for dynamic flows**



DOCSIS 3.0 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 (dynamic bonding change)* messaging**
- **Multicast Filtering and Replication within the CM**
  - **Based on DSIDs**
  - **GMAC promiscuous operation**

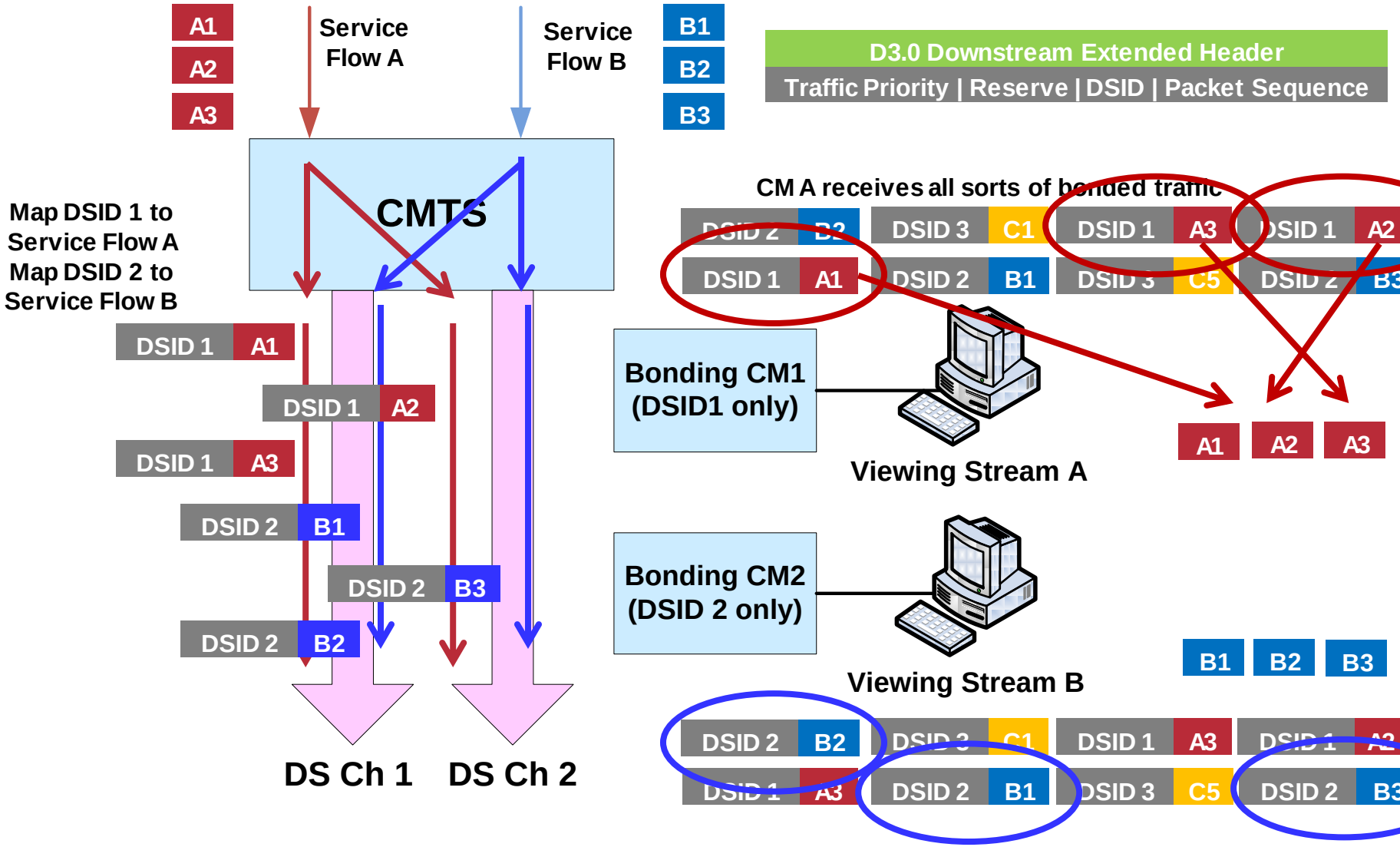
DSID – What are they?

- **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.**

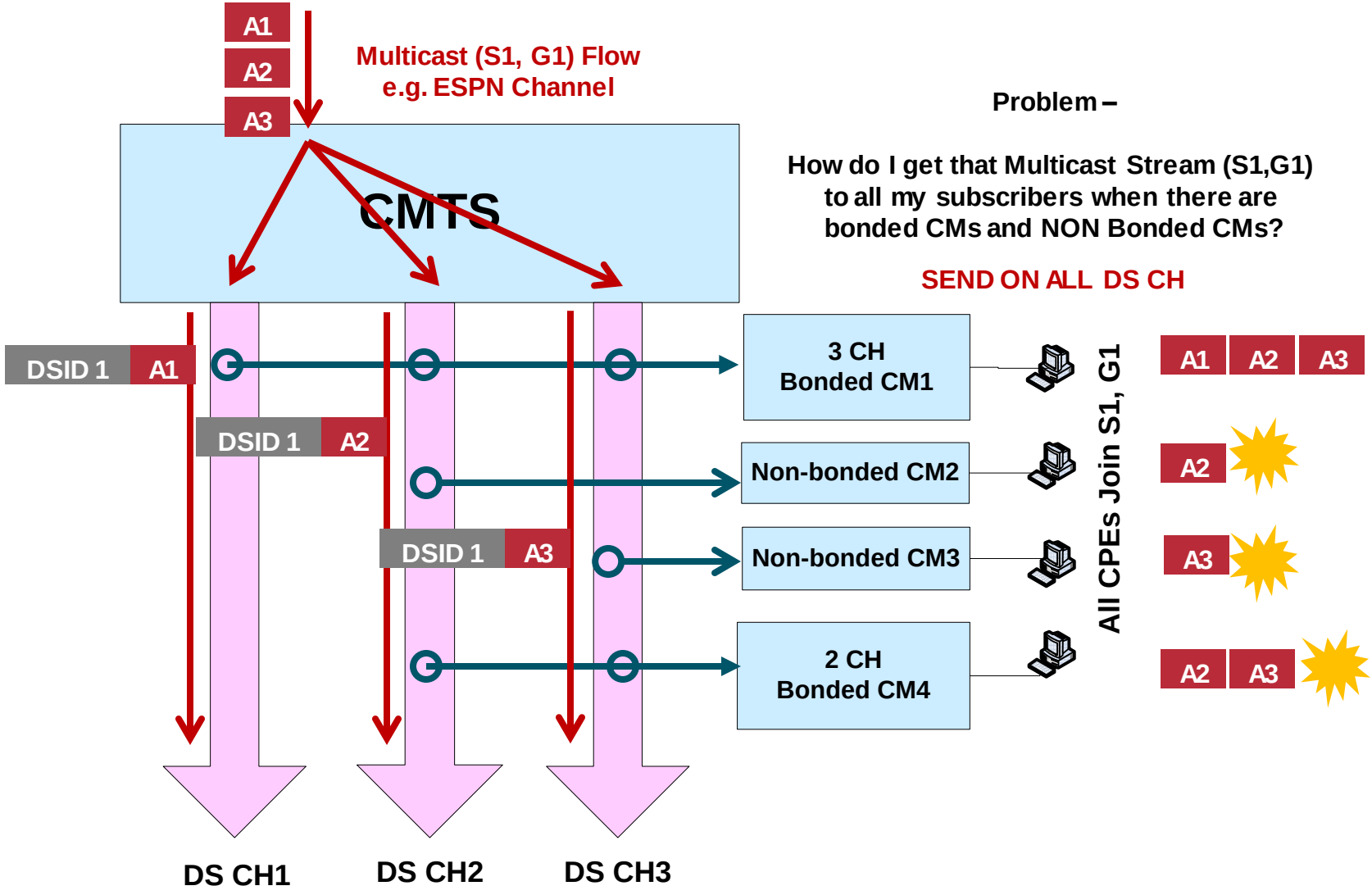
DSID – What are they?

- **The DSID serves as:**
  - **A re-sequencing index**
  - **DSIDs can be used only on a specific set of QAMs (DCS)**
  - **A tag to identify unicast flows**
  - **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**

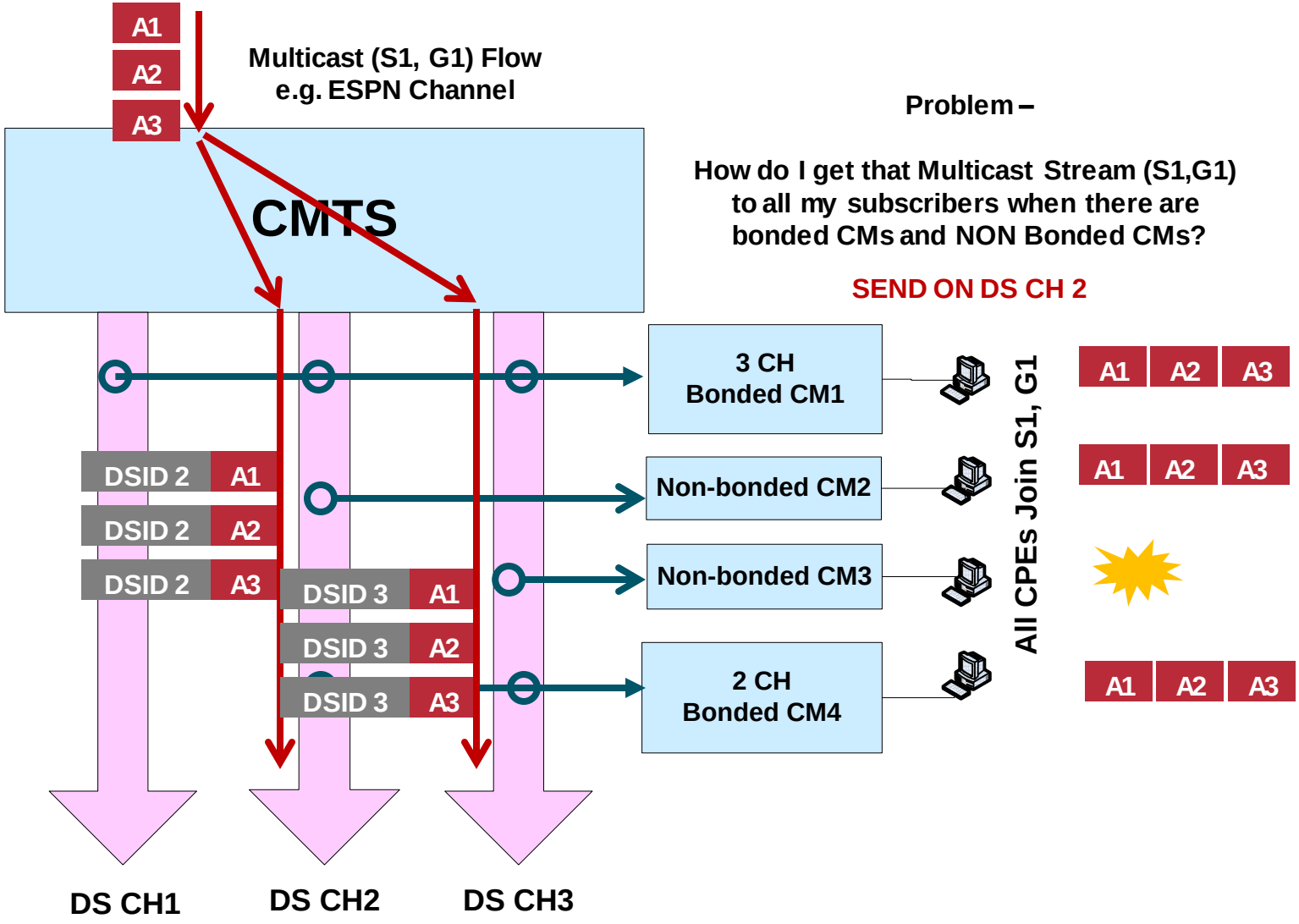
DSID Example – In a Unicast Scenario



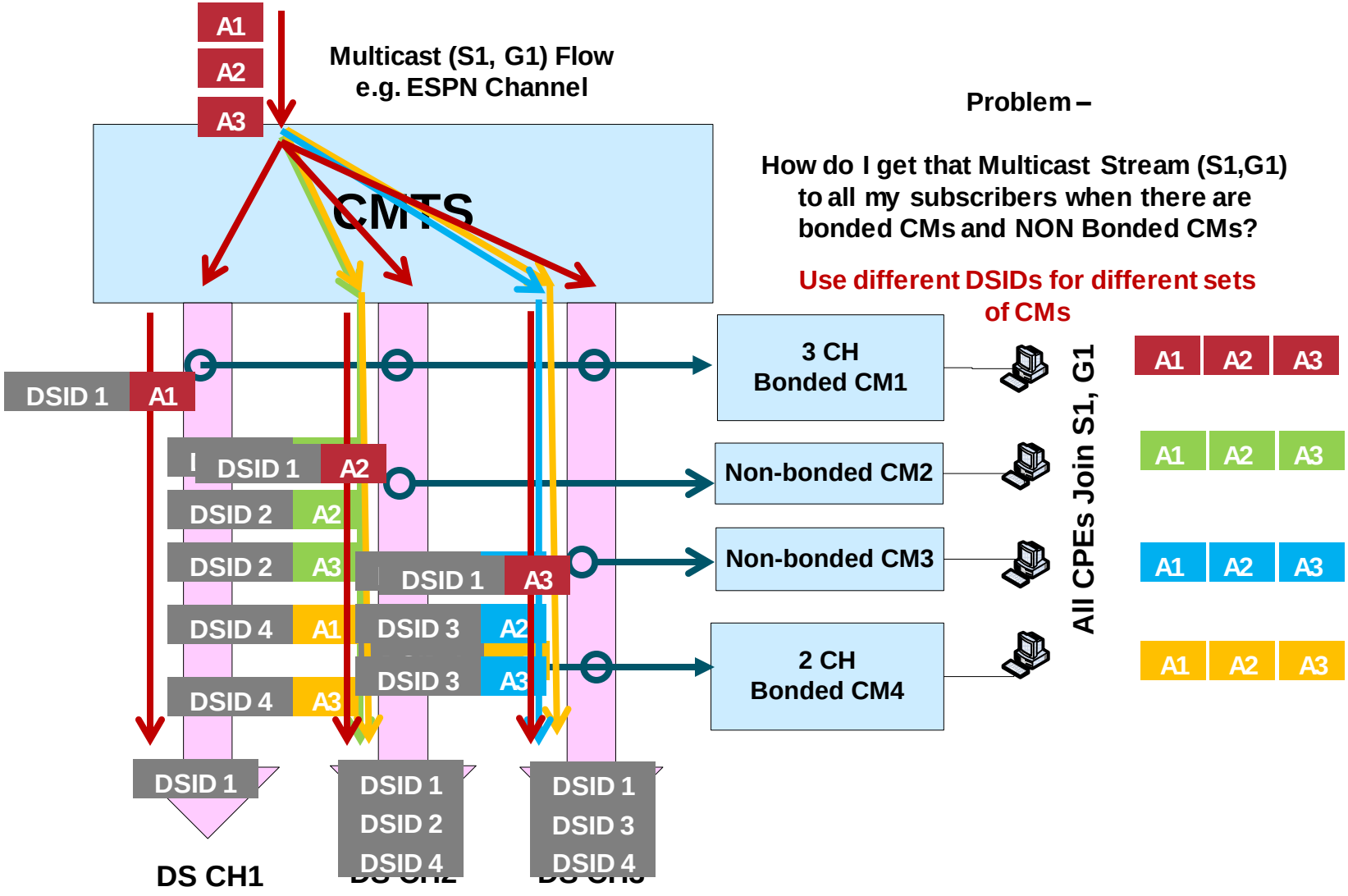
Duplicate prevention through D3.0 CMs



Duplicate prevention through D3.0 CMs



Duplicate prevention through D3.0 CMs



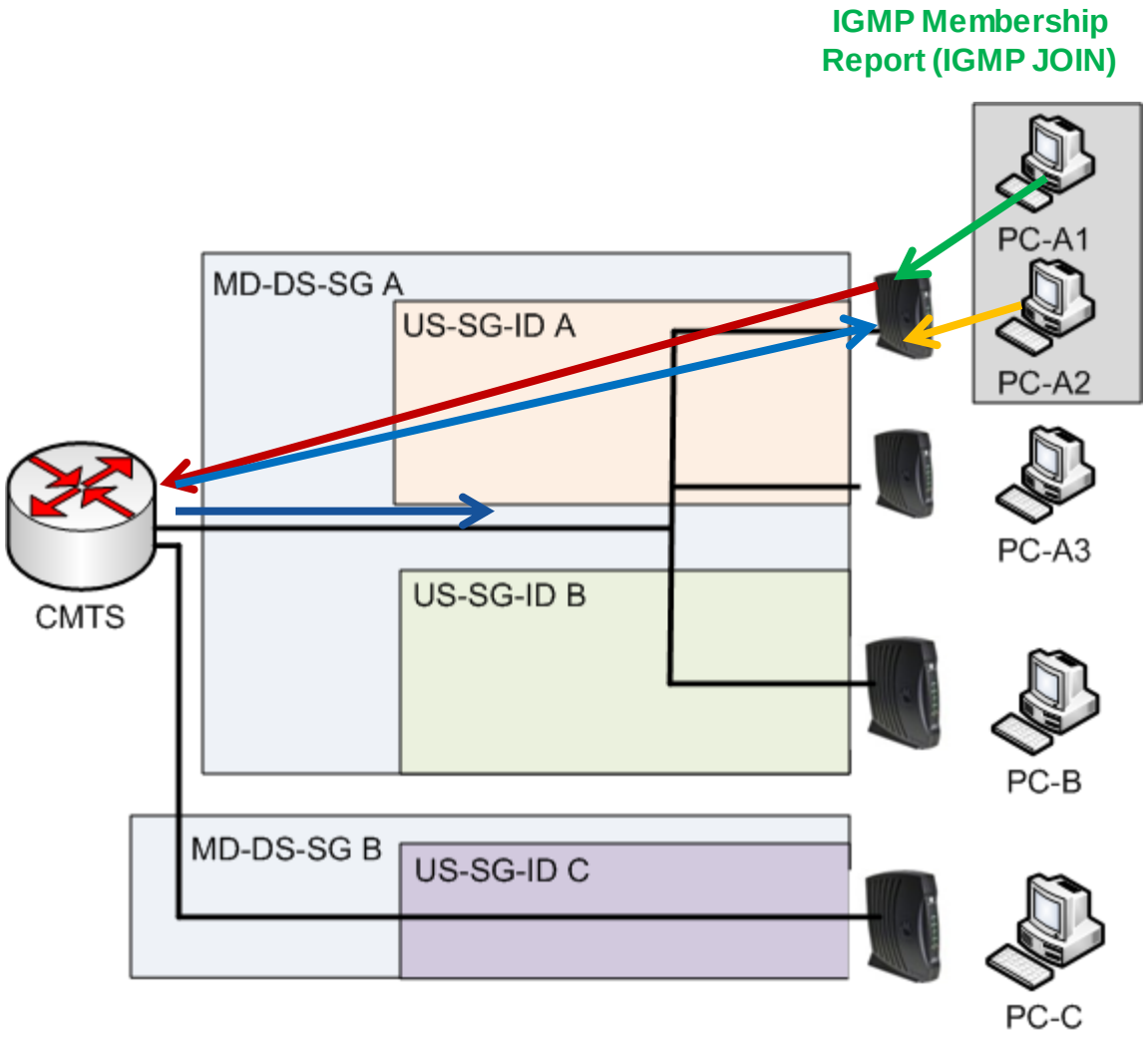
D3.0 Dynamic Multicast Support

- 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

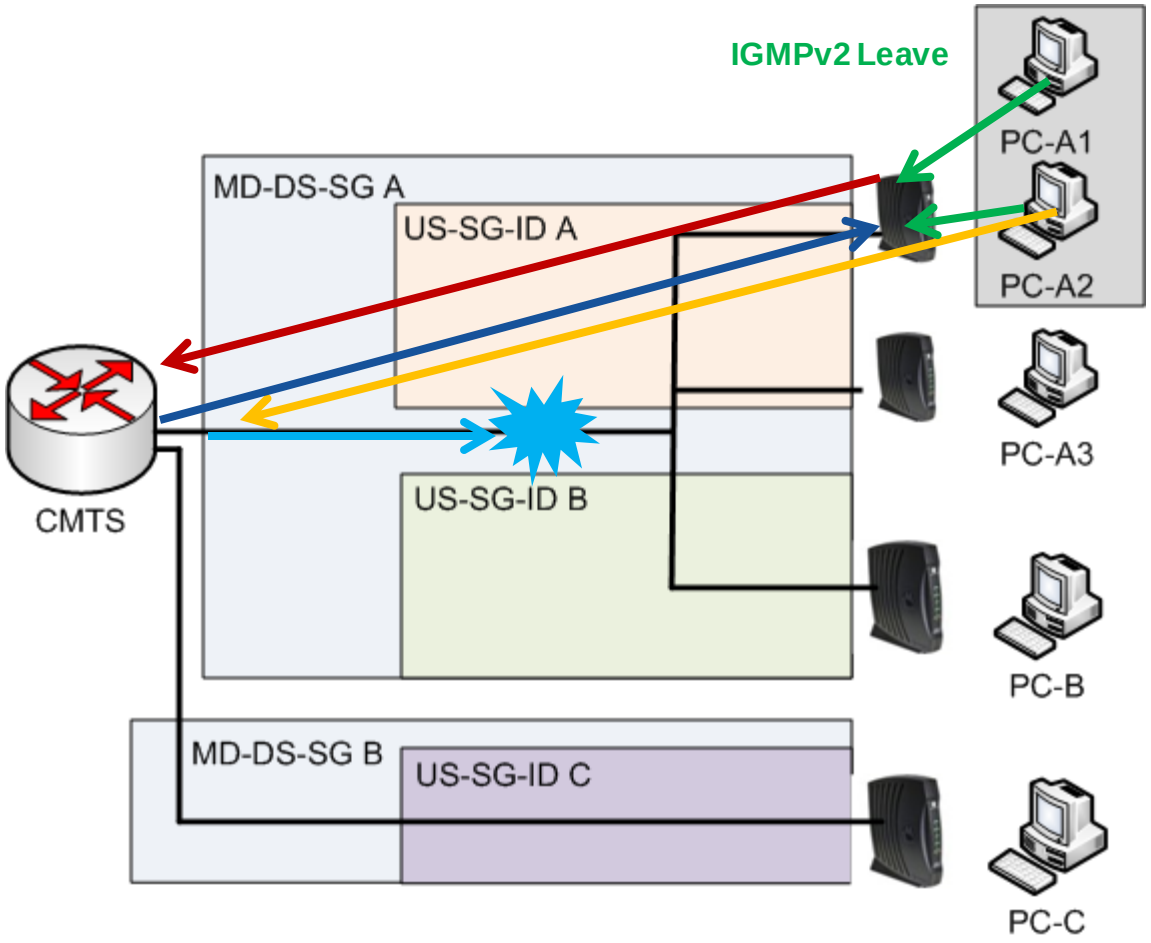
- When CMTS receives join request from a multicast client, it signals the DSID to the CM using DBC messaging with client MAC address and encryption info
- If CMTS receives join request from another multicast client behind that CM, it signals that client MAC address to the CM to control stream replication 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

Multicast Support in D1.1/2.0



1. PC-A1 Sends IGMP Membership Report (by CPE Interface)
2. CM Forwards the IGMP JOIN to CMTS
3. If not already created, a DSID is created for multicast flow and CMTS forwards the traffic to the appropriate multicast hosts.
4. CMTS replies with DBC Message with DSID and Encryption info to the CM (not IGMP echo as in D2.0)
5. PC-A2 sends an IGMP Membership Report. CM signals the CMTS. If same Multicast group the replication happens at CM.

Multicast Support in D1.1/2.0

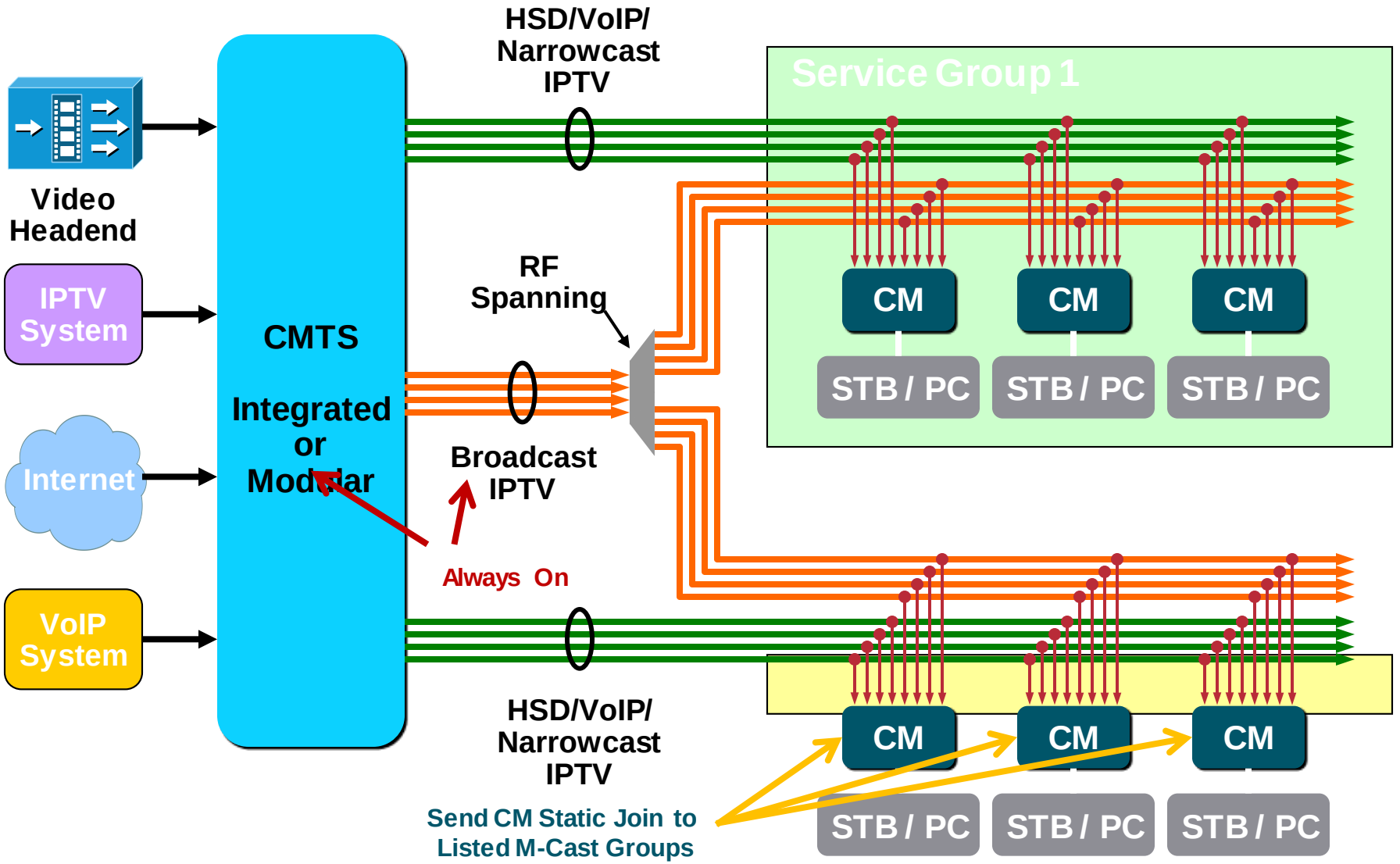


1. PC-A1 Leaves – Sends IGMPv2 Leave message
2. CM Forwards the IGMP Leave to CMTS
3. CMTS Checks for additional receivers behind the CM with group-specific query
4. PC-A2 replies to the Group Specific Query and the Multicast stream continues
5. PC-A2 Leaves – Sends IGMPv2 Leave message
6. CMTS Checks for additional receivers behind the CM with group-specific query
7. Group specific query to the CM times out and it signals CM to delete the DSID
8. If no other Multicast hosts exists, CMTS stops the Multicast flow

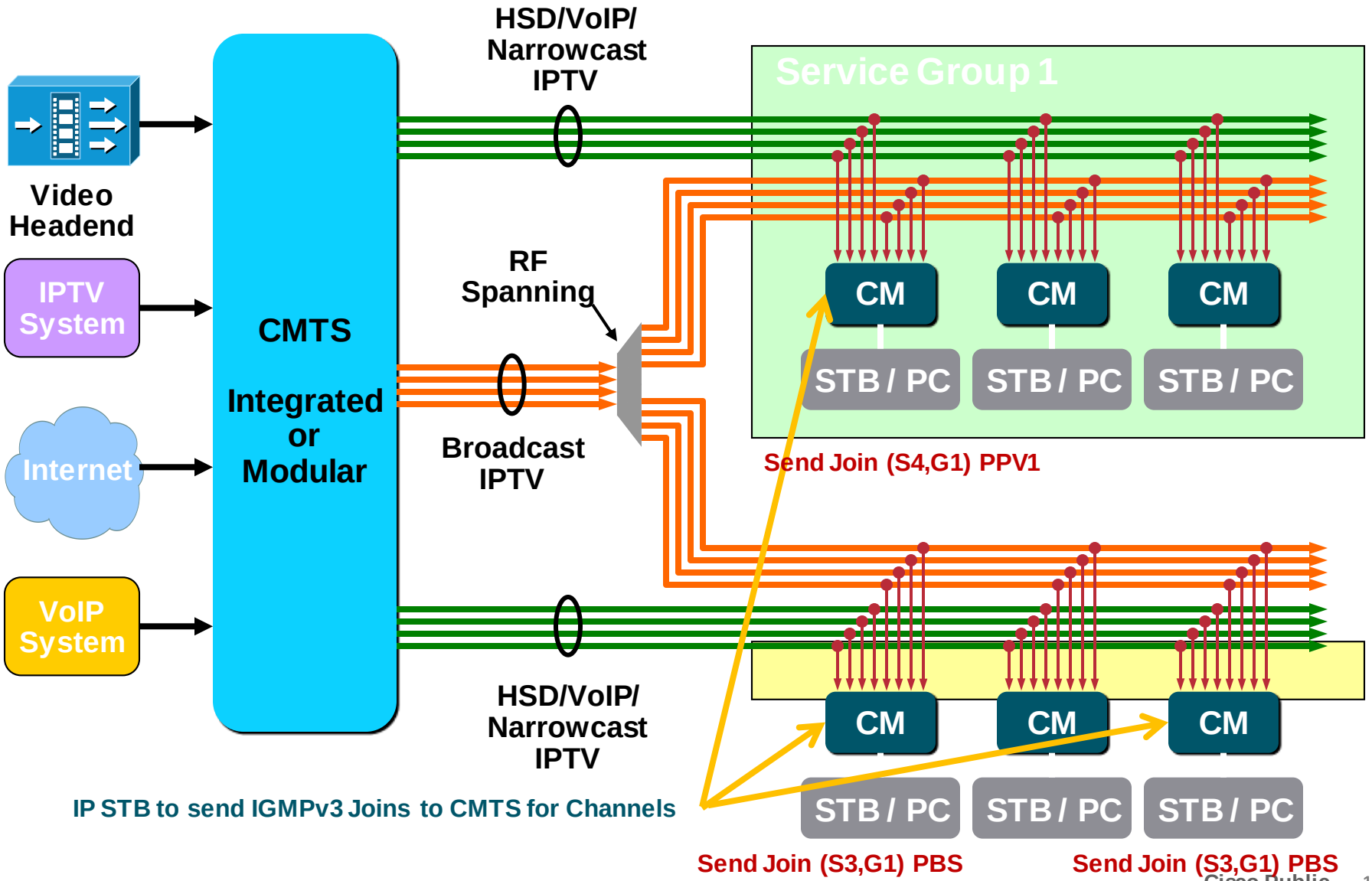
Questions?

BACKUP SLIDES

D3.0 Static M-Cast Example



D3.0 Dynamic M-Cast Example



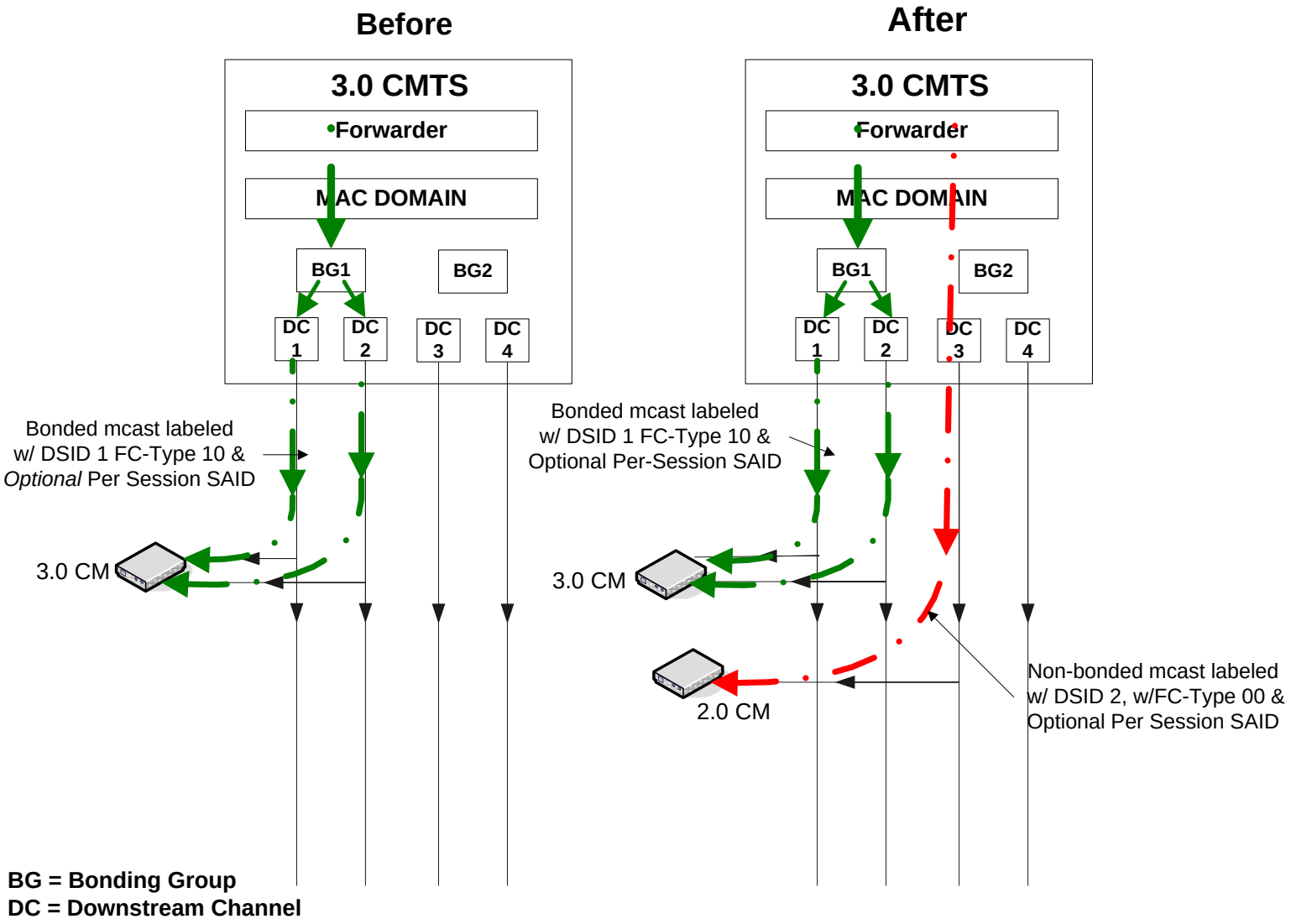
Duplicate prevention through legacy CM

- **Need to ensure that legacy CMs don't forward part of bonded replication along with the full non-bonded replication**
- **Downstream Service Extended Header with DSID is ignored by legacy CMs**
- **D3.0 traffic can be isolated from legacy CMs by**
  - **Setting FC-type to binary 10**
  - **Using SAID filtering**
    - ***Isolation SAID***
    - **Per-Session SAID unknown to legacy CMs**
- **Multicast packets meant for legacy CMs must have FC-type set to binary 00**

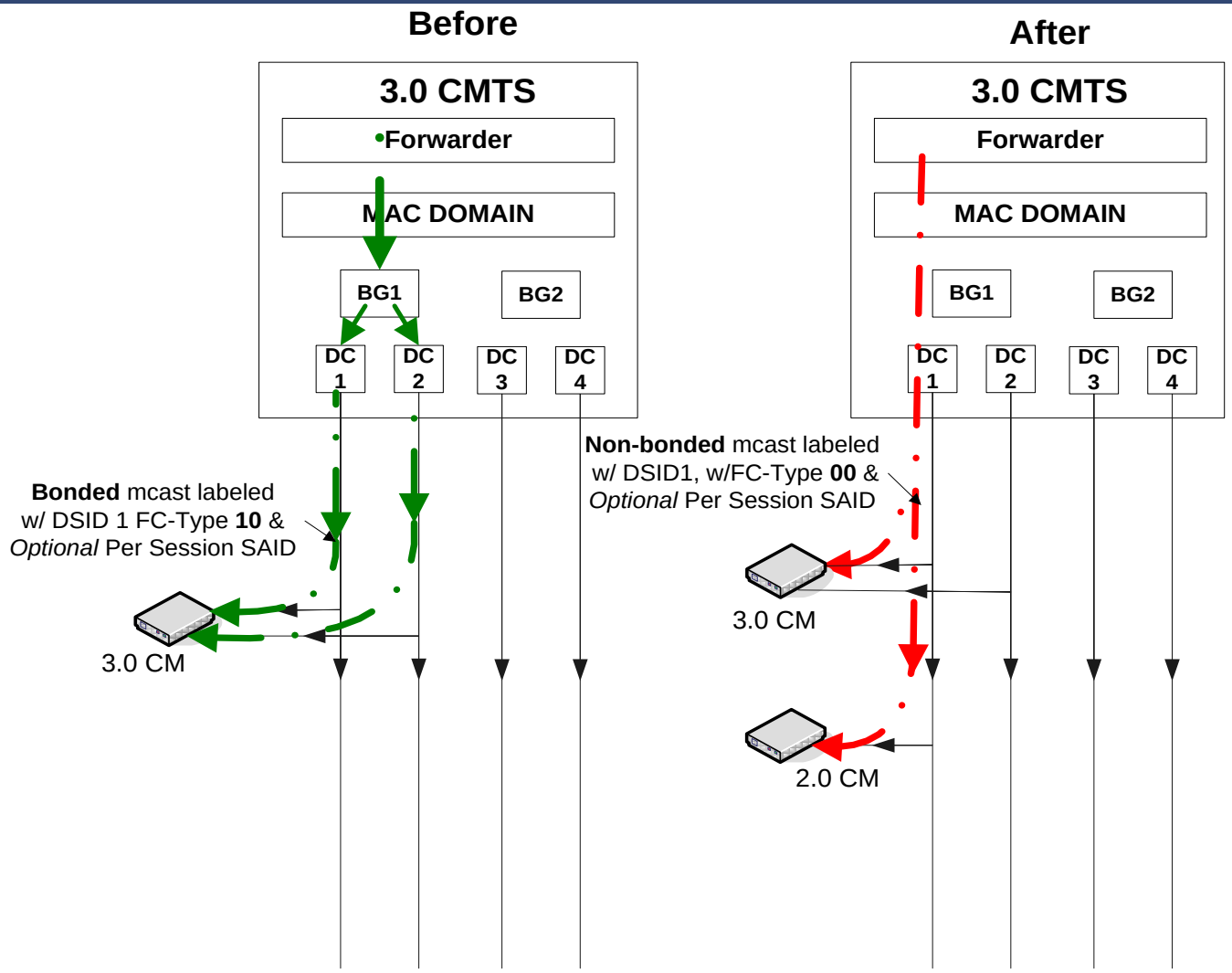
D3.0 Multicast - Encryption

- **D3.0 support Per-Session SAIDs**
  - **Unique within the MD-DS-SG**
- **Dynamic SAs are communicated during CM registration for static multicast and by DBC messaging for dynamic multicast joins**
  - **Replaces SA Map request and reply mechanism**
- **SAID filtering and decryption is completely independent of DSID filtering**

Multicast Replication Example 1

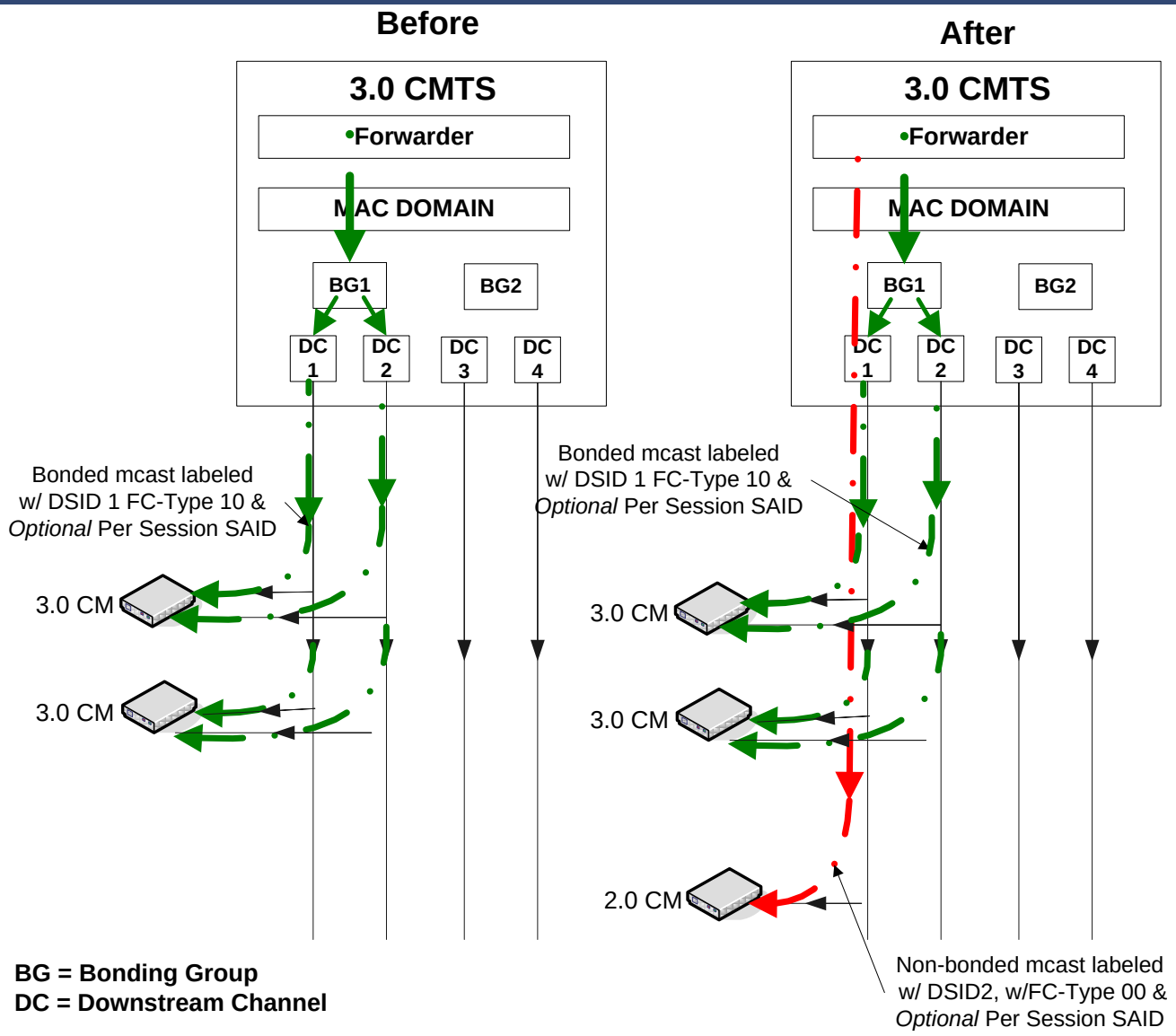


Multicast Replication Example 2



BG = Bonding Group
DC = Downstream Channel

Multicast Replication Example 3



BG = Bonding Group
DC = Downstream Channel

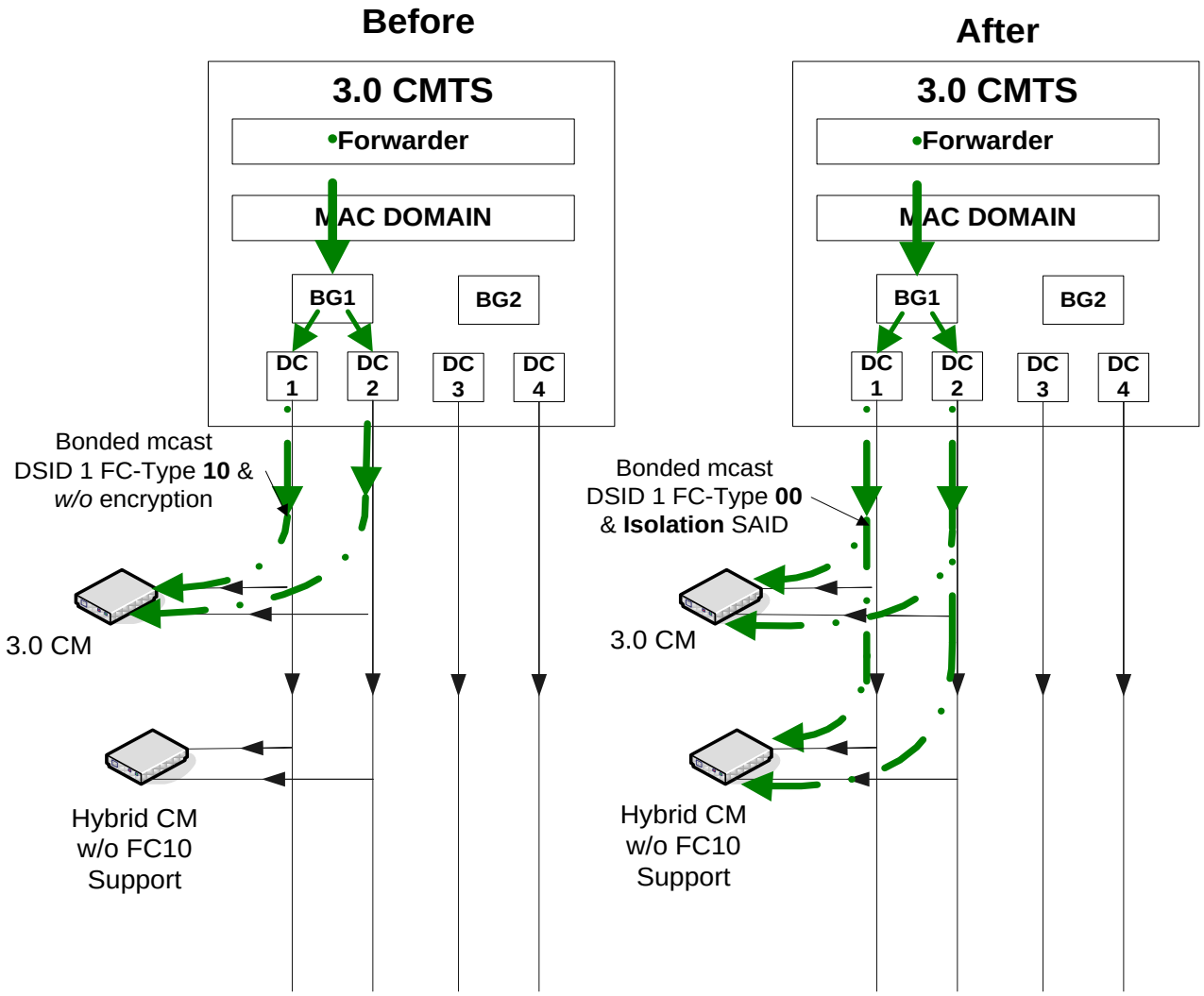
D3.0 Multicast – Support for Hybrid CMs

- Hybrid CM is a D2.0 CM with some D3.0 capabilities
- D3.0 introduces MDF and FC-Type capability encodings
- Hybrid CMs may not support FC-Type of binary 10
  - CMTS must isolate traffic using SAID filtering
- Reports Group MAC address (GMAC) explicit Multicast DSID Forwarding capability (MDF = 1)
- CMTS sets the MDF mode on the CM

D3.0 Multicast – GMAC Explicit MDF

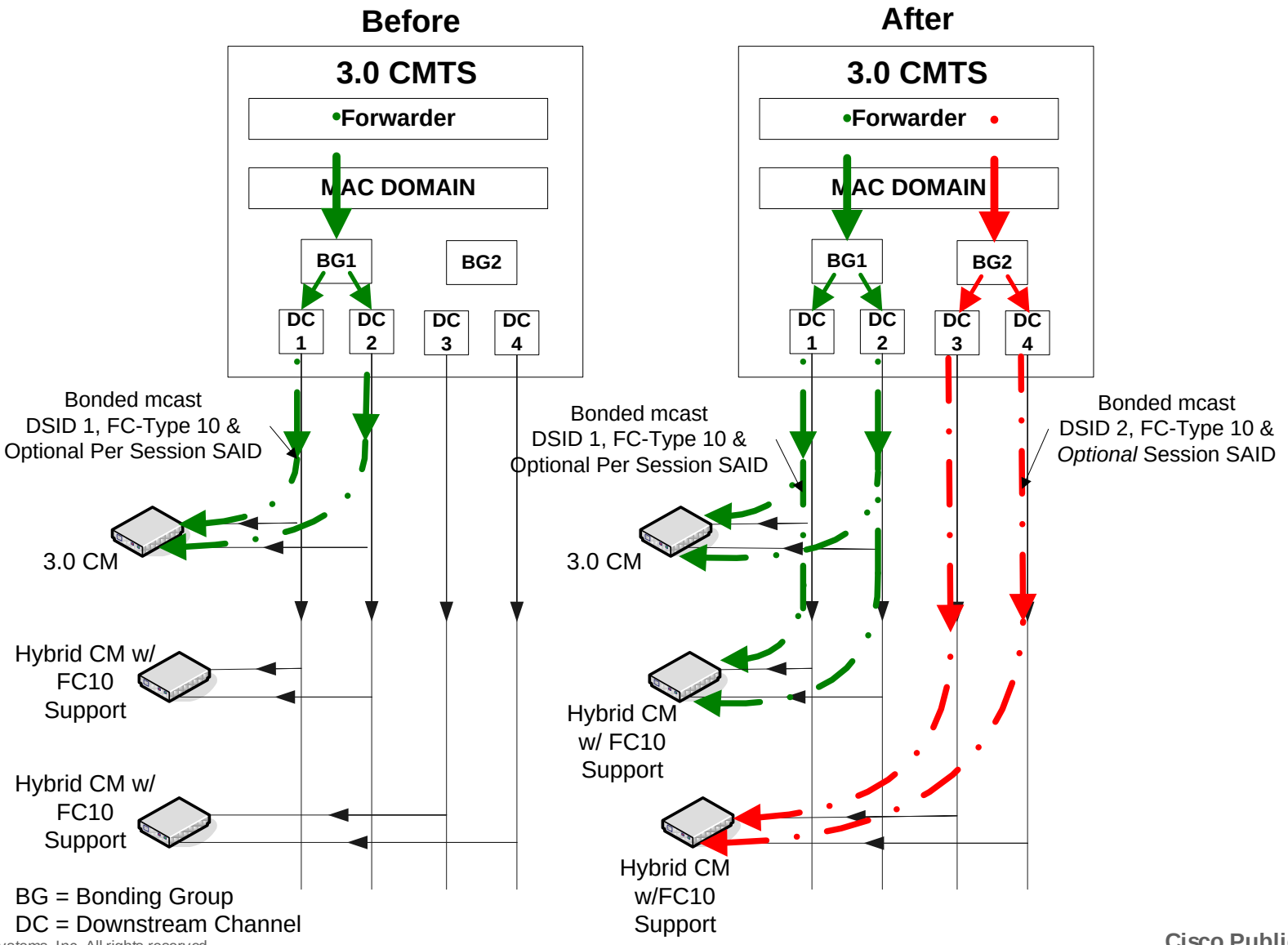
- Defined for hybrid CMs that don't implement DSID filtering in hardware
- CM in GMAC-explicit MDF mode is signaled the GMAC along with the DSID in DBC message
- CM does GMAC filtering
  - MAC Filtering is independent of DSID filtering
- If CMTS overrides MDF capability of Hybrid CM to GMAC-promiscuous, it provides SAID to the CM to facilitate hardware filtering

Multicast with Hybrid CM Example 1



BG = Bonding Group
DC = Downstream Channel

Multicast with Hybrid CM Example 2



D3.0 Multicast: MDF disabled mode

- CMTS can set MDF capability of a CM to MDF disabled
- CM operates like a D2.0 CM
  - Performs IGMP snooping
  - Supports Static Multicast MAC Address Encoding TLV
  - Forwards multicast traffic from primary DS channel
  - Drops multicast traffic from other DS channels
  - Uses SA map request mechanism

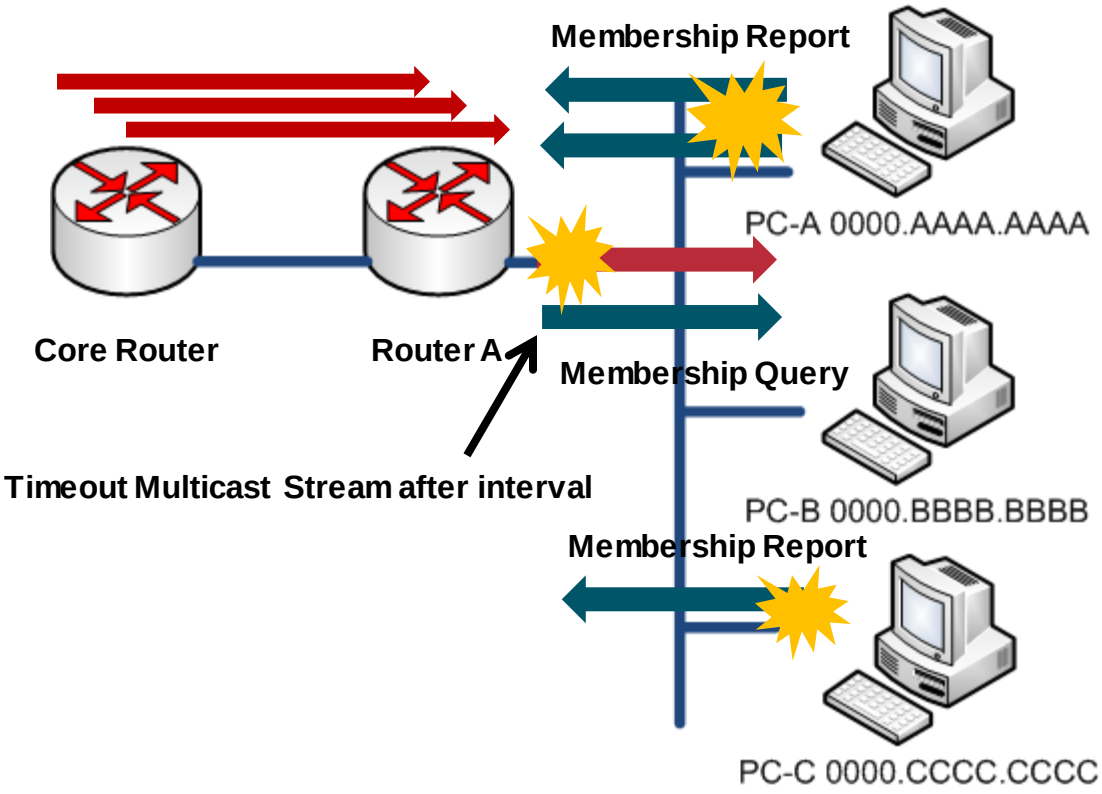
D3.0 Pre-registration multicast support

- **Required for IPv6 control plane packets used by CMs prior to registration**
- **CMTS labels these packets with a *Pre-Registration DSID***
- **Forwarded only to the CM IP stack**
- ***Pre-Registration DSID* is advertised in MDD message**
- **CMTS can encrypt pre-registration packets if CM supports Early Authentication and Encryption (EAE)**

IP Multicast: IGMP Protocol

IGMPv1

- Hosts send IGMP Report to join an ASM group
- Router send periodic queries to ensure ASM group has active listeners
- Hosts respond to queries and support *report suppression*
- No group-specific queries (e.g. All Multicast Streams forwarded)



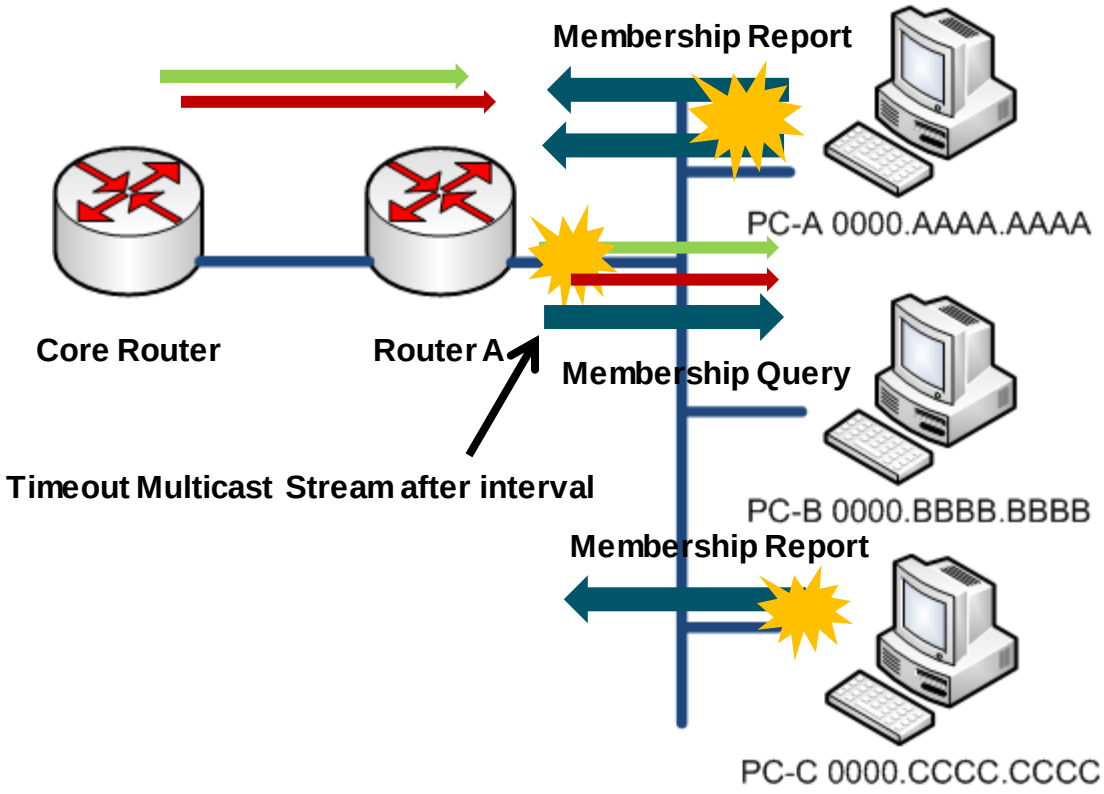
IP Multicast: IGMP Protocol

IGMPv2

- Adds explicit *leave mechanism*
- Group Specific Queries

IGMPv3

- Adds Include/Exclude Source Lists
- No Report Suppression to allow explicit tracking and better "channel" change behavior



Video over DOCSIS

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Jack Yu
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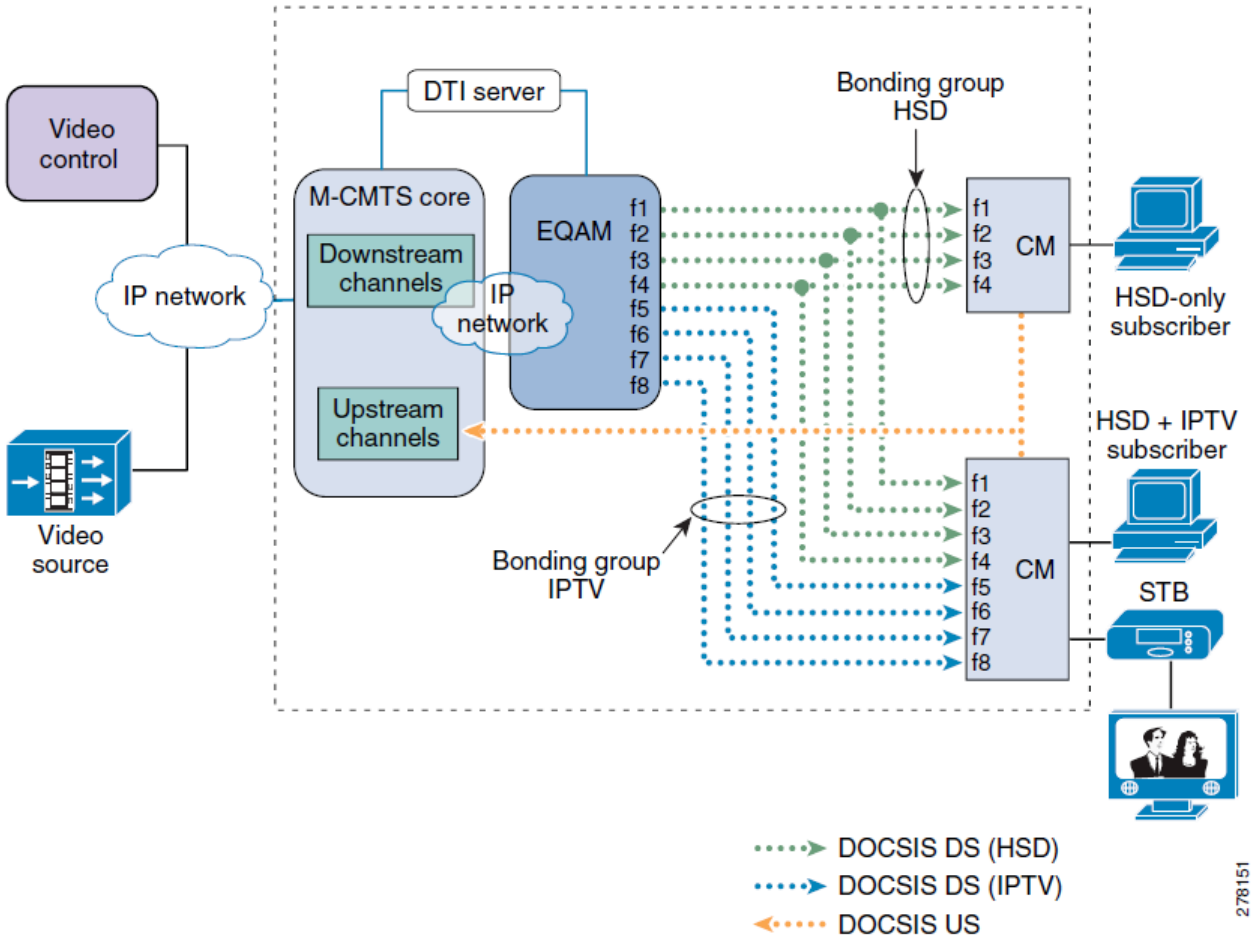
VDOC Introduction

Video Over DOCSIS

- **What is it ?**
  - **Solution for the delivery of managed IPTV services over a DOCSIS network**
  - **Broadcast TV and VoD services**
  - **TV, PC, and other devices in the home**
  - **Provide user experience subscribers expect from their cable operator**

DOCSIS 3.0 and IPTV

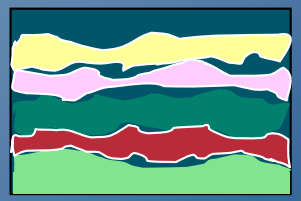


- **Primary and Secondary Bonding groups**
- **HSD Subscribers can lock Primary**
- **Video Subscribers can lock Secondary**
- **IP Set top box**
- **IPTV Broadcast is not taking bandwidth away from Primary Bonding Group or HSD Subscribers**

Motivations for Cable IPTV

New Devices New Content New Access

Bandwidth Efficiency



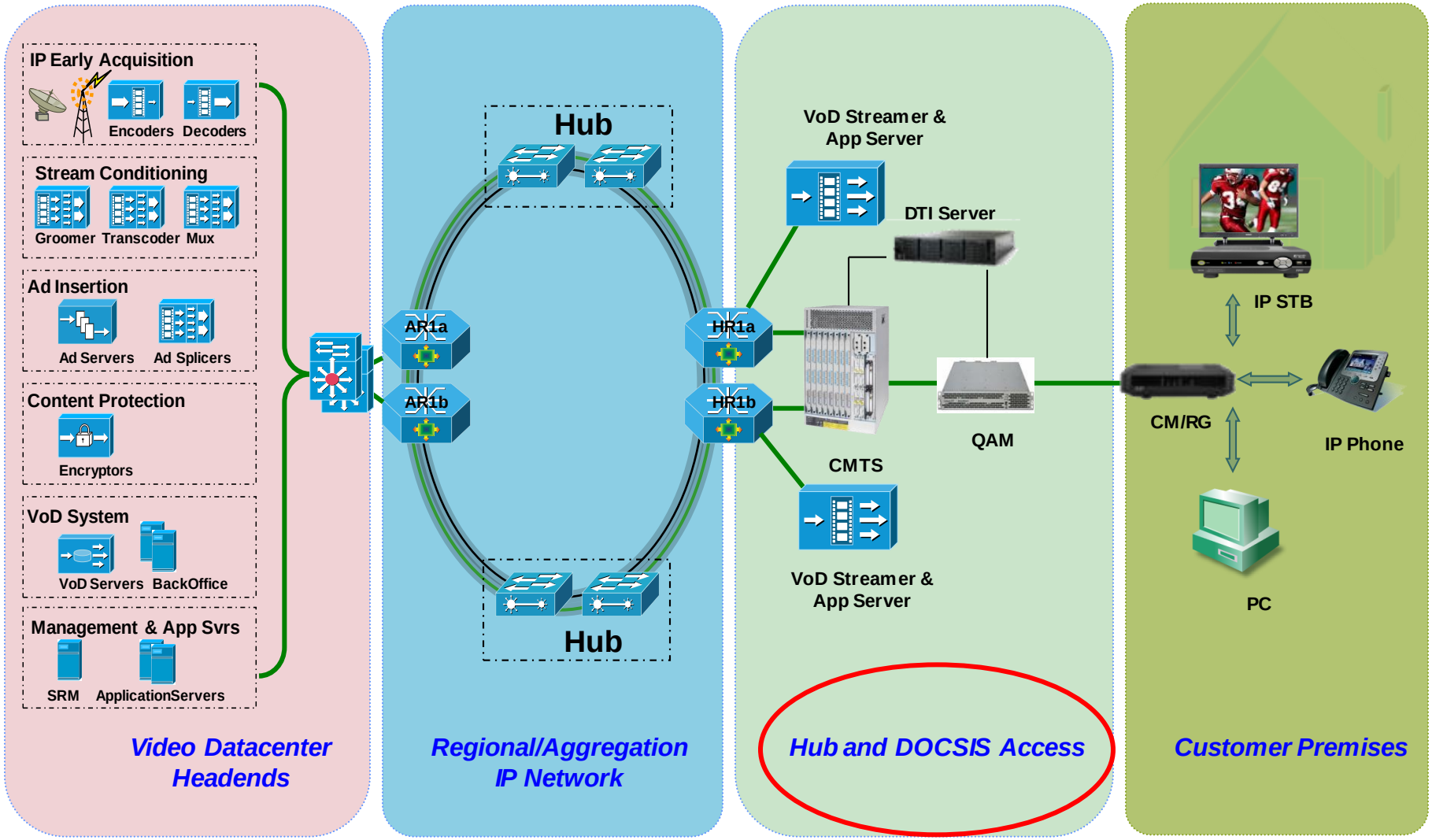
Enhanced User Experience

Capital Cost Savings

Operational Cost Savings

New Application Service Velocity

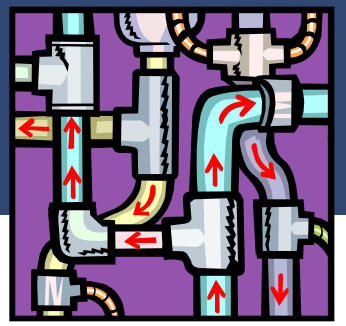
Cable IPTV System Reference Architecture



Benefits of VDOC

- **Bandwidth Efficiency**
  - Variable Bit Rate (VBR) Content Delivery (40% Efficiency Gains)
  - Long Tail / Broadcast Content by Switching
  - DOCSIS 3.0 Efficiency Gains (Channel Bonding vs Single Channel Gains)
- **Cost Efficiency**
  - Elimination of the traditional STB with IP STB
  - No QAM tuners in IP STB
  - For detailed analysis: http://spsu-nsite.cisco.com/publications/viewdoc.php?docid=5651
  - Ubiquitous IP Transport

Making the Transition to Cable IPTV



XoD, nPVR

Linear Video
Niche Programming

HSD

VoIP

VoD

On Demand

Personal
Channels

Linear TV

Broadcast/
Edge
QAMs

Router

PacketCable

CMTS
Packet Shelf

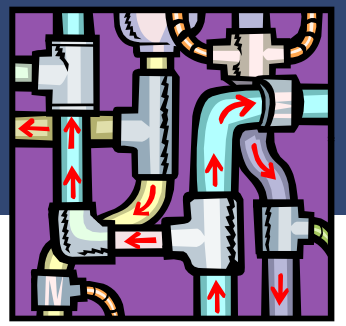
M-CMTS

STB

Cable
Modem

Phone

Making the Transition to Cable IPTV



Capital Cost Savings

XoD, nPVR

Linear Video
Niche Programming

HSD

VoIP

VoD

On Demand

Personal Channels

Linear TV

Router

PacketCable

CMTS Packet Shelf

M-CMTS

Broadcast/ Edge QAMs

STB replaced with IP STB
No need for QAM Tuner

STB

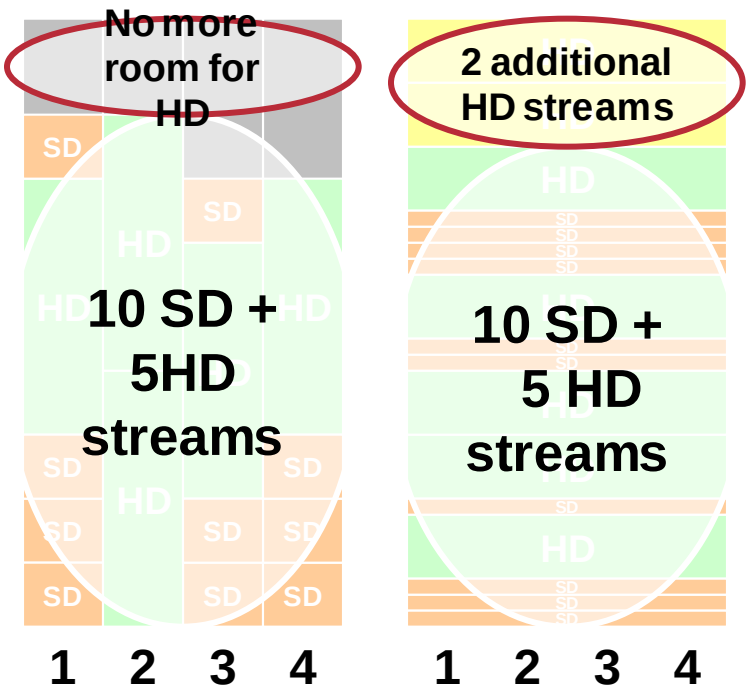
Cable Modem

Phone

IP STB

Channel Bonding creates efficiency gains
Big Channel "Packing Advantage"

Channel capacity



Unbonded channels create inefficient boundaries

Bonding drives efficient "Packing"

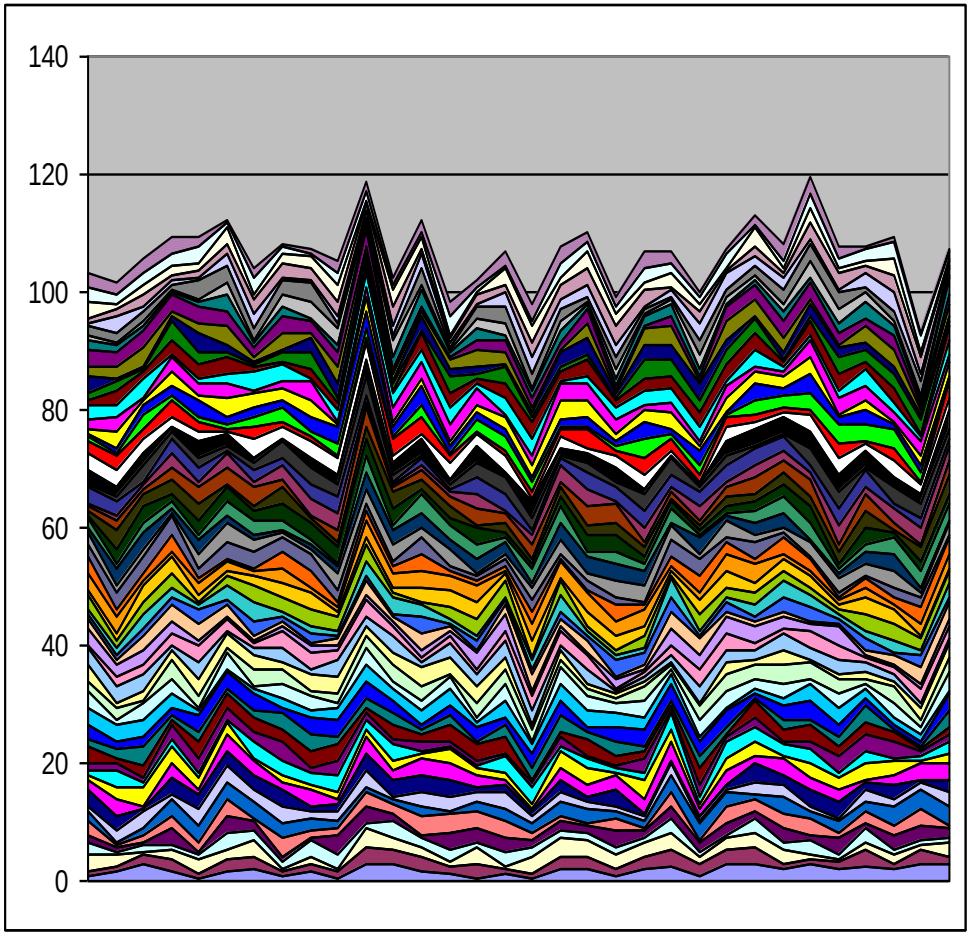
Benefit varies

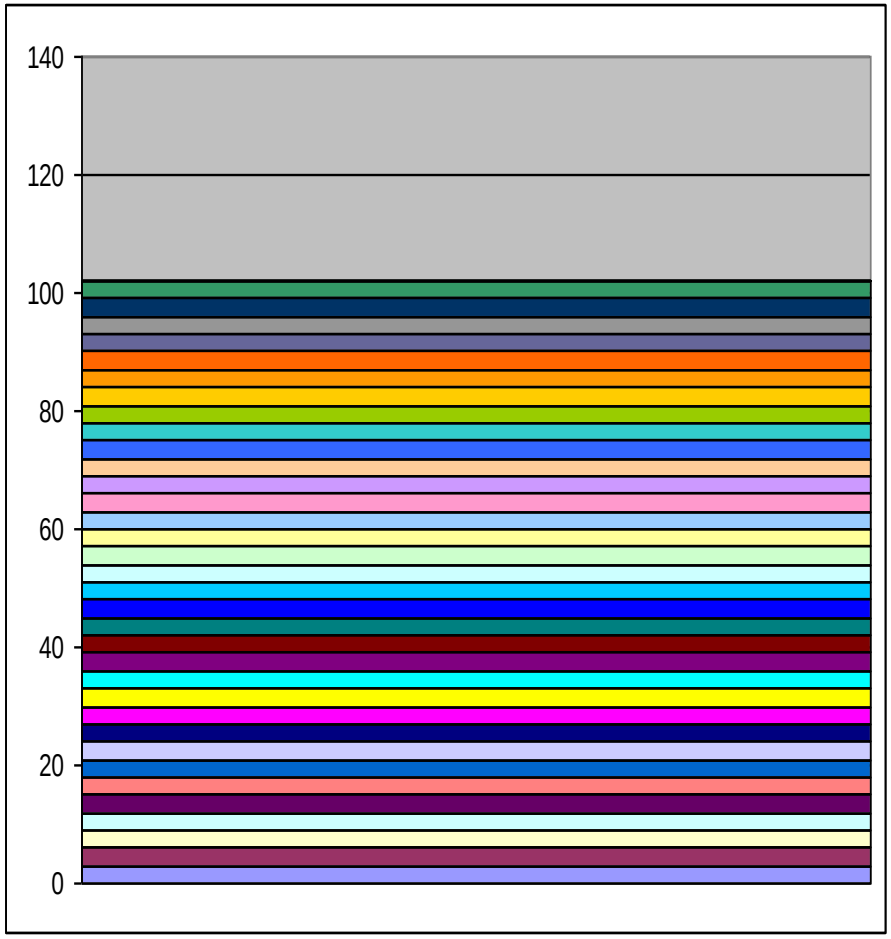
MPEG2/4 HD/SD mix

Bonding group size

Efficiency Gains from VBR Video – 40-60%

- VBR streams provide equivalent/better quality at lower avg BR
- Law of large numbers favors simple VBR multiplexing in large pipe





VDOC Technology Overview

CMTS Features for VDOC

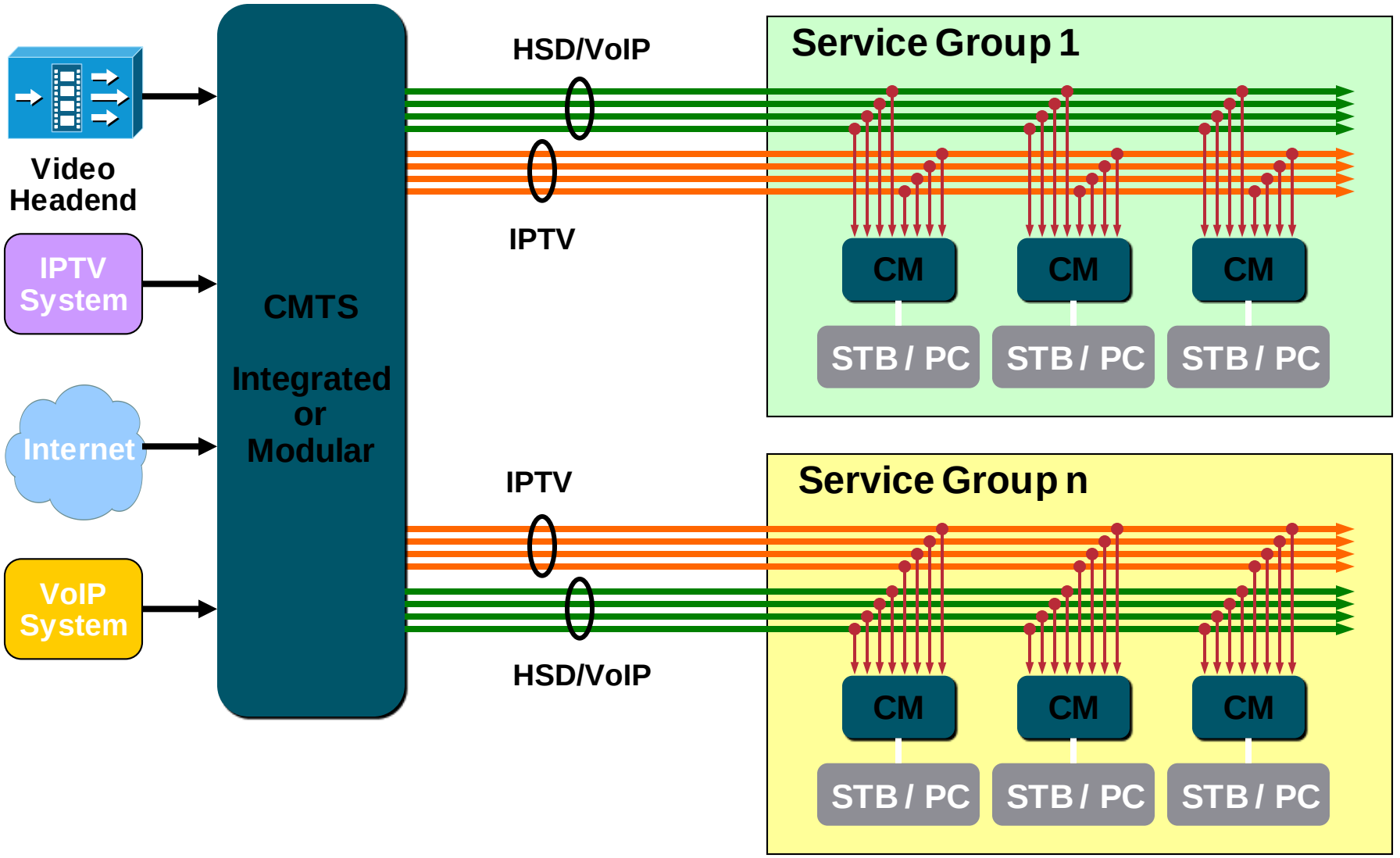
- DOCSIS 3.0 channel bonding
- Dynamic bandwidth sharing
- DOCSIS 3.0 multicast
- RF spanning
- Admission control and QoS
- VBR video and IP statmuxing

DOCSIS 3.0 Multicast Features

- SSM and IGMPv3
- IPv6 multicast support (pre and post registration)
- Multicast QoS
- Support for bonded multicast
- Non-IGMP based multicast
- Support for multicast authorization
- Multicast encryption

DOCSIS 3.0 Channel Bonding

Separate DS bonding groups for HSD/Voice and IPTV

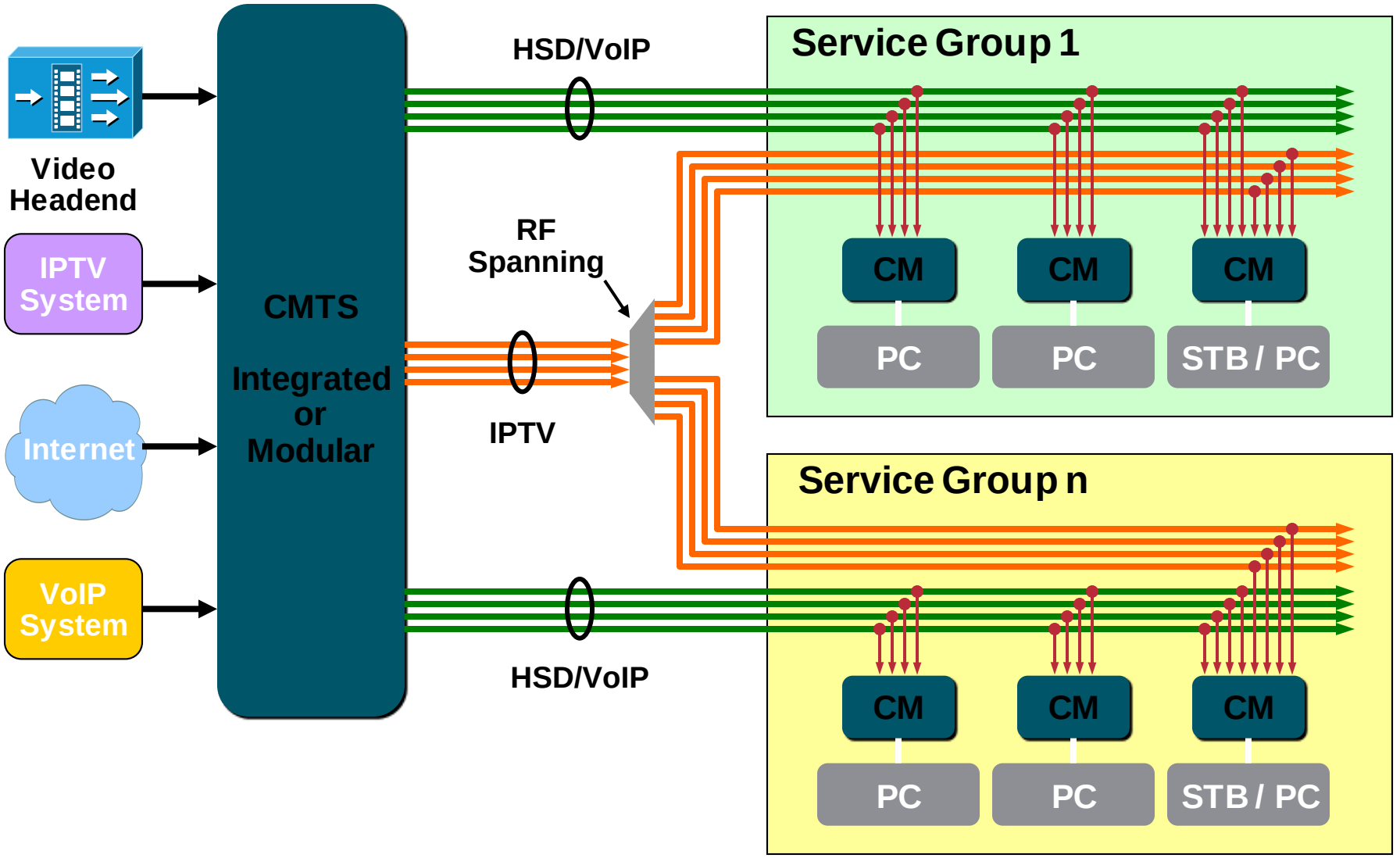


RF Spanning

- **A set of downstreams can be split to multiple/all SGs served by the CMTS**
  - **Similar to broadcast QAMs, but limited to CMs served by a CMTS**
  - **Downstreams use same RF frequencies in each SG**
- **Useful for initial deployments where penetration rate may be low**
  - **IPTV clients may be lightly distributed across multiple SGs**
  - **Operator can deploy a handful of downstreams to start IPTV service**
- **When combined with static multicast, can replicate a broadcast style architecture**

RF Spanning

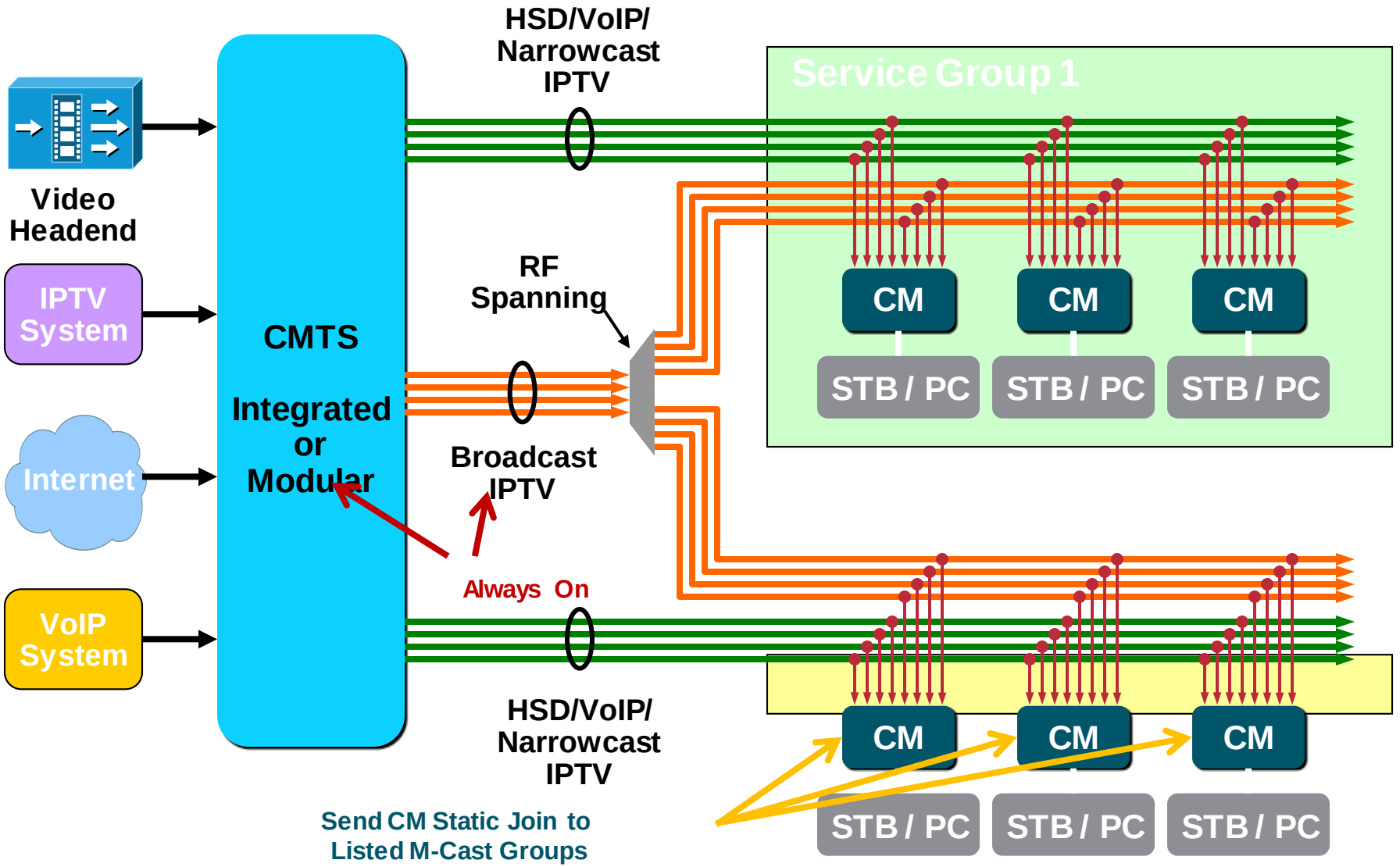
Initial low-penetration IPTV deployments



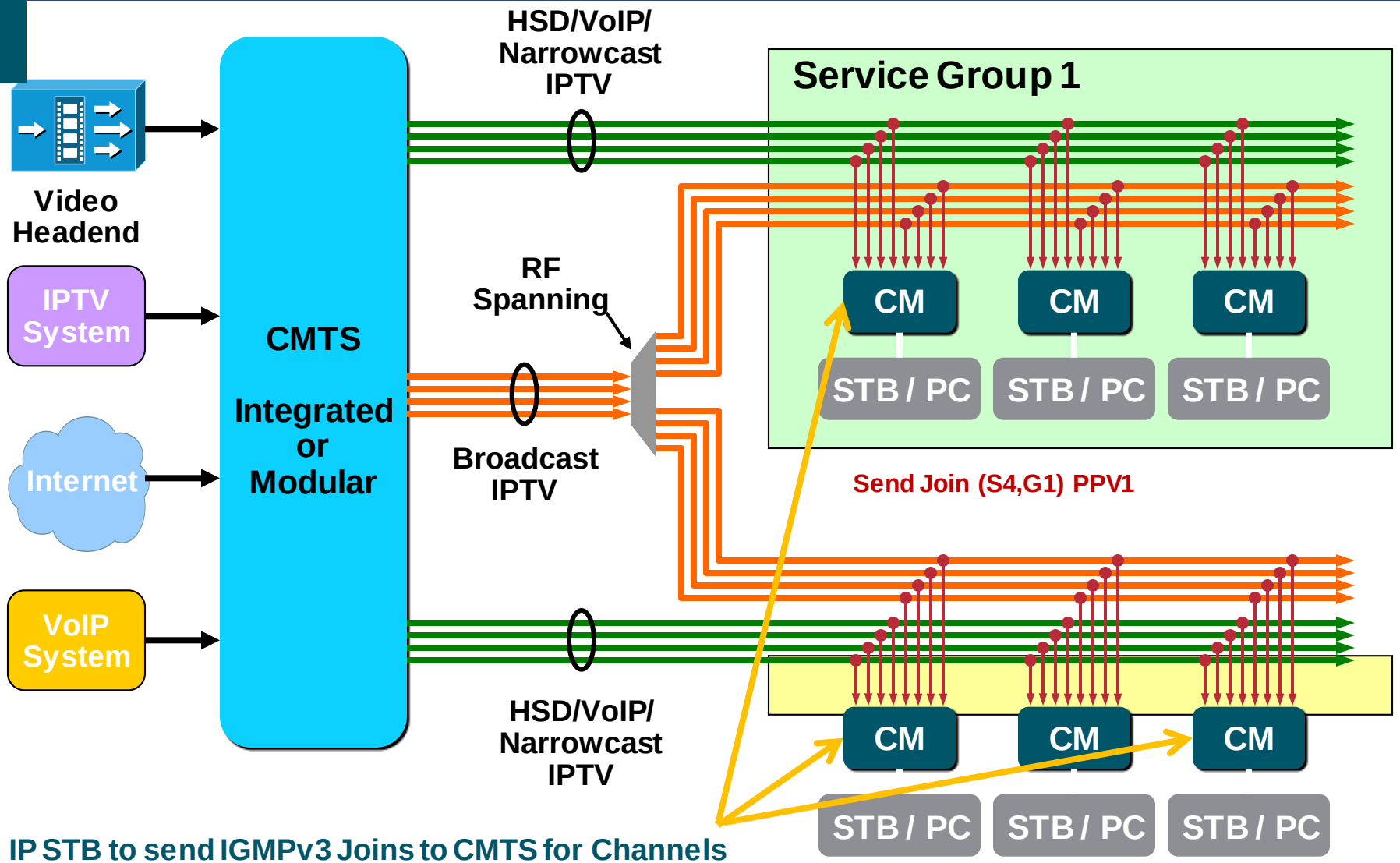
Bonded Multicast

- **A BG is RF-spanned to all SGs and carries multicast IPTV streams**
  - **IPTV streams are delivered at all times as static multicast flows – regardless of viewership**
  - **Most popular content can be carried in a 4-channel BG**
  - **Long-tail content is carried over narrowcast BGs**
- **Subset of receive channels on CM are statically tuned to this RF-spanned BG to receive multicast IPTV streams**
- **Trade-offs**
  - **Less spectrum efficient than narrowcast BGs if all static multicast IPTV streams are not viewed by at least one CM in each SG at all times**
  - **Requires CMs with additional receive channels**
  - **The number of video streams that can be carried in such fashion is dependent on number of receive channels available on CM and spectrum availability**

Bonded Static Multicast



(Bonded) Dynamic Multicast



Where is VDOC Today?

- **Cisco Newcastle 1.1/2.0 Solution Architecture has been in development for the last 2 years.**
- **Currently one Eastern Europe SP has VDOC deployed**
- **Currently one US MSO has a trial VDOC deployed**
- **There is interest from US Service Providers**
- **Most SPs are still in the discussion phase with VDOC**

Questions?