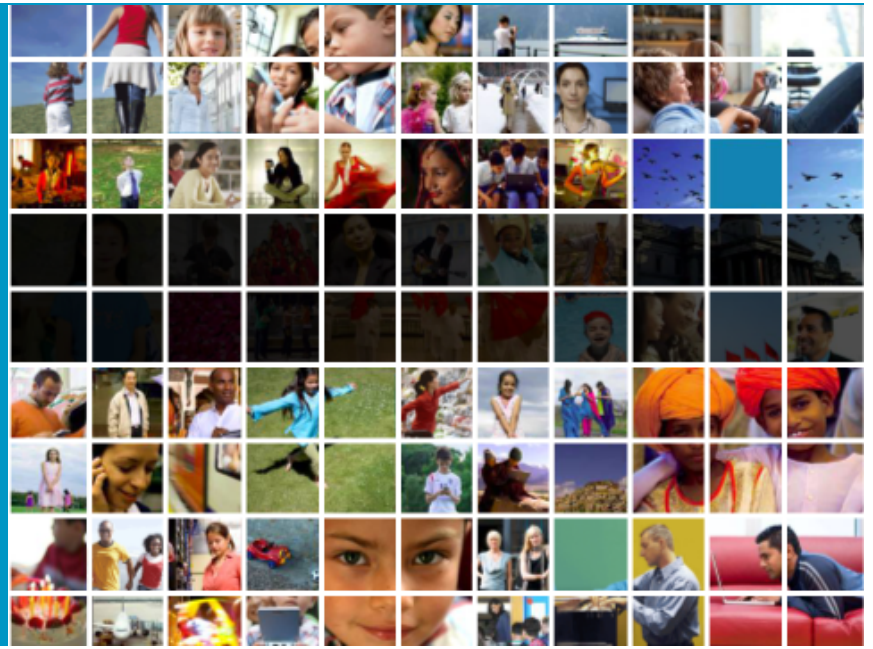
Video Over DOCSIS (VDOC) Tutorial



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Cisco Systems Inc.

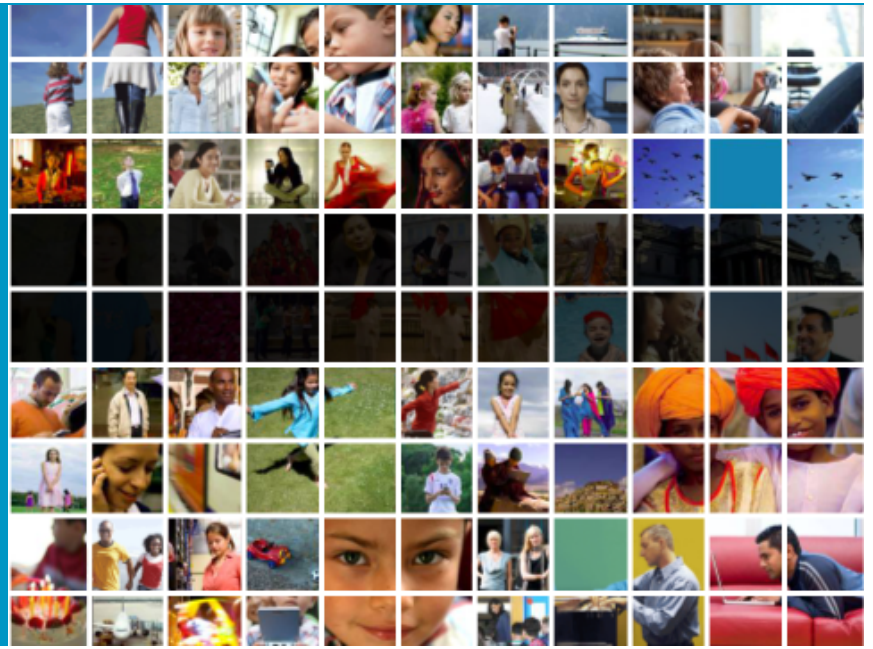
Acronyms/Abbreviations

- AM = Application Manager
- AS = Application Server
- ASM = Any Source Multicast
- BG = Bonding Group
- CIN = Converged Interconnect Network
- CM = Cable Modem
- CMTS = Cable Modem Termination System
- COPS = Common Open Policy Service
- DBC = Dynamic Bonding Change
- DEPI = Downstream External PHY Interface
- DIBA = DOCSIS IPTV Bypass Architecture
- DOCSIS = Data-Over-Cable Service Interface Specification
- DQoS = Dynamic QoS
- DRFI = Downstream Radio Frequency Interface
- DS = Downstream
- DSID = Downstream Service Identifier
- DTI = DOCSIS Timing Interface
- EQAM = Edge QAM
- FN = Fiber node
- GMAC = Group Media Access Control
- HFC = Hybrid Fiber Coaxial
- HSD = High Speed Data
- I-CMTS = Integrated CMTS
- IGMP = Internet Group Management Protocol
- IPTV = IP TeleVision
- M-CMTS = Modular CMTS
- MDF = Multicast DSID based Forwarding
- MLD = Multicast Listener Discovery
- MSO = Multiple Service Operator
- PCMM = PacketCable Multimedia
- PS = Policy Server
- RF = Radio Frequency
- RSVP = Resource reSerVation Protocol
- SF = Service Flow
- SRM = Session & Resource Manager
- SSM = Source Specific Multicast
- STB = Set-Top Box
- TP = TelePresence
- US = Upstream
- VDOC = Video over DOCsis
- VoD = Video On Demand
- VoIP = Voice over IP

Agenda

- Video over DOCSIS (VDOC) Technology Introduction
- VDOC Technology Key Drivers
- DOCSIS High Level Overview
- DOCSIS 3.0 Multicast Enhancements
- PCMM High Level Overview
- VDOC Architectures
- CMTS Bypass Architecture for VDOC
- CMTS Direct Architecture for VDOC
- Scaling the DOCSIS Network for Video
- TelePresence over DOCSIS Overview
- Summary/Q & A

VDOC Technology Introduction



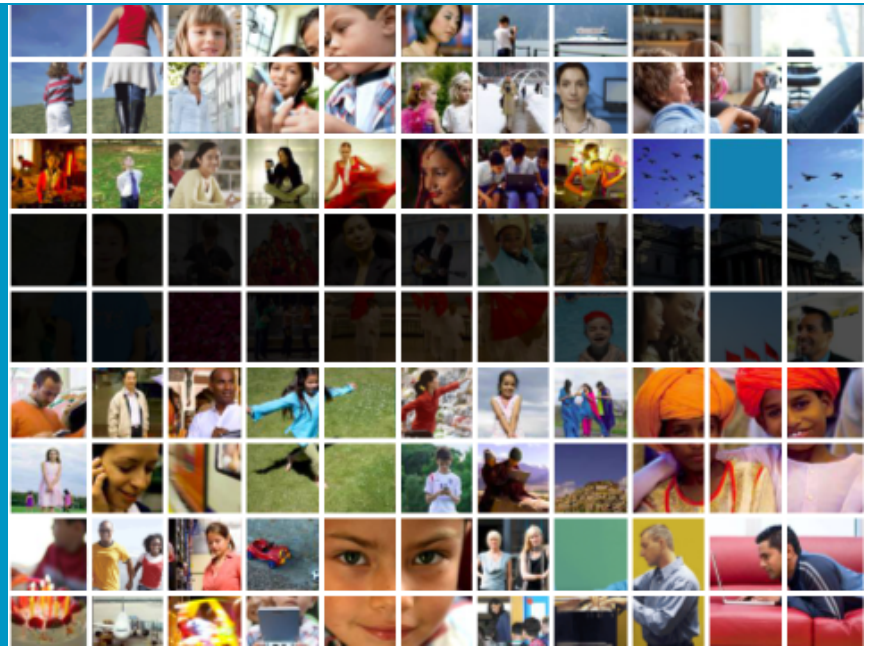
What is VDOC?

- VDOC stands for Video over DOCSIS
- The technology covers aspects of IP based video services over the same cable infrastructure used today for high speed data and Voice over IP services
- Today high speed Internet subscribers receiving Internet based video content is indistinguishable to the cable operator from other types of data traffic (commonly referred to as “over-the-top” video).
- As a result of this QoS for video is not easily achievable nor a means for preventing the duplication of traffic when multiple subscribers are viewing the same video content

What is VDOC? Contd..

- Three aspects of video content streaming are covered
  - Video on Demand (VoD)
  - Broadcast Video (i.e. IPTV)
  - Video Telephony and TelePresence
- Provides DOCSIS QoS to video streams
- Managed video service delivered via IP to the home
- Provides cost effective broadcast video solution
- VoD is unicast
- Broadcast video is multicast
- IP end points – PC , STB , TelePresence End Point

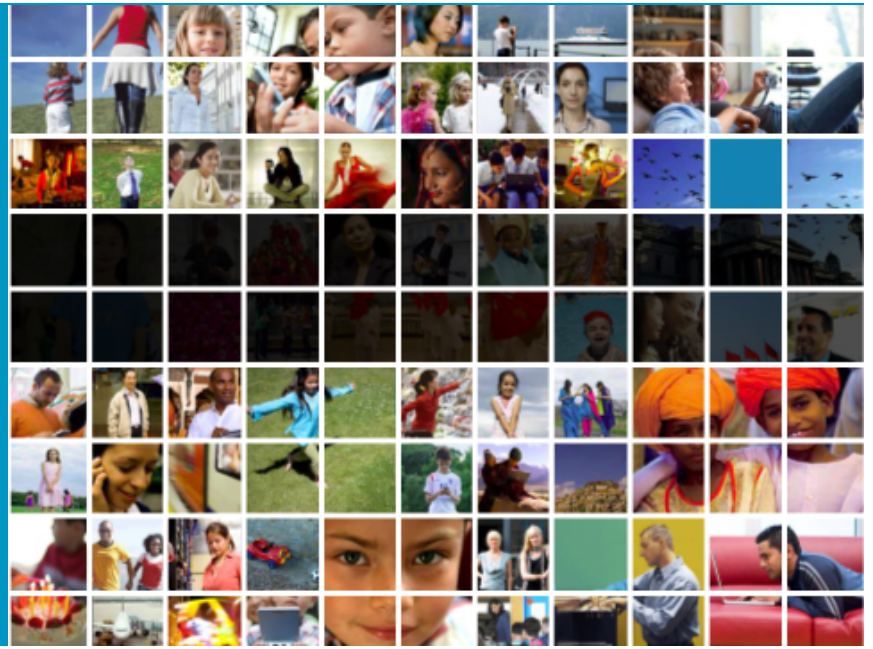
VDOC Key Technology Drivers



VDOC Key Technology Drivers

- With the introduction DOCSIS 3.0, Cable Operators are able to support much higher service tiers such as 100 Mbps bidirectional
- These higher tiers equip operators with the transport mechanism to offer new IP based video services
- Unified network infrastructure for providing triple services
- Use of common infrastructure for triple play services results in reduced CAPEX and OPEX
- Deliver IPTV services to multiple devices including TVs and PCs and Mobile devices
- Exponential Growth in Internet based video content

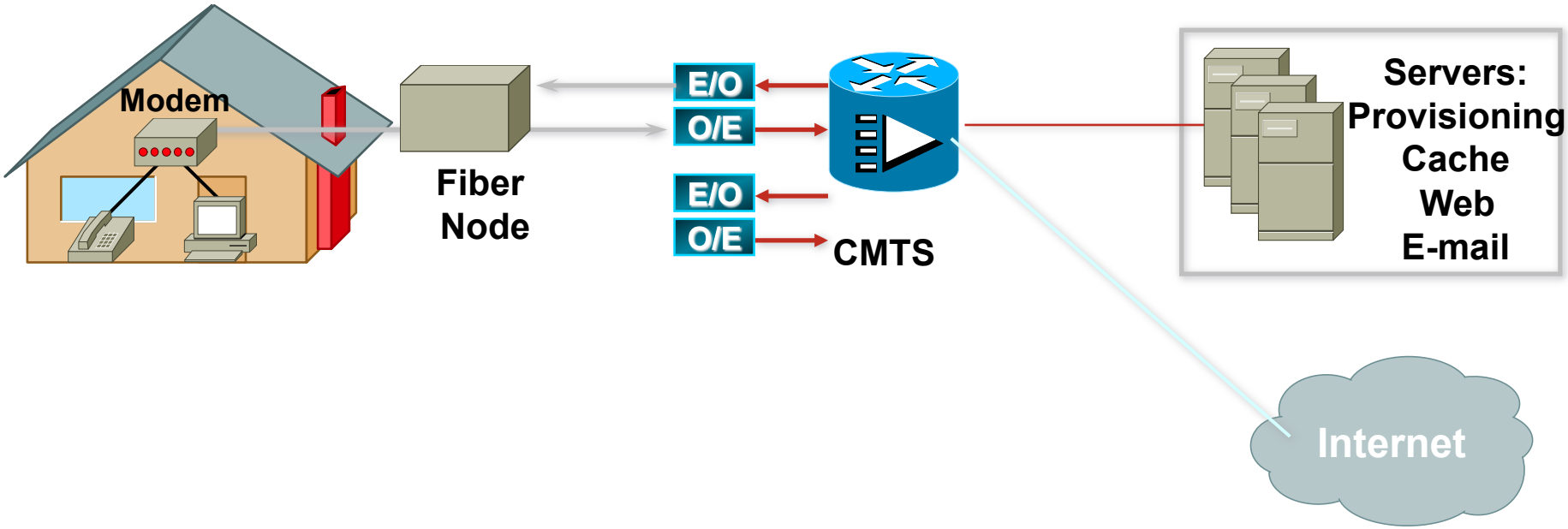
DOCSIS High Level Overview



DOCSIS

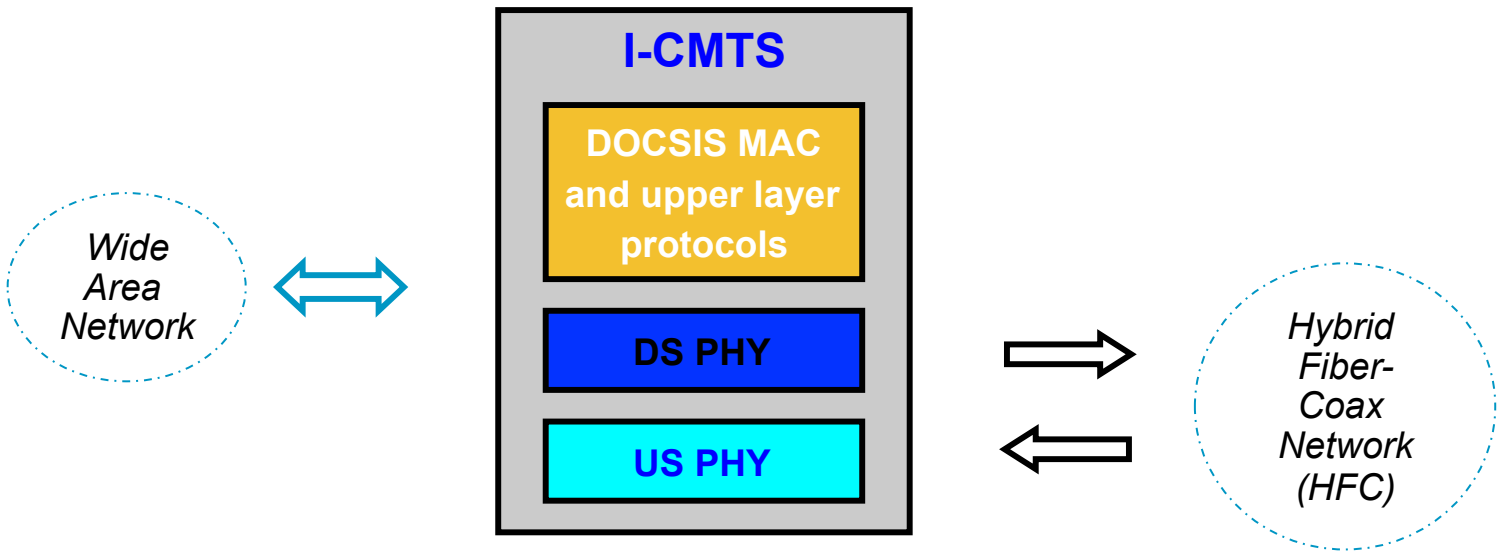
- Data Over Cable Service Interface Specification (DOCSIS) Radio Frequency Interface Specification provides minimum recommended technical performance requirements for data
- Defines interface requirements for cable modems involved in high-speed data (HSD) distribution over cable television system networks
- www.cablemodem.com/specifications

Basic Cable System Topology

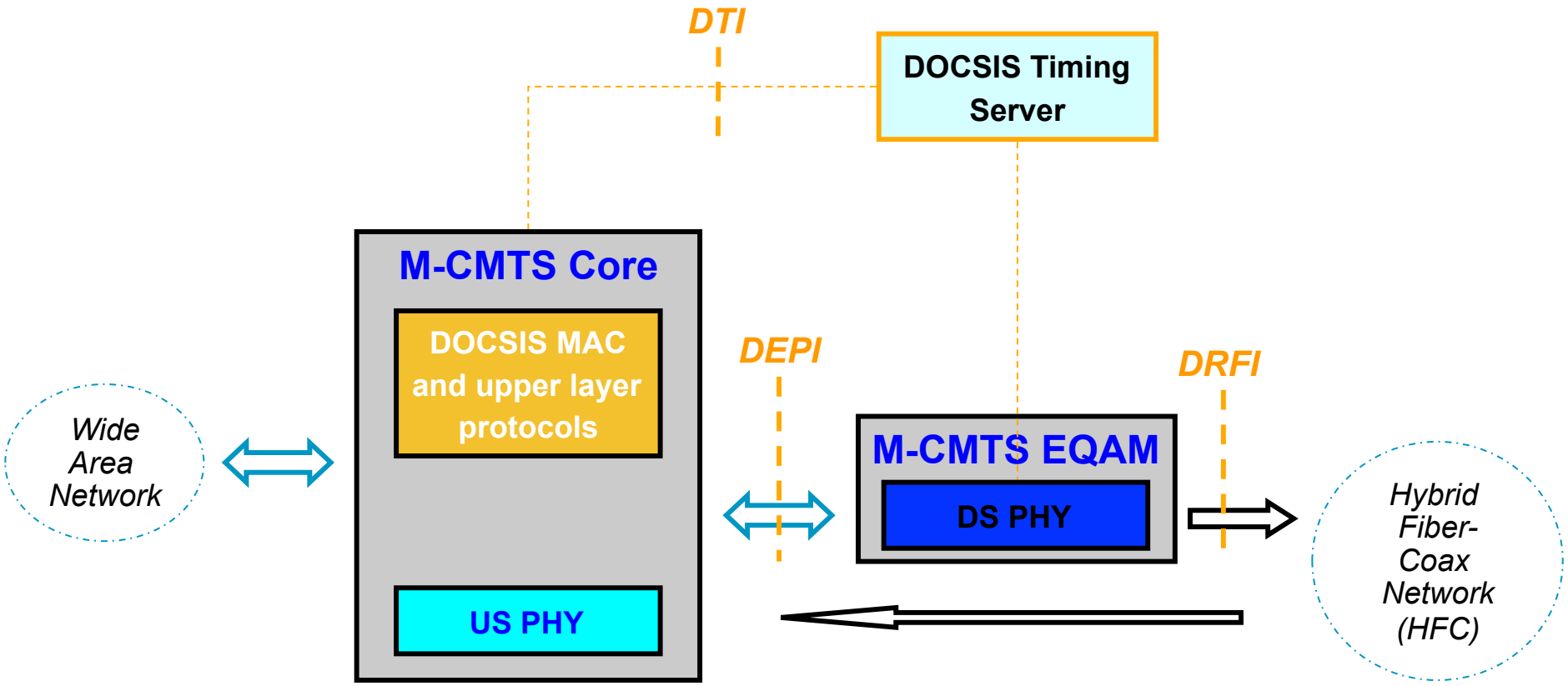


Note: E/O and O/E refer to the Electrical to Optical conversion of the signals in a cable HFC system

Integrated-CMTS Logical Functions



Modular-CMTS Logical Functions



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

DOCSIS 3.0 Introduction

- Series of Specifications that define the third generation of high speed data over cable systems
- 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: Ideal for Video

- **Channel Bonding**
  - Faster speeds provide competitive advantage for cable operators
  - Fatter pipes enable greater efficiency
- **Multicast Enhancements**
  - Deliver linear IPTV via static or dynamic multicast
- **IPv6**
  - Scale IP addresses for IP set-tops and other devices
- **Converged Network**
  - Operate one network for all services

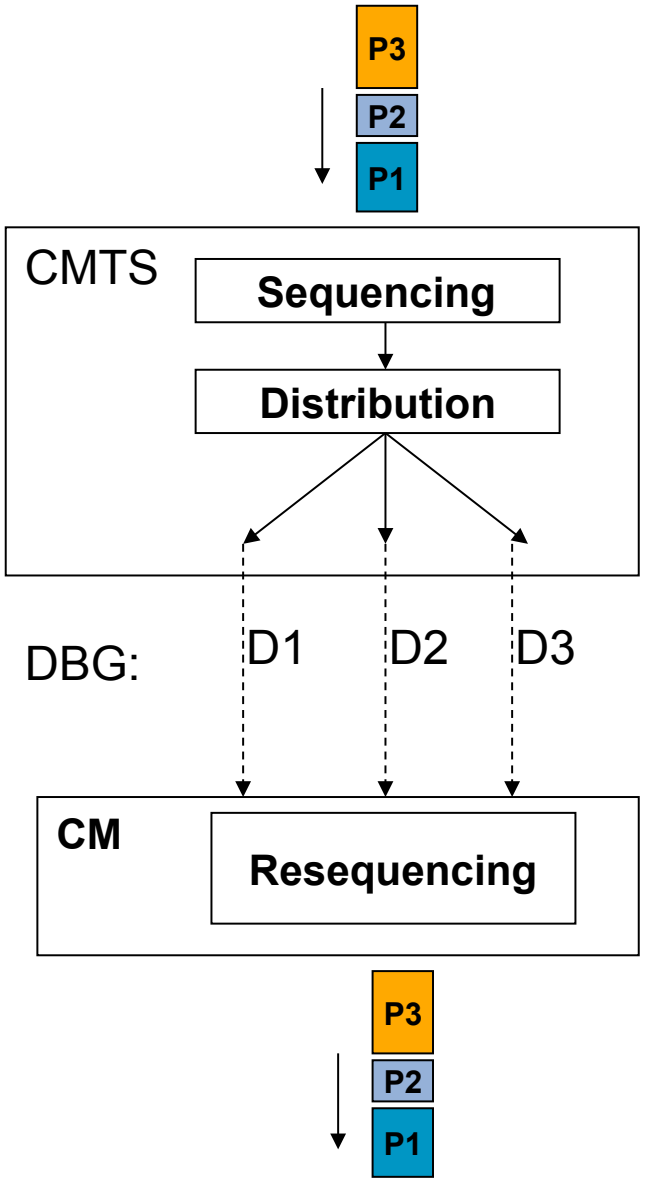
What is downstream channel bonding ?

- **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

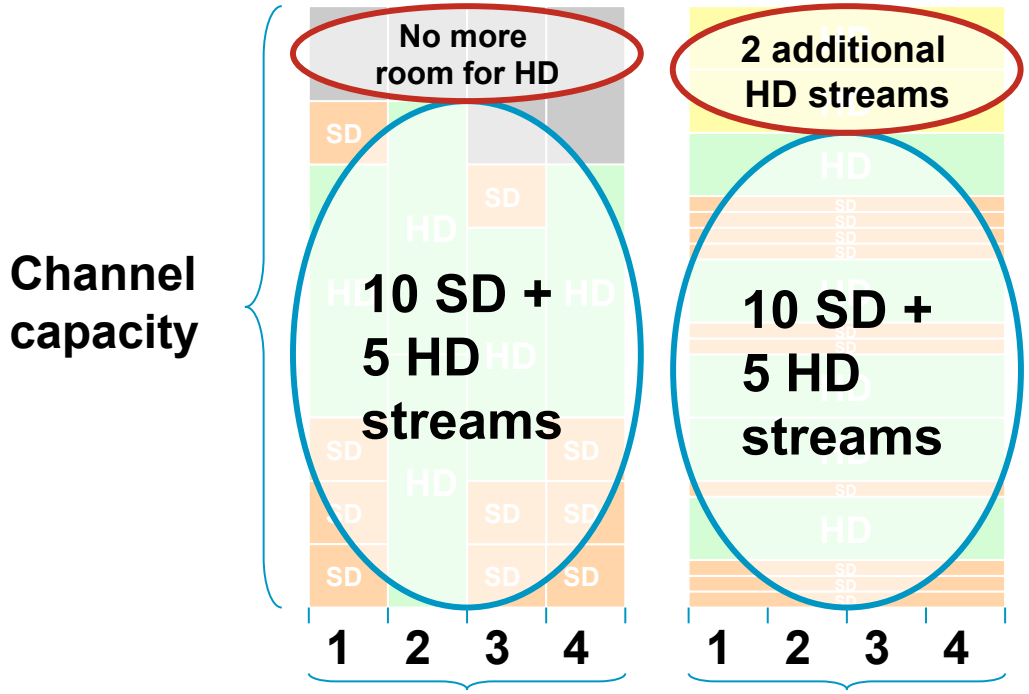
DS Channel Bonding (Contd..)



- 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.

Channel Bonding creates efficiency gains

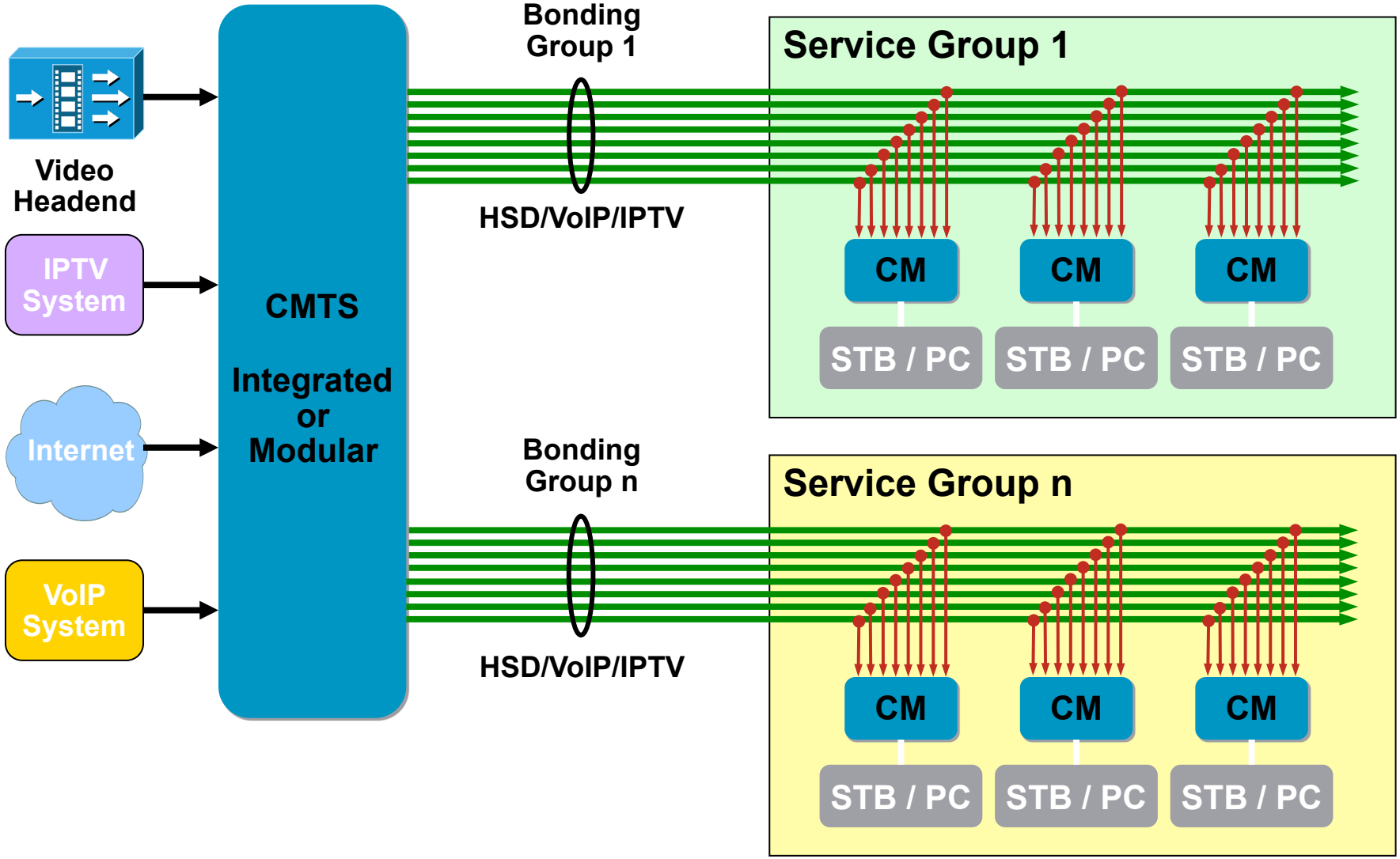
Big Channel "Packing Advantage"



- Unbonded channels create inefficient boundaries
- Bonding drives efficient "Packing"
- Benefit varies
  - MPEG2/4 HD/SD mix
  - Bonding group size

DOCSIS 3.0 Channel Bonding

DS bonding group shared by all services with 8x4 CM



DOCSIS 3.0 Channel Bonding Concepts

- A CM is unaware of the concept of bonding groups; it is only aware of the set of downstreams it must tune to and the flows it must forward, as instructed by the CMTS
- A CM can receive traffic from multiple BGs simultaneously

  Bonding groups may have different aggregate BW based on services supported
- Different CMs in a Service Group can receive traffic from different bonding groups
- CM may tune to a subset of the downstreams configured for a SG

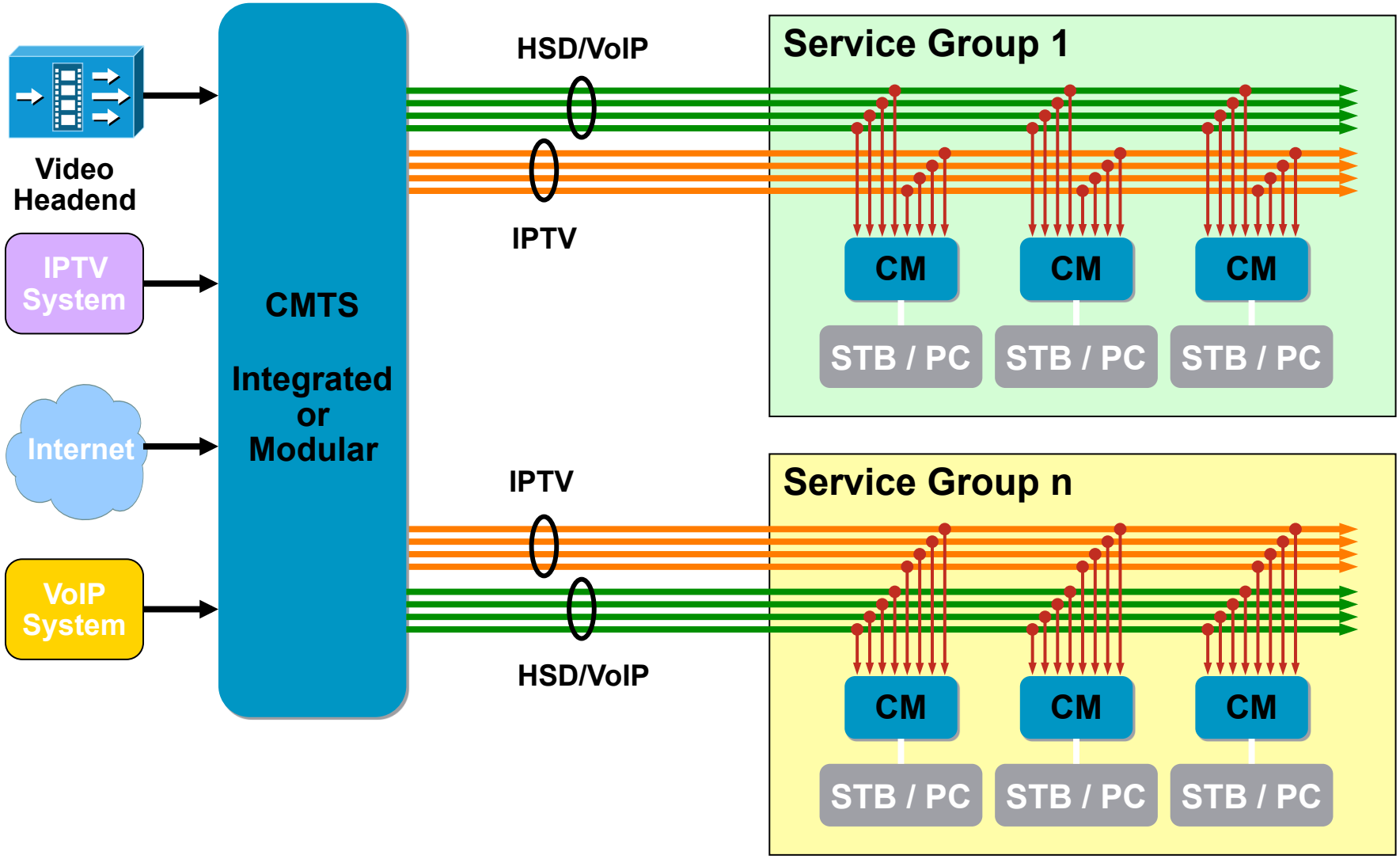
  *Number of receive channels on CM **does not** need to equal number of RF channels allocated to DOCSIS service (HSD/VoIP/IPTV)*

Bonding Group Selection

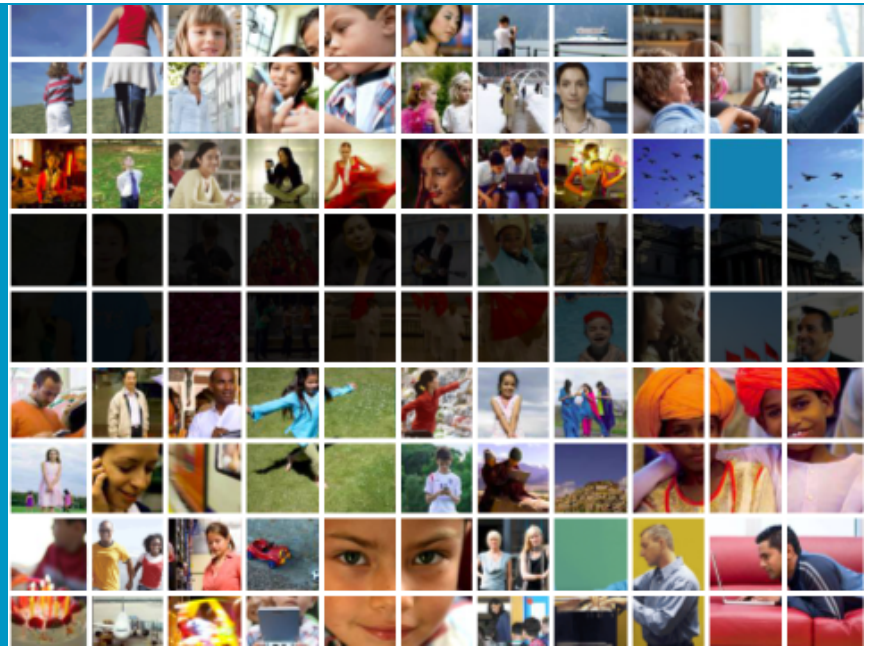
- A CM can receive traffic from multiple BGs
- Operator can steer flows to particular BGs by configuring Service Flow attributes for each BG
  - CMTS uses SF-attributes when selecting BG for a flow
- Operator could choose to set aside a BG for Cable IPTV and a separate BG for HSD/VoIP

DOCSIS 3.0 Channel Bonding

Separate DS bonding groups for HSD/Voice and IPTV



DOCSIS 3.0 Multicast Enhancements



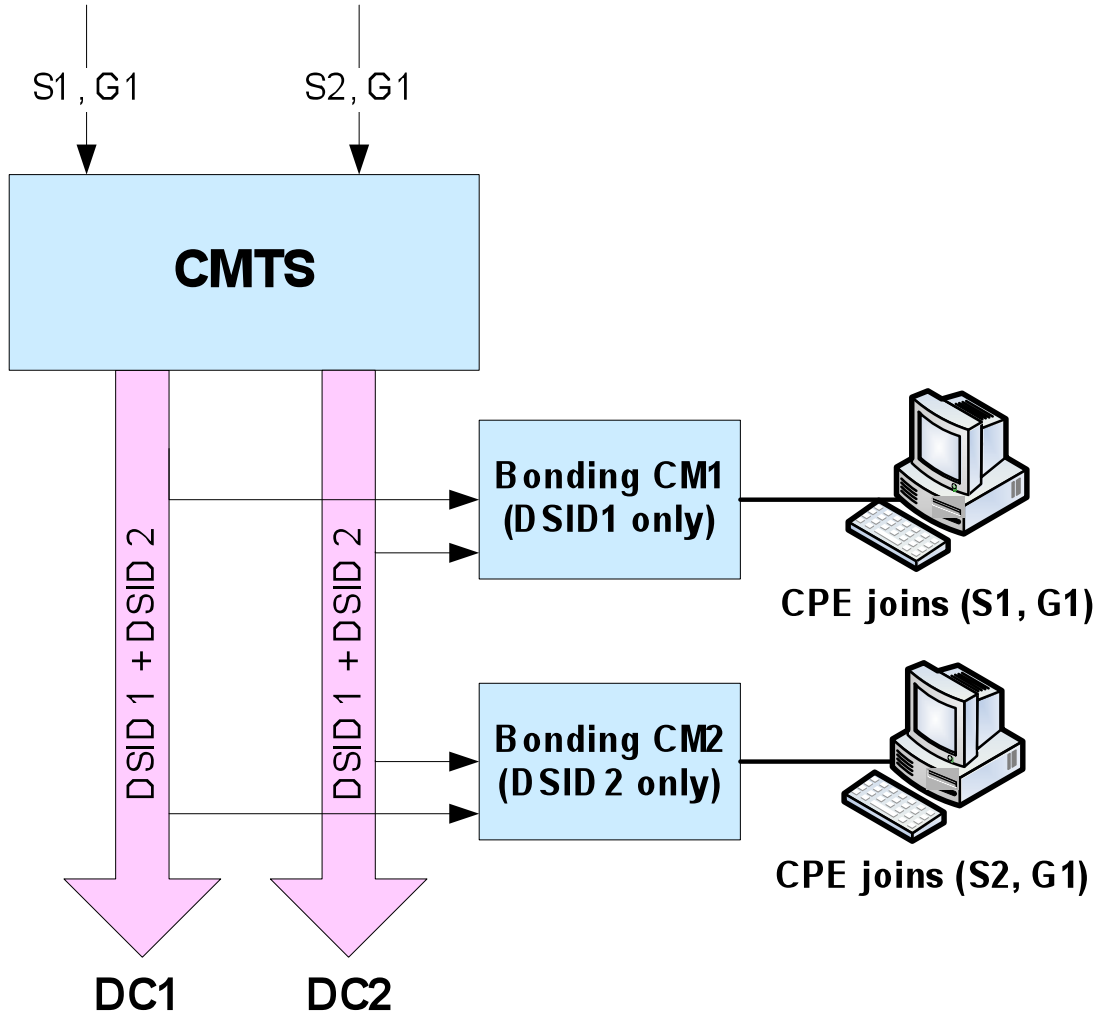
DOCSIS 3.0 Multicast Features

- SSM and IGMPv3
- IPv6 multicast support (pre and post registration)
- Multicast QoS
- Support for bonded multicast
- Support for multicast authorization
- Multicast encryption
- Backward compatibility with legacy DOCSIS devices
- Explicit tracking of multicast listeners

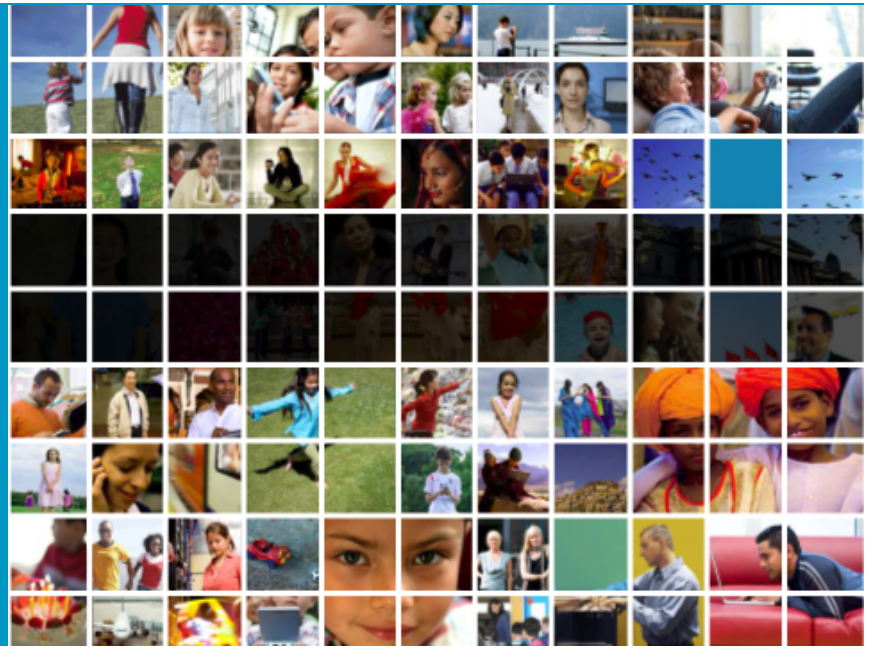
DOCSIS 3.0 Multicast Architecture

- 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 messaging
- Multicast filtering and replication within the CM
  - Based on DSIDs
  - GMAC promiscuous operation

Multicast DSID forwarding (MDF) support



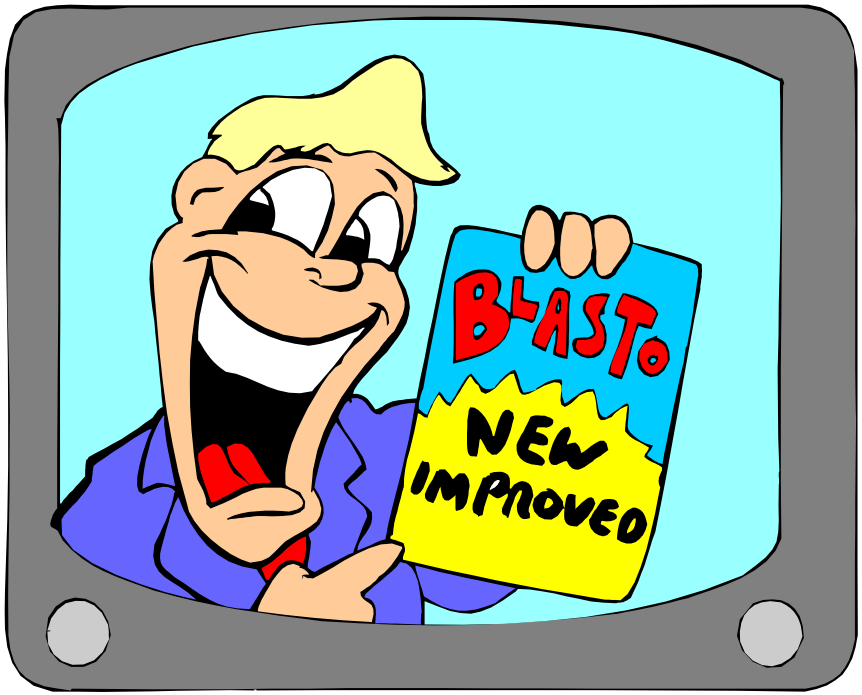
PCMM High Level Overview



PacketCable Multimedia

Improved way of obtaining QoS!

- **Signaling Agnostic**
- **More Generic compared to PacketCable Telephony**
- **Does not address application specifics (i.e. signaling, provisioning)**
- **MSO generated Policy Controls**
- **Dumb devices = less $$**



PacketCable Multimedia

- Prescribes how DQoS and BW can be used to create services that are *formidable competitive weapons.*
- Provides a generic application framework for enabling cable QoS for non-QoS-aware devices.

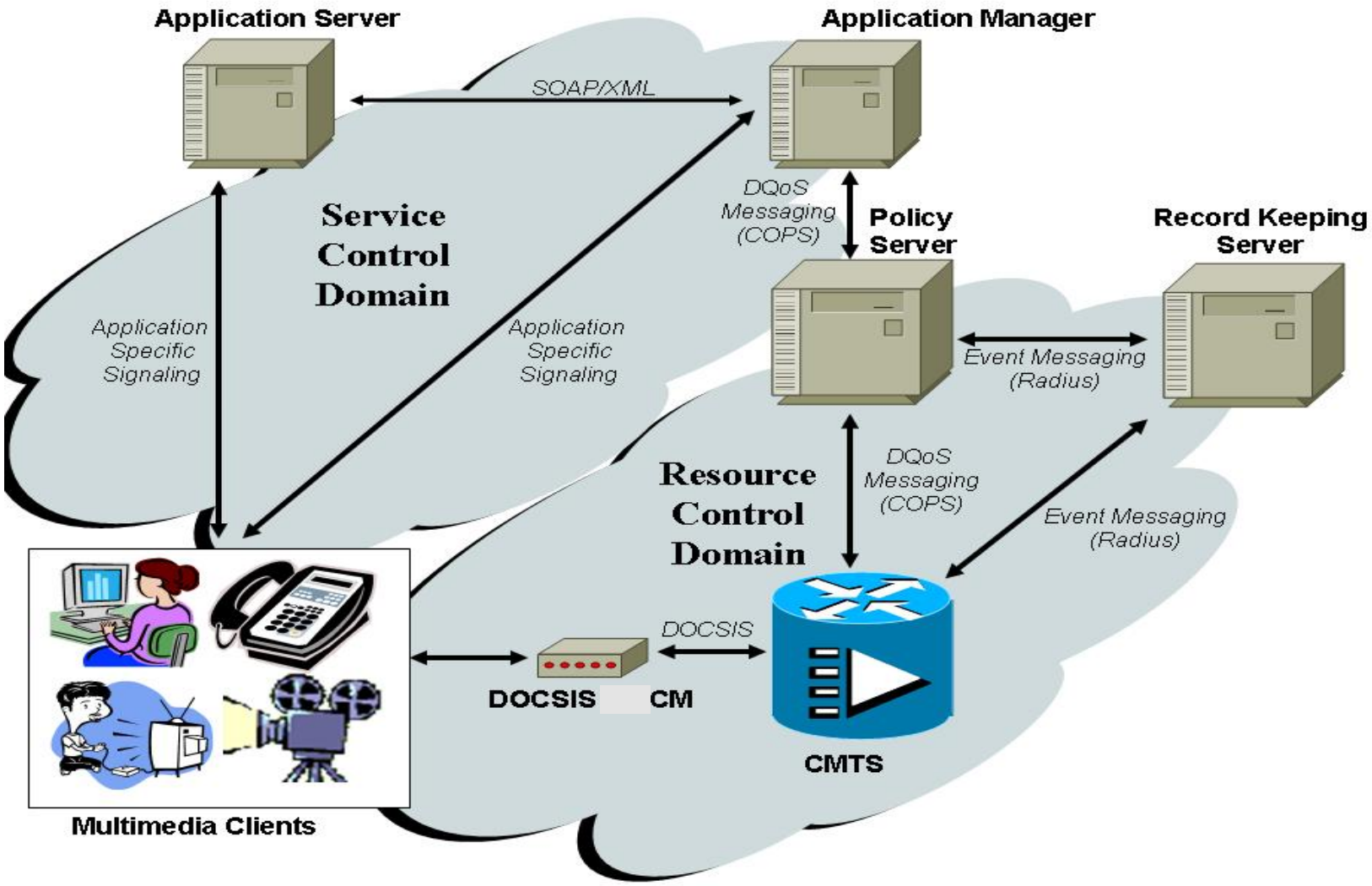
Soft-phones	X-Box/Playstation gaming consoles
Residential S-MTA	Business-class IADs, IP Phones

- Builds upon DOCSIS and PacketCable, enabling numerous voice, video, and data applications:

Bandwidth on Demand	Video Telephony
Low-latency Gaming	IM/Chat with QoS voice and video
Gaming with Audio/Video	'Presence-based' voice/video

- Also can be used in conjunction with Deep Packet Inspection (DPI) devices

PCMM Architecture



PCMM client types

- Client type 1: (*)

  Policy is pushed to the CMTS, CMTS establishes the resources. Referred to as “QoS unaware” clients.

- Client type 2:

  Policy is pushed to the CMTS, endpoint requests resources from the CMTS. Referred to as “Push model” clients.

- Client type 3:

  Policy is pulled from the Policy Server by the CMTS, triggered by an RSVP request from the endpoint. Referred to as “Pull model” clients.

* Currently, only Client type 1 is fully defined in the PCMM specifications.

Application Server (AS)

- Handles multimedia session requests on behalf of the client.
- AS may or may not be managed by the MSO.
- Protocol used between client and AS unspecified.

Application Manager (AM)

- Handles client requests either directly or via AS.
- The AM authenticates and authorizes client (or AS) requests based on pre-defined policies.
- Protocol between client and AM unspecified.
- Protocol between AS and AM is defined by PCMM (SOAP/XML).
- The AM determines the particular QoS parameters necessary to deliver the service to the client; could be specific or generic.
- It then sends a request for these resources to the appropriate Policy Server

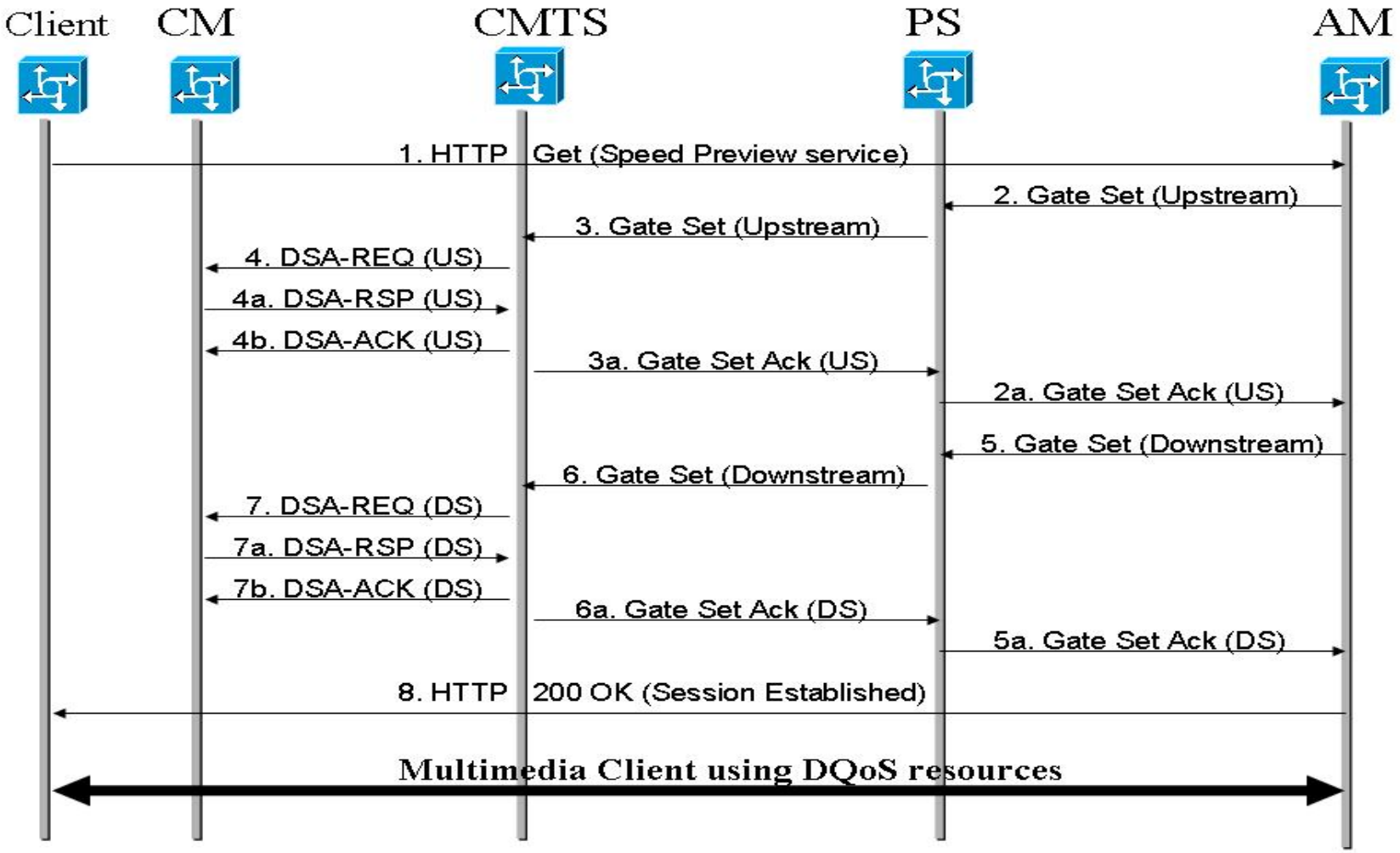
Policy Server (PS)

- Takes service requests from the AM and converts them to resource policy requests used to set up CMTS QoS resources.
- PS implements MSO defined authorization and resource-management rules. (examples include limits on number of gates per subscriber, types of QoS authorized for a given subscriber, limits on the impact of service on the CMTS, etc.)
- Policy servers can be deployed in a hierarchical topology to satisfy scalability and redundancy concerns
- PS can be “stateful” or “stateless”; if “stateful” can keep track of gates and resources.
- Protocol between AM and PS is COPS.

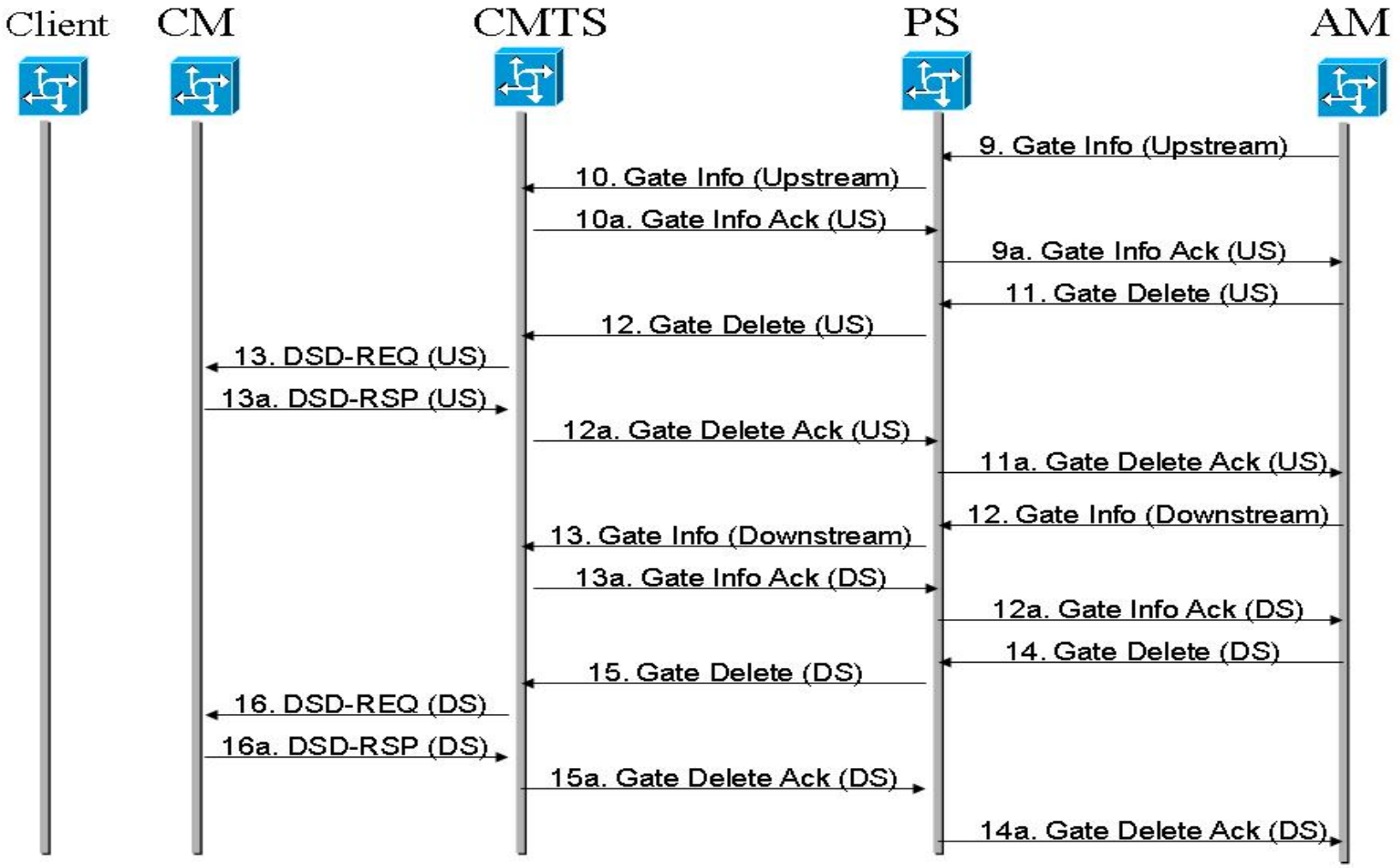
CMTS

- Policies can be “pushed” to the CMTS from the PS or “pulled” from the CMTS to the PS
- Since currently only client type 1 is defined they will always be “pushed”.
- Thus DOCSIS DSX message transactions will always initiate from the CMTS
- CMTS can track DOCSIS resources based upon volume and time requirements.

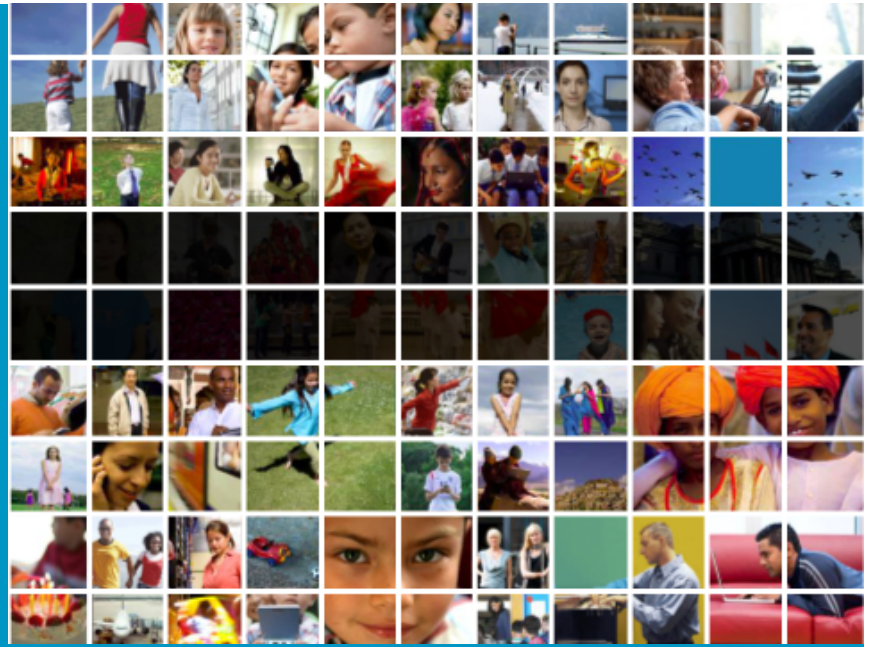
Sample Signaling Flow – Part I



Sample Signaling Flow – Part II



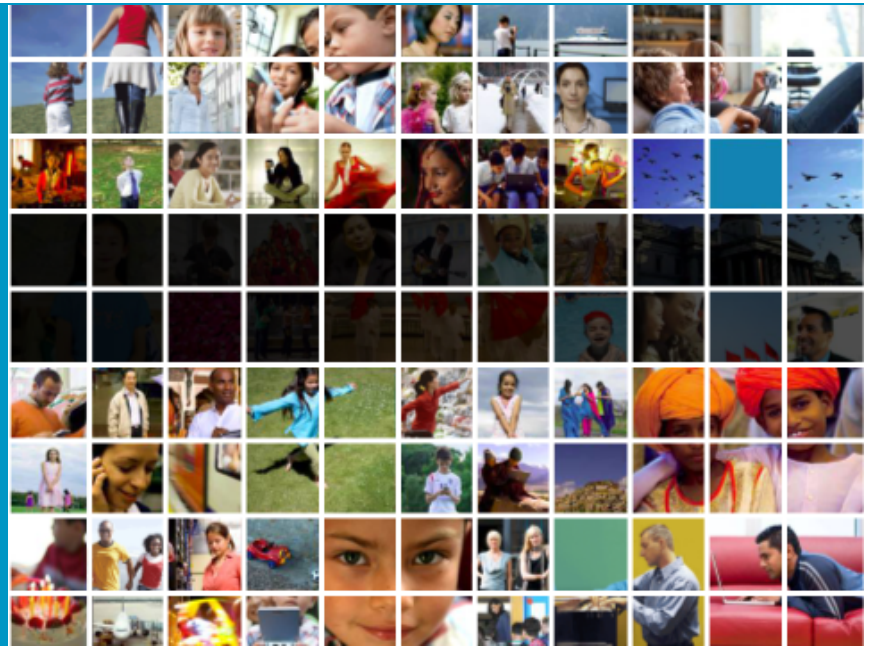
VDOC Architecture



VDOC Architecture

- Two different architectures
  - CMTS Bypass
  - CMTS Direct

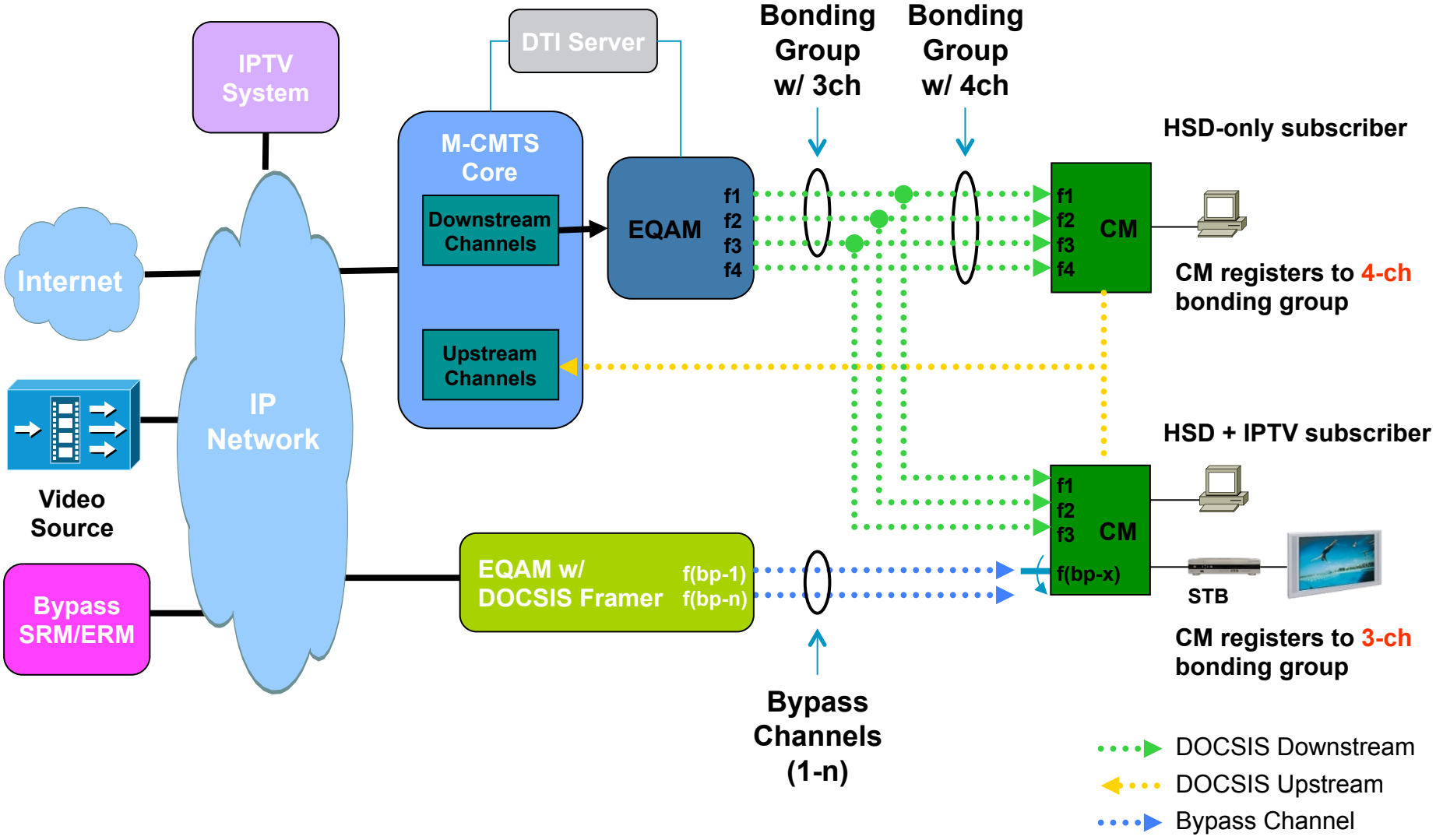
CMTS Bypass Architecture for VDOC



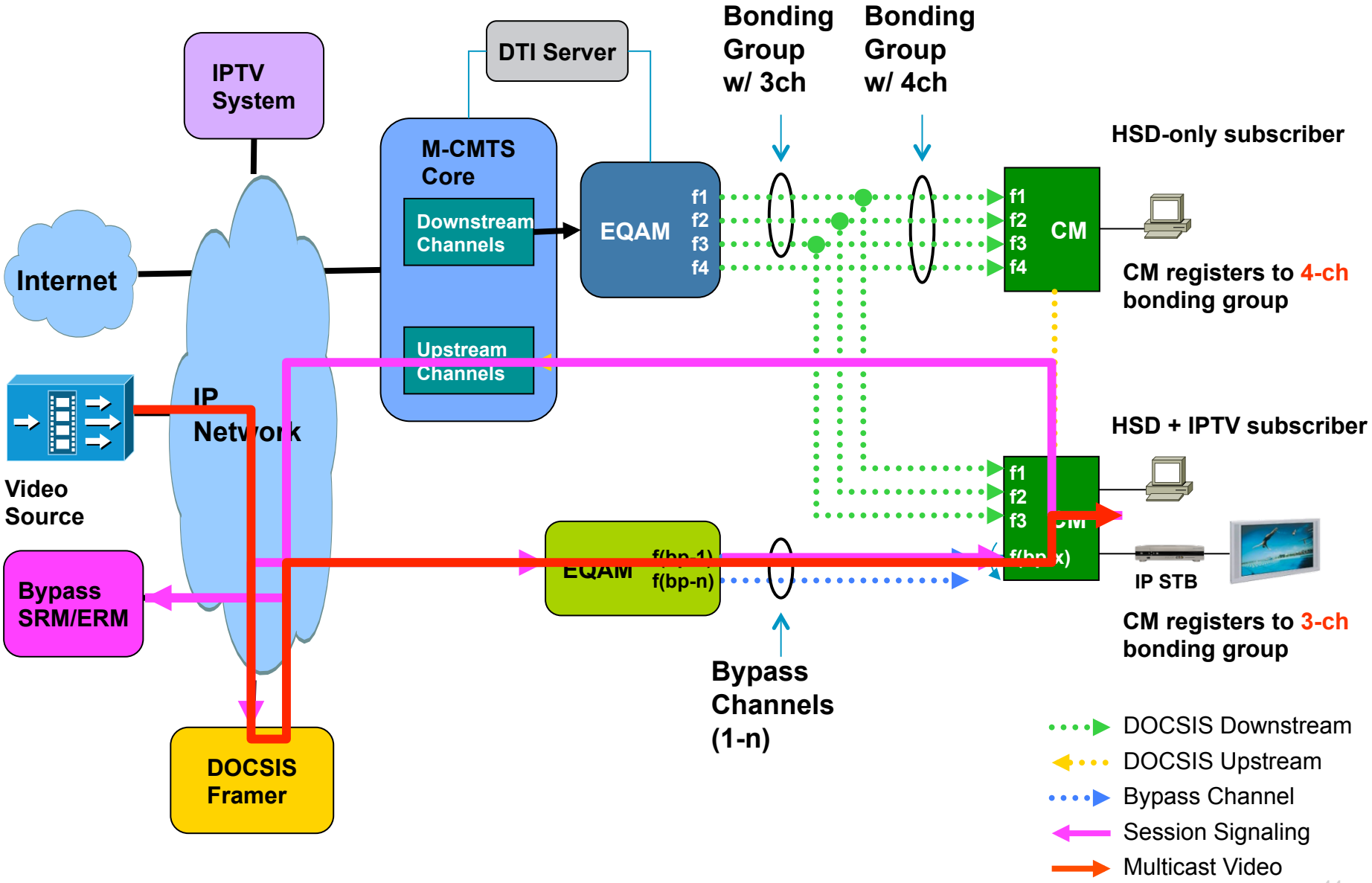
CMTS Bypass Solution - Overview

- Also referred to as DIBA – DOCSIS IPTV Bypass Architecture
- One (or more) cable modem tuners dedicated to IPTV service (under control of Bypass System)
  - Two entities controlling the modem (Bypass System and CMTS)
  - Multiple tuners required per cable modem
- Channel change signaled from IP Set-top box to Bypass SRM/ERM
  - Utilizing upstream channel from cable modem to CMTS
- DOCSIS Framer/Edge QAM performs IGMP join as instructed by Bypass SRM/ERM and forwards multicast video to IP Set-top box via Bypass channel
- CMTS is unaware of Bypass channels
- EQAMs don’t need to be DOCSIS 3.0 capable

CMTS Bypass Solution



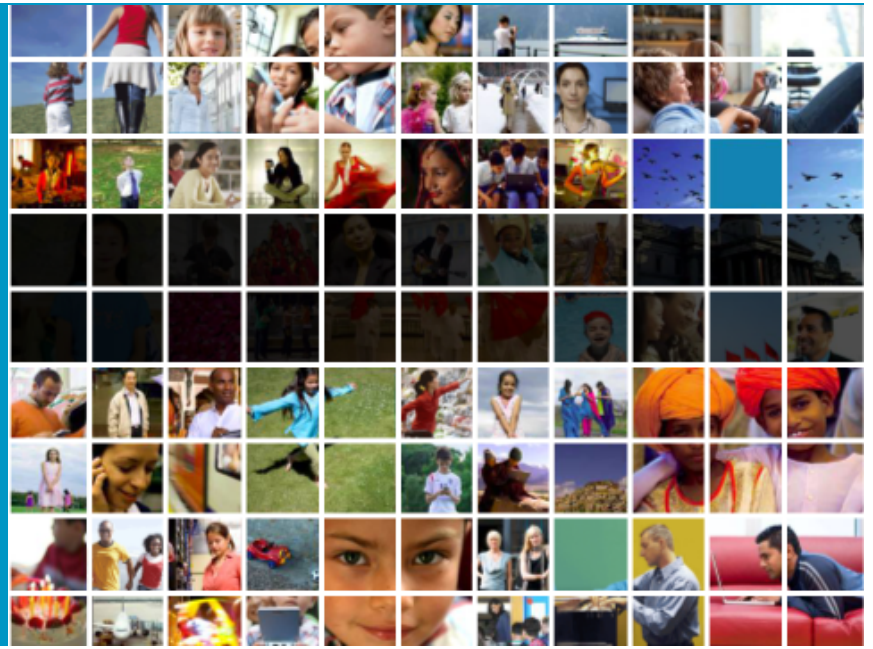
CMTS Bypass Solution Example: Multicast Video



CMTS Bypass: Architecture and implementations caveats

- Custom Cable Modems
- Proprietary EQAM
- Non-DOCSIS 3.0 operation
  - Multicast, DBC etc
- Need for Bypass SRM
- Network Silos
  - Inability to re-purpose network capacity for other services
  - Inability to dynamically share bandwidth across different MSO-managed services based on business rules
- Operational complexity
- Bypass cost savings only applicable to IPTV service

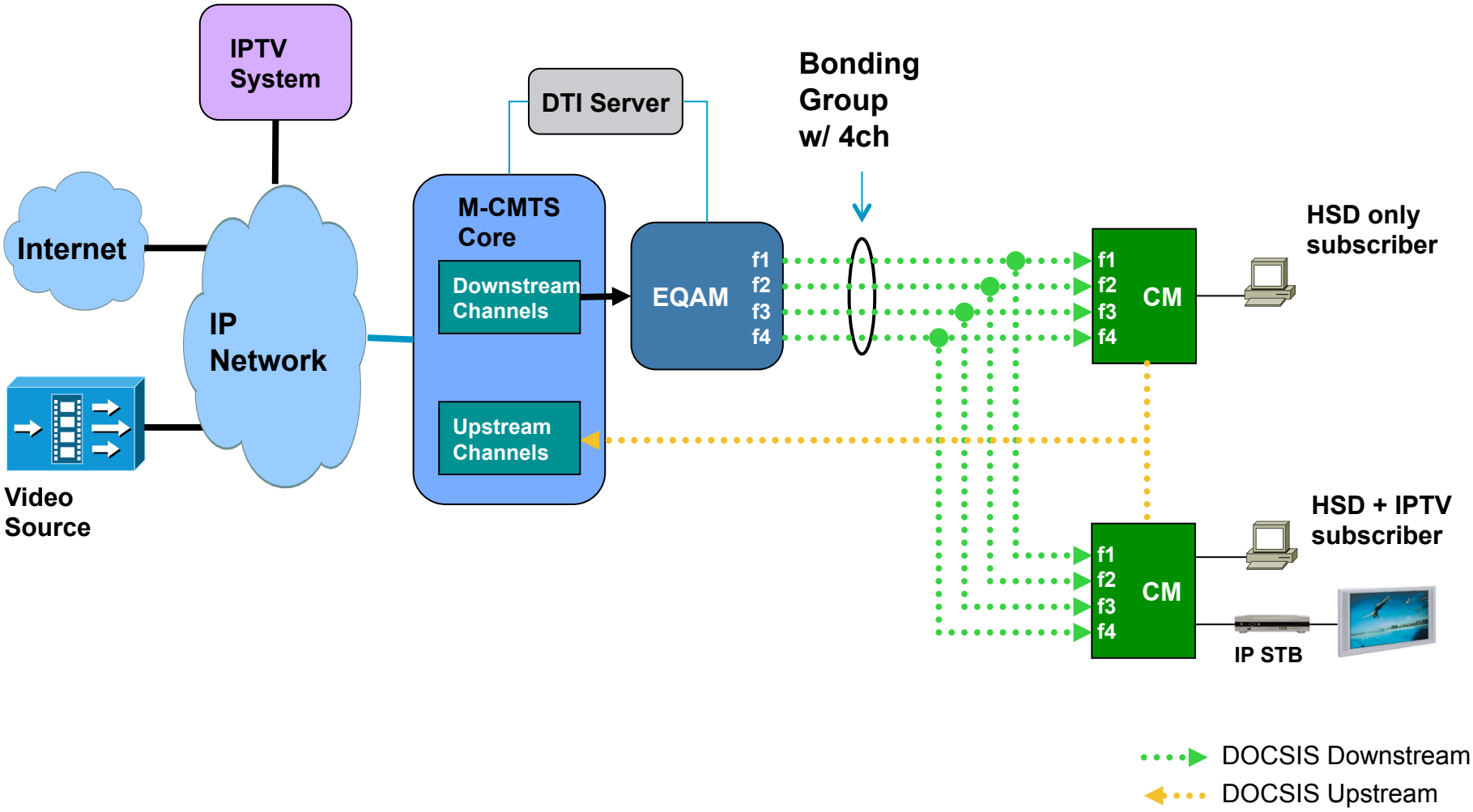
CMTS Direct Architecture for VDOC



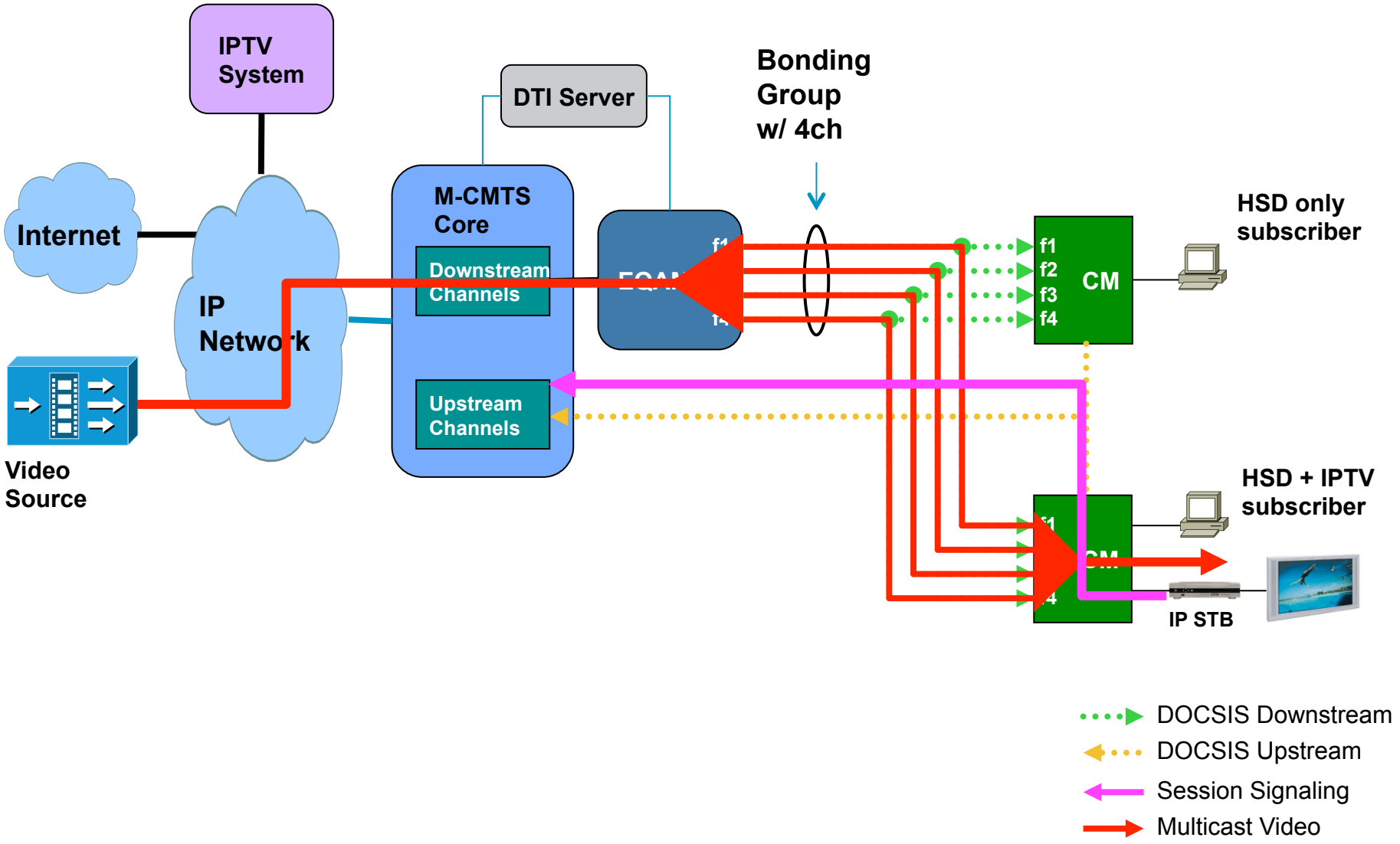
CMTS Direct Solution for VDOC

- CMTS Direct Architecture
  - Modular/Integrated CMTS with DOCSIS 3.0 Downstreams
  - All applications are routed through D3.0 CMTS
  - All control plane signaling is routed through D3.0 CMTS
  - D3.0 CMTS provides cable modem/set-top box registration, configuration, etc.
- Build a CMTS platform that:
  - Provides all features for all services with one common transport
  - Is based on existing DOCSIS 3.0 and M-CMTS specifications
  - Is highly scalable
  - Provides a price point per downstream that is competitive with existing video infrastructures

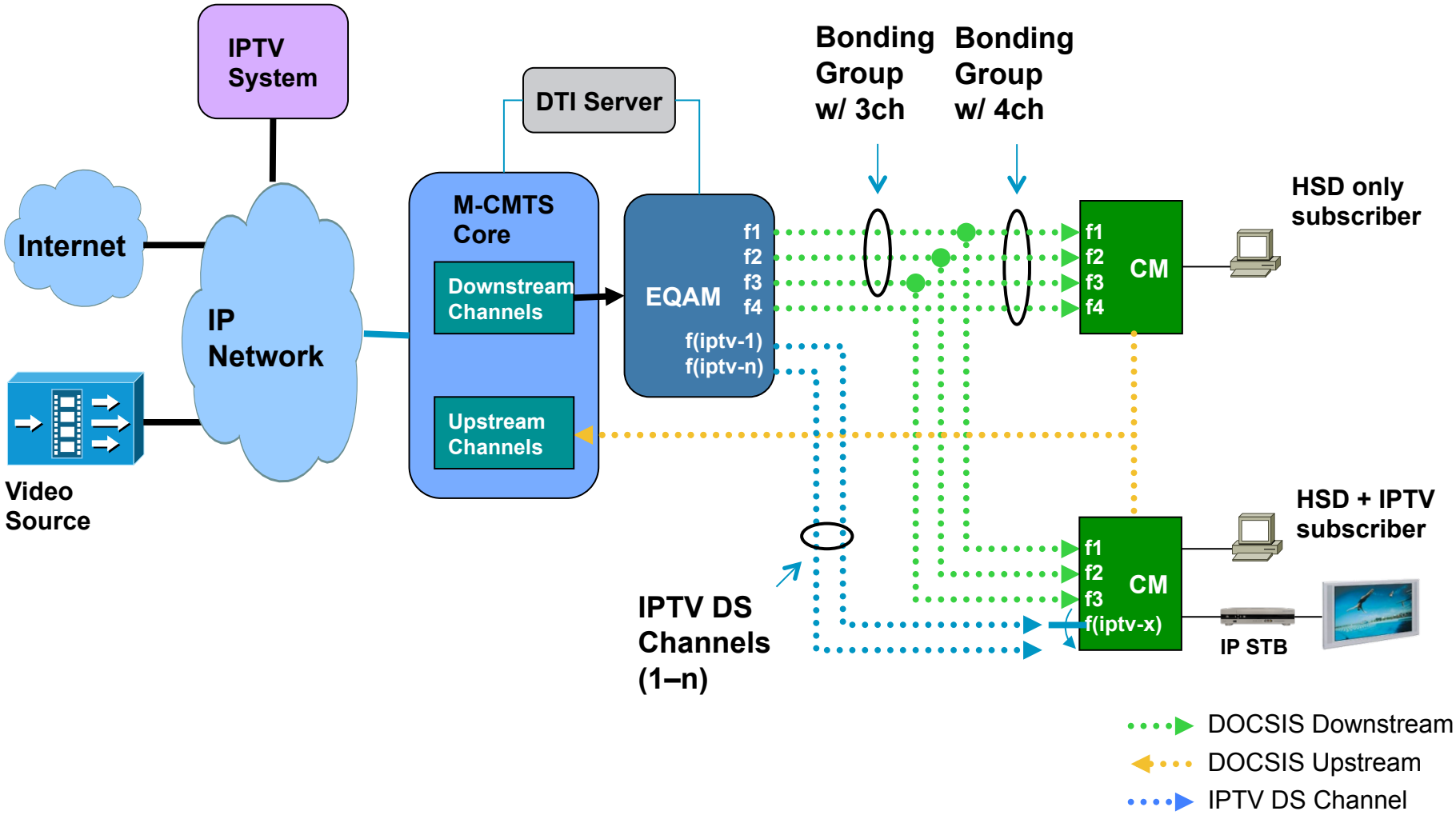
CMTS Direct Solution (M-CMTS model)



CMTS Direct Solution Example: Multicast Video



CMTS Direct Solution with Dedicated IPTV DS Channels



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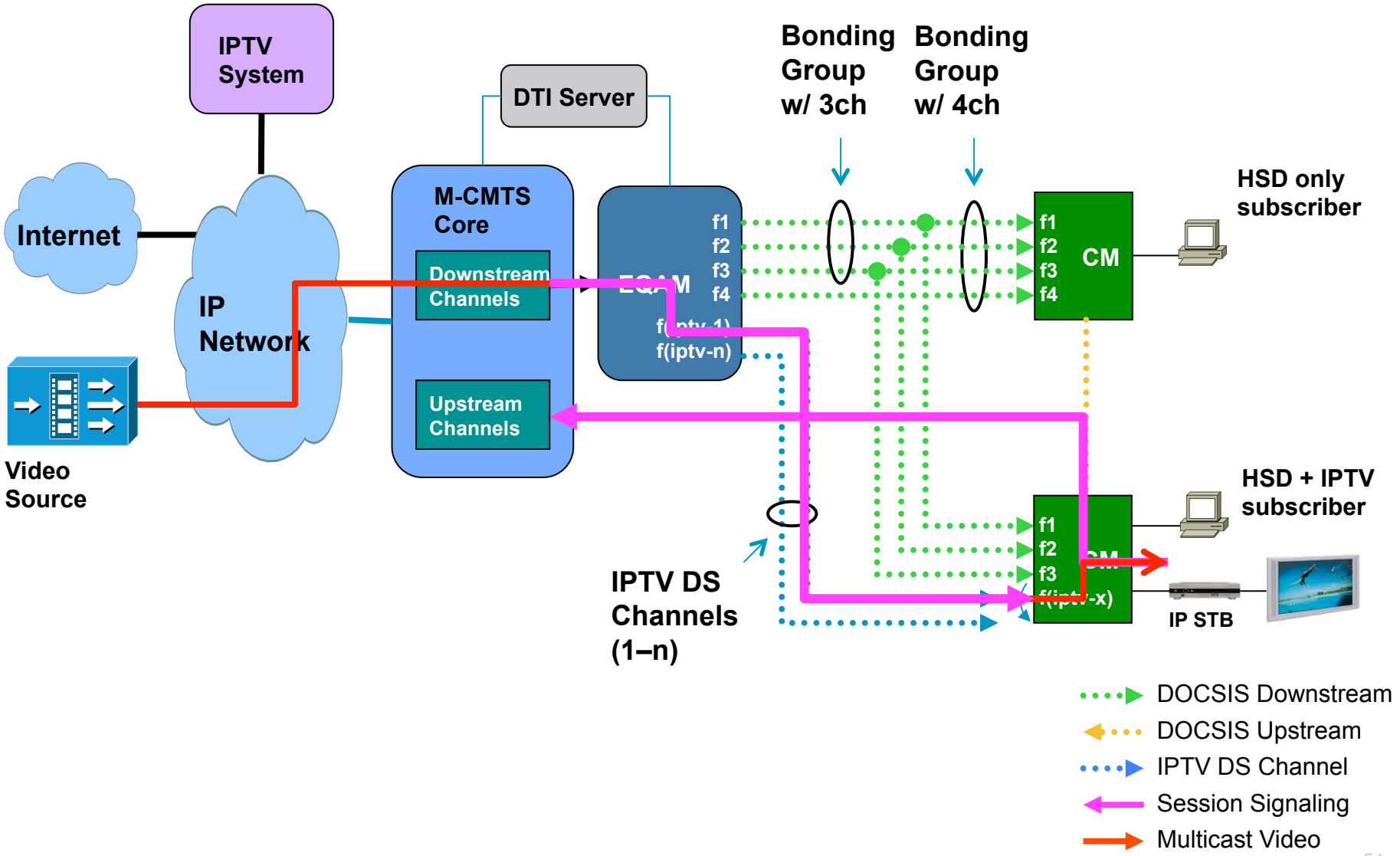
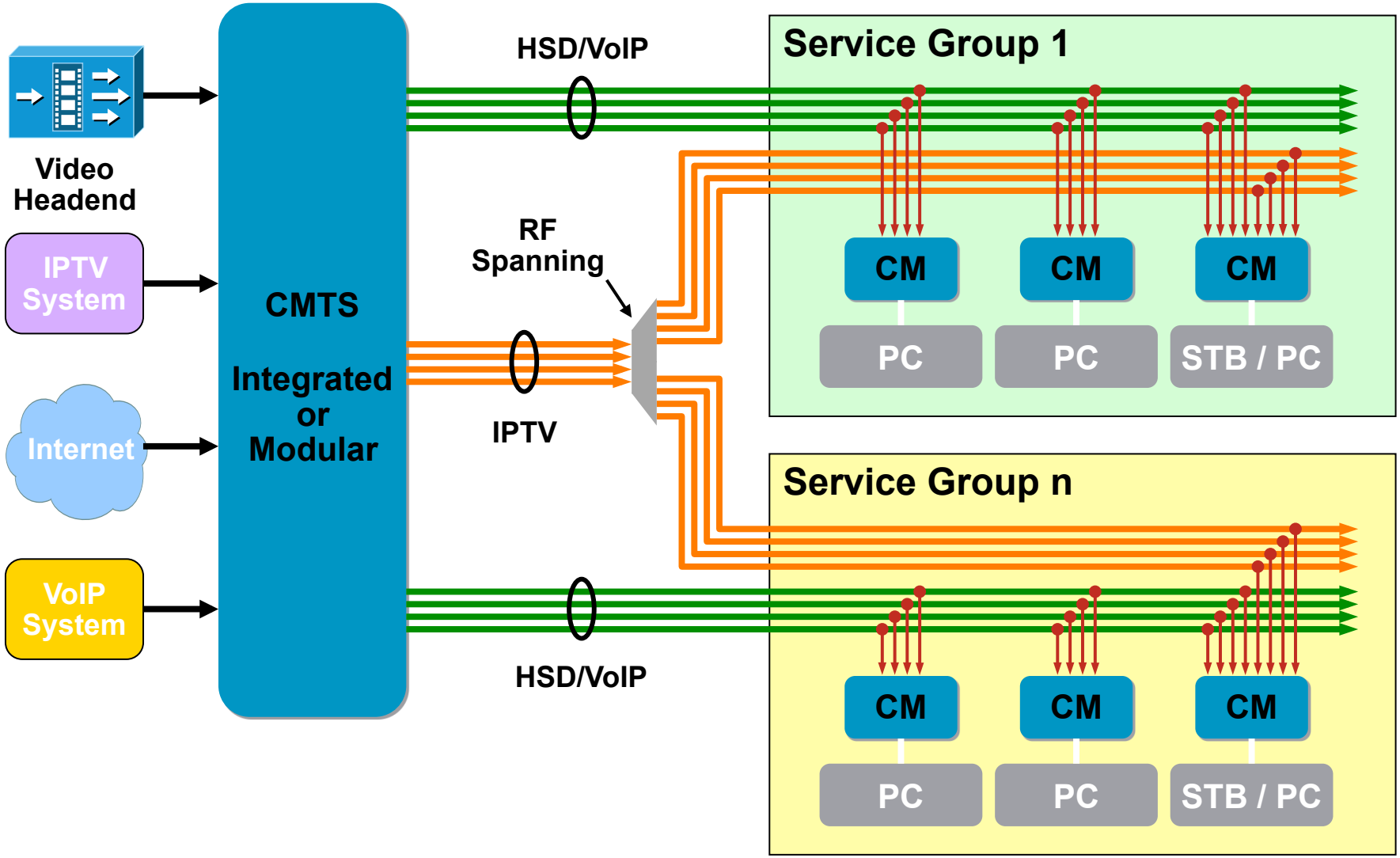


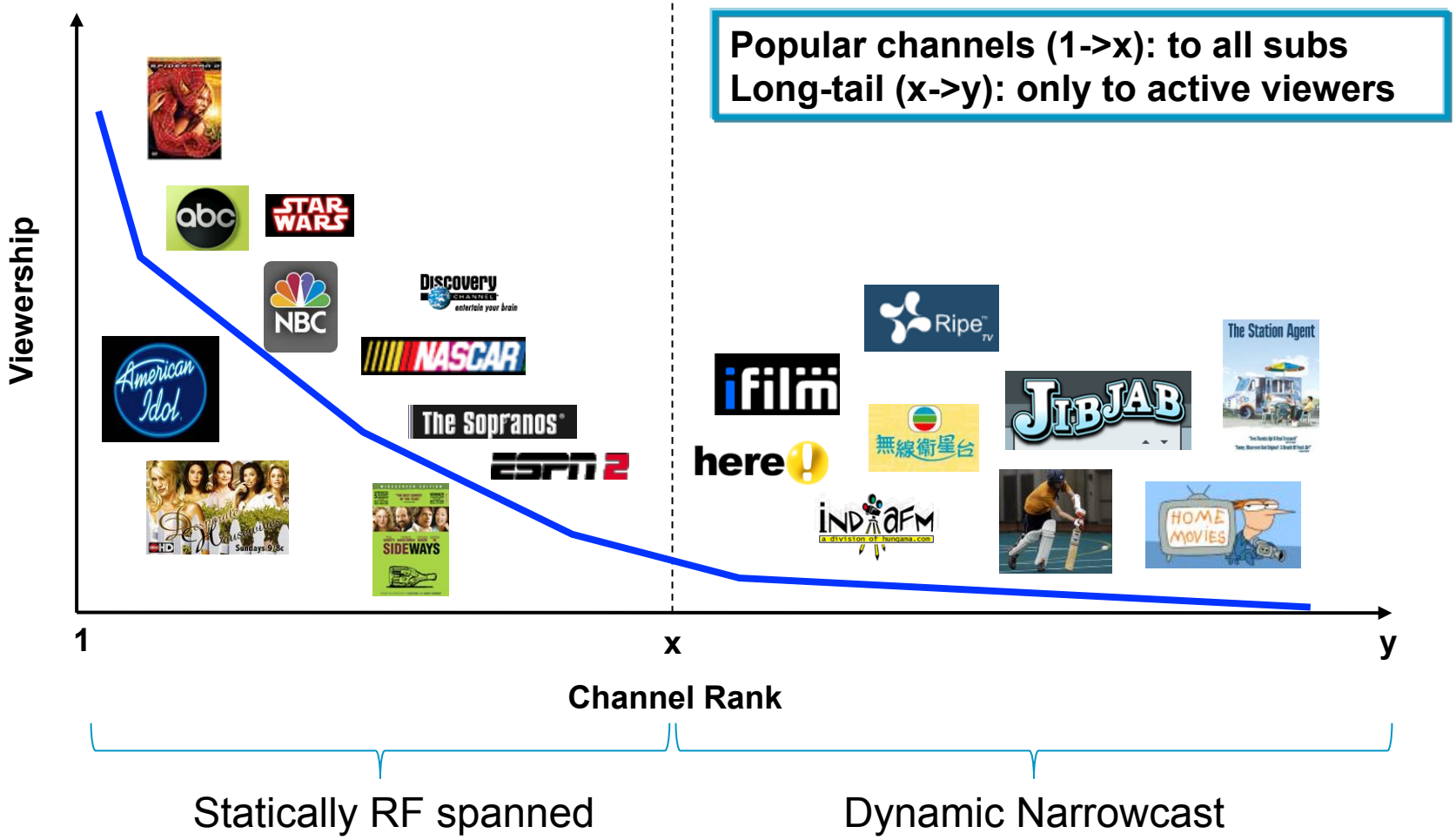
RF Spanning

- 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
- The cost of these downstreams is amortized across multiple SGs
- 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



D30 Multicast for Linear IPTV

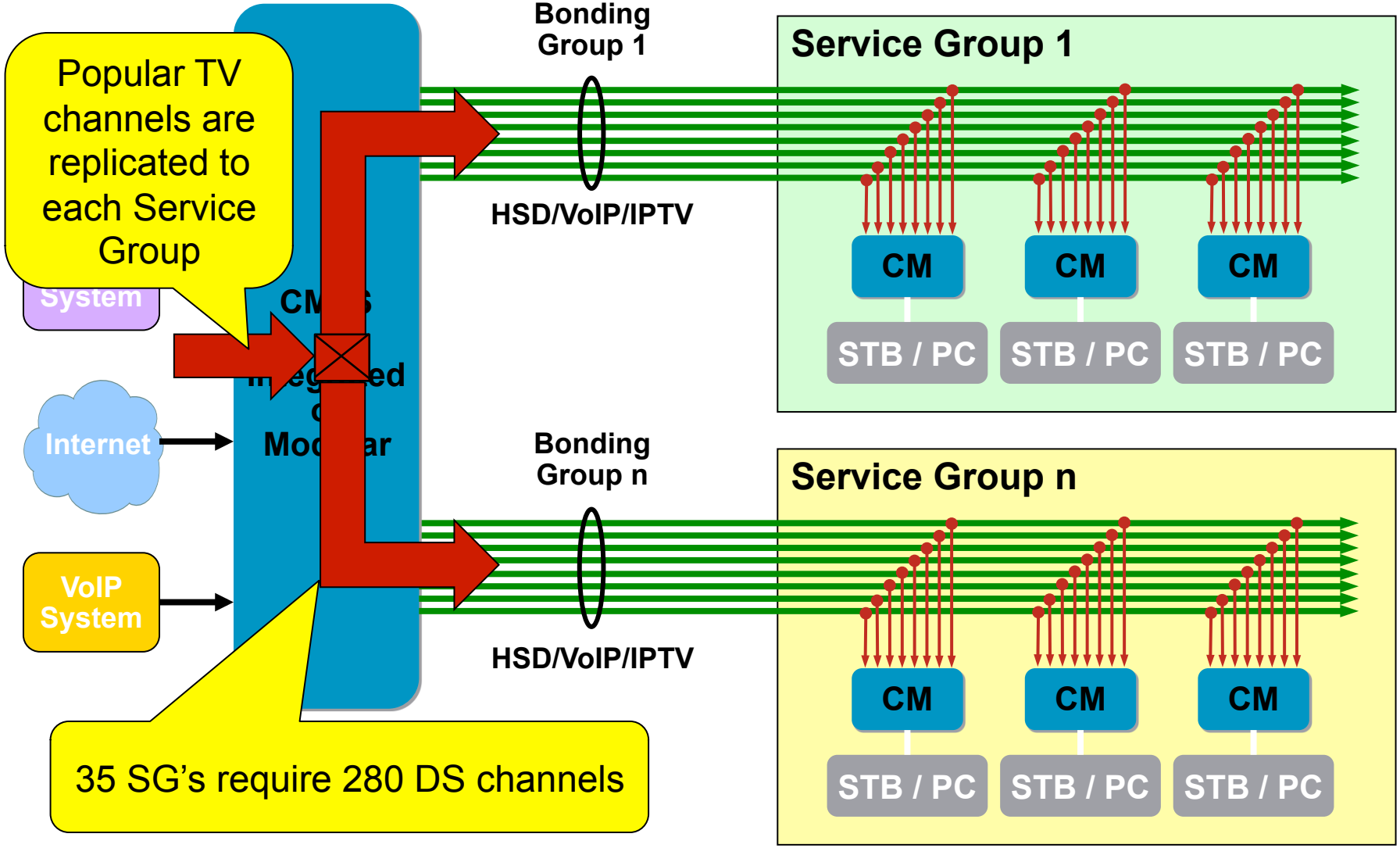


Bonded Static Multicast

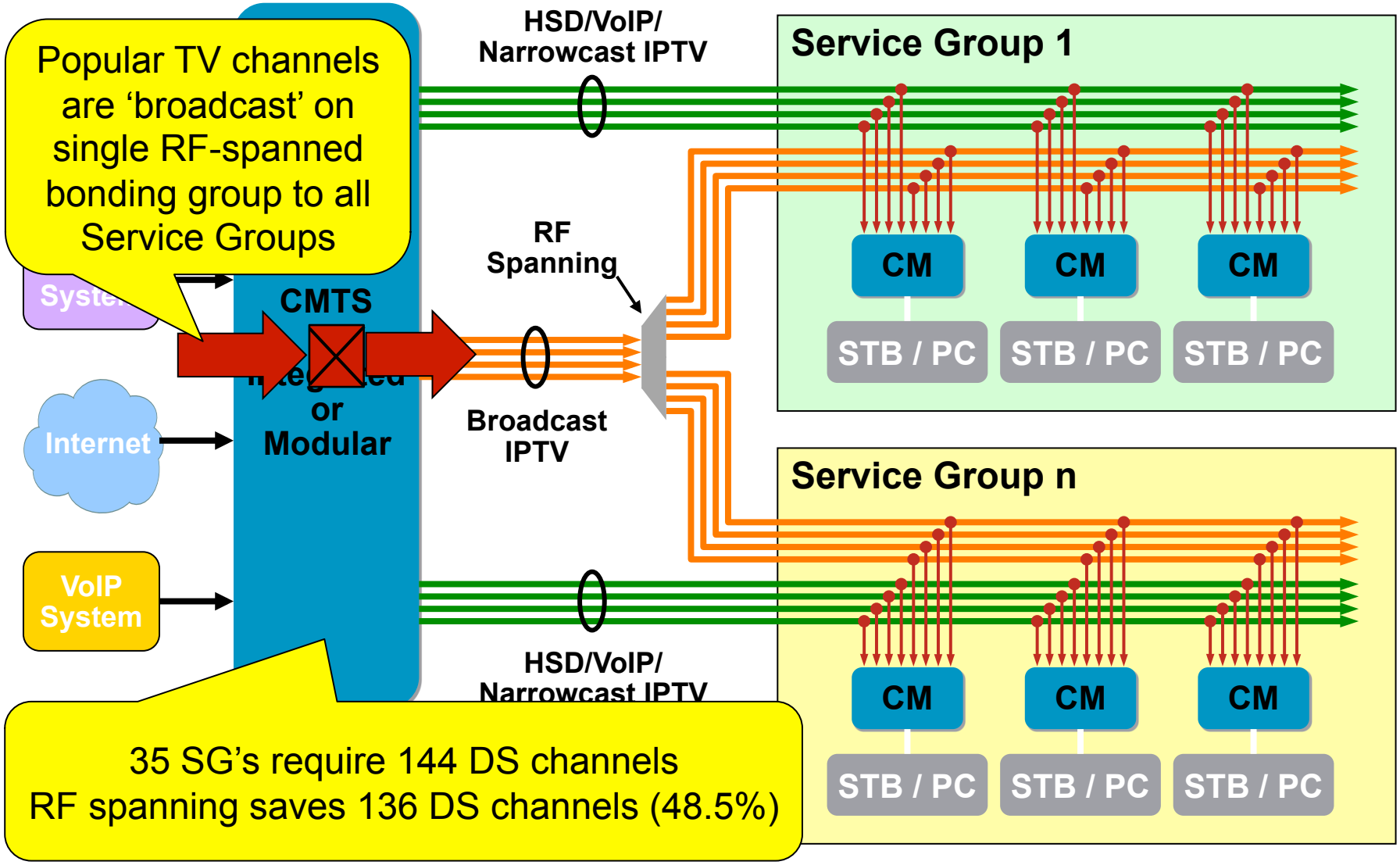
- A BG is RF-spanned to all SGs and carries multicast IPTV streams
  - IPTV streams are delivered at all times as static multicast flows – regardless of viewership
  - Most popular content can be carried in a 4-channel BG
  - Long-tail content is carried over narrowcast BGs
- Subset of receive channels on CM are statically tuned to this RF-spanned BG to receive multicast IPTV streams
- Trade-offs
  - The cost of the RF-spanned downstreams is amortized across multiple SGs
  - 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

DOCSIS 3.0 Channel Bonding

DS bonding group shared by all services with 8x4 CM



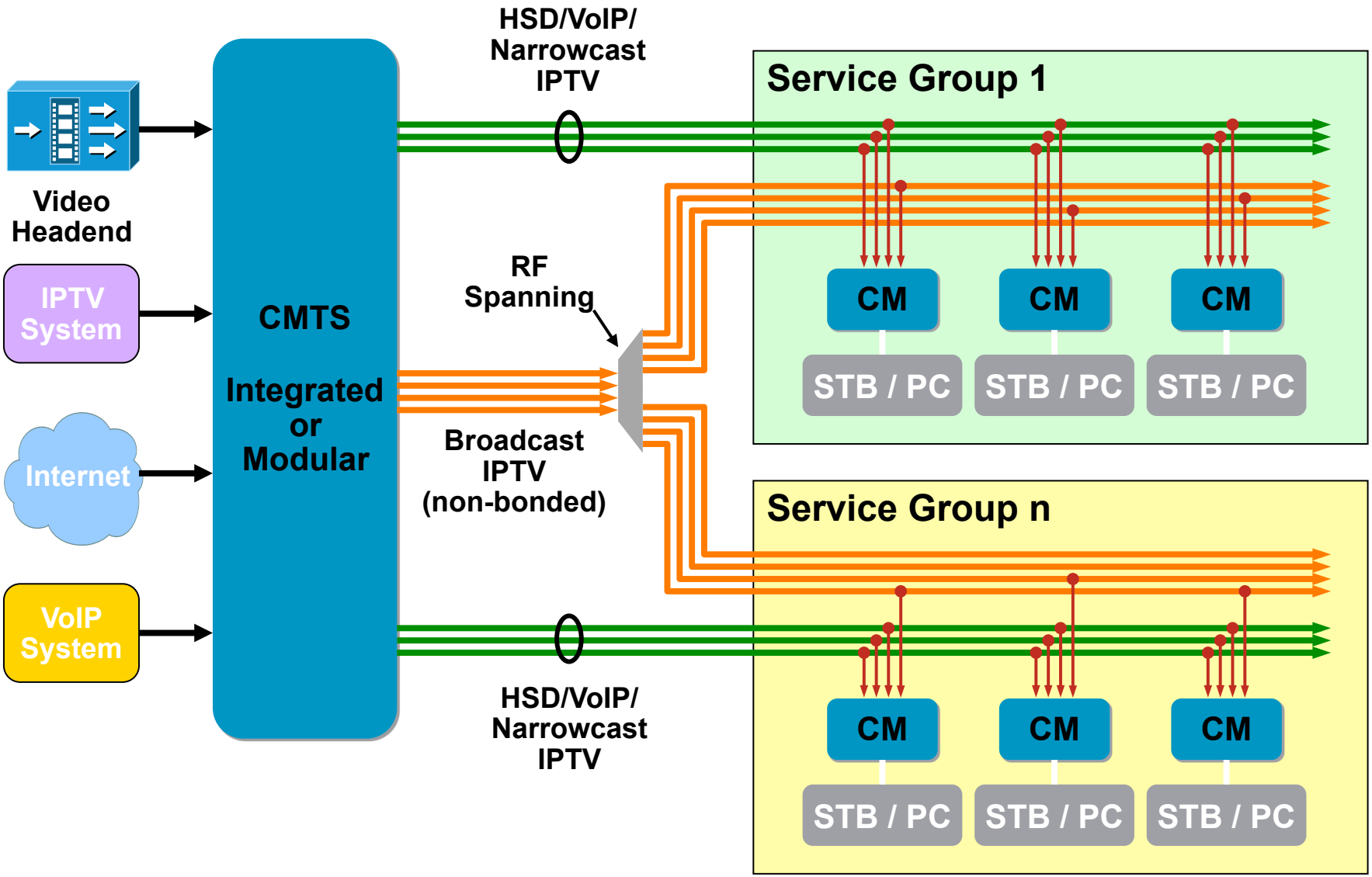
Static Multicast w/ RF Spanning



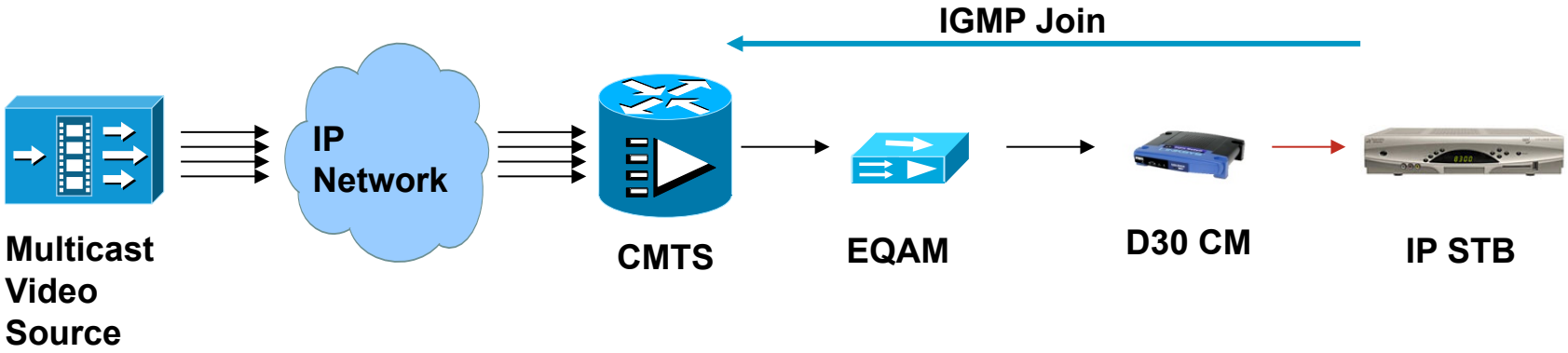
Static Multicast with CM tuning

- A set of downstreams carrying multicast IPTV streams are RF-spanned across all SGs
  - These downstreams are not bonded
  - The IPTV streams are delivered at all times as static multicast flows – regardless of viewership
- Receive channels on CM can be dedicated to tune to one of these RF-spanned downstreams to receive a multicast IPTV stream
  - CM can forward one IPTV stream from each receive channel
- Trade-offs
  - The cost of the RF-spanned downstreams is amortized across multiple SGs
  - Number of IPTV streams that can be part of static multicast line-up is not limited by the number of CM receive channels
  - 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, and independent tuning capability (or large capture window)

Static Multicast with CM Tuning



Multicast Video over DOCSIS
Dynamic Multicast



Notes:

- CMTS dynamically forwards multicast video streams based on IGMP traffic from STB
- Entitlement is performed prior to STB issuing IGMP join
- CMTS configured with BW per multicast group address (CLI or SNMP)

Scaling the DOCSIS Network for Video

Scaling the DOCSIS Network for Video

- **IP Statistical Multiplexing with VBR Video**

  Utilize CMTS capabilities to deliver more video streams in less bandwidth

- **Dynamic Bandwidth Sharing**

  Increase bandwidth utilization for all services

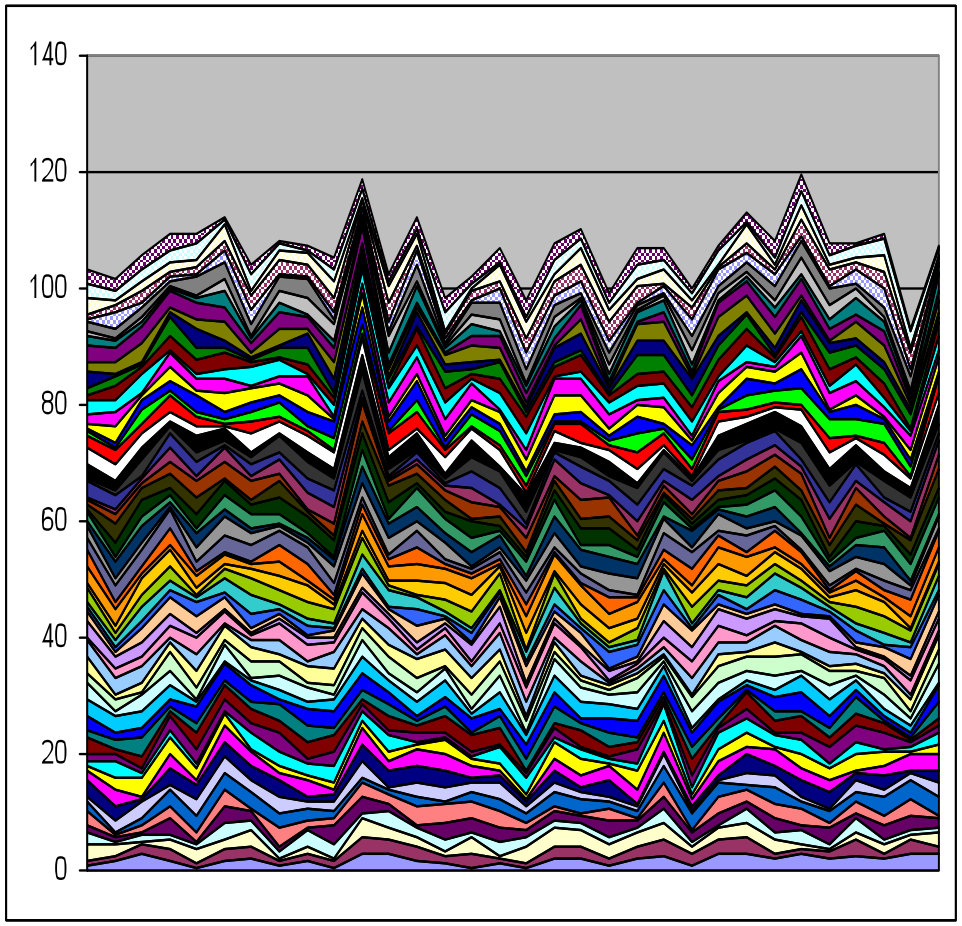
- **Admission Control and QoS**

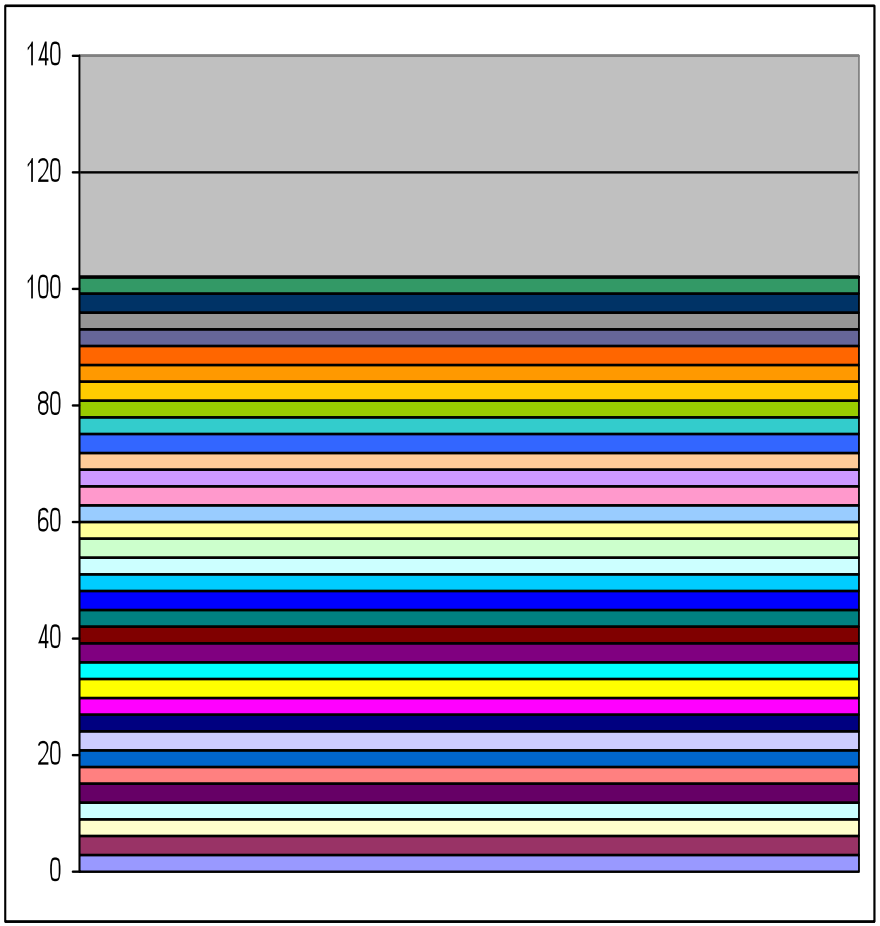
  Reserve DOCSIS bandwidth and ensure video quality

- **Cable Modem Load Balancing**
  - Support multiple bonding groups per Service Group as IPTV grows

Efficiency Gains from VBR Video

- Support 40 – 60% more streams with VBR video
- Law of large number works in favor of VBR statmux in fat pipe

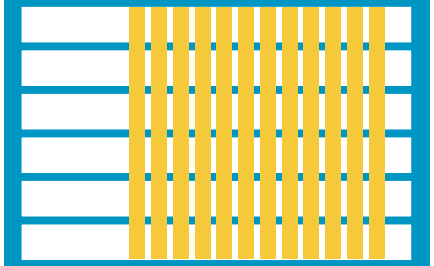




Delivering VBR Video over DOCSIS Networks

Fat Pipe

DOCSIS 3.0 Channel Bonding



Law of large numbers

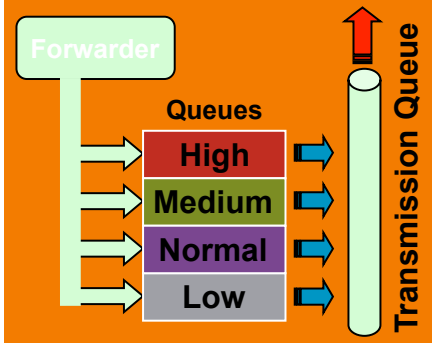
Asynchronous

100ms CPE Jitter Tolerance

60ms CMTS jitter

CMTS QoS

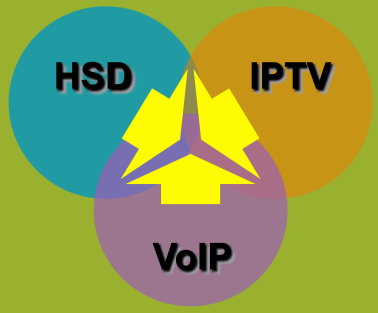
Shaping Priority



No transrating

Convergence

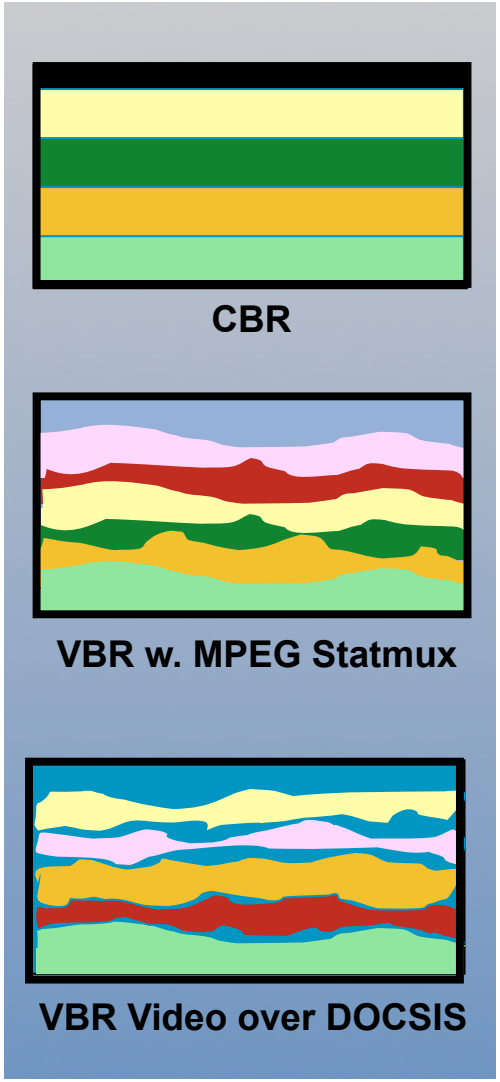
Service / Device



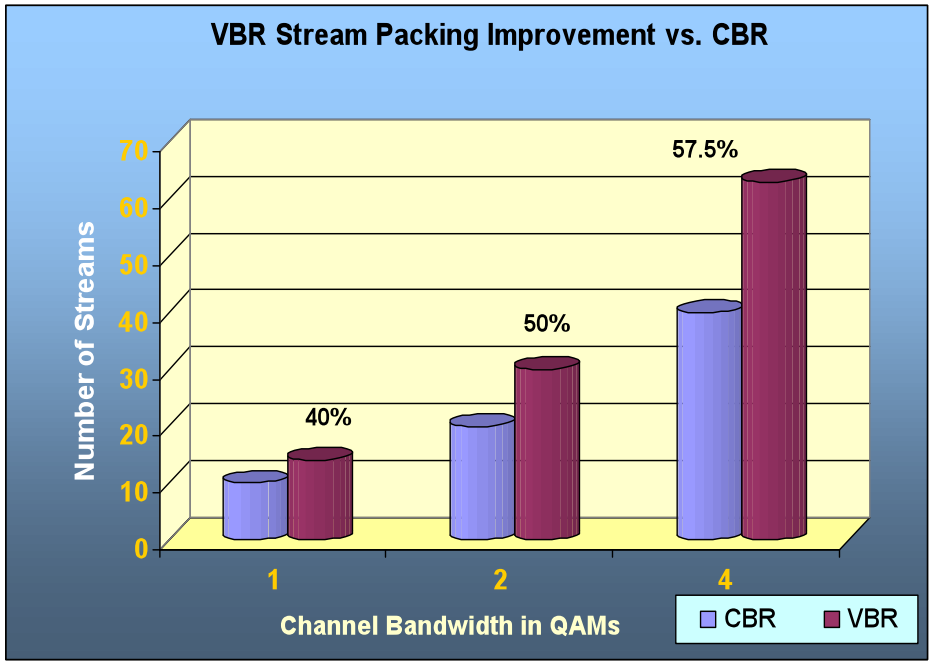
100% BW utilization

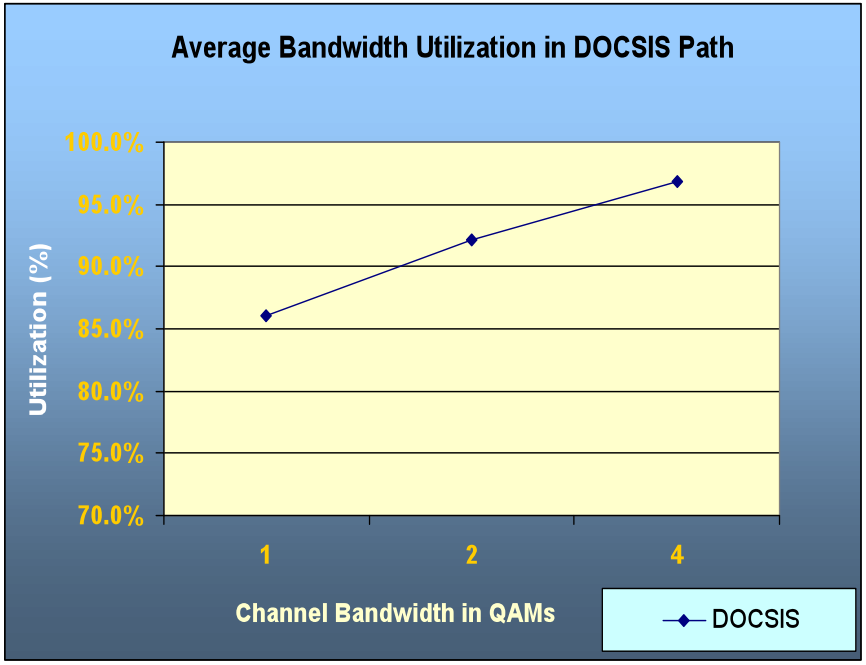
VBR Video over DOCSIS with IP Statmuxing

- Unprecedented bandwidth efficiency
  - Up to 50% more streams than CBR video (with 4-channel bonding)
  - 100% bandwidth utilization for convergence
- Cost effective & scalable
  - CMTS queuing instead of transration
  - Scalability independent of codec complexity
- Low latency
- Encryption agnostic
- Superior picture quality



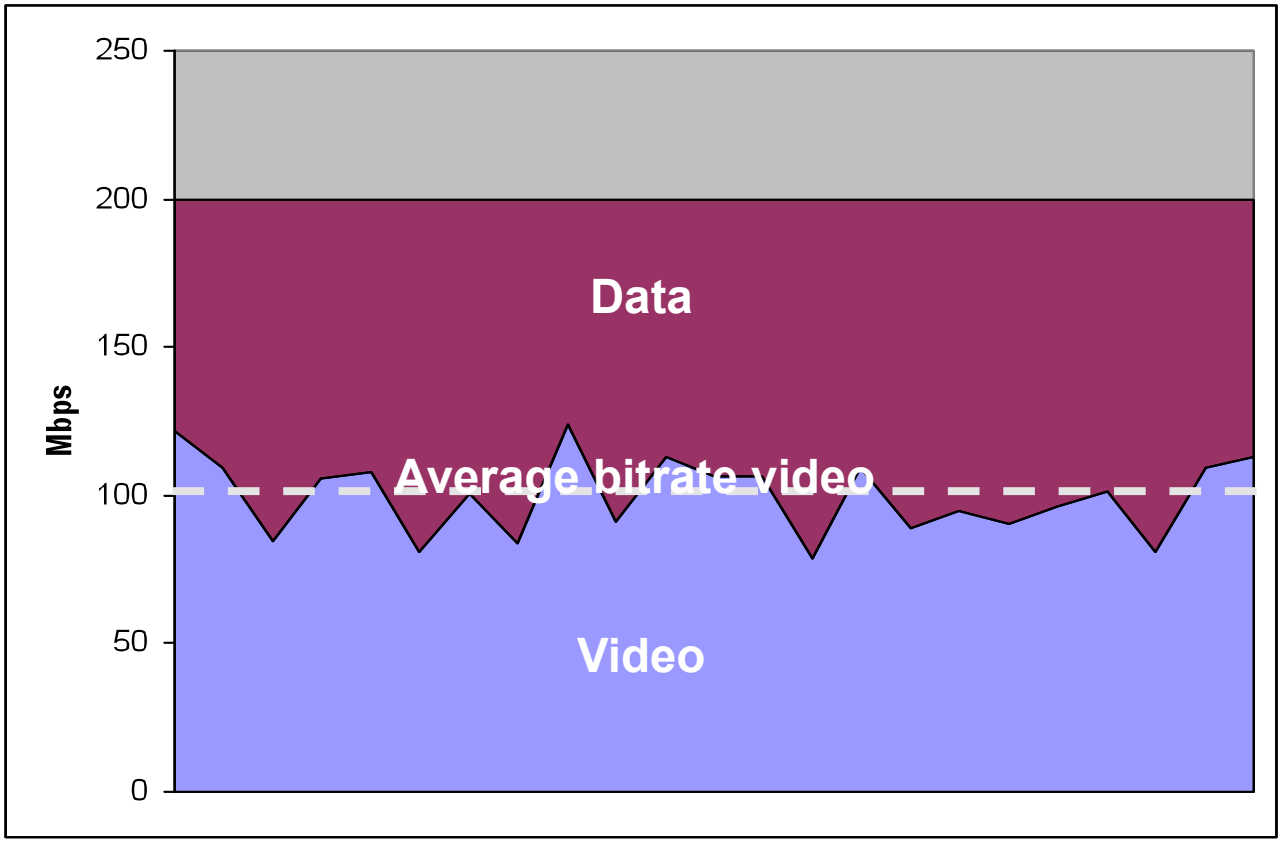
VBR over DOCSIS: Packing Efficiency





Dynamic Bandwidth Sharing

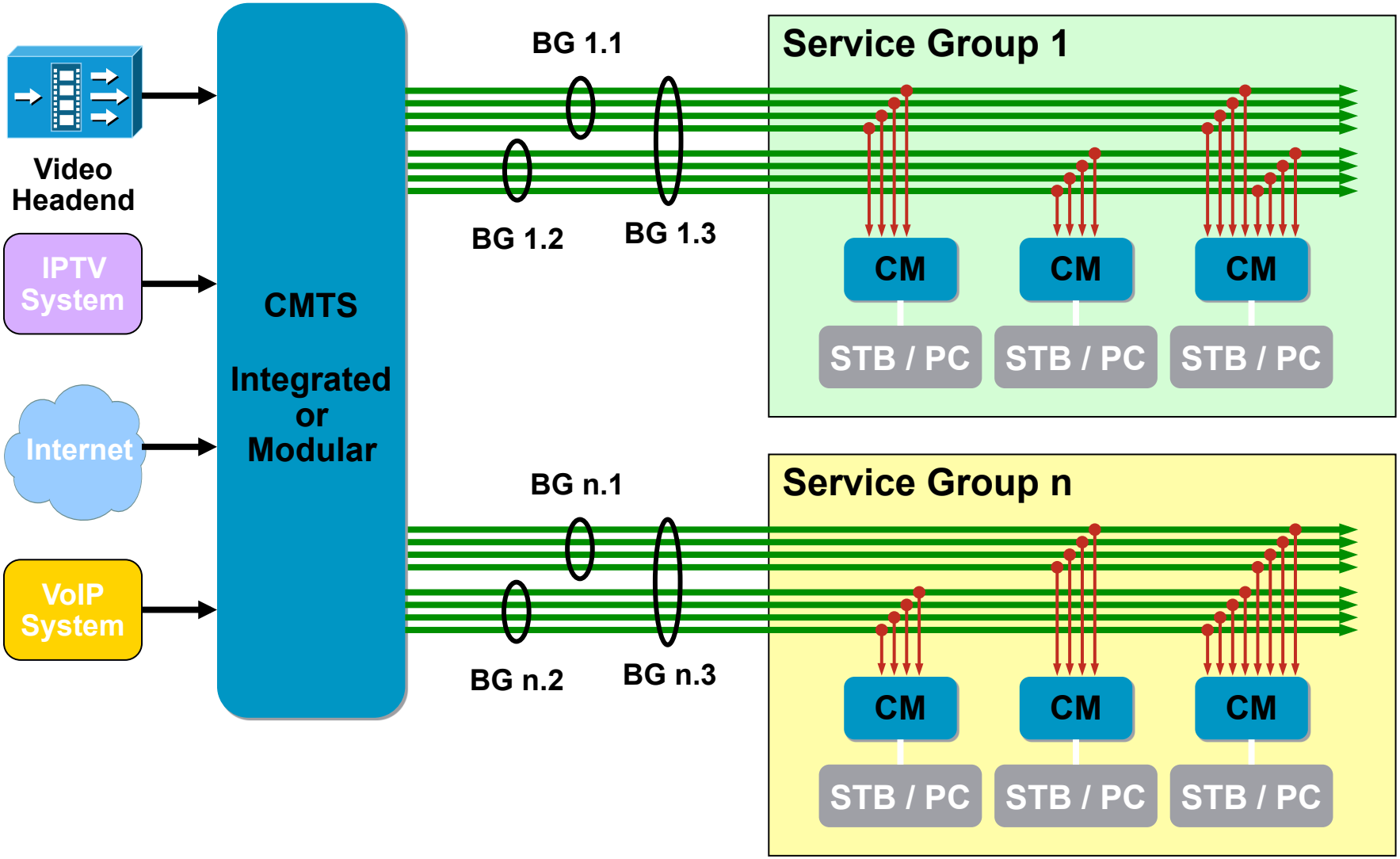
- Data and video services delivered in shared bonding group
- Data service “sponges” excess bandwidth not used by video



Dynamic Bandwidth Sharing

- Bonding Groups may overlap across a set of downstreams
  - For overlapping BGs, a portion of the BW of each downstream is allocated to each BG via configuration
- CMTS is capable of dynamically sharing bandwidth across overlapping bonding groups based on the services consumed by the CMs receiving the BGs
- Enables the deployment of a mix of CMs with different number of receive channels
  - Example: Deployment of 8-channel CMs doesn't require separate set of RF channels from those used for 4-channel CMs.

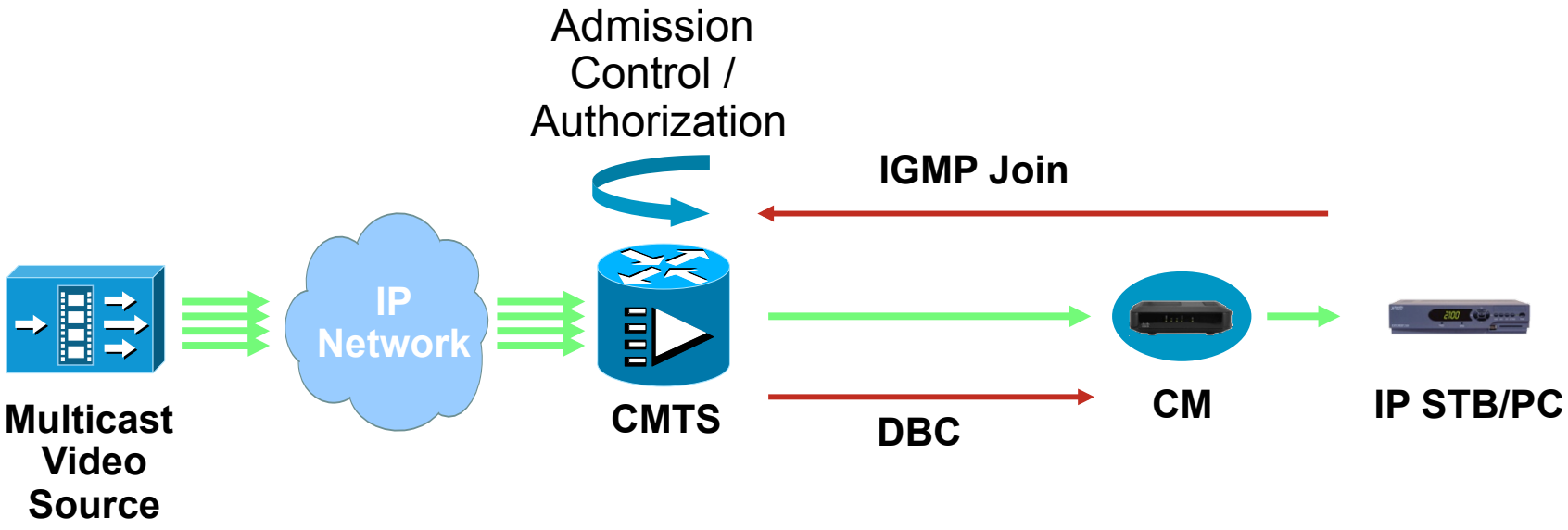
Dynamic Bandwidth Sharing with Overlapping Bonding Groups



Admission Control

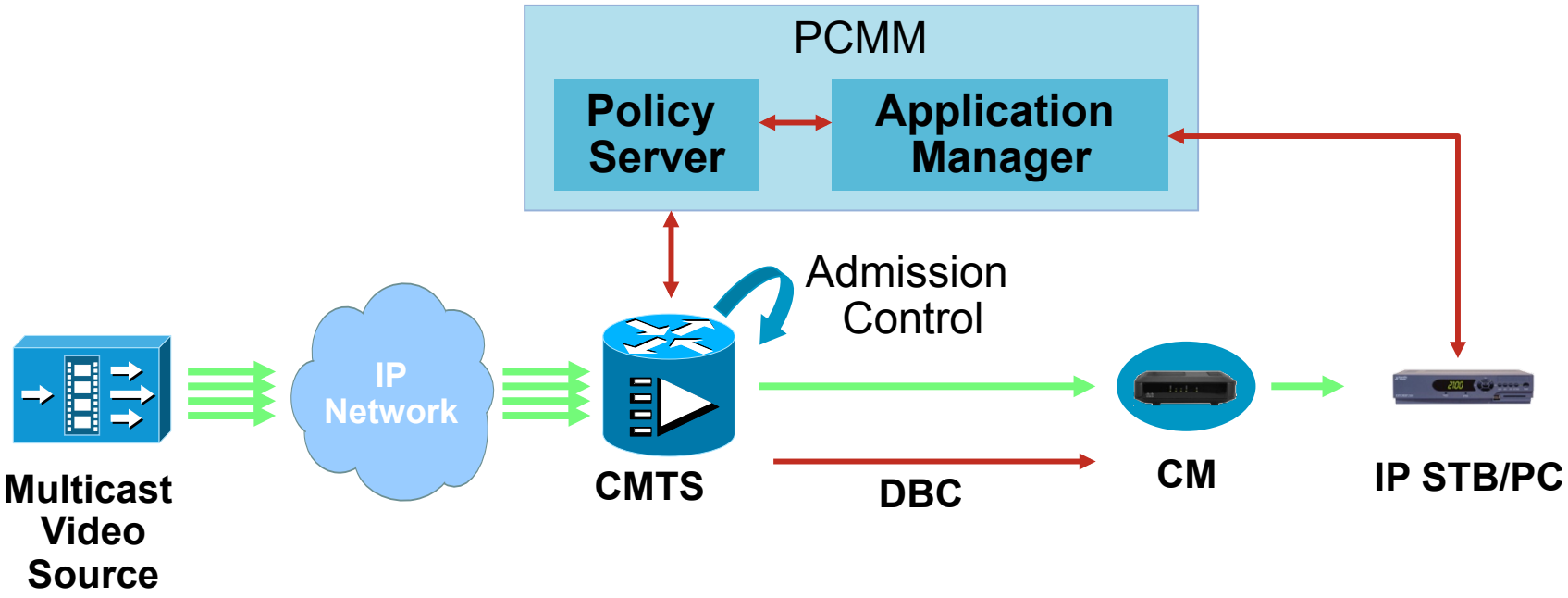
- Ability to reserve set BW for video services per interface
- Ability to limit the flows that are admitted on an interface based on set criteria
- Admission Control is needed when bandwidth utilization starts approaching interface bandwidth
- Required for both multicast and unicast services
- CMTS can perform Admission Control
  - Requires bandwidth requests to be signaled to the CMTS

Admission Control and QoS
Multicast: IGMP



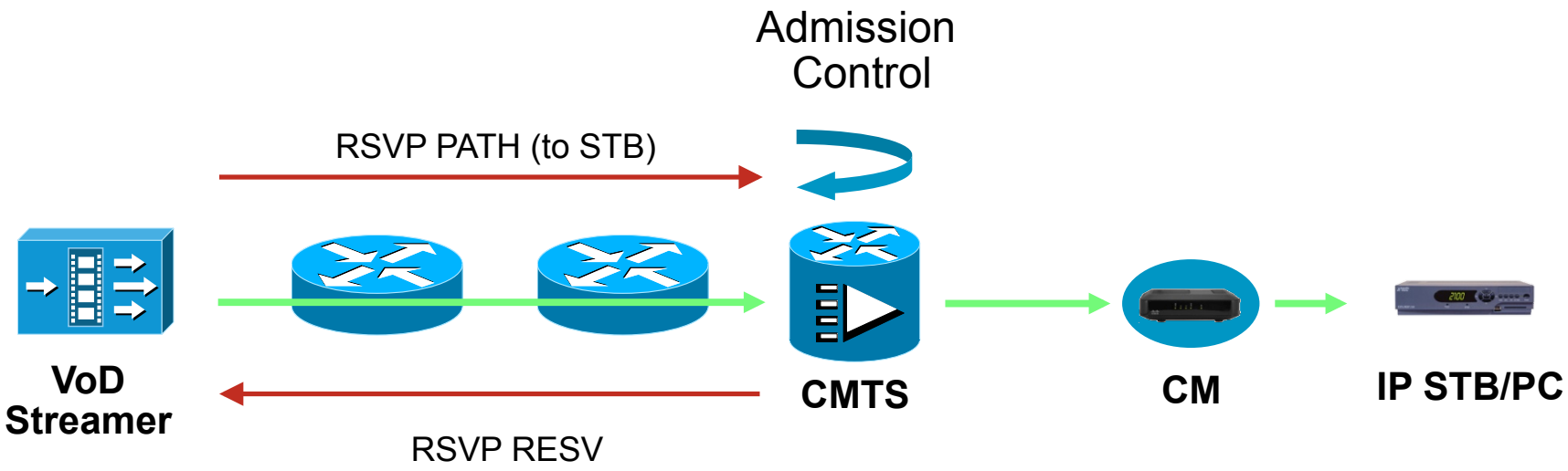
- CMTS forwards multicast video streams based on IGMP traffic from STB/PC
- CMTS pre-configured with video service class
  - CMTS is configured with service-class per multicast group address
- CMTS performs admission control
  - CMTS can perform multicast authorization

Admission Control and QoS
Multicast: PCMM



- Multicast extensions added to latest version of PCMM spec (PCMM I05)
- CMTS dynamically forwards multicast video streams based on PCMM signaling
- Policy Server performs authorization checks and signals CMTS with QoS requirements
- Upon receipt of Gate-Set, CMTS creates classifier and service flow and reserves BW
- Flexible forwarding to cable interface based on service flow attributes

Admission Control and QoS
VoD: RSVP

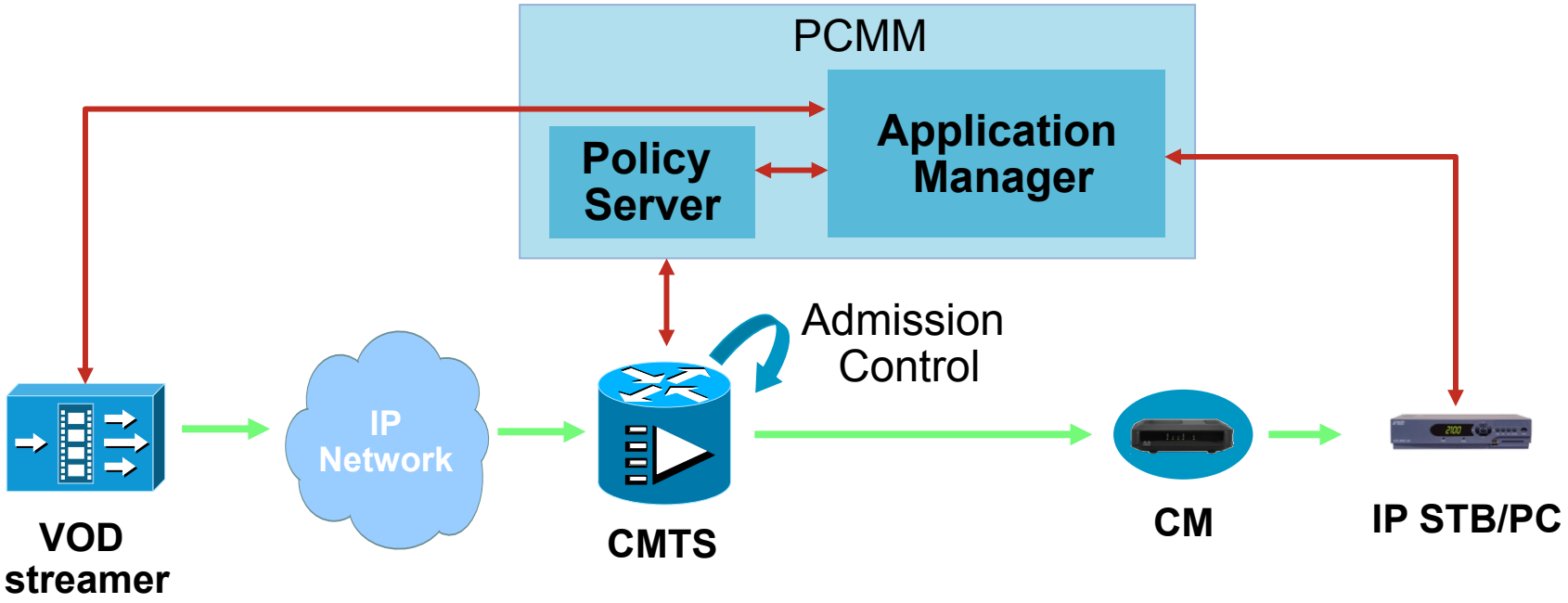


- Entitlement performed prior to initiating the above sequence
- CMTS pre-configured with video service class
- Flexible forwarding to cable interface based on service flow attributes
- Upon receipt of RSVP, CMTS creates classifier and service flow and reserves BW

VOD: Video On Demand

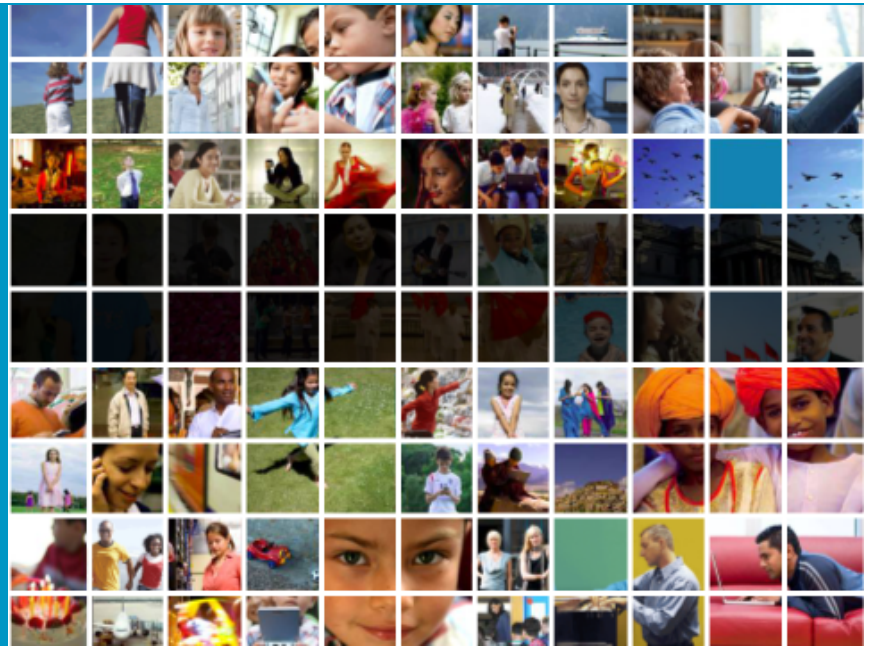
- Signaling based approach for reserving DOCSIS QOS
- RSVP (Resource Reservation Protocol) used for signaling QOS
- CMTS acts as RSVP proxy and terminates RSVP
- STB is unaware of RSVP signaling

Admission Control and QoS
VoD: PCMM



- CMTS forwards unicast video streams based on PCMM signaling
- Policy Server performs authorization checks and signals CMTS with QoS requirements
- Upon receipt of Gate-Set, CMTS creates classifier and service flow and reserves BW
- Flexible forwarding to cable interface based on service flow attributes

TelePresence over DOCSIS Overview



TelePresence over DOCSIS (TPoD) Overview

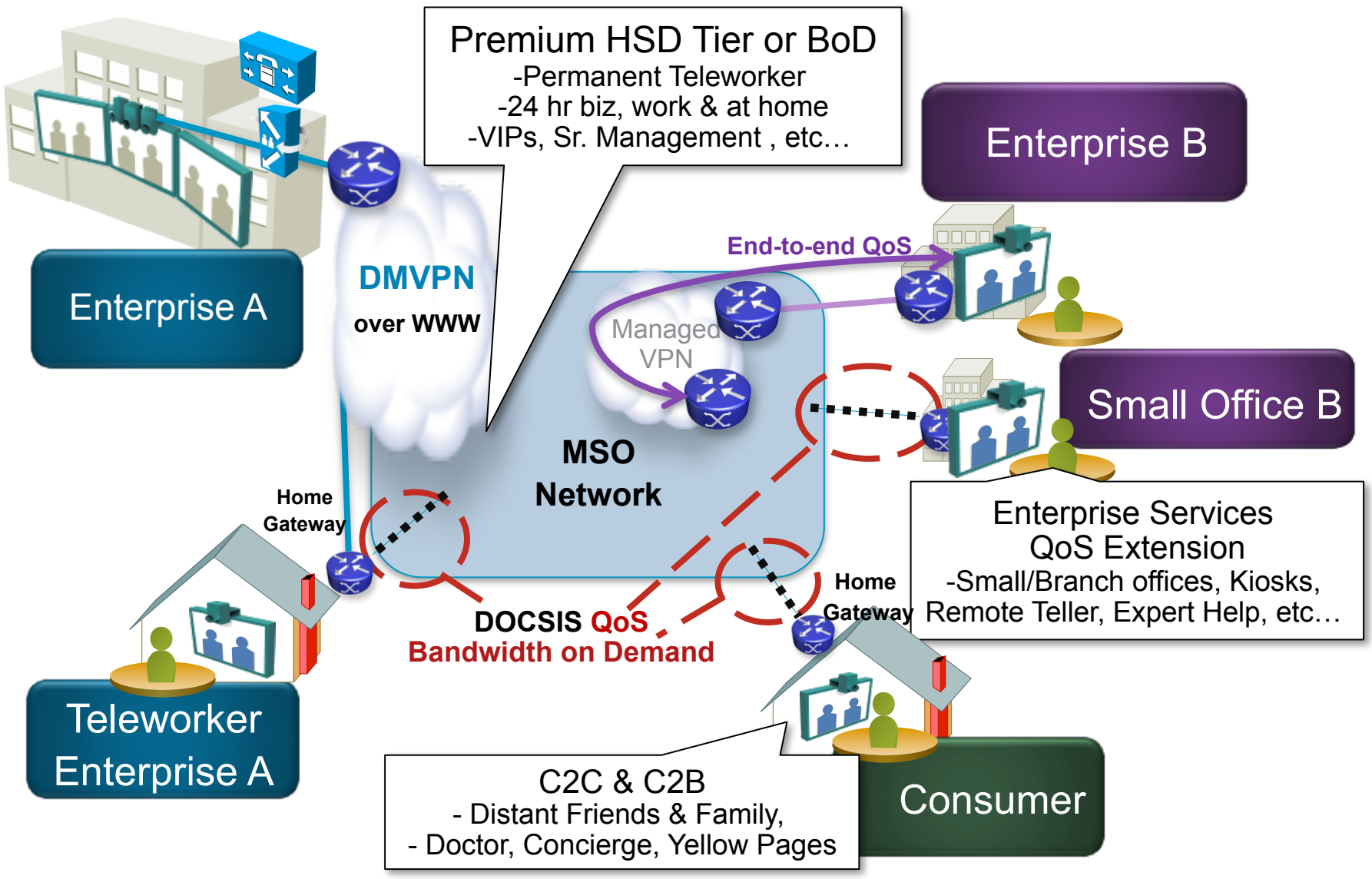
- TelePresence is a technology that allows people who are in physically separate locations to communicate with each other as if they were in the same room.
- TelePresence combines professional video, professional audio, and networking to create a real-time in-person experience.
- TPoD could be for one of the following markets:

  Teleworker: The user is an employee of an enterprise and is working at home. The TelePresence is generally owned and operated on behalf of the corporation, and the service provider is providing transport.

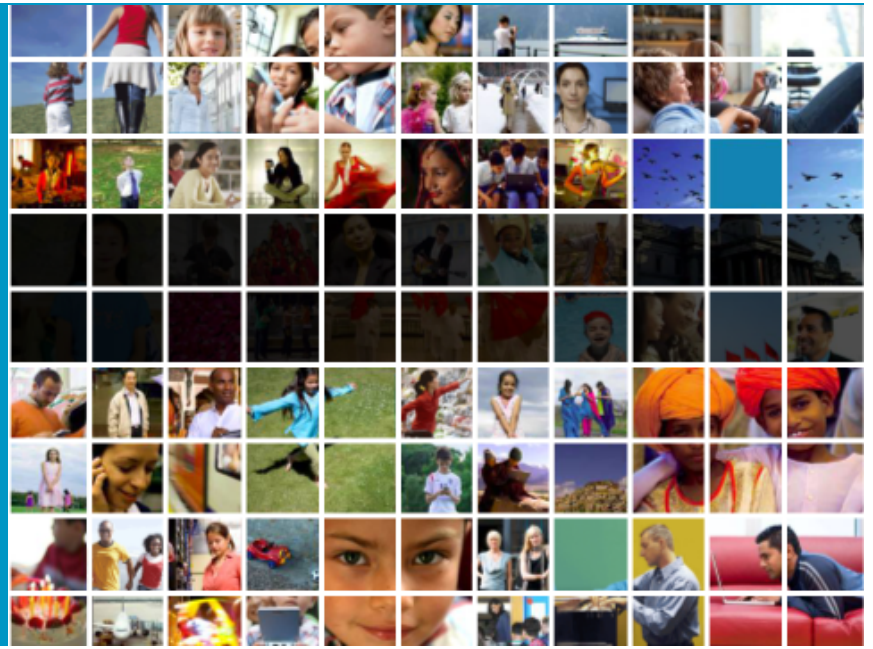
  Consumer TelePresence: The user is a consumer who wants to use TelePresence for their own personal use. The service is managed by the service provider (SP) or by a third party. The service provider provides transport. for network connectivity

Business TelePresence over DOCSIS drivers

Teleworker/SOHO with Enterprise Hosted TP services



Summary/ Q&A



Summary

- Increasing interest in IPTV and other video based services over DOCSIS
- VDOC Architecture highly leverages DOCSIS 3.0 and M-CMTS
- IP Video services are evolving.
  - Replacement of current services will likely not be good enough.
  - Service velocity will eventually require the full suite of DOCSIS services
  - Have to demonstrate the value of IP
- PacketCable Multimedia and RSVP can be used to enable the dynamic creation, modification, and deletion of QoS for these video based services
- TelePresence enables communication between remote parties as if they were sitting in the same room

Questions/Answers