DOCSIS 3.0

The road to 100 Mbps

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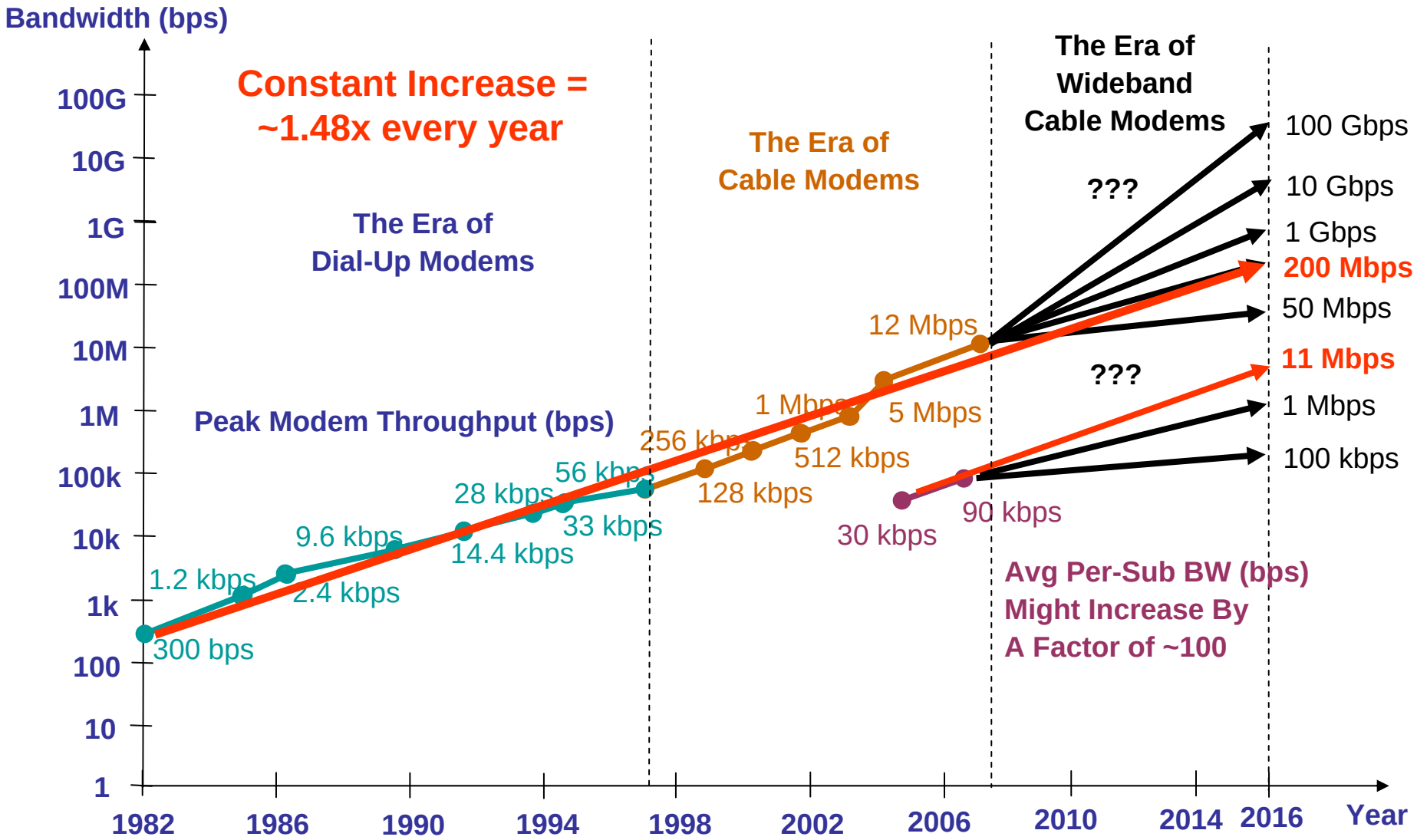
Historical Peak Modem Throughput Trends Predict 200 Mbps Modems in 2016

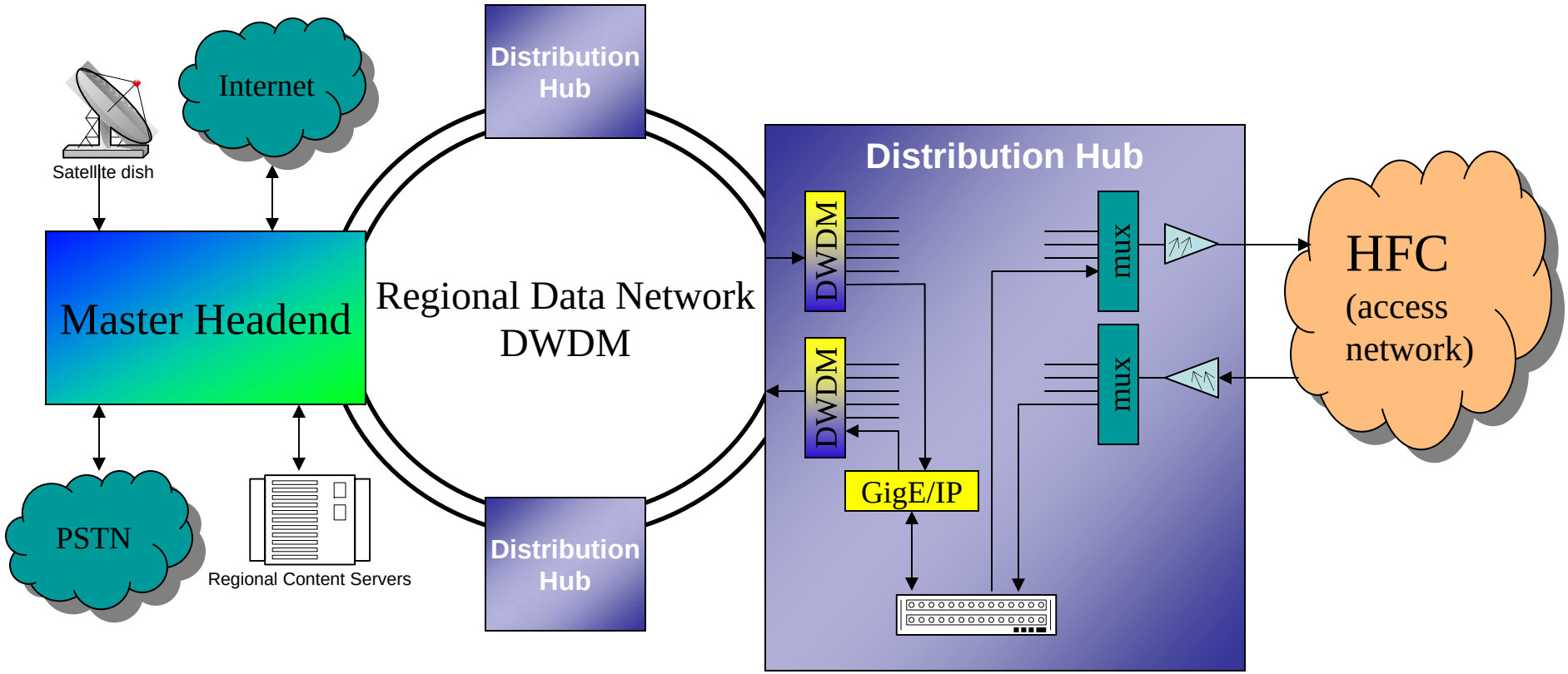


Graph courtesy of ARRIS

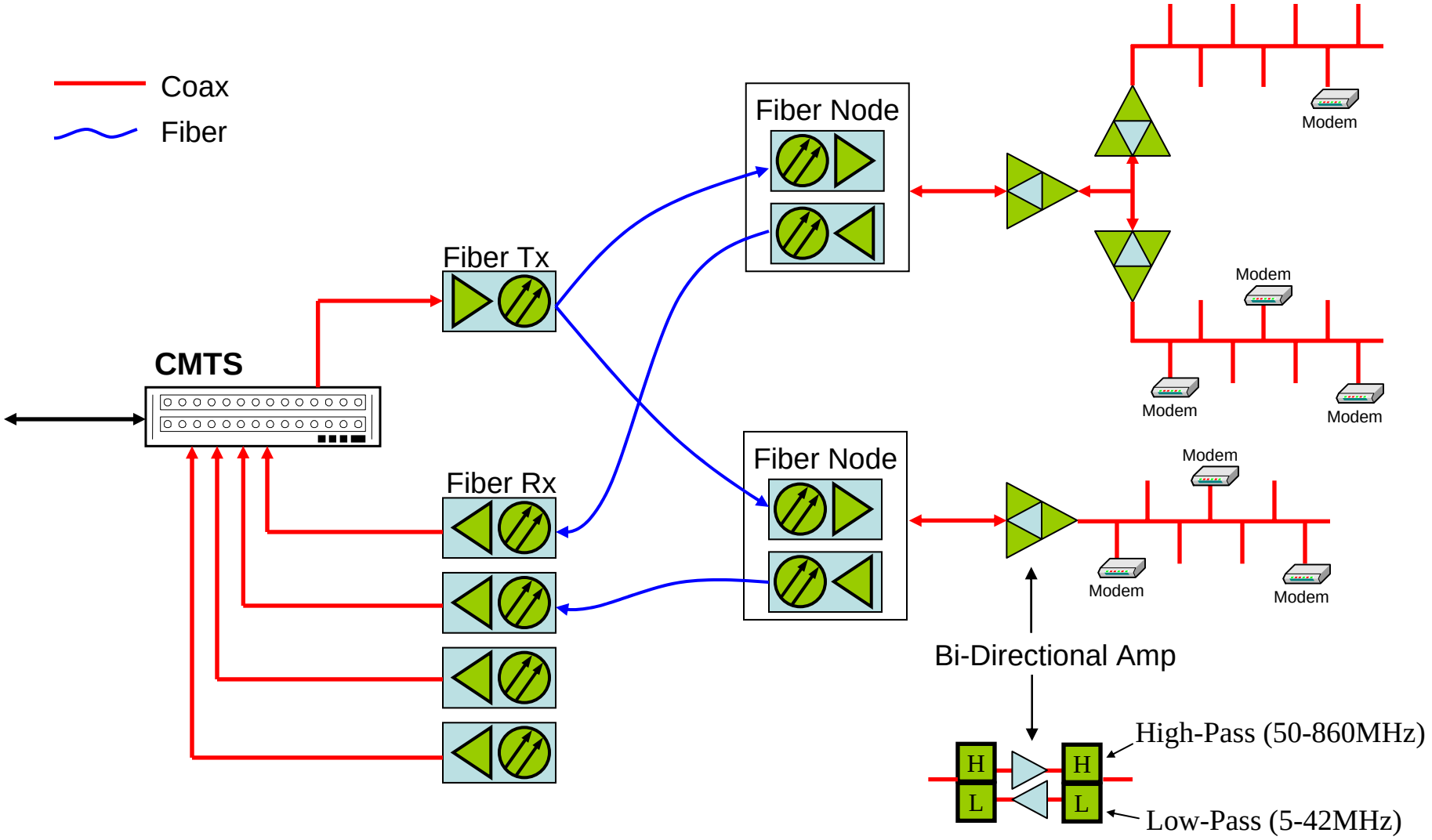
Cable Network Architecture

- Cable is FTTN (fiber to the node)
- Total Downstream Capacity with today's technology ~5 Gbps
  - » Mostly used for analog and digital video
  - » Upstream is more limited

Modern Cable Data Network
(Aggregation Network)



Hybrid Fiber-Coaxial Network
(Access Network)

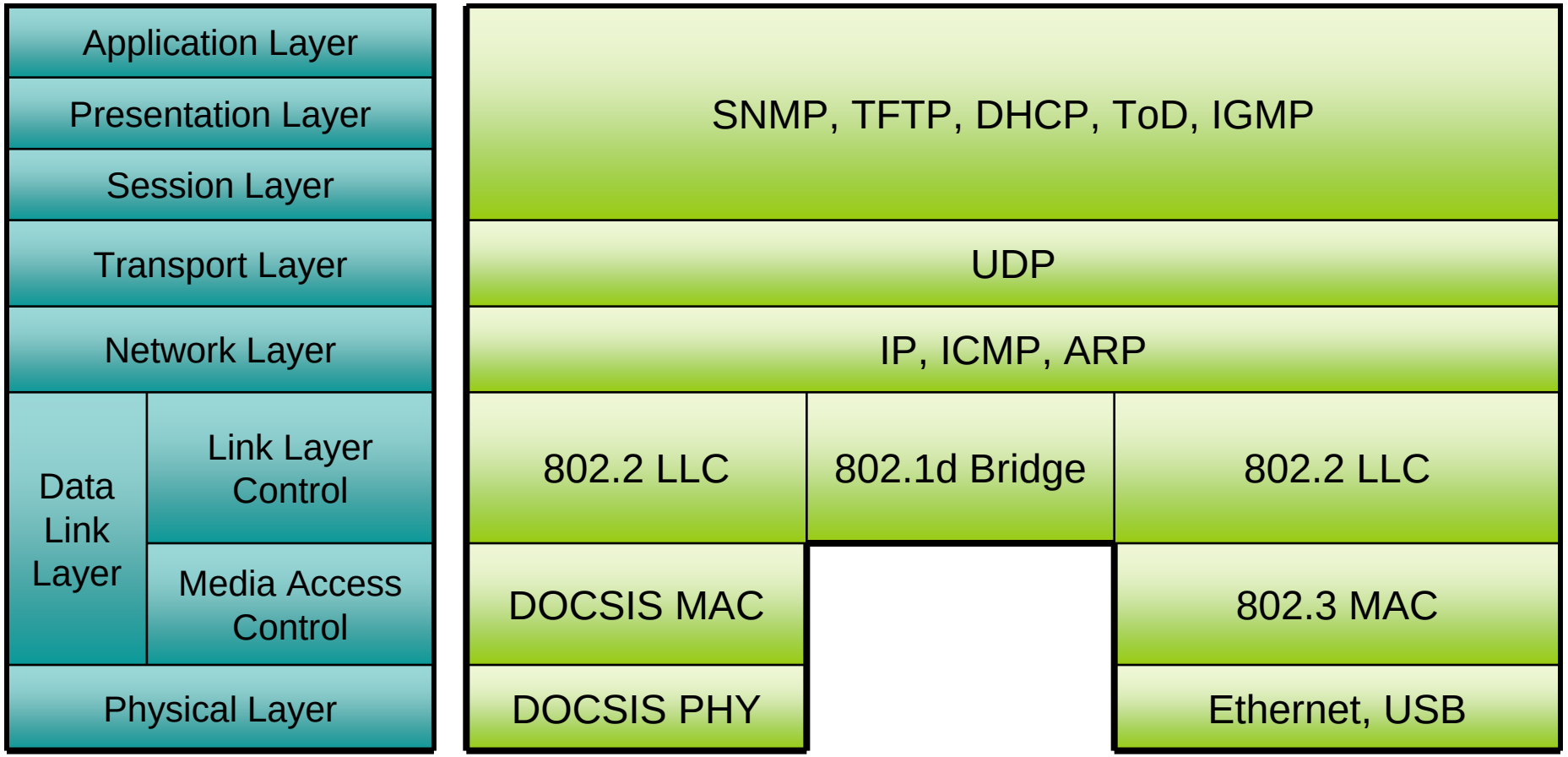


What is DOCSIS ?

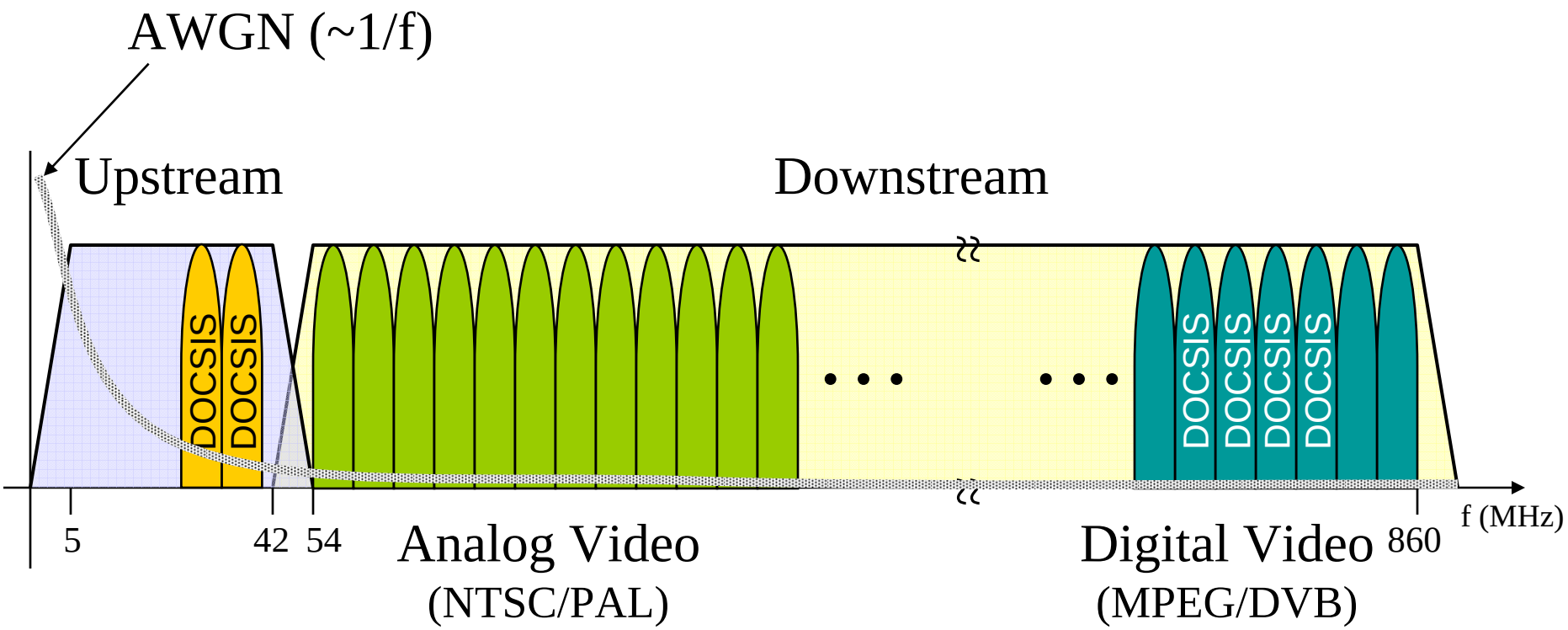
- DOCSIS defines the PHY & MAC layer protocol for communication and Ethernet frame carriage between the CMTS and the CM.
- DOCSIS also defines a provisioning and management framework
- Four published versions:*
  - » DOCSIS 1.0 (ca. 1996) (ITU-T J.112-B (3/98))
  - » DOCSIS 1.1 (ca. 1999) (ITU-T J.112-B (3/04))
  - » DOCSIS 2.0 (ca. 2001) (ITU-T J.122)
  - » DOCSIS 3.0 (ca. 2006) (ITU-T J.222)

*available at www.cablemodem.com

Cable Modem Protocol Stack



HFC Spectrum Allocation



Downstream Physical Layer

Region	**North America**		**Europe**	
Standard	ITU-T J.83-B		ETSI EN 300 429 (DVB)	
Modulation	64QAM	256QAM	64QAM	256QAM
Channel Spacing	6 MHz	6 MHz	8 MHz	8 MHz
Symbol Rate (Mbaud)	5.057	5.361	6.952	6.952
Raw Data Rate (Mbps)	30.34	42.88	41.71	55.62
TCM rate	14/15	19/20	N/A	N/A
Reed-Solomon FEC	(128,122)	(128,122)	(204,188)	(204,188)
Post-FEC Data Rate (Mbps)	**26.97**	**38.80**	**38.44**	**51.25**

Upstream Physical Layer

Version	**DOCSIS 1.x**	**DOCSIS 2.0/3.0**
Format	Bursted F/TDMA	Bursted F/TDMA, **F/S-CDMA**
Modulation	QPSK, 16QAM	QPSK, **8QAM**, 16QAM, **32QAM, 64QAM, 128QAM**
Channel Width (MHz)	0.2, 0.4, 0.8, 1.6, 3.2	0.2, 0.4, 0.8, 1.6, 3.2, **6.4**
Symbol Rate (Mbaud)	0.16, 0.32, 0.64, 1.28, 2.56	0.16, 0.32, 0.64, 1.28, 2.56, **5.12**
Raw Data Rate (Mbps)	0.32 – 10.24	0.32 – **35.84**
Pre-Equalization	8-tap FIR (opt. in 1.0)	**24**-tap FIR
Trellis Coded Modulation Rate	N/A	**Optional: n/n+1**
Reed-Solomon FEC	T=0-10; k=16-253	T=0-**16**; k=16-253
Post-FEC Data Rate (Mbps)	**0.14 – 10.24**	**0.11 – 30.72**

DOCSIS Upstream PHY Modes

- Time Division Multiple Access (TDMA)
  - » CMs take turns transmitting, one at a time, each occupies the entire upstream channel during transmission.
  - » Transmissions consist of: preamble, data burst, guard time
  - » Better immunity to narrowband interferers
  - » Generally performs better above 15 MHz
- Synchronous Code Division Mult. Access (S-CDMA)
  - » DOCSIS 2.0/3.0 only
  - » Direct Sequence Spread Spectrum
  - » Multiple CMs can transmit simultaneously
  - » Much shorter preamble, no guard time
  - » Slightly more efficient, better immunity to burst noise
  - » Generally performs better below 15 MHz

Ranging

- Ranging is used to synchronize CMs and align them with the CMTS receiver.
  - » TDMA requires coarse alignment (±800 nsec)
  - » S-CDMA requires accurate alignment (±1 nsec).
  - » CM sends a RNG-REQ message
  - » CMTS responds with a RNG-RSP message
    - – Contains Timing Adjust (Resolution = 0.3815 nsec.)
    - – also Power adjust, Frequency adjust, Pre-EQ params.
- Ranging is a two-step process:
  - » Initial maintenance (coarse time alignment).
  - » Periodic station maintenance (fine time alignment).

DOCSIS MAC

- Media Access Control (MAC) Sub-Layer
  - » Controls access to the Physical Layer (the channel)
  - » Allows multiple users to share a communications channel
- One-to-many architecture
- Separate physical channels (upstream/downstream) controlled by the CMTS
- No direct peer-to-peer (CM-to-CM) communication

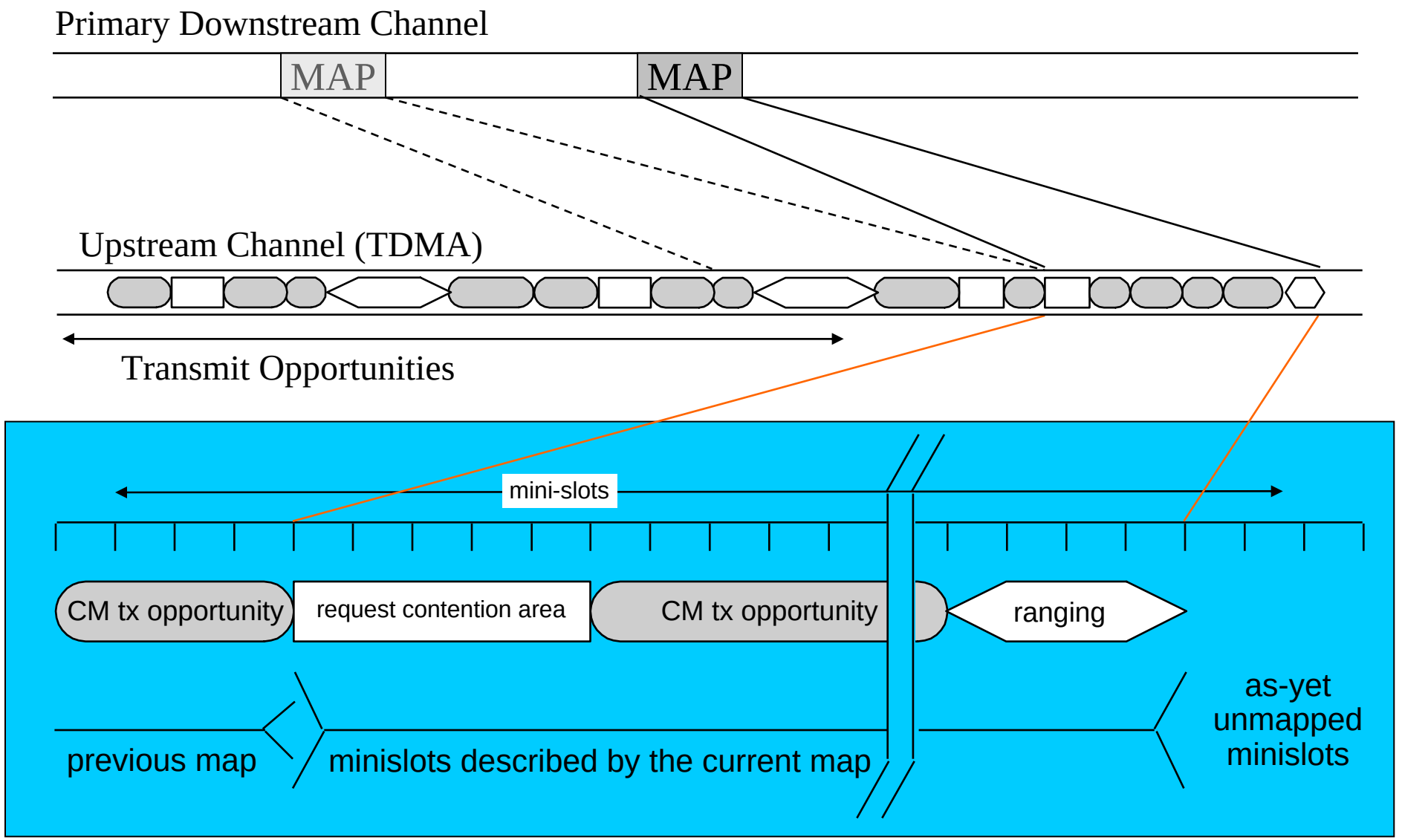
DOCSIS Downstream MAC

- Only one transmitter - the CMTS
- Multiple receivers - the CMs
- CMTS manages its own transmissions
- Quality of Service can be assured by:
  - » Token bucket rate limiting
  - » Reserved data rates
  - » Traffic Priority

DOCSIS Upstream MAC

- Multiple transmitters - the CMs
- One receiver - the CMTS
- The CMTS arbitrates access to the channel
  - » Each upstream channel is described in minislots
    - – 2^n*6.25µs in TDMA mode
  - » "MAP" messages are broadcast downstream to describe who gets to transmit and when
    - – Each CM listens for MAP messages on its "primary" downstream
  - » One MAP message per upstream channel per MAP interval (chosen by CMTS, 2-5ms typical)
- Access Control is Reservation based
  - » Reservation requests are sent in contention ("Slotted-Aloha")
  - » Reservations can also be pre-scheduled at periodic intervals

MAPs are broadcast by the CMTS on “primary” downstream channels

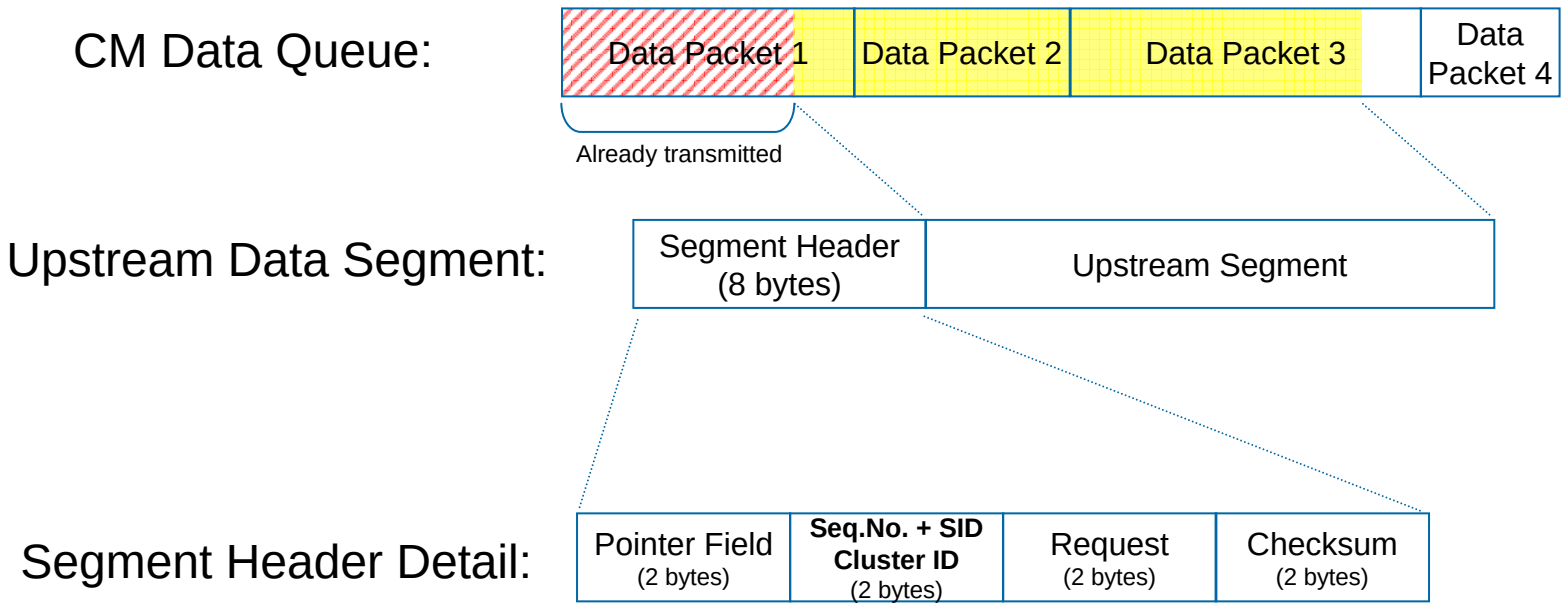


The Reservation Mechanism – Requests and Grants

- When a CM has data to send, it:
  - » Randomly selects a Request contention interval among all upstream channels
  - » Transmits a 7-byte REQ message to the CMTS, which:
    - – identifies the CM (via Service ID)
    - – specifies the number of bytes in queue
  - » Retransmits its request, if no response from the CMTS
- The CMTS then:
  - » Queues/prioritizes REQs
  - » Selects an upstream channel and reserves future minislots for the requesting CMs
  - » An individual request can be split into multiple “grants” on different channels
  - » Communicates the grants to the CMs via MAP messages.

Continuous Concatenation & Fragmentation

- Grants are not tied to packet boundaries
- CM packs as much data into each grant as will fit
- Segment header provides sequence number, “piggyback” request field, etc.



CM Provisioning

- During initialization, the CM downloads (via TFTP) a configuration file from the cable operator
- Config file defines:
  - » Quality of Service (QoS) Parameters
    - – Priority, rate limiting, bandwidth guarantees, etc.
  - » Filters
    - – e.g. block Windows file sharing (netBIOS, SMB, CIFS)
  - » Privacy (encryption) parameters
  - » Etc.
- The CM then sends a Registration Request message to the CMTS containing the QoS parameters

CM Initialization Sequence

1. Downstream Channel Acquisition
   - » Scan for digital channels, acquire QAM,FEC,MPEG lock, identify DOCSIS PID (program ID)
   - » Receive MAC Domain Descriptor (MDD) Message
2. Topology Resolution & Upstream Channel Acquisition
   - » Tune additional downstream frequencies to determine service group
   - » Select upstream channel listed in MDD
   - » Initial Ranging
     - – Find Initial Maintenance interval in MAP messages
     - – Send RNG-REQ, receive RNG-RSP, adjust transmitter, repeat if necessary
3. Initialize Encryption
   - » CM Authentication & Key exchange with CMTS
4. Establish IPv4 or IPv6 Communications (DHCP)
5. Download Configuration File (TFTP)
6. Registration
   - » Send REG-REQ, receive REG-RSP, send REG-ACK

DOCSIS 3.0 Major Features Overview

- Much higher bandwidth through channel bonding
  - » Starts at 160 Mbps Downstream, 120 Mbps Upstream and goes up from there
  - » Multiple independent channels are bound, treating them logically as one
  - » A minimum of four channels are bound, can be more
  - » Channel bonding in both upstream and downstream
- IPv6 for advanced networking capabilities
  - » Expanded address space
    - – IP addresses are lengthened from 32 bits (4.3 billion possible addresses) to 128 bits (3.4 duodecillion possible addresses) so that address space will not run out.
  - » Improved operational capabilities
- IP Multicast to support IPTV-type applications
  - » Use existing standard protocols to manage IP video service
  - » Efficient “switched-video-like” bandwidth usage
    - – Programs are only delivered when viewers are present.
  - » Quality-of-Service so network congestion doesn’t impact video quality

Channel Bonding

- Feature Description
  - » Simultaneous data transmissions on multiple channels
    - – Current requirement is for the support of at least 4 upstream & 4 downstream channels (can support more)
    - – Channels don't have to be adjacent
  - » DOCSIS 1.0, 1.1 and 2.0 CMs supported on each channel
- Why was this incorporated?
  - » MSOs expressed a desire to achieve higher data rates
- Benefits
  - » Scalable deployment
    - – MSO can choose to bond any number of channels (2,3,4,etc.) to provide adequate bandwidth to their customers
  - » Enables business and backhaul services
  - » Subscriber gain of ~10%-25% more customers per channel due to greater statistical multiplexing

Channel Bonding (cont.)

- Benefits (cont.)
  - » Higher Data Rates
    - – Downstream Capacity with 6MHz & 256QAM
      - ▫ Four channels, 160 Mbps
      - ▫ Three channels, 120 Mbps
      - ▫ Two channels, 80 Mbps
    - – Upstream Capacity with 6.4MHz & 64QAM
      - ▫ Four channels, 120 Mbps
      - ▫ Three channels, 90 Mbps
      - ▫ Two channels, 60 Mbps
  - » Increased Robustness
    - – CMs can survive loss of all but one channel
    - – Flexibility to avoid upstream ingressors
      - ▫ Multiple smaller channels can be bonded
- Requirements and restrictions for deployment
  - » Must have available spectrum

Source Specific Multicast-SSM

- Feature Description
  - » Delivery of multimedia (audio/video) services from one source to multiple subscribers' CPEs (IPv4 & IPv6) based on customer request
- Why was this incorporated?
  - » Previous versions did not support MSO directed multicast (any member of the multicast group could transmit)
- Benefits
  - » Enables operators to offer broadcast-like services over DOCSIS based on subscriber demand (e.g. IPTV service)
  - » Enables bandwidth efficient on-demand multimedia services as compared with unicast
  - » Facilitates offering of interactive video/audio and data services
- Requirements and restrictions for deployment
  - » Requires DOCSIS 3.0 CMTS & 1.1 or greater CM

QoS Support for Multicast

- Feature Description
  - » Provides guaranteed bandwidth for multicast sessions
  - » Provides the ability to cap the bandwidth taken up by unsupported multicast traffic
- Why was this incorporated?
  - » Required to offer entertainment quality video services over DOCSIS
- Benefits
  - » Enables differentiation of QoS-enabled multicast services
  - » Enables service level guarantees to be offered to the end customer
  - » Enables offering of QoS-enabled packages to third parties
- Requirements and restrictions for deployment
  - » Requires 3.0 CMTS & 1.1 or greater CM
  - » Cable operator needs to configure QoS parameters for various multicast sessions

IPv6 Provisioning & Management of CMs

- Feature Description
  - » 3.0 CMs can be provisioned with an IPv6 address
- Why was it incorporated?
  - » Some MSOs are running out of the private IPv4 address space needed to provision & manage CMs
- Benefits
  - » Solves the MSO's address crunch problem without creating isolated networks
- Requirements and restrictions for deployment
  - » MSO Operations Support Systems need to be upgraded to support IPv6
  - » CMTS must be upgraded to support IPv6 based CM provisioning

Alternative Provisioning Mode & Dual-stack Management Modes for CMs

- Feature Description
  When enabled by MSOs, allows for:
  - » CMs to failover to IPv4 provisioning when IPv6 provisioning fails & vice-versa
  - » MSOs to manage CMs via IPv4 & IPv6 addresses concurrently
- Why was it incorporated?
  - » Enables phased migration strategy
  - » Provides an optional fall-back mode when migrating to IPv6 from IPv4
- Benefits
  - » Allows MSOs to begin using IPv6 for provisioning and management without doing a hard cut-over.
  - » Will allow MSOs to communicate with CMs when there are IPv4 or IPv6 specific network outages
- Requirements and restrictions for deployment
  - » CM consumes both an IPv4 and an IPv6 address. (Does not benefit MSOs who are running out of IPv4 address space.)

IPv6 Connectivity for CPEs

- Feature Description
  - » CMTS enables IPv6 address configuration and connectivity to the customer devices
- Why was it incorporated?
  - » Other CableLabs specified devices need to be capable of being provisioned and managed via IPv6 due to IPv4 address space constraints
  - » In the future customer devices will look for IPv6 addressing by default
- Benefits
  - » Allows MSOs to rollout new IP based services that would not be possible because of the lack of IPv4 address space
- Requirements and restrictions for deployment
  - » MSO CMTS and management systems need to be upgraded to support IPv6
  - » CableLabs specs need to be updated with IPv6 capabilities and devices need to be procured against these specs.

DOCSIS 3.0 Major Benefits Summary

- Higher shared channel capacity, more raw bandwidth
- Higher peak capacity to an individual cable modem
- More efficient usage of the capacity through statistical multiplexing gains
- Support for IPTV services
- Virtually unlimited addressing for IP devices
- Support for device mobility through IPv6
- Simplified device provisioning through IPv6 auto-configuration

Roadmap

- Current deployments of “pre-3.0” gear
  - US: Comcast (50Mbps)
  - Canada: Videotron (50Mbps)
  - Singapore: StarHub (100Mbps)
  - Korea: Hanaro, CJ Cablenet, C&M (100Mbps)
  - France: Numericable (100Mbps)
  - Japan: J:Com (160Mbps)
- Deployment “plans”
  - US: Comcast (20% of footprint in ’08)
  - US: Charter, Mediacom (begin testing in ’08)
- Available “Certified” Equipment
  - CMTS (ARRIS, Casa, Cisco, Motorola)
  - CableModems (Ambit, ARRIS, Cisco, Motorola and SMC)