Deploying DOCSIS 3.0

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Agenda

- Introduction
  - The Broadband Network Engineering Team
  - What is DOCSIS 3.0?
  - Where are we with DOCSIS 3.0 and how did we get here?
- Introducing two new DOCSIS 3.0 line cards
  - MC88V
  - MC2020V
- Deploying DOCSIS 3.0
  - Channel bonding specifics
  - I-CMTS best practices
- Accelerating DOCSIS 3.0 with Advanced Services
- Deployment examples
- Scalability and Cost Efficiency
- Q&A

The Broadband Network Engineering Team

- John Downey and Jeff Forhan

  Established and respected industry wide with CMTS operational and best practices expertise

- Corey Chapman

  New to the team (Jan). Previous 4 ½ years as Cisco SE in Cable

- ***Team Vision: Facilitate rapid and seamless adoption of new and emerging cable access technology***

- Current areas of focus

  New D3.0 Linecards - education and customer deployment planning

  VDOC engagements

  Reactive system level troubleshooting as needed

  Best practices updates

  USCB, I-CMTS/M-CMTS/hybrid, SNMP Monitoring

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

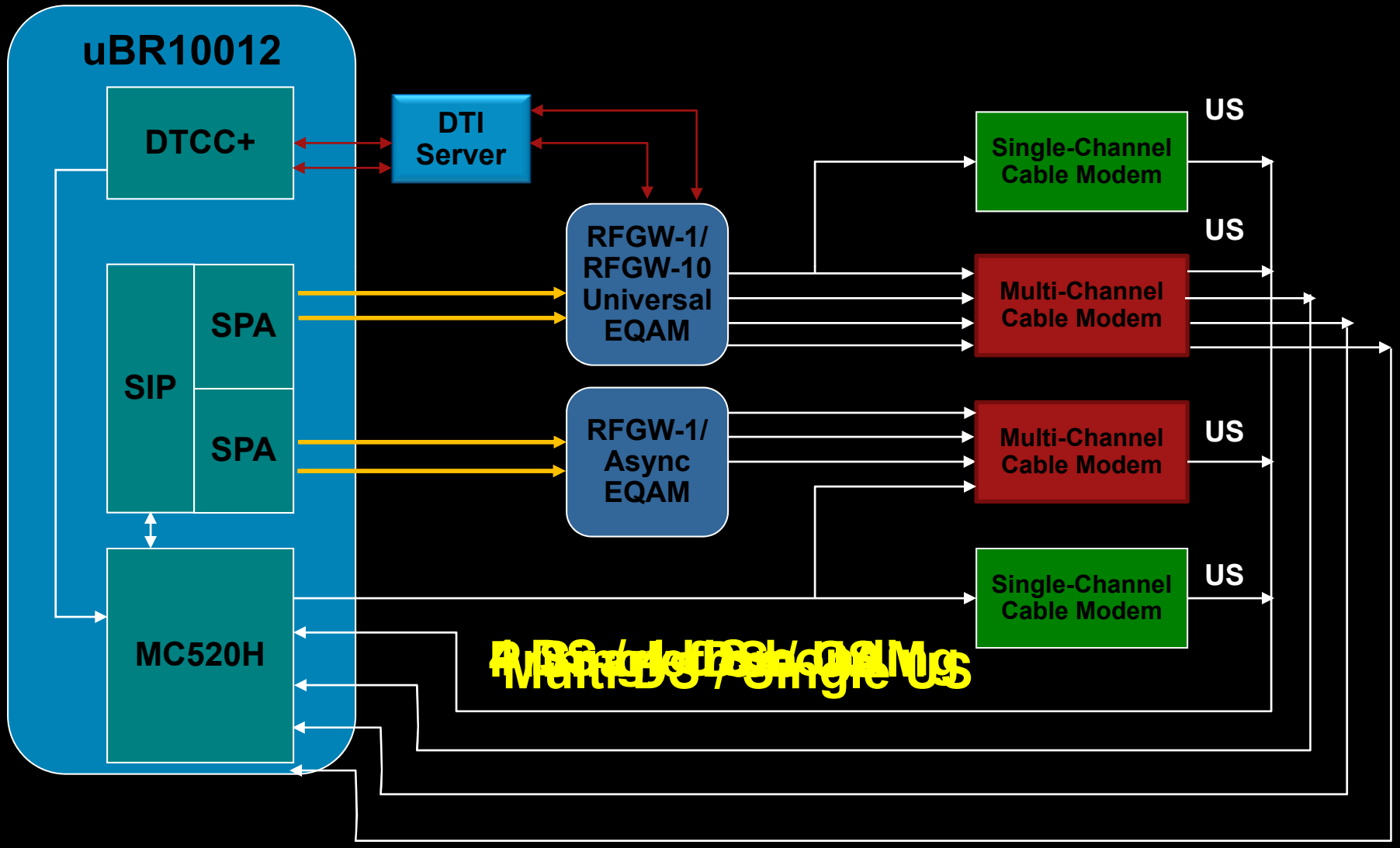
Cisco DOCSIS 3.0 Milestones

"Cisco is delivering DOCSIS 3.0 first"

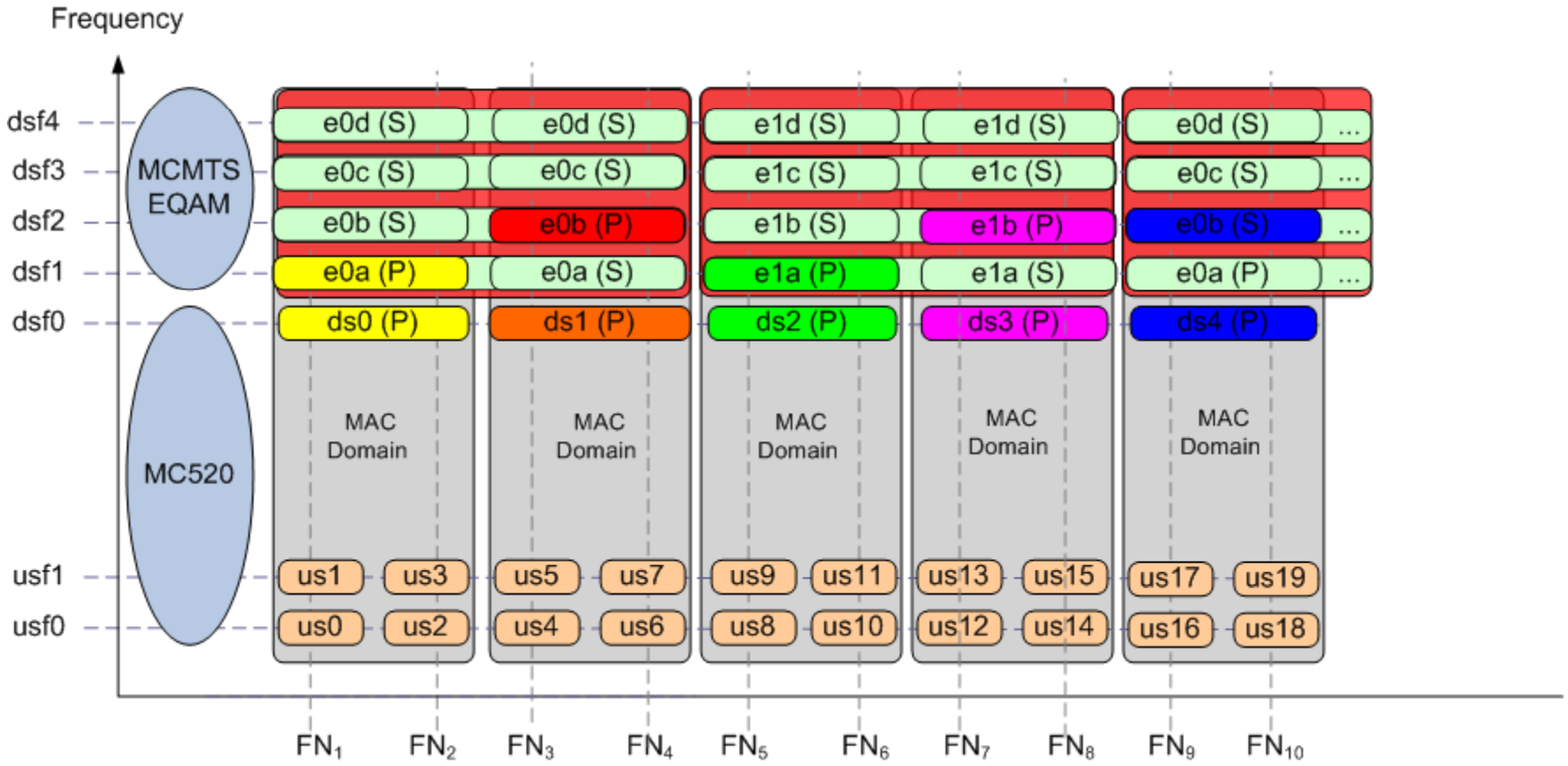
- Invented channel bonding (Wideband) in 2001
- First public demo of DS Channel Bonding in 2005
- First 3.0 + M-CMTS integration in 2006
- Highest speed channel bonding trial – 293 Mbps
- DOCSIS 3.0 hardware shipped Dec. 2006
- First US Channel Bonding interop in July 2007
- Bronze qualification in 1st Cert Wave Dec. 2007
- US bonding code in Bighorn release Nov 2009
- **Over 4M Wideband subscribers worldwide**
- **Over 50M 3.0-capable homes passed**

M-CMTS

Cisco's initial path to DOCSIS 3.0



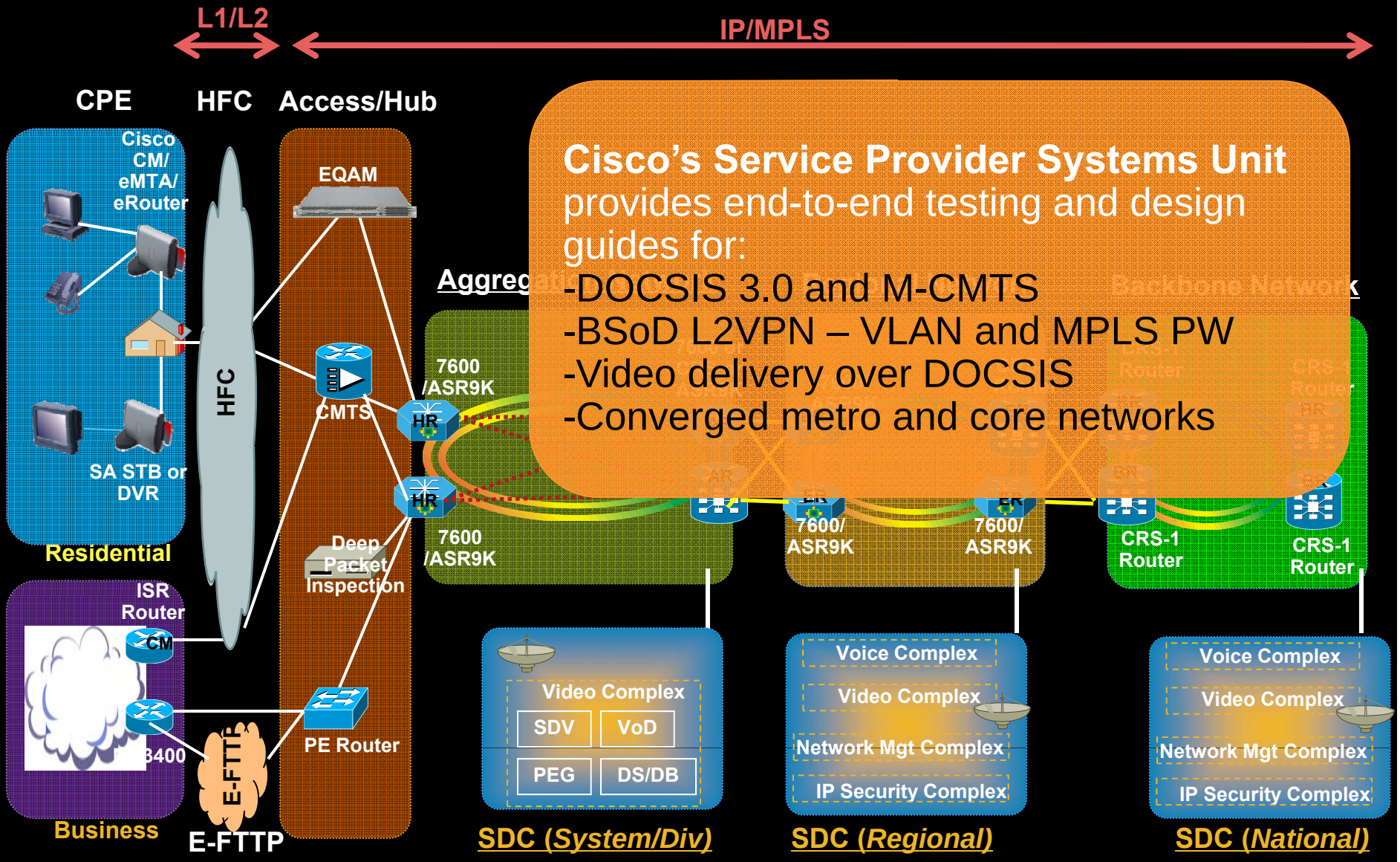
M-CMTS enables flexible, cost effective D3.0 coverage
Common 2010 deployment configuration



- 10K serving 35SG
  - 7+1 5x20
  - 3 DS SPAs
- 2 10ks connect to 1 RFGW10 with 3+1 DS48

End-to-End Cable NG Network

Network evolution in all areas of the network



Cisco's Service Provider Systems Unit provides end-to-end testing and design guides for:

-DOCSIS 3.0 and M-CMTS
-BSoD L2VPN – VLAN and MPLS PW
-Video delivery over DOCSIS
-Converged metro and core networks

Introducing Two New DOCSIS 3.0 Linecards

CMTS Product Portfolio

uBR7225VXR

- Ideal for small sites
- 1M pps
- 4 x 16 Capacity with D2.0 Linecard
- Expandable to 16 x 16 with new D3.0 Linecard
- I-CMTS

uBR7246VXR

- 30K chassis sold
- 1M pps
- 8 x 32 Capacity with D2.0 Linecard
- Expandable to 32 x 32 with new D3.0 Linecard
- I-CMTS

uBR10012

- 6M pps
- Carrier Class
- 304 x 160 Capacity with new D3.0 Linecard
- I-CMTS & M-CMTS

Common DOCSIS & IOS Software features

UBR-MC88 Line Card

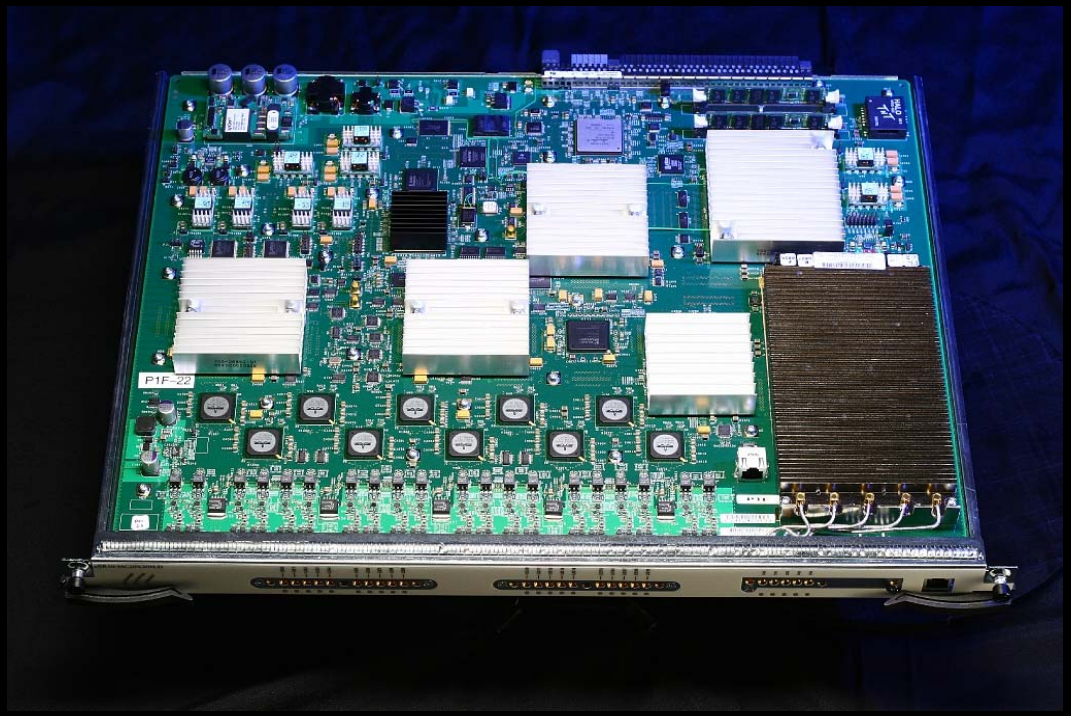
Extending UBR7200 Series to DOCSIS 3.0

- New fully compliant DOCSIS 3.0 line card for UBR7200 Series
- Operates in 8 DS, 8 US mode on UBR7225VXR
- Operates in 8 DS, 8 US mode on UBR7246VXR
- 4x DS density of the existing MC28U line card
- Requires NPE-G2

UBR-MC88V

- Shipping since March, 2010
- Now shipping in volume

Cisco uBR10K MC2020V Linecard



- **Full DOCSIS 3.0 support**
  - Downstream Bonding
  - Upstream Bonding
  - IPv6
  - Multicast
  - AES
- **Upgrade for MC520 LCs**
  - Same RF Cabling
  - Very low operational impact
- **>7x DS capacity in same 10K footprint**
  - 40➞88➞184➞304 DS ports
  - >10Gbps CMTS solution
- **Full HA support**
- **Works with PRE2**
  - PRE4 a capacity engineering decision
- **Licensing options for adding downstreams via software**

- Shipping since December, 2009
- Now shipping in volume

20x20 Line Card Pricing

Licensed based – "pay as you grow"

	List Price	Product ID
0x20	$ 81,000	UBR-MC20X20V-0D
5x20	$ 91,000	UBR-MC20X20V-5D
20x20	$121,000	UBR-MC20X20V-20D
5DS license	$ 10,000	UBR-SWLIC-MC5DS
15DS license	$ 30,000	UBR-SWLIC-MC15DS
20DS license	$ 40,000	UBR-SWLIC-MC20DS

DOCSIS 3.0
Deployment Considerations

Jeff Forhan *Network Consulting Engineer – Cable Access BU*

Cisco/DOCSIS 3.0 Terms

- **Fiber Node – Describes the plant topology, the set of US and DS channels that can be seen by a group of modems.**
- **Controller Modular-Cable – The Modular-Cable controller represents a Wideband SPA and an instance of this controller is created for each SPA in a Jacket card. EQAM connectivity information and physical parameters such as QAM frequency, modulation type etc. are configured under the controller. We will continue to use the WB CLI to enter the DS channel id here.**
- **Interface Modular-Cable – An instance of the Modular-Cable interface is exposed to the user when the corresponding RF channel of the SPA is designated as a primary capable (NB) downstream channel. Layer 3 features such as cable bundle, cable ARP, DSG, static multicast, etc. are configured under this interface.**
- **Interface Wideband-Cable –interface to represent a Bonding Group. The SPA RF channels that make up this Bonding Group are configured under this interface**
  - **Max of 24 because 48 max supported channels for 2 SPAs and at least 2 channels per bonding group.**
- ***Downstream Modular-Cable* command – Used under cable interface to specify primary capability of QAM chs as well as association of US channels to DS QAMs.**

DOCSIS 3.0 DS Channel Bonding over SPA at a Glance

- Uses external QAMs connected to SPA
- Increase legacy downstream port density of ubr10k
- Uses M-CMTS compliant Edge-QAM (EQAM) devices
  - –Cisco RFGW-1D and RFGW-10
  - –Other M-CMTS compliant Edge-QAMs
- Uses DTI timing source for DS channels
- Enables legacy DOCSIS [1.x/2.0] modems to use external QAMs for operation
  - –Allows MxN mac domains
- Eliminates the need for a PC from 5x20 card
- Allows bonding on all channels in a BG
  - –Hits the 150 Mbps BW mark on a 4-channel modem (ITU-B @ 256QAM)

Modem Steering

- Restrict legacy eMTAs to Local DS
  - `cable service attribute voice-enabled downstream-type HA-capable`
- Enforce legacy CMs to only register on Primary-only DS or move to a specific DS frequency
  - `cable service attribute non-ds-bonded downstream-type bonding-disabled`
  - `cable service attribute non-ds-bonded legacy-ranging downstream-type frequency <Hz>`
- Force 3.0-capable CMs to initialize on Remote/e-qam DS
  - `cable service attribute ds-bonded downstream-type bonding-enabled enforce`
- Can specify UCDs sent for each DS
  - Example CLI: `interface Cable5/0/0`
  - `downstream Modular-Cable 1/0/0 rf-channel 0 upstream 1 3`
  - `downstream local upstream 0 2 4`

I-CMTS Design Considerations

- 52 dBmV max power in quad-stacked mode
  - –Best practice: design for 50 dBmV output so 52 dBmV can be reached for Protect card
- Verify Fiber Node configs with US connector assignments
  - –Upstreams required in Fiber Node config in 12.2(33)SCC and later
- Remove cable service attribute non-ds-bonded downstream-type bonding-disabled
  - –Most I-CMTS deployments have all channels as primary and bonding
- Validate BW % statements for VoIP and CIR
  - –Used for Call Admission Control even if AC is not configured
- Utilize DS Ch ID defaults

What is DOCSIS 3.0 Upstream Channel Bonding?

- Requires DSCB
- Bonds multiple, physical upstream transmit channels to form a larger, logical upstream channel.
- DOCSIS 3.0 required that CM must have 4 or more upstream channel transmitters. This translates into the possibility of 100mbps+ upstream rate…
- Removed DOCSIS 2.0/1.x single request-grant cycle bottleneck.
- Bonded Flows allow multiple outstanding BW-REQ.
- BW can be requested on any of the bonded upstream channels
- Requests can be granted on any of the bonded upstream channels
- Reduced upstream latency (TCP ACK) also increases DS throughput. [TCP application]

USCB Important terms

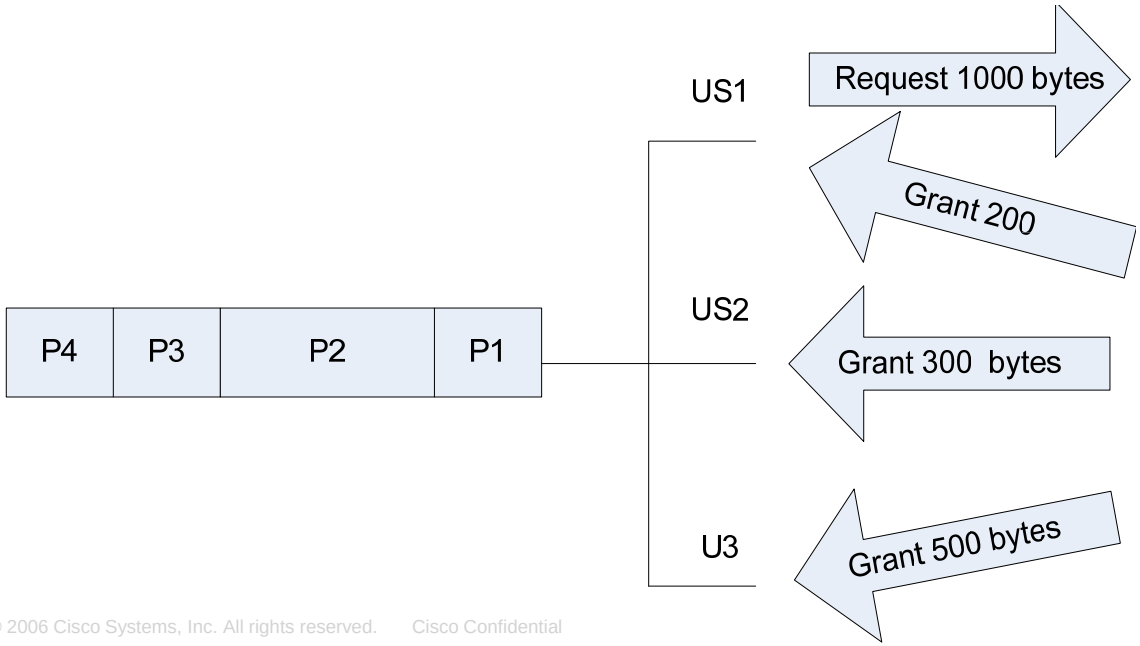
- **SID Cluster**
  - A group of SIDs containing one and only one SID for each upstream channel within an upstream bonding group
  - treated the same from a request/grant perspective.
- **SID Cluster Group** - The set of all SID Clusters associated with a specific service flow.
- **MTC Mode -** Multi-transmit channel mode.
- **Transmit Channel Configuration (TCC)**
  - TLV settings in Registration and DBC MAC Management Messages
  - Define operations such as addition, deletion, change, replacement, or re-ranging of one or more US channels in the TCS of a cable modem.
- **Transmit Channel Set (TCS)**
  - Set of upstream channels that a CM is configured to use for upstream transmission
  - Each upstream service flow of the cable modem may be associated with some or all of the channels in the TCS
  - The TCS of a cable modem is conveyed from a CMTS to a cable modem through the TCC field in the REG-RSP message
- **Upstream Service Group**
  - Complete set of Upstream Channels (UCs) within a single CMTS potentially reachable by the transmission of a single Cable Modem
  - In an HFC deployment, an US-SG corresponds to the physical combining of the upstream from one or more Fiber Nodes reaching a single CMTS.
- **MAC Domain Upstream Service Group**
  - The subset of an Upstream Service Group (US-SG) which is confined to the Upstream Channels of a single MAC Domain
  - A MD-US-SG differs from a US-SG only when multiple MAC domains are defined per US-SG.
- **T4 Timeout Multiplier**
  - Value added by CMTS to RNG-RSP messages to modems in MTC mode.
  - Helps reduce overhead associated with scheduling RNG-REQ slots and processing RNG-RSP messages
- **Continuous Concatenation and Fragmentation (CCF)**
  - Treats each bonded SF as a continuous stream of data
- **Ambiguity Resolution** – Topology resolution

<=D2.0 Upstream Bandwidth Scheduling

- The upstream is TDMA, ATDMA, or SCDMA, all of which state multiple access
  - –The upstream is defined in terms of minislots.
  - –A mini-slot is a specified number of bytes, typically 16.
- The CMTS provides a MAP that describes which minislot is owned by which SID and for what purpose.
  - –MAPs are sent ahead of time (“Map Advance Time”). Typically 5 ms.
  - –MAPs represent a period of time. Typically 2 ms.
  - –MAPs also contain the backoff parameters for contention slots (request and ranging)
- Less MAP advance time and shorter MAPs provide a shorter REQ-GNT round trip time, and this higher upstream throughput per CM

D3.0 Upstream Channel Bonding

- Upstream bonding
  - –Single flow can consume all BW on multiple USs
- Continuous Concatenation & Fragmentation (CCF)
  - –Improved form of concatenation and fragmentation that is needed for DOCSIS 3.0 operation



Bonded US SF: CCF Segmentation Header On

- Queue Depth Request
  - Support q-depth piggy back request
- Multiple outstanding request/grants…
- SID Cluster
  - Up to 8 SID cluster per service flow (TI & BCM support 2 currently)
  - SID cluster is used to account for req/grant in given window (time, number of request, total byte…) to avoid additive delay to use lost sync of req/grant.
  - SID cluster switching
- Segmentation Header
  - CCF operates on a segment basis
  - A segment is an individual data grant to a service flow
  - CCF packs the grants with data in a streaming manner
  - The segmentation with CCF is performed on a per-service flow basis

CCF Segment Headers

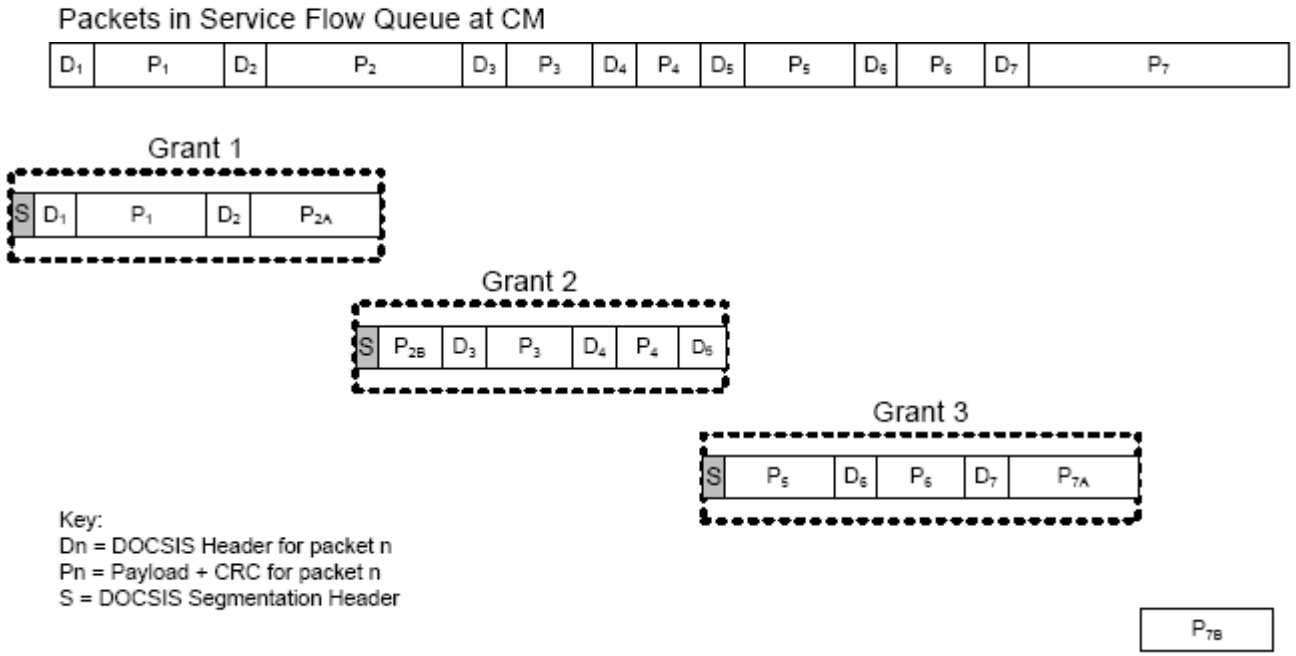


Figure 7–4 - CCF using Segment Headers

Upstream MAC: Channel Bonding

- Requests made based on bytes, not minislots
- All burst profiles available for data
  - –CCF requests are made in bytes
  - –CMTS is free to use any IUC to grant data (IUC5,6,9,10,11)
  - –Opens the path to new forms of spectrum management and reduces the need for logical channels.

MTC Mode and Multi-Channel Ranging

- Multi-transmit channel mode
  - Modems make queue-depth based requests
  - CMTS decides how to allocated grants over the upstream channels usable for that service flow
  - Queue-Depth request is in unit of byte vs DOCSIS 1.x/2.0 mini-slot based request.
- REG-RSP with Transmit Channel Config [TCC] TLV
  - Adds a list of upstream channels into cable modem transmit channel set.
- Multi-Channel Ranging
  - Instantiation of per channel ranging parameters
  - Per channel ranging state machine / scheduling
  - CM instance data structure contains:
    - An array of transmit channel info
    - US Ambiguity Resolution Upstream Channel Set
    - CM upstream TCS
    - CM upstream capability, such as number of transmitters…
  - Dynamic Ranging Window
  - DOCSIS 1.x/2.0 CM behaves as a special case, that has ONLY 1 transmit channel.
  - Modem goes offline, if all upstream channels associated with primary US service flow are down
  - T4 Multiplier to reduce number of RNG MAC message
    - Valid range of 1 to 10
    - Default T4 of 30 seconds (T4 Multiplier of 1)

Plant Topology Resolution

- Plant Topology
  - –In DOCSIS 3.0 it is mandatory that the plant topology (fiber nodes and how they are split/combined) is configured in the CMTS
- Ambiguity Resolution
  - –An efficient process for determining which FN a CM is physically connected to (or more precisely, which downstream service group its connected too) is possible thanks to the fact that plant topology is reflected in the MDD

Troubleshooting USCB modems

- CMTS considerations:
  - –Is DSCB configured? USCB requires DSCB
  - –Are the US assigned to an USBG?
  - –Are the US configured correctly and “no shut”?
  - –What MTC-mode are you using?
    - •Do you need a required attribute mask?
    - •Is the attribute in the CM bin file?
  - –Does the USBG have the correct channels?

Troubleshooting USCB modems

- Modem/Plant/Subscriber side considerations:
  - –Is there too much attenuation in the US RF path?
    - •Look at the show cable modem <MAC> verbose
      - •What are the ranging status of each channel?
        - IM = waiting for initial maintenance
        - SM = waiting for station maintenance
        - Cont = continuous ranging (ranging miss or adjustment is needed)
        - STA = station maintenance
        - DR = down & recovery with extended ranging opportunities
        - DT = down due to timeout, and no recovery
        - DI = down due to interface shutdown
    - •What is the Tx power of each channel?
      - •Channel Tx PWR within the dynamic ranging window?
    - •Are there excessive corrected or uncorrected code words?

Cable Modem & Service Flow Attributes

- DOCSIS 3.0 introduces the concept of attribute masks
- Can be used for ANY DOCSIS modem (1.x/2.0/3.0)
- Two main types:
  1. Cable Modem (CM) Attribute Masks
  2. Service Flow Attribute Masks

Advanced Services

Adeel Ahmed *Manager, Advanced Services – US SP Cable Infrastructure*

Product & Technology Focus

- Cable / CMTS
  - CMTS – uBR10K, uBR7246VXR
  - EQAM – RFGW-1, RFGW-10, NSG9000
  - Cable NMS & Provisioning - CNR/ BAC
  - DOCSIS 1.x, 2.0, 3.0
  - DOCSIS Set-top Gateway (DSG), Switched Digital Video (SDV), Video-Over-DOCSIS (VDOC)
  - PacketCable Voice, PCMM
  - Cable Security
- IP Core
  - CRS, 7600, GSR, 6500 & Catalyst Switches etc.
  - Routing & Switching, MPLS/VPLS, IPv6
  - Multicast Video

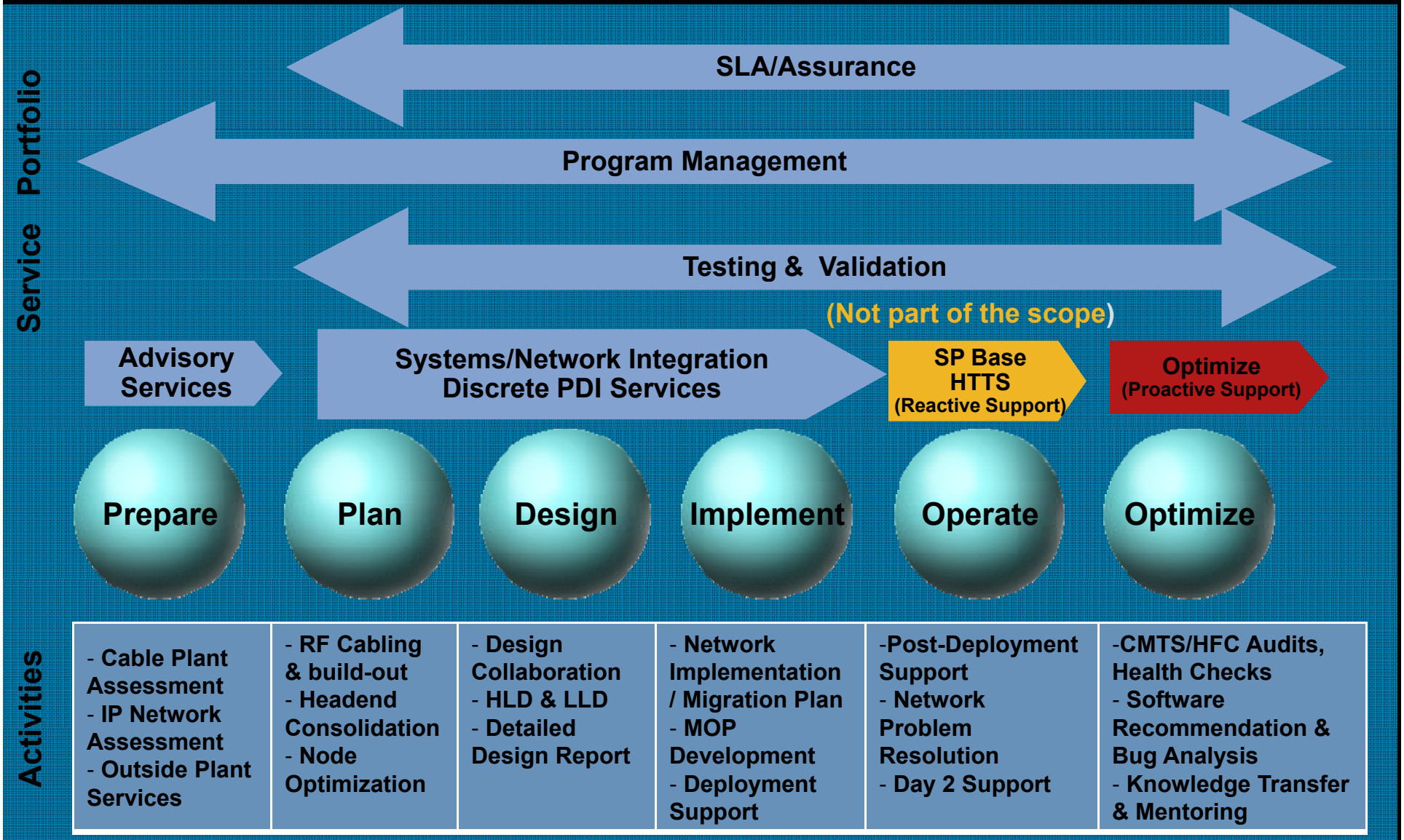
Top Customer Activities (Day 2)

- Design/Implementation Support: HLD and LLD, configuration template, troubleshooting, customer queries related to specific features etc.
- MOP Development: SW/HW upgrades, new feature deployment, data collection for problem resolution etc.
- Software Recommendation: Software strategy, IOS Risk Assessments and Bug Analysis.
- Knowledge Transfer: Provide training to customers, other teams in CA, Sales & Partners.
- Network Change Support: Support for customer maintenance windows, new feature/service deployment etc.
- P1/P2 Network Outages: Recreates for customer problems for root-cause analysis and providing work-around.

Day 0/1 CMTS Services

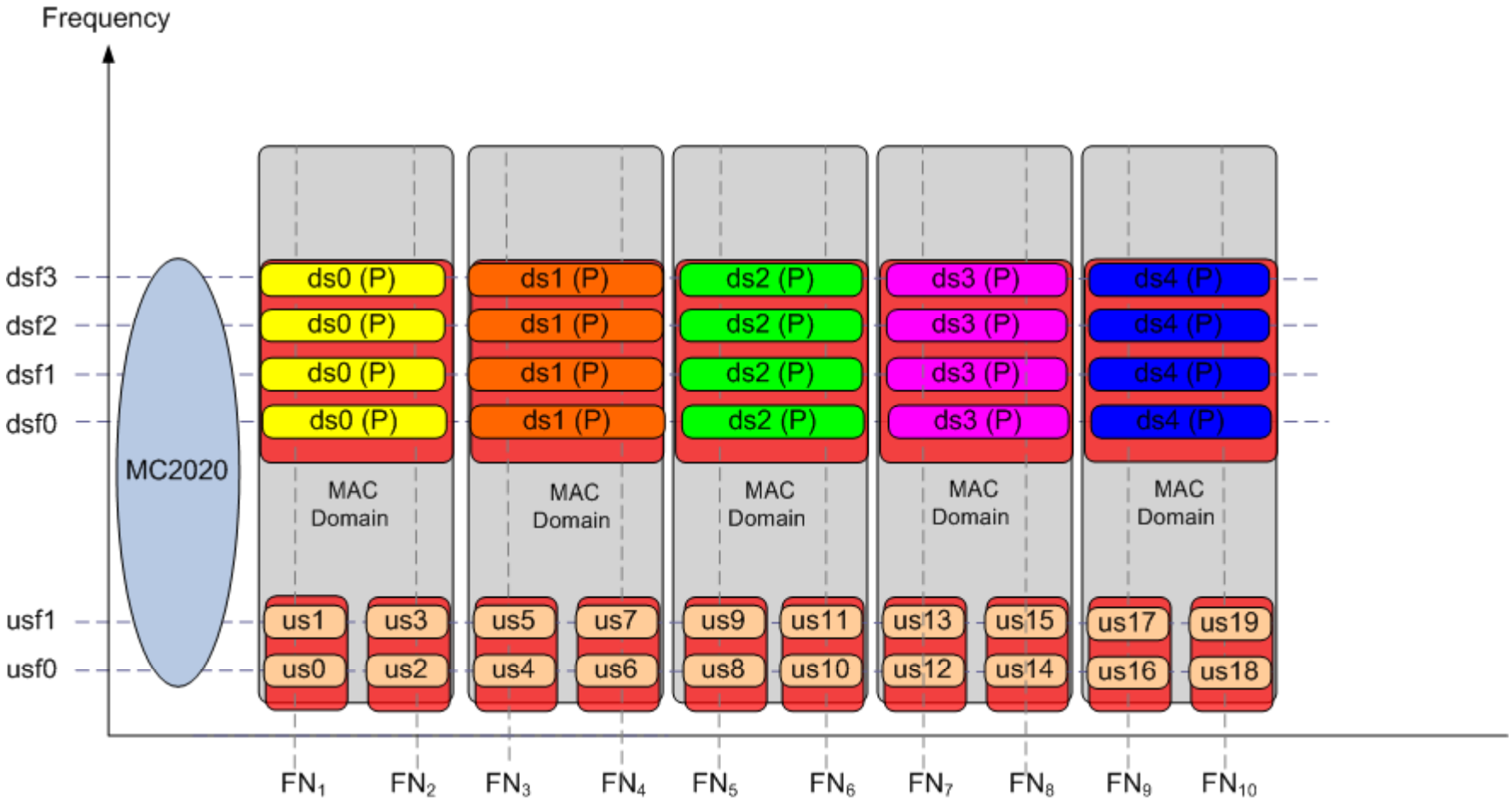
- Deployment Support
  - Basic installation (EF&I)
  - Test & Turn-up
  - Configuration loading
- RF Cabling
- Migration Support
  - Remote NOC cutover support
  - Onsite migration support
- Node Combining Plan (NCP) creation
- Proof of Concept Testing
  - Validate DOCSIS 3.0 design and features
  - Basic turn-up of CMTS with features listed in the HLD/LLD documents
  - eMTA readiness testing
- Network Ready for Use (NFRU) testing

Integrated Services Model for Cable
Service Offerings

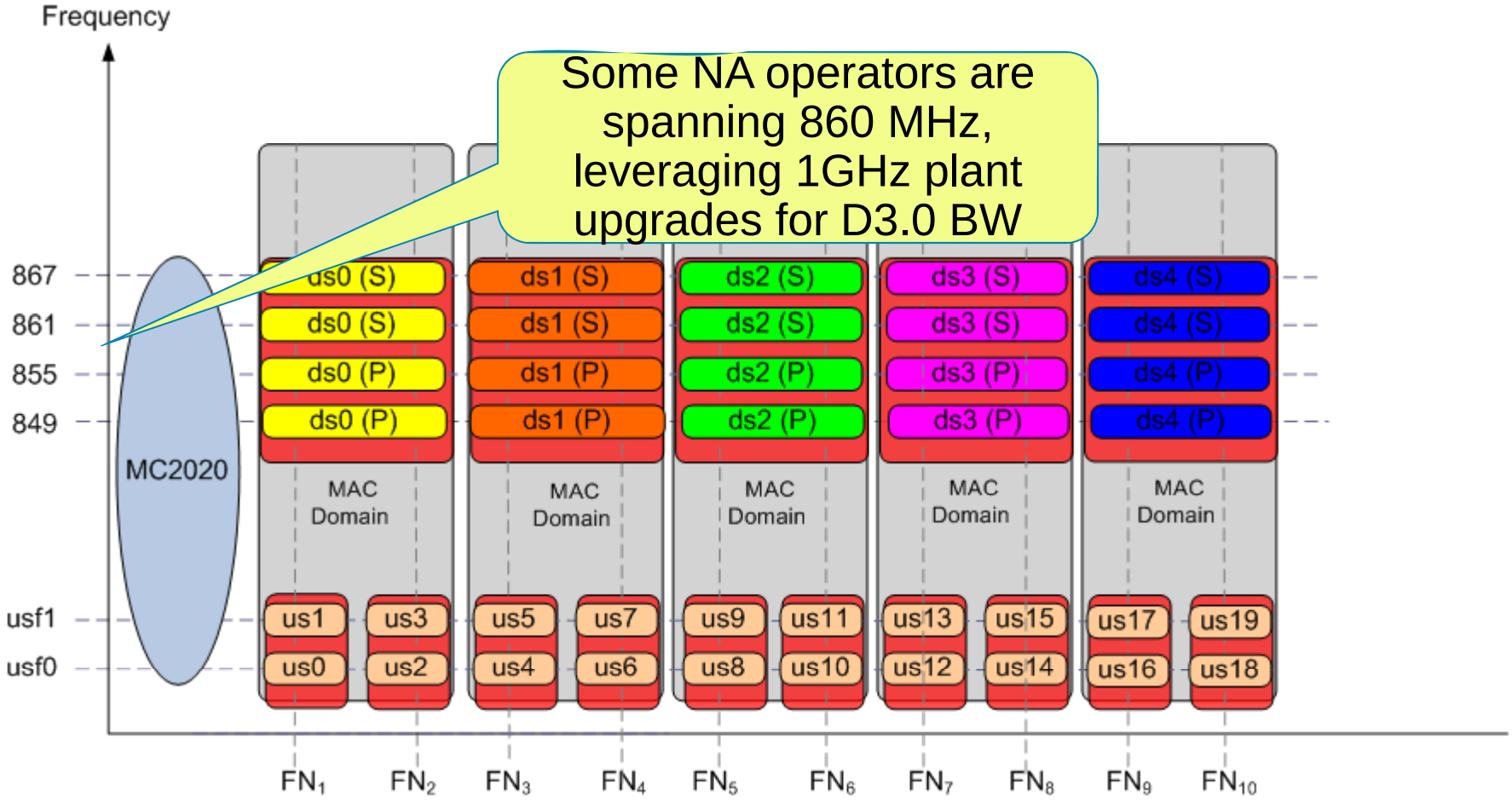


DOCSIS 3.0
Deployment Examples

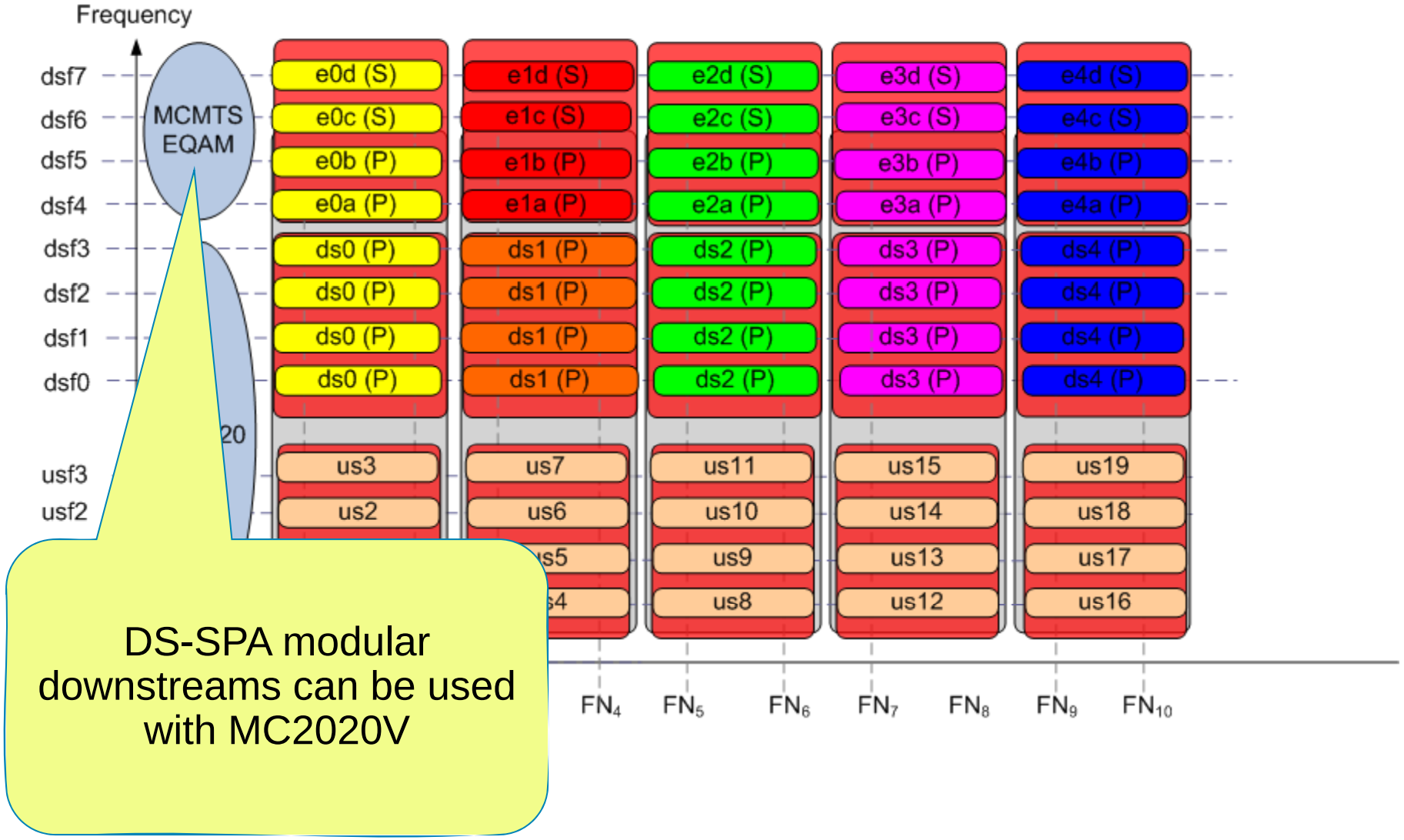
MC2020V and MC88V provide direct path for 4x4 MAC domain



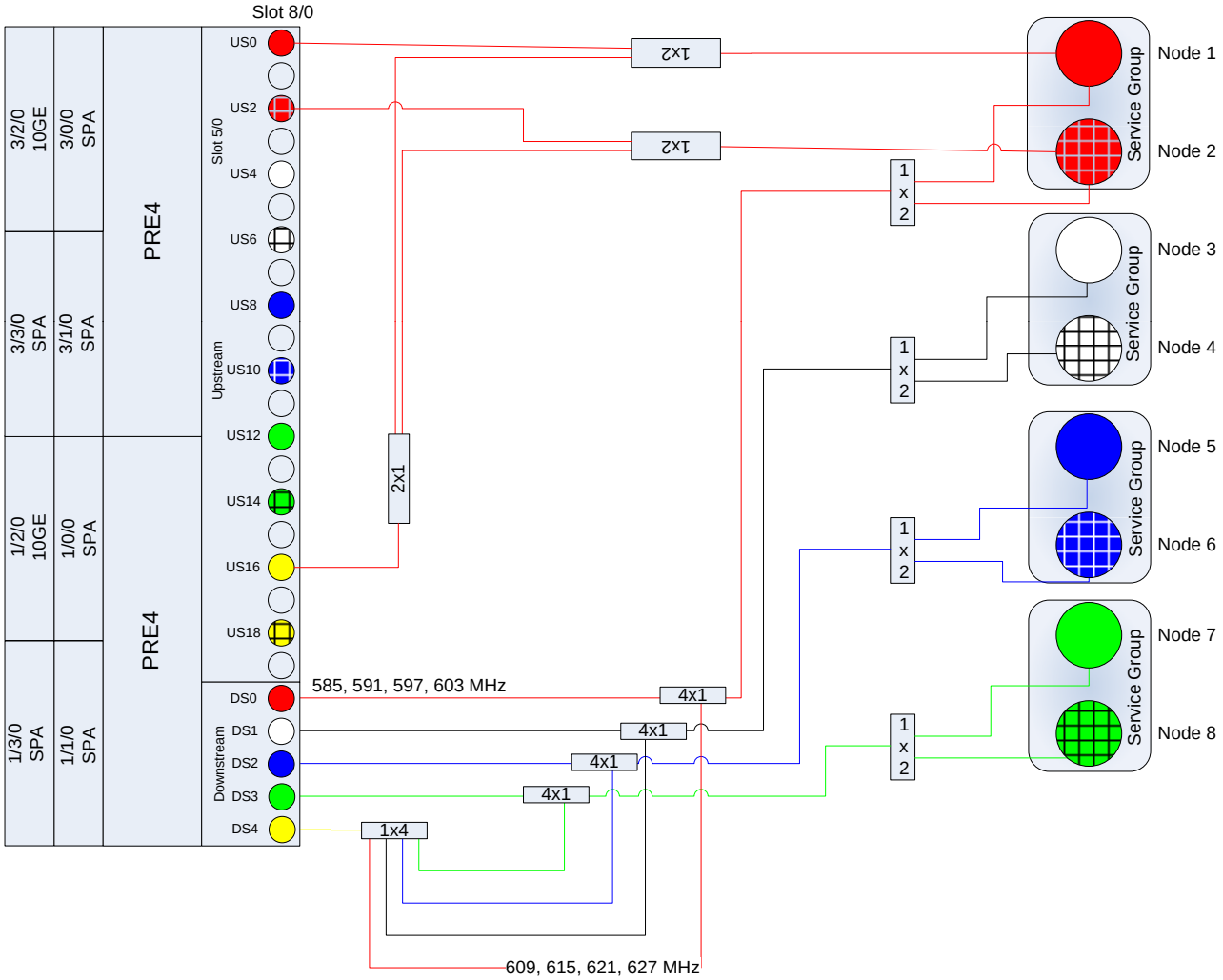
MC2020V and MC88V provide direct path for 4x4 MAC domain



Option for recombining the upstream in split return scenario for 4 channel upstream bonding



RF Spanning Option with MC2020V

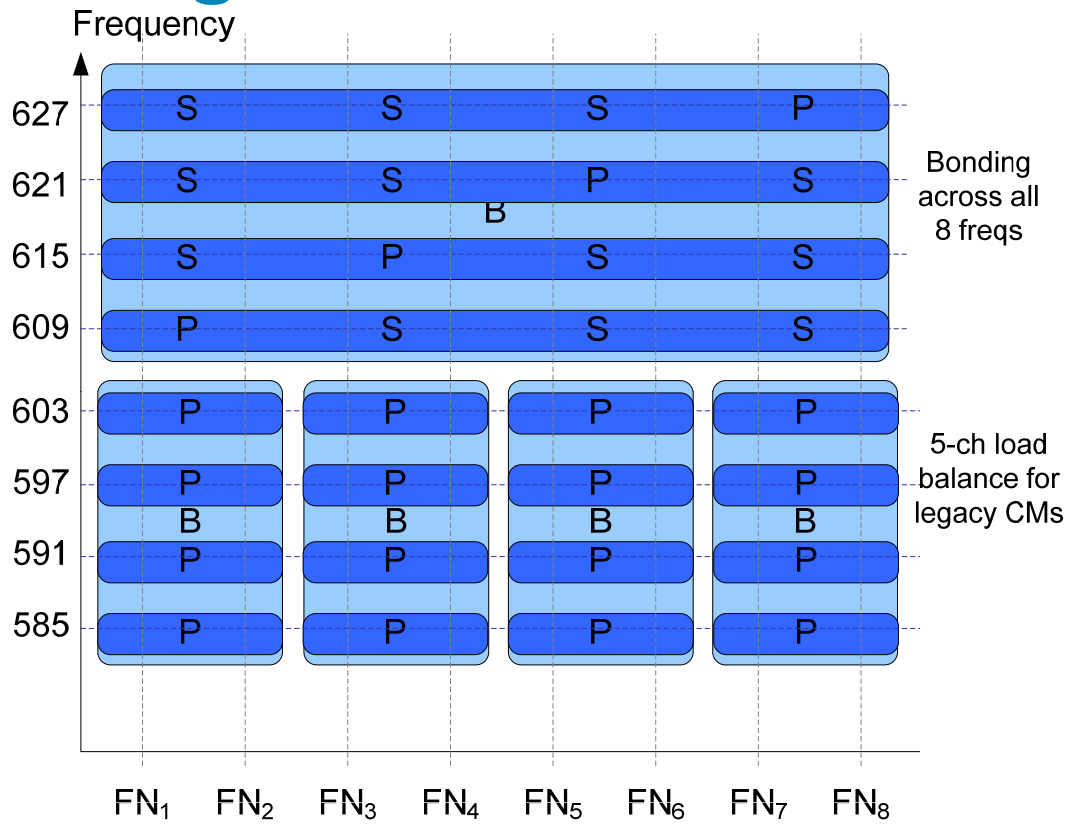


Resources (Per SG)

- 8 DS frequencies
  - 5 Primary
- 4 US frequencies
  - 2 ch US bonding

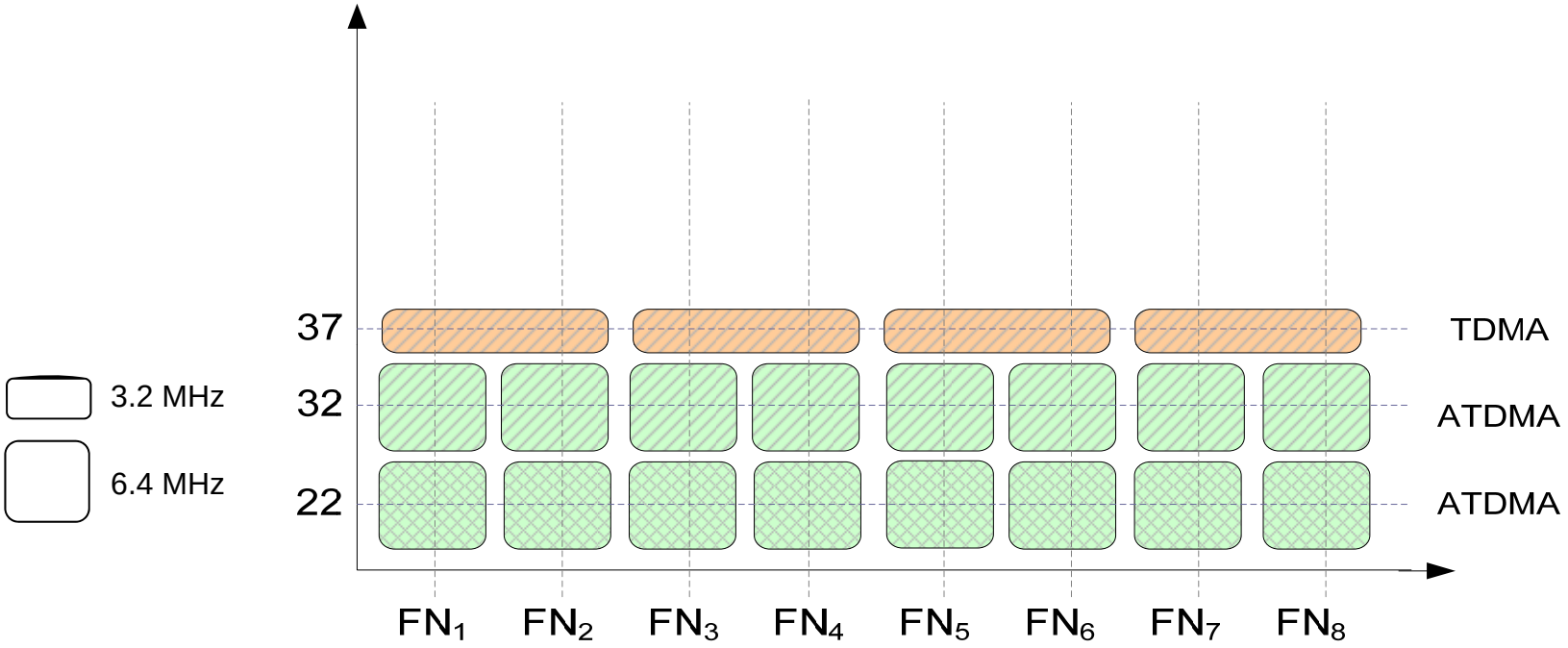
RF Spanning with MC2020V - DS

- 8 DS freqs
- 3 US freqs



- 4, 5x5 MAC domains with ATDMA & TDMA US
  - 2-ch US bonding
- DS4 overlaid for 8 nodes
  - 8-ch DS bonding
- 5 Primary chs available for LB

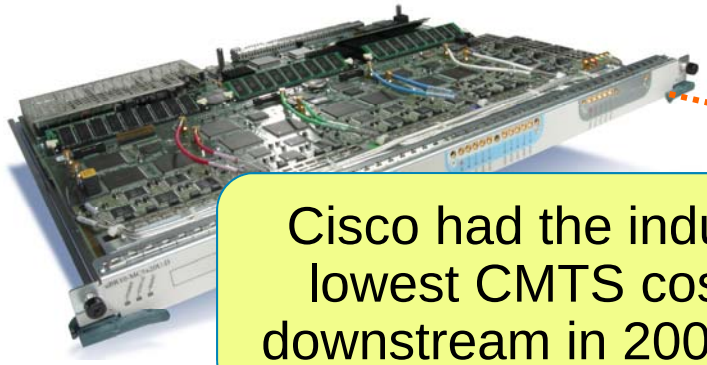
RF spanning with MC2020V - US

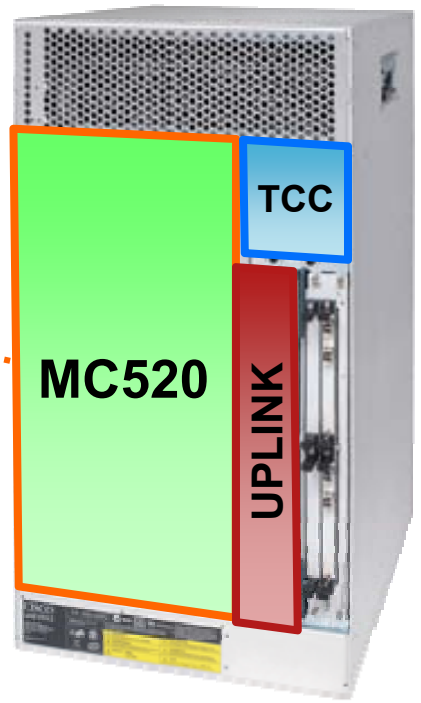


- 4, 5x5 MAC domains with ATDMA & TDMA US
  - 2-ch ATDMA US bonding (50 Mbps)
  - TDMA = “quarantine” ch for 1.x CMs and DSG settop
  - Legacy 2-ch US load balance

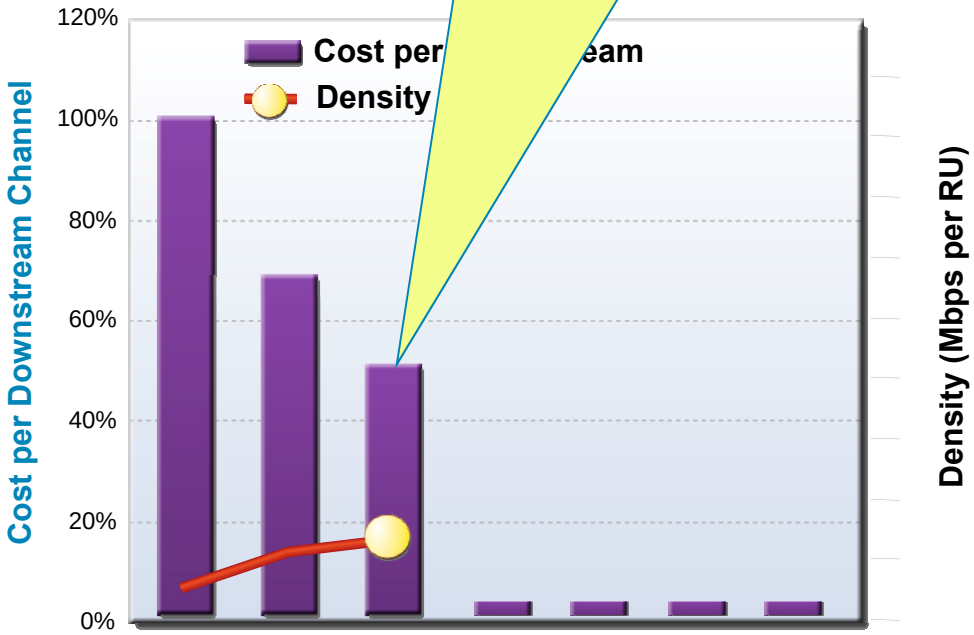
DOCSIS 3.0
Scalability and Cost Efficiency

2006 – MC520 Line Card





Cisco had the industry's lowest CMTS cost per downstream in 2006-2007

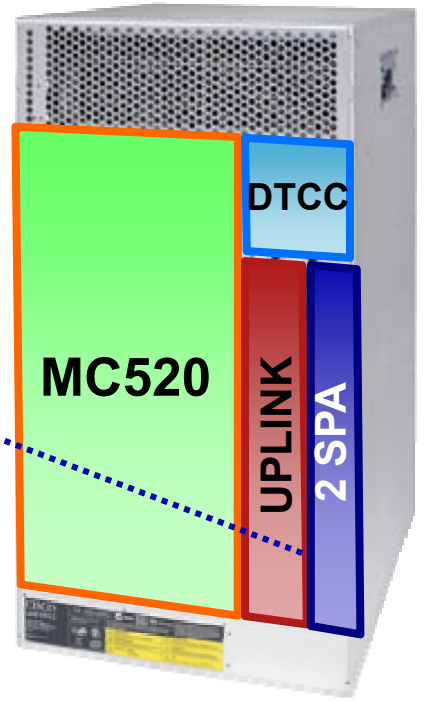


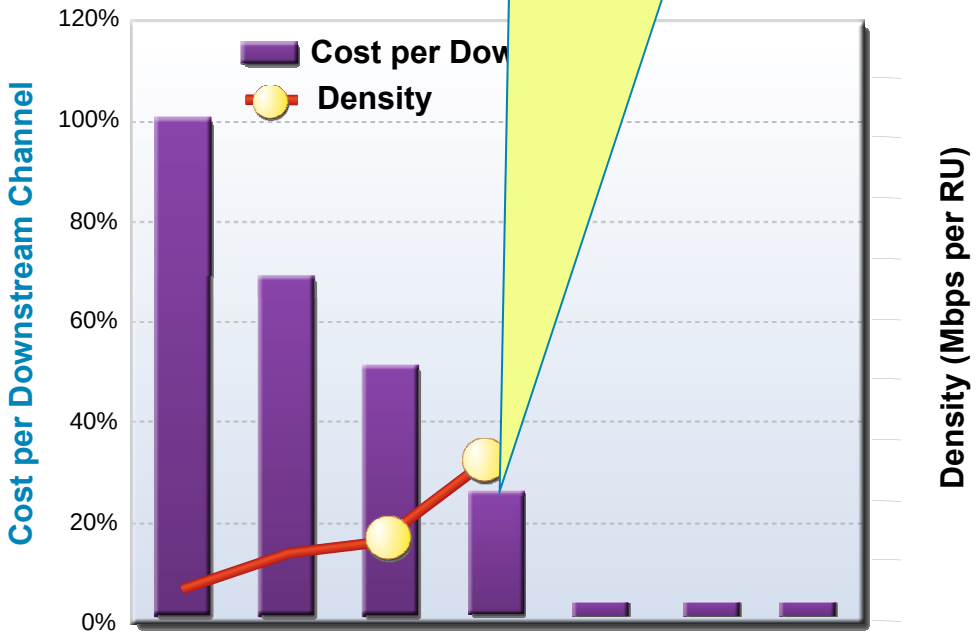
- DS : 40
- US : 160
- DOCSIS : 1.x, 2.0

- RF Performance
- RF Density
- HA
- IPv6 MC520

2007 – 2 x D3.0 DS SPA

Starting in 2007, Cisco provided 45% lower cost with D3.0 Wideband SPAs



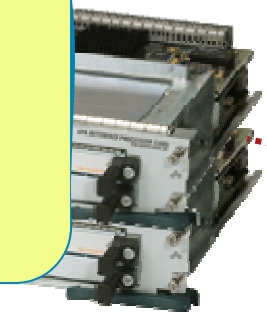


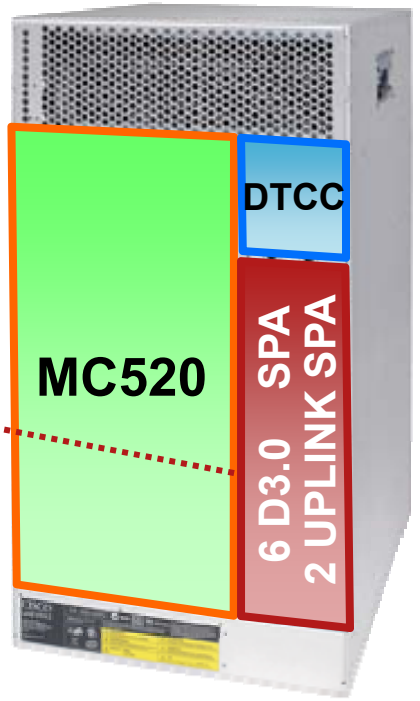
- DS : 40→88
- US : 160
- DOCSIS : 1.x, 2.0, 3.0 BRONZE
- I-CMTS & M-CMTS

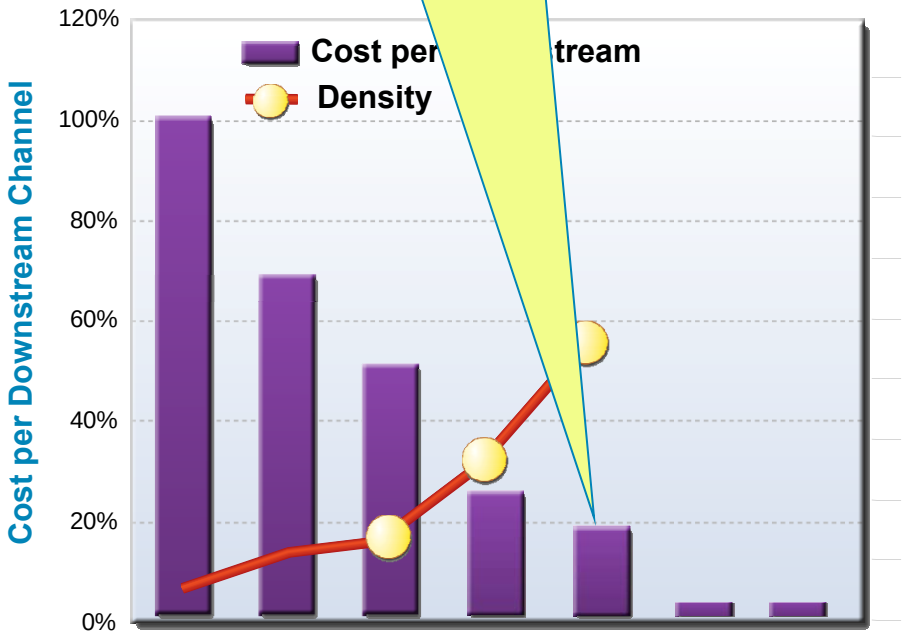
- >2x DS Capacity
- D1.x/2.0 Load Balancing
- D3.0 Bonded Services
- NO RF Re-Cabling – Lo OPEX

2009 – 6 x D3.0 DS SPA

In Q1 2009, Cisco delivered another 41% cost reduction with SIP-600 & 4 additional SPAs







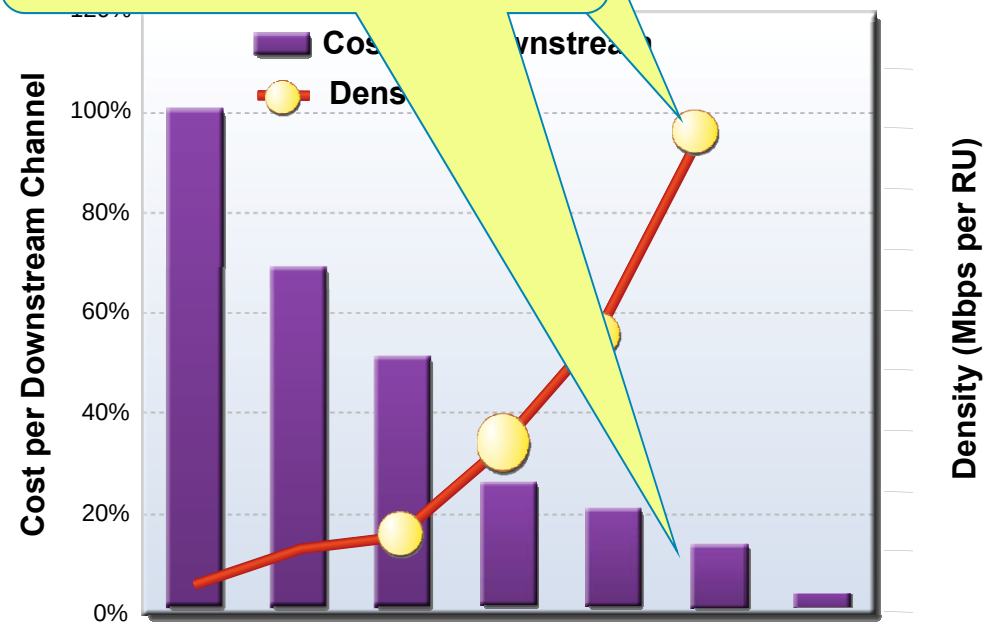
- DS : 40→88→184
- US : 160
- DOCSIS : 1.x, 2.0, 3.0 BRONZE
- I-CMTS & M-CMTS

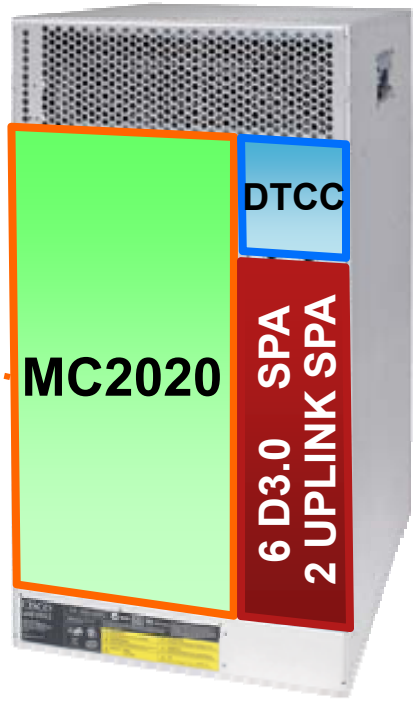
- >4x DS Capacity
- Scale and High Availability
- D1.x/2.0 LB and D3.0 Bonding
- NO RF Re-Cabling – Lo OPEX

2009 – MC2020V Line Card

In Q4 2009, Cisco provides 2 times the density in the same chassis

AND another 25% cost reduction!





- DS : 40→88 →184→304
- US : 160
- DOCSIS : 1.x, 2.0, 3.0 FULL
- I-CMTS & M-CMTS

- >7x DS Capacity
- Large Scale, HA & USCB
- D1.x/2.0 LB and D3.0 Bonding
- NO RF Re-Cabling – Lo OPEX

Cisco DOCSIS 3.0 Migration Summary

- Efficient
  - –Re-use 10k components for DOCSIS 3.0.
  - –Delivering the right D3.0 features at the right time
- Incremental
  - –Allows customers to incrementally add downstream capacity without affecting other services or currently deployed assets
  - –Licensing model that minimizes operational impact but allows incremental growth model
- Cost Effective
  - –Minimal equipment investment to add DS channel bonding or additional DOCSIS 2.0 DS capacity
  - –No up front loading of capacity, pay as you grow
  - –Investment Protection, no chassis forklifts
- Scalable support organization
  - –AS, SEs, BU/BNE, SPSU