

HFC Cable Architecture

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3/22/2018

[all images from CableLabs, Cisco, Arris or otherwise noted]

Agenda

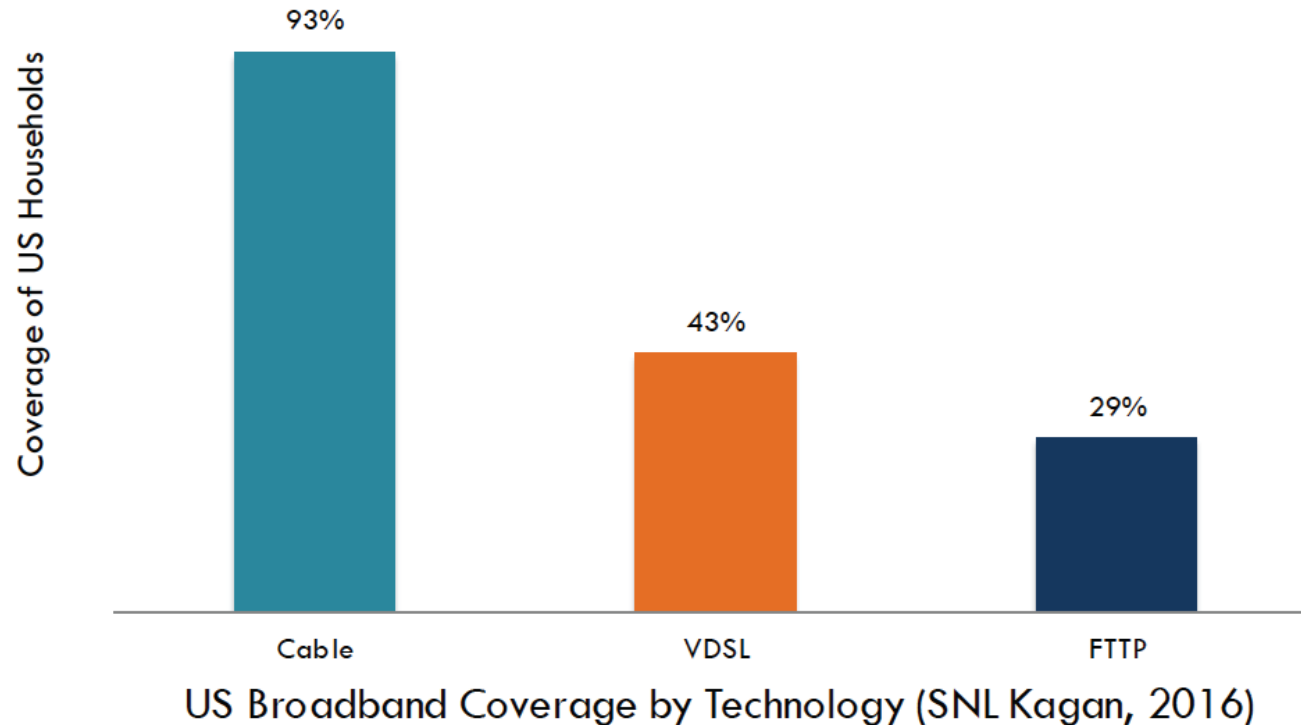
- Overview of Cable as a technology: what the future holds
- Architecture overview and terminology
- The PHY layer
 - Hybrid Fiber Coaxial (HFC) system
 - Spectrum allocation, division, FDD
- The MAC layer
 - DOCSIS, symbols, modulation
- CPE
 - Products, speeds, performance in practice
- Operations and Maintenance

Cable is generally not a popular topic..



Why Cable matters (even if we don't like it)

- HFC can deliver speeds in excess of 10gb/s on existing infrastructure
- Franchise agreements in place, power, right of way, fiber-deep



Version and speed evolution

Broadband Generation	DOCSIS 1.0	DOCSIS 1.1	DOCSIS 2.0	DOCSIS 3.0	DOCSIS 3.1
Highlights	Initial cable broadband technology	Added voice over IP service	Higher upstream speed	Greatly enhanced capacity	Capacity and efficiency progression
Downstream Capacity	40 Mbps	40 Mbps	40 Mbps	1 Gbps	10 Gbps
Upstream Capacity	10 Mbps	10 Mbps	30 Mbps	100 Mbps	1-2 Gbps
Production Date	1997	2001	2002	2008	2016

Cable Broadband Technology Evolution, 1990s to Present

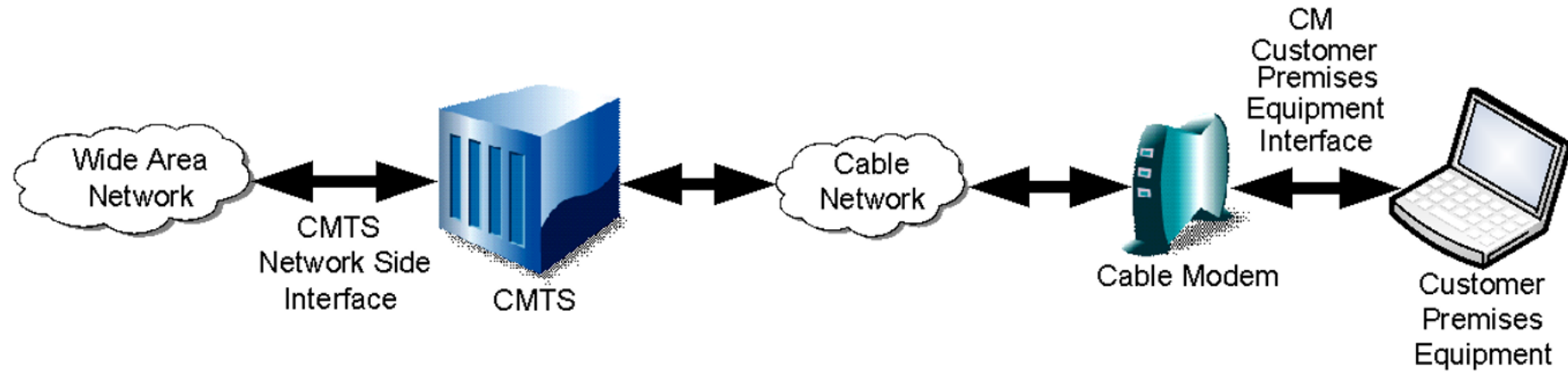
Future of Cable broadband is bright

- DOCSIS 3.1 in early phases with 10-15 year useful life in current form
- Full duplex DOCSIS emerging (FDX) which allows for 10gb symmetric
- Fiber-deep architecture enables FTTH and node+0 technology
- OFDM/OFDMA allows for highly efficient use of spectrum
- LDPC replaces FEC in 3.1, adding efficiency
- LTE can run over HFC, and it is headed that way with FDX
- DOCSIS has been used over unlicensed wireless to add robustness

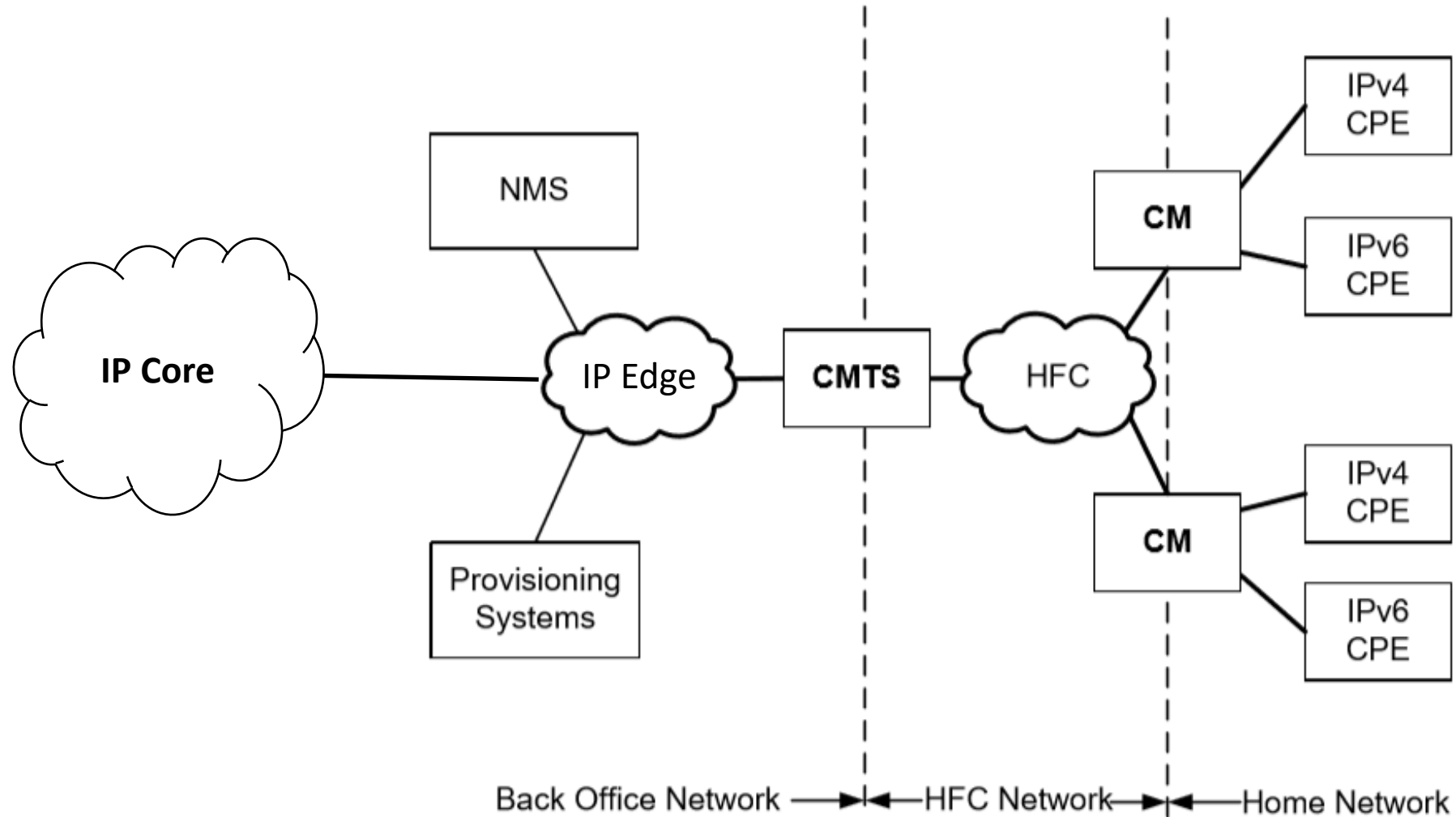
Terminology and Equipment

- CMTS: Cable Modem Termination System
- DOCSIS: Data over cable system interface standard
- Cable Modem: Customer premise cable termination device
- Node: a passive (but powered) optical to radio frequency transceiver
- HFC: Hybrid fiber coaxial: a blend of optical and RF for distribution
- Amplifier: a passive device to perform non-linear RF amplification
- Spectrum: the RF band from 0-1.2GHz (typical) used in Cable
- SC-QAM: single-channel QAM, normally 6.0 MHz (DS), 6.4 MHz (US)
- Node+: Number of nodes in cascade
- Upstream / Downstream: direction of RF amplification and data flow

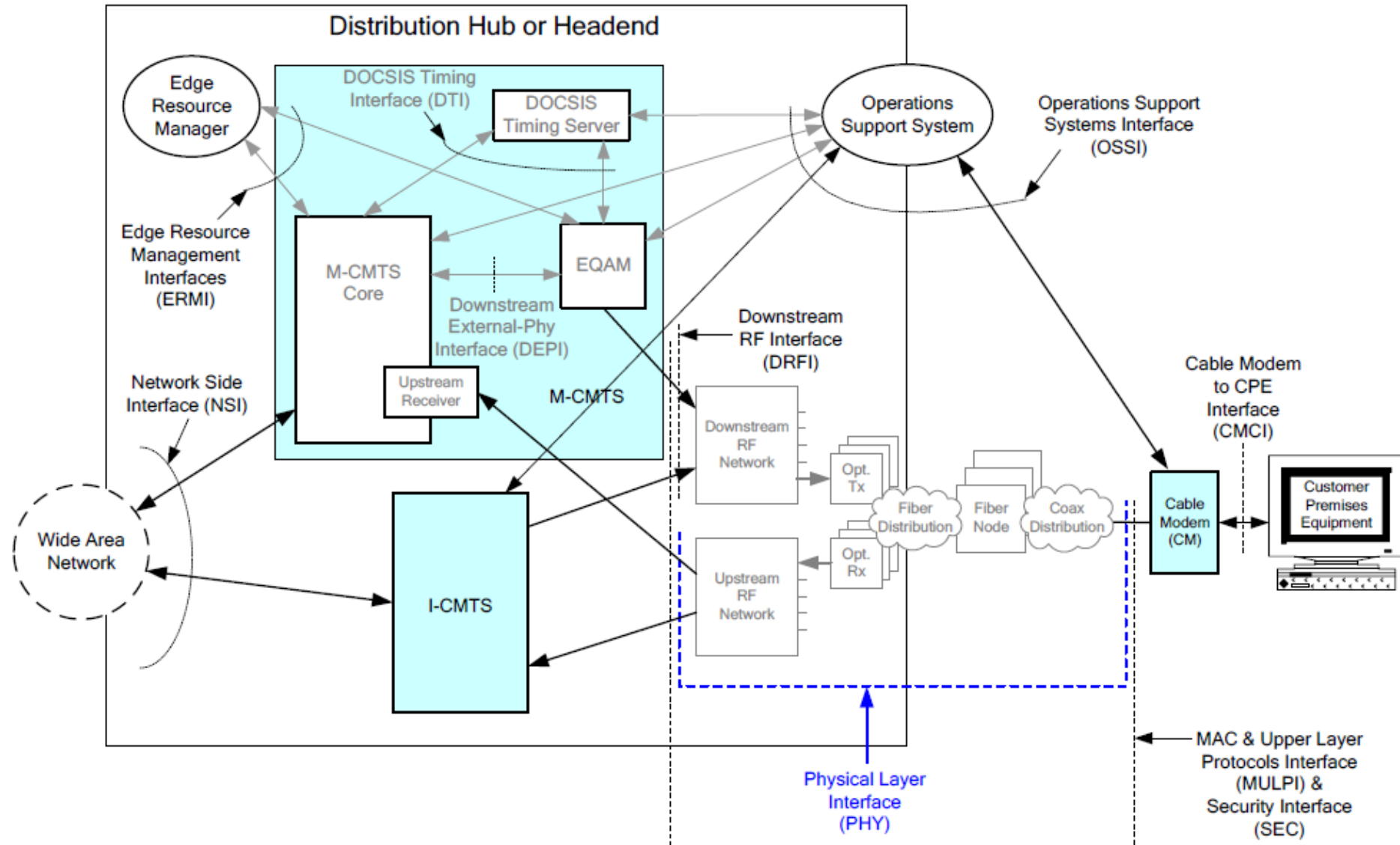
Simplistic view of DOCSIS Network



Basics of Cable Network



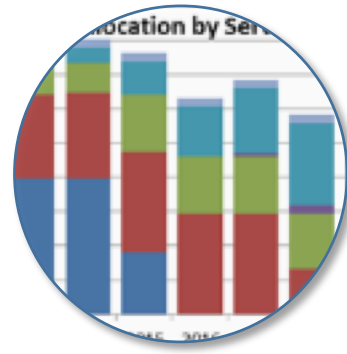
The HFC Reference Architecture



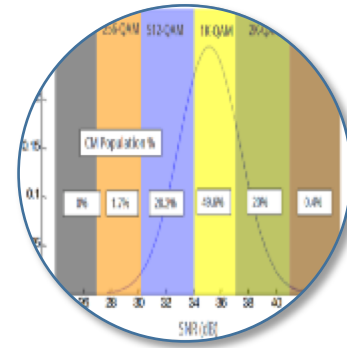
DOCSIS requires 4 management areas



CMTS



Spectrum



Plant



Customer

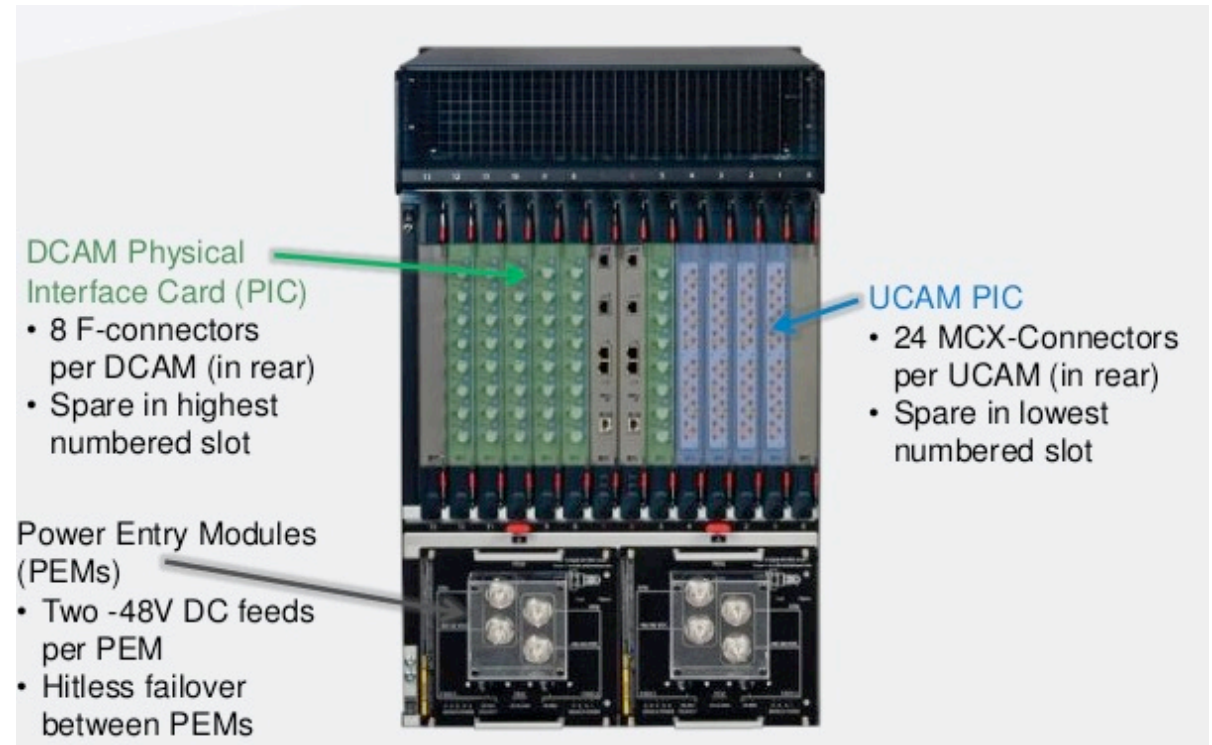
Roles in a Cable network

- RF Engineer
- Network Engineer
- Headend Tech
- Maintenance Tech
- Field Tech
- OSS Solution Engineer
- BSS Integration
- Customer Support (inside tech)

Cable Modem Termination System (i-CCAP)

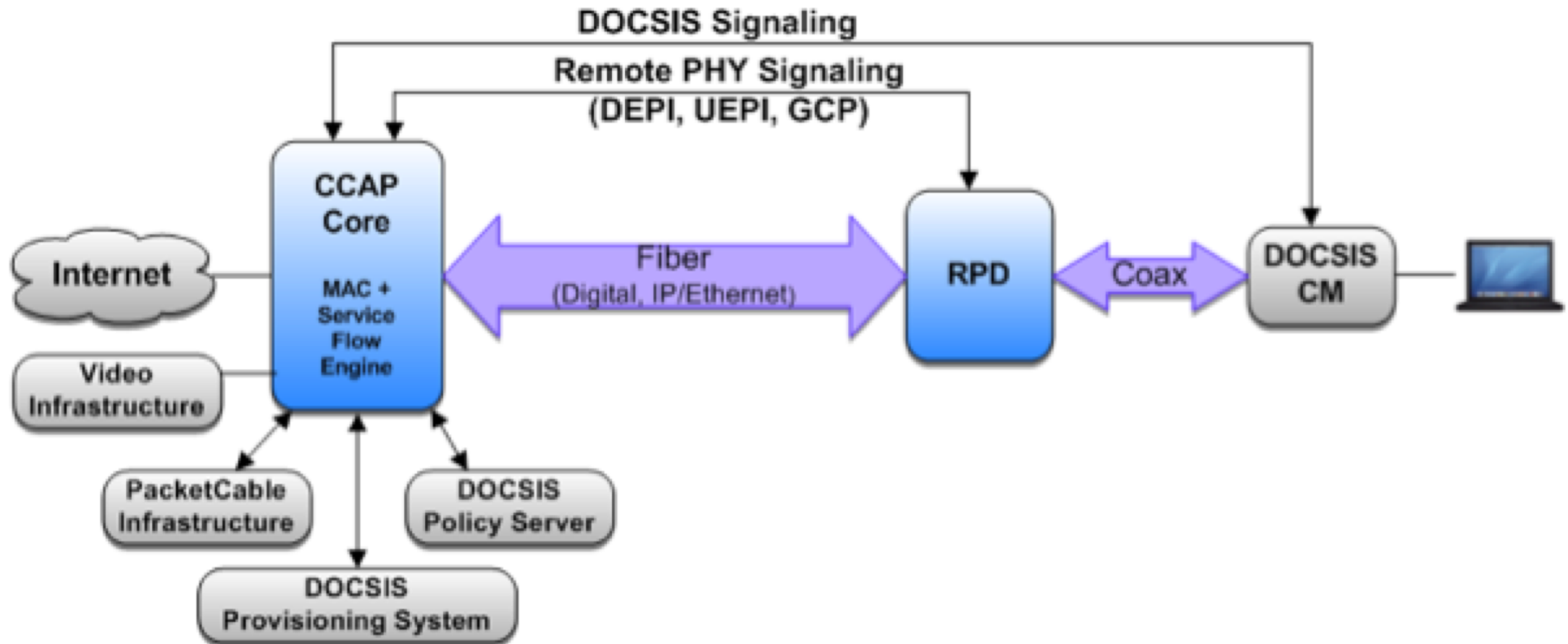


Cisco cBR8



Arris E6000

Remote PHY



Sample Output on CMTS

Upstream Service Group

```
Router# show cable mac-domain cable 7/1/0 upstream-service-group
Cable MD 7/1/0
US-SG-ID : 1      US-Chan : U0,1,2,3,4
Primary-DS: 5/1/0:0  US-SG-ID: 1
  MDD US-List  : U0,1,2,3
  MDD Ambiguity : U0,1,2,3
Primary-DS: 3/0/0:0  US-SG-ID: 1
  MDD US-List  : U0,1,2,3,4
  MDD Ambiguity : U0,1,2,3,4
Primary-DS: 3/0/0:1  US-SG-ID: 1
  MDD US-List  : U0,1,2,3,4
  MDD Ambiguity : U0,1,2,3,4
Primary-DS: 3/0/0:2  US-SG-ID: 1
  MDD US-List  : U0,1,2,3,4
  MDD Ambiguity : U0,1,2,3,4
Primary-DS: 3/0/0:3  US-SG-ID: 1
  MDD US-List  : U0,1,2,3,4
  MDD Ambiguity : U0,1,2,3,4
```

Downstream Service Group

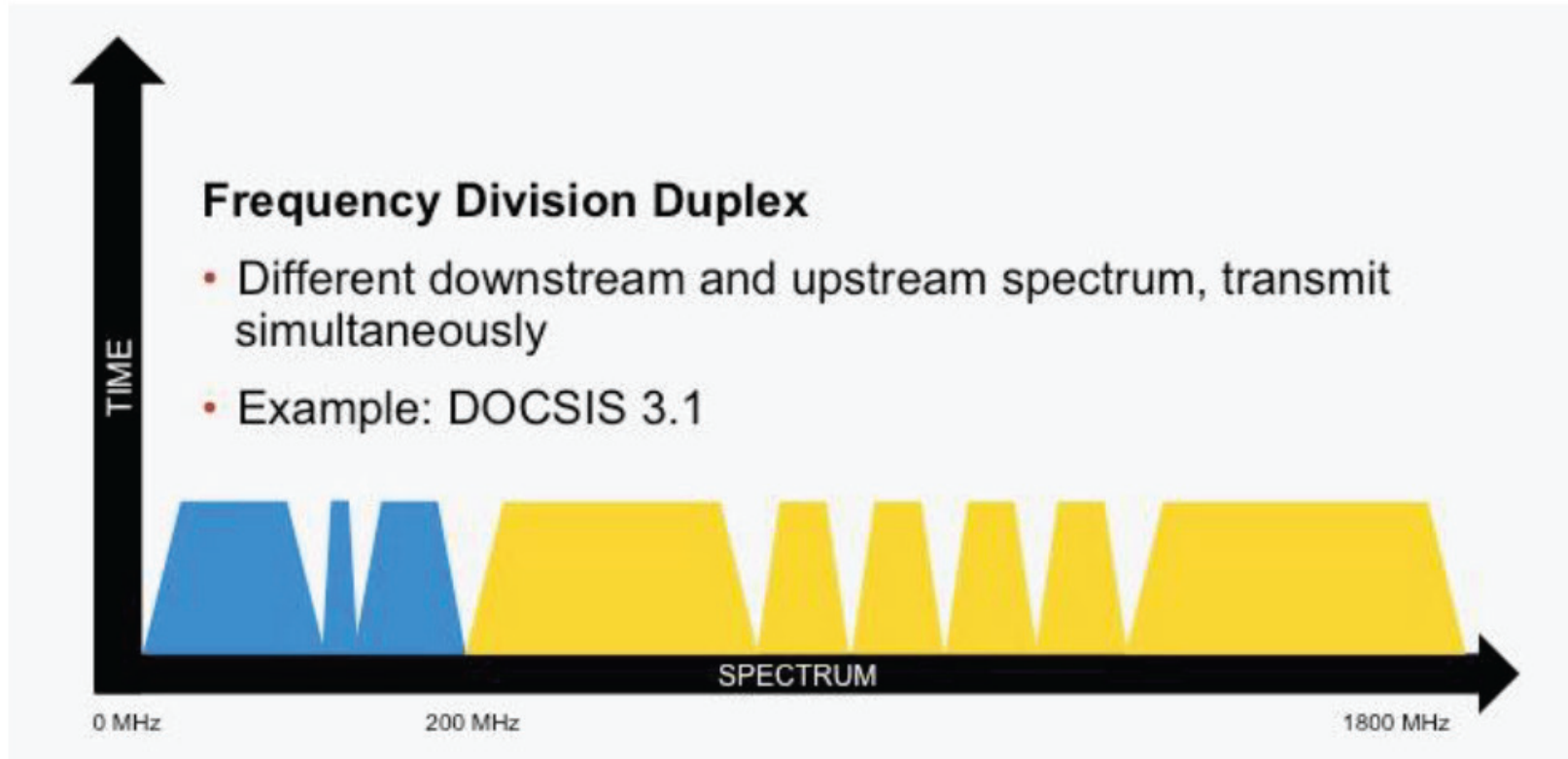
```
router#show cable mac-domain cable 7/0/0 rcc 5 simplified
RCC ID      : 5
Created Via  : Wideband - Wi7/0/0:1
CM attribute mask : 0x80000000

Primary Receive Channel List:
  Chan Idx  RF Chan      DCID Freq
  1         In7/0/0:0    1    453000000

Non-Primary Receive Channel List:
  Chan Idx  RF Chan      DCID Freq
  2         In7/0/0:1    2    459000000
  3         In7/0/0:2    3    465000000
  4         In7/0/0:3    4    471000000
  5         In7/0/0:4    5    477000000
  6         In7/0/0:5    6    483000000
  ...
  24        In7/0/0:23   24   591000000
  25        In7/0/0:158  159  663000000

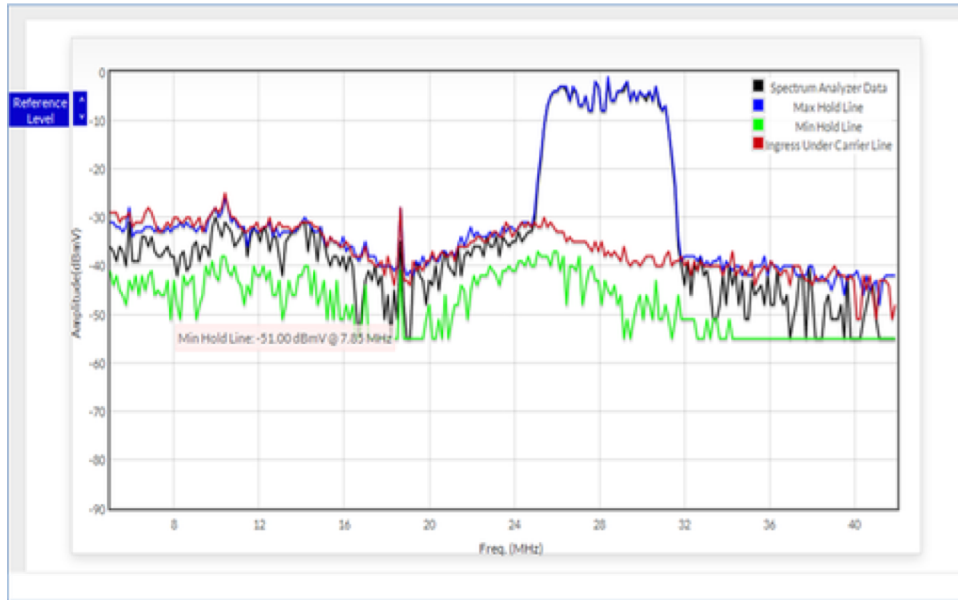
OFDM Receive Channel List:
  Chan Idx  RF Chan      DCID PLC-Freq  Profiles
  25        In7/0/0:158  159  663000000   0 1 2
```

Return and Forward split at 42, 85 or 200MHz

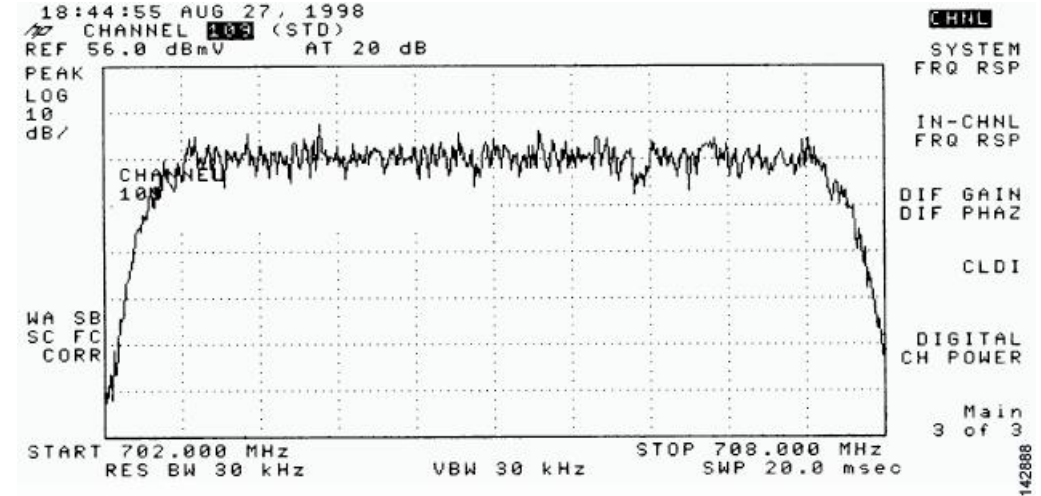


Frequency Division Duplex, used in current cable networks

Spectrum Allocation, Channels, Noise

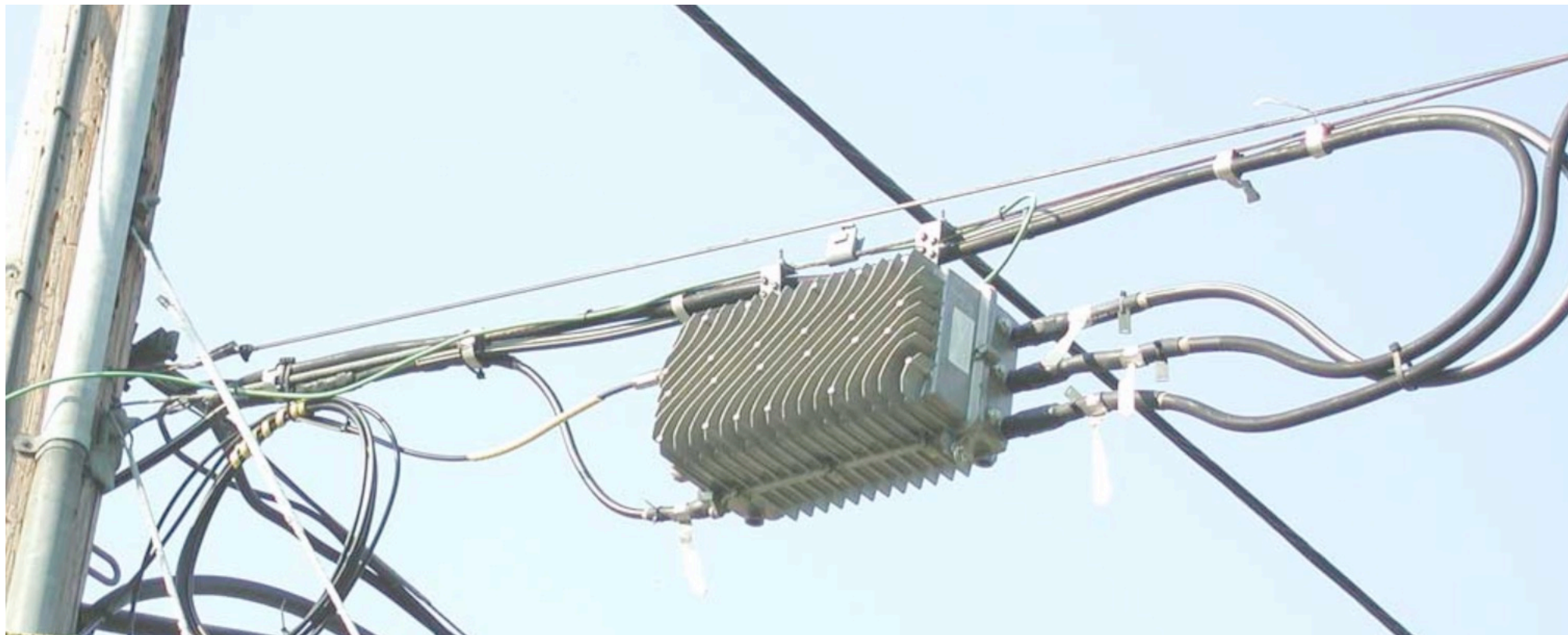


Upstream, single 6.4Mhz carrier



Downstream, single 6.0Mhz carrier

Outside Plant



		Capacity Relationship with Modulation (H) and Spectrum (V) (Gb/s)					
		256 -QAM	512-QAM	1024-QAM	2048-QAM	4096-QAM	8192-QAM
Mhz	EIA	5.33 b/Hz	5.63 b/Hz	6.39 b/Hz	6.99 b/Hz	7.60 b/Hz	8.20 b/Hz
384	64	2.04	2.16	2.45	2.68	2.91	3.14
336	56	1.79	1.89	2.14	2.34	2.55	2.75
288	48	1.53	1.62	1.84	2.01	2.18	2.36
240	40	1.27	1.35	1.53	1.67	1.82	1.96
192	32	1.02	1.08	1.22	1.34	1.45	1.57
144	24	0.76	0.81	0.92	1.00	1.09	1.18
96	16	0.51	0.54	0.61	0.67	0.72	0.78
48	8	0.25	0.27	0.30	0.33	0.36	0.39

License (\$)



Maintenance and Process (dB)

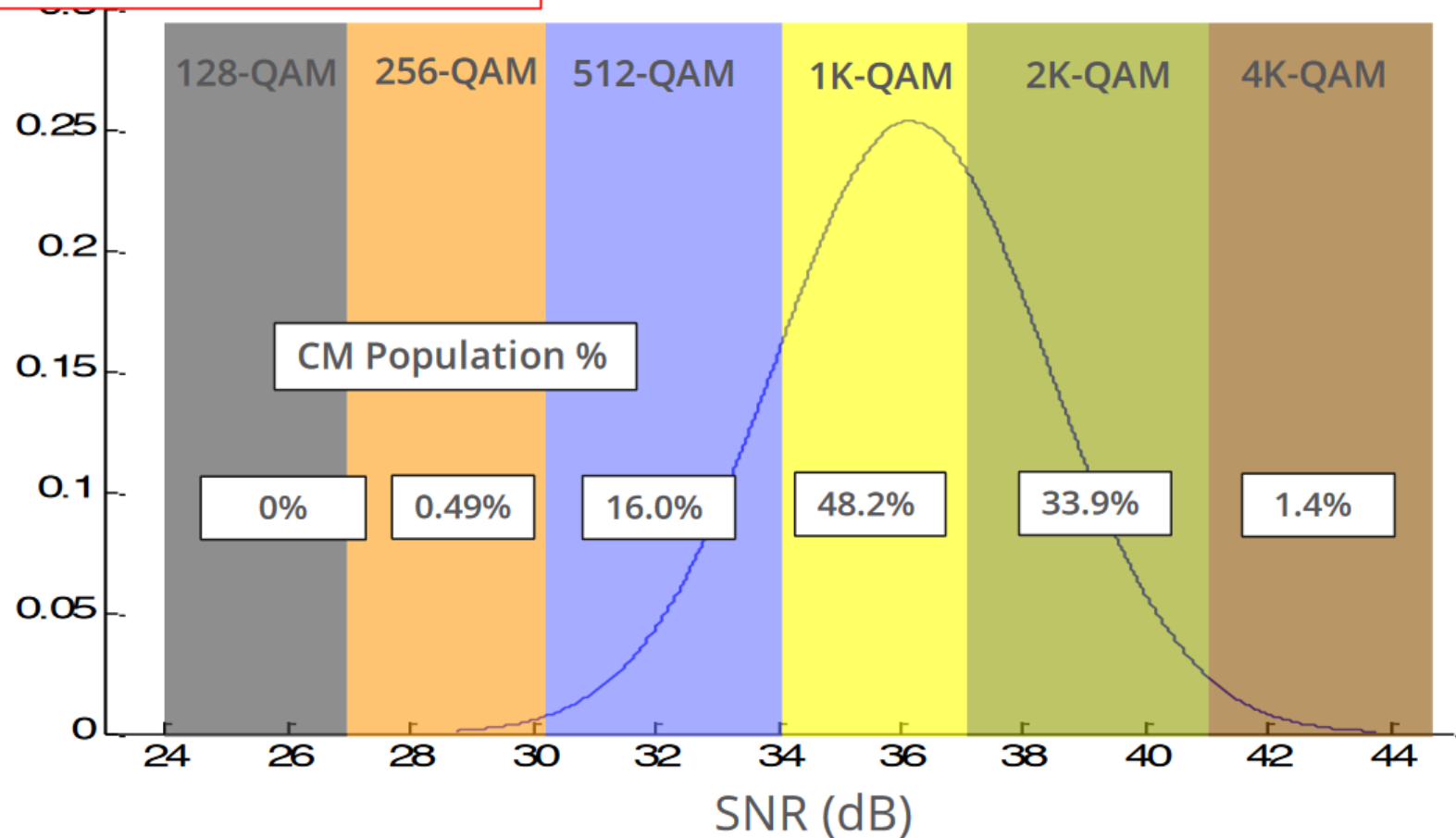
Capital (\$)

Effort and cost increase with higher modulation

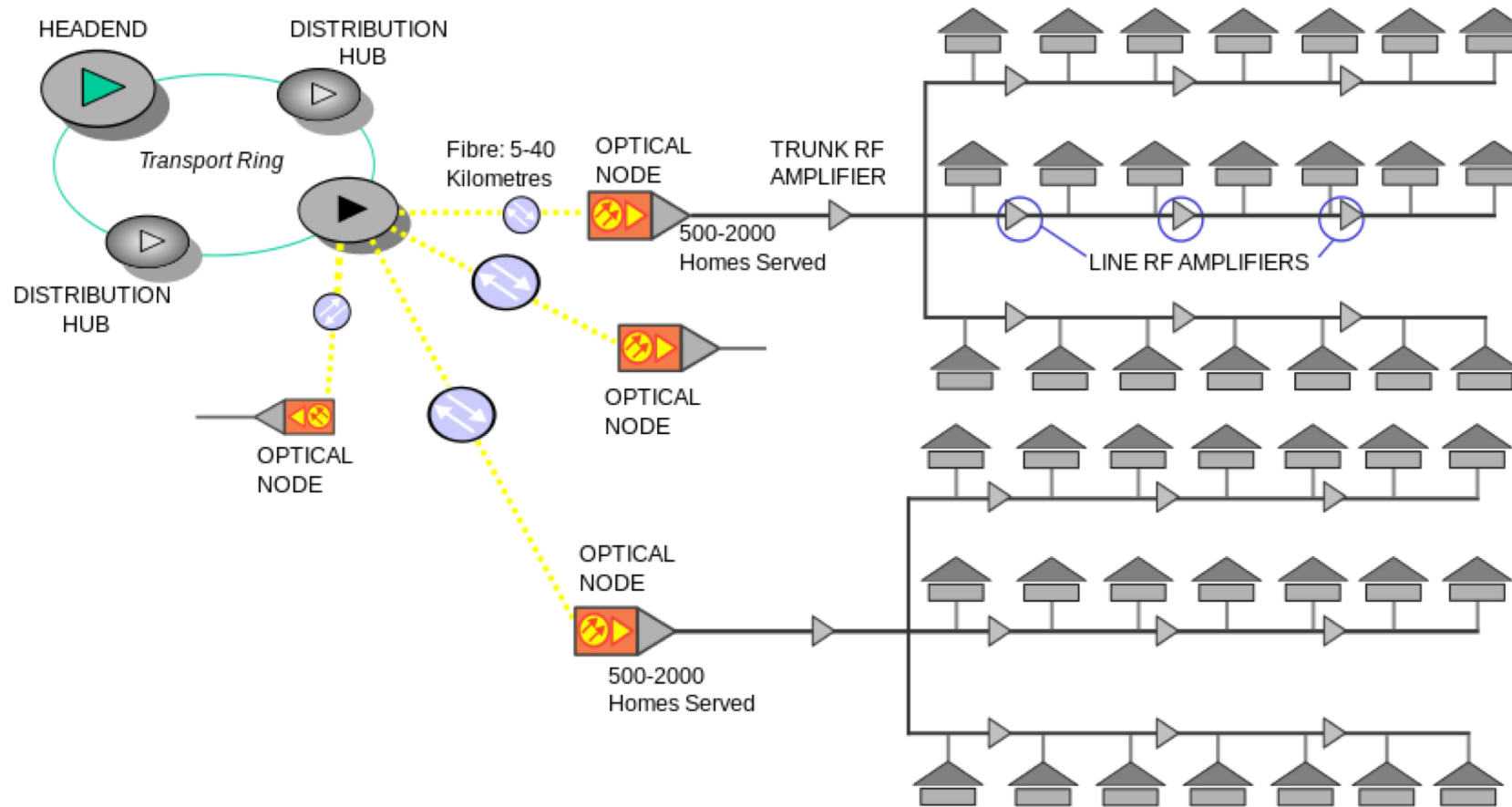
Plant Performance

**% Weighted average Improvement
over Max D3.0:**
8K FFT: 30%
4K FFT: 20%

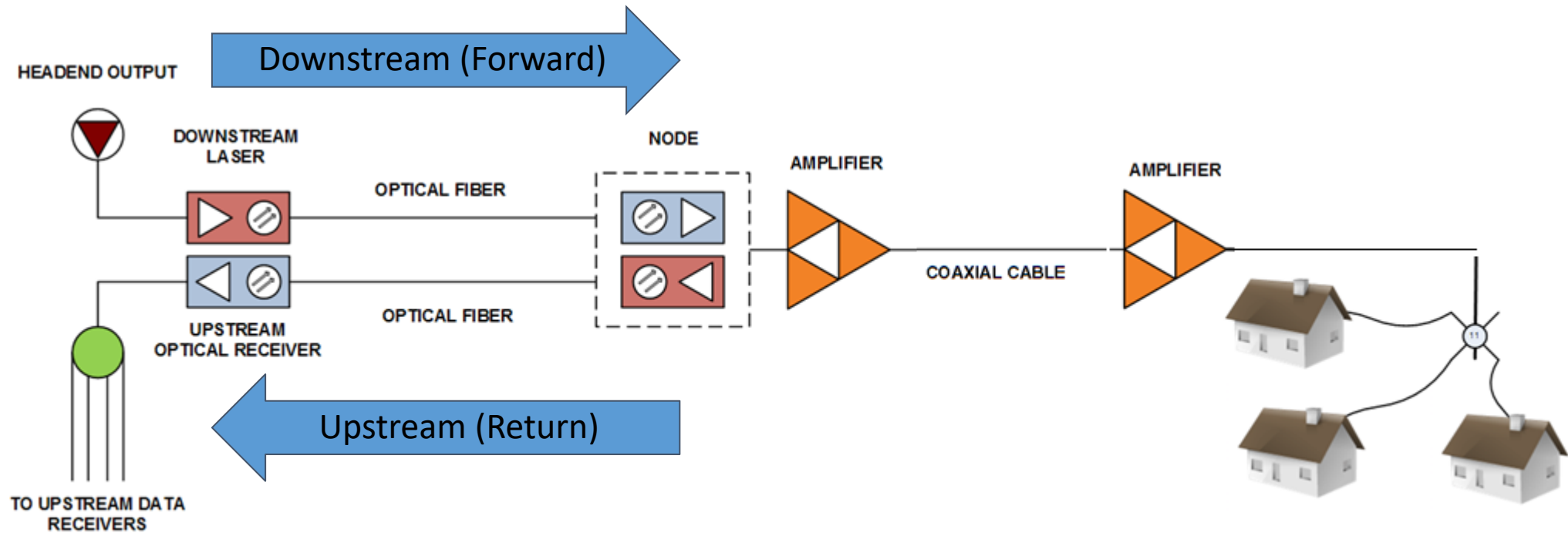
— SNR margin = 0 dB



Physical Layer

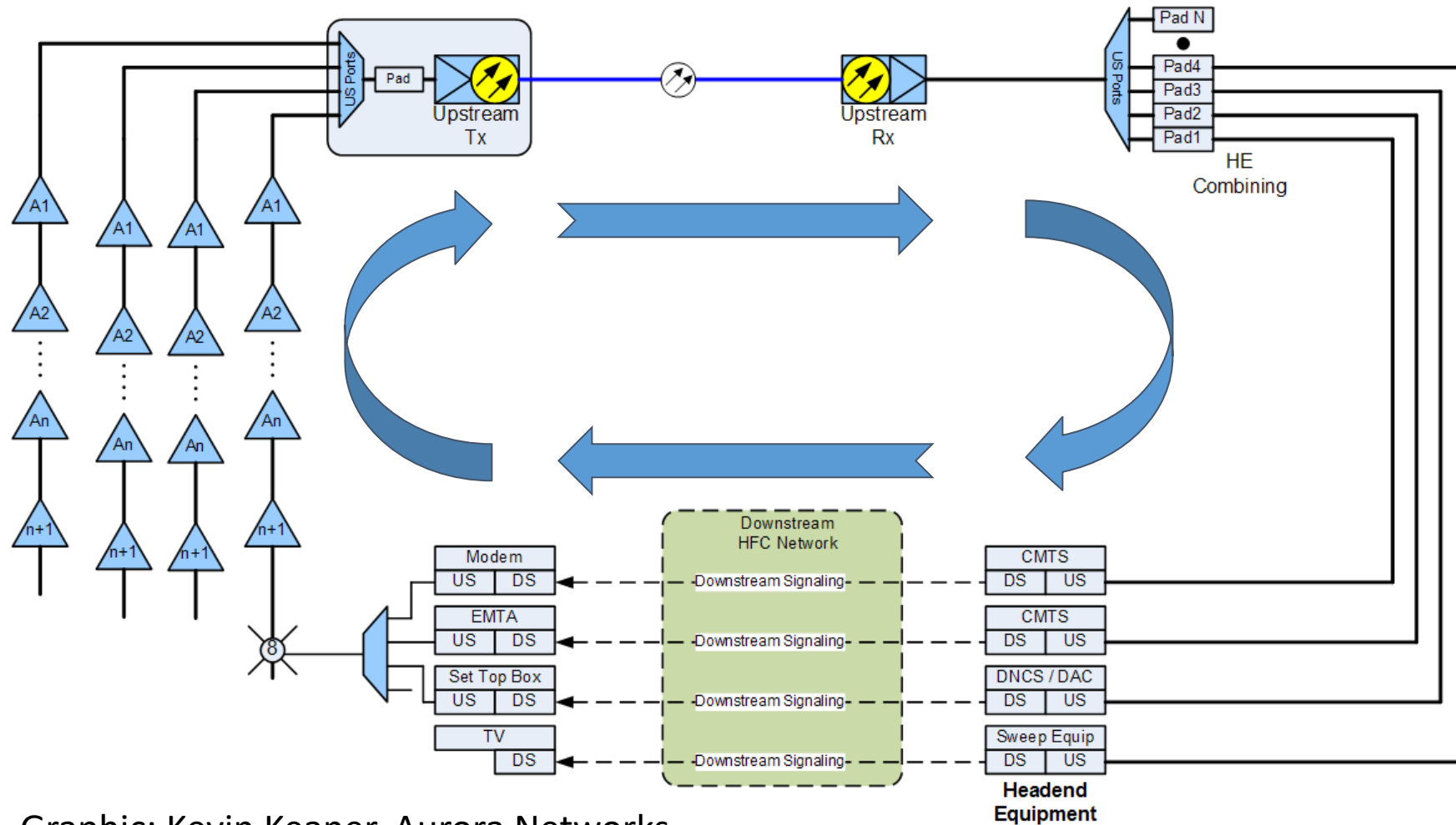


Two-Way Plant, commonly a “service group”



Graphic adapted from: Kevin Keaner, Aurora Networks

Another view of HFC



Graphic: Kevin Keener, Aurora Networks

CPE Options

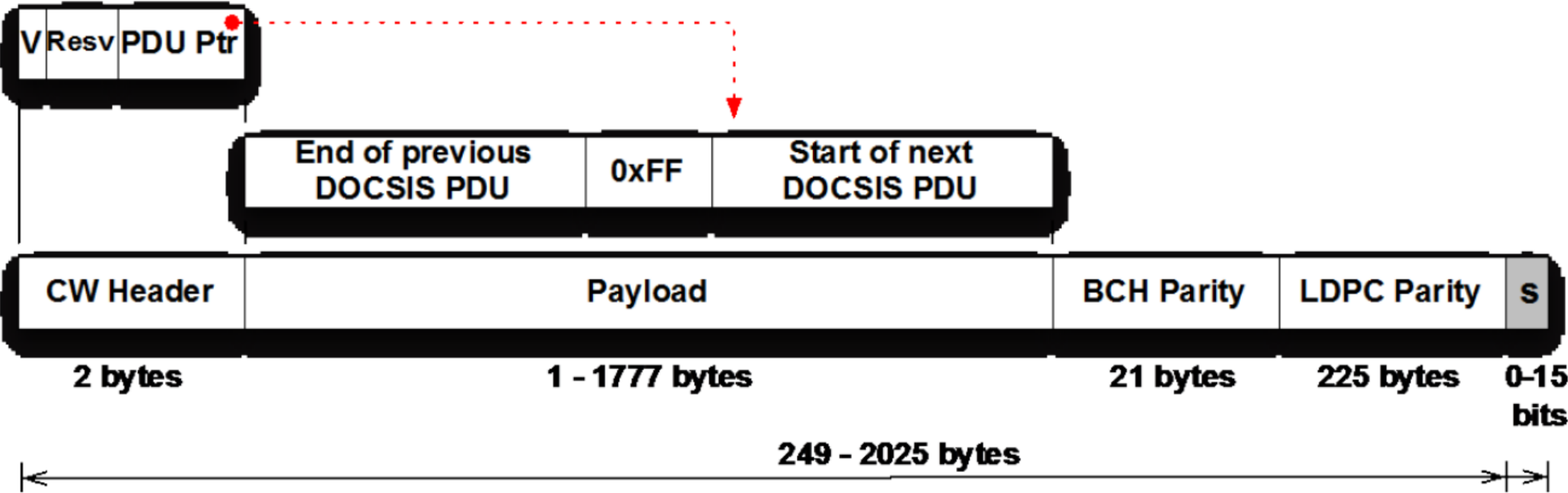


Bridge



Gateway

DOCSIS Frame (w/ LDPC)



Other Notes

- Plant power for nodes and amplifiers is 90v, field supplied
- Leakage, flyover, sweeps
- Unity Gain and RF maintenance
- PNM
- RDK, areas of industry leadership

Excellent Resources

- [Return Path Optimization from Aurora](#)
- [CableLabs](#)
- Arris and Cisco, largest CMTS manufacturers
- [SCTE – Society of Cable and Telecommunications Engineers](#)
- [Spectral Efficiency of DOCSIS 3.1](#)

Distributed Port Design

