Fiber Deep, POD & R Phy Overview

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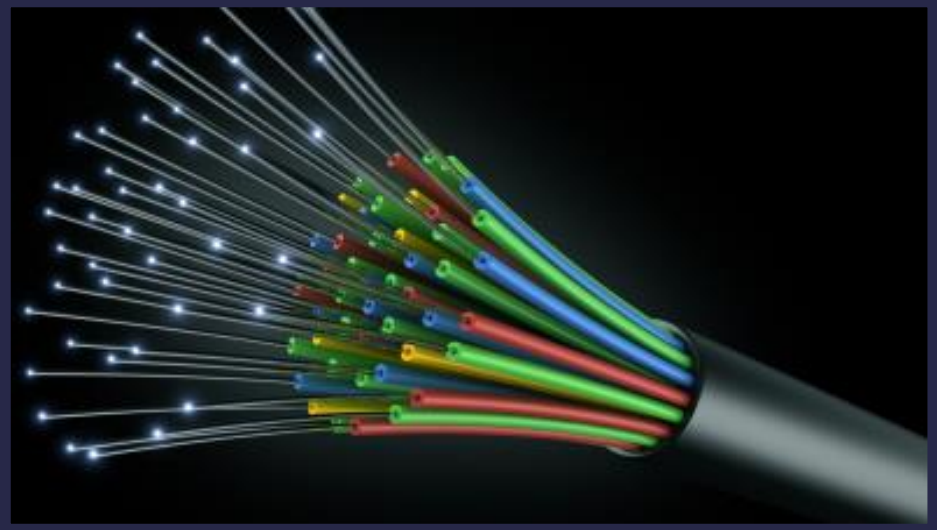
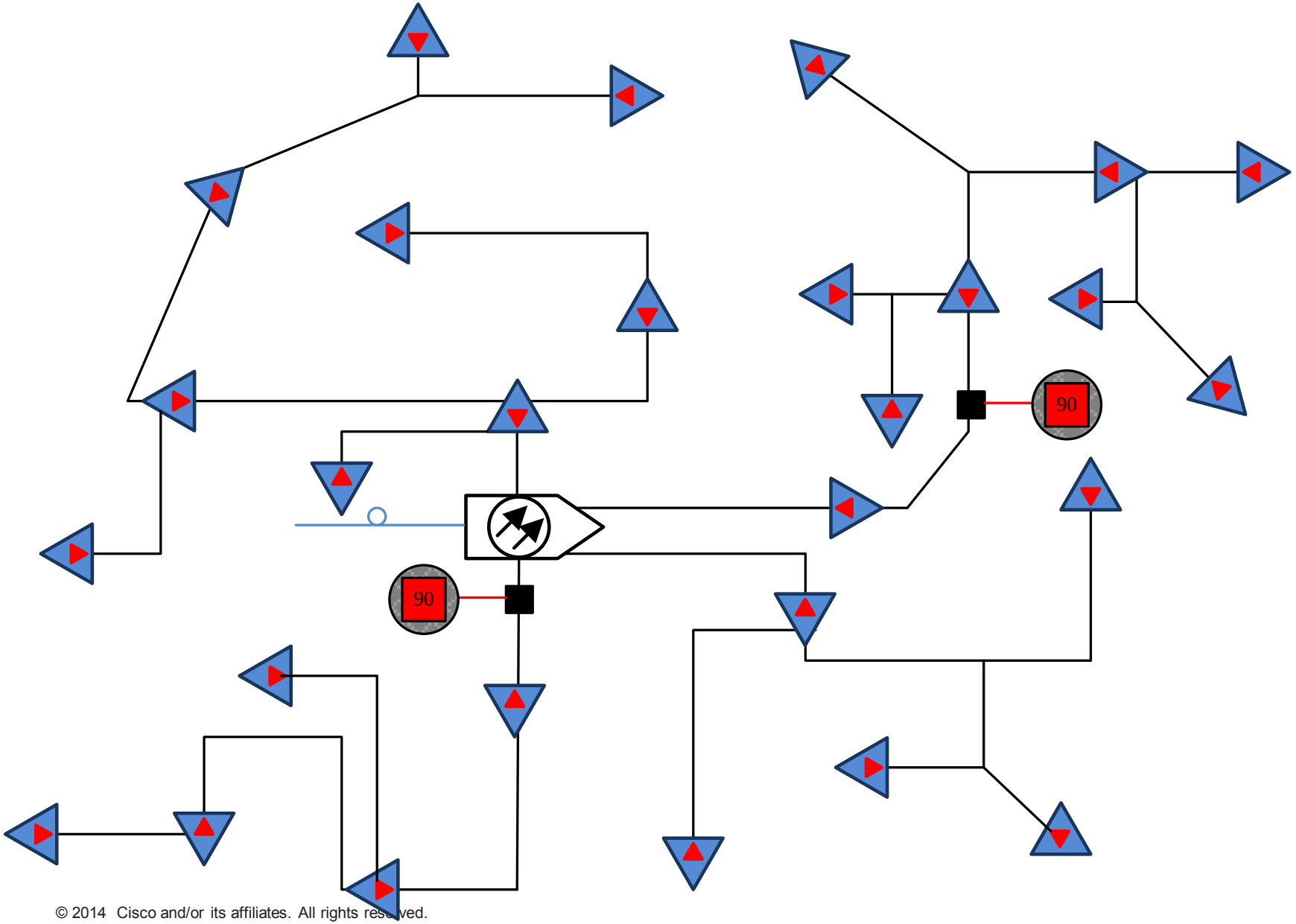


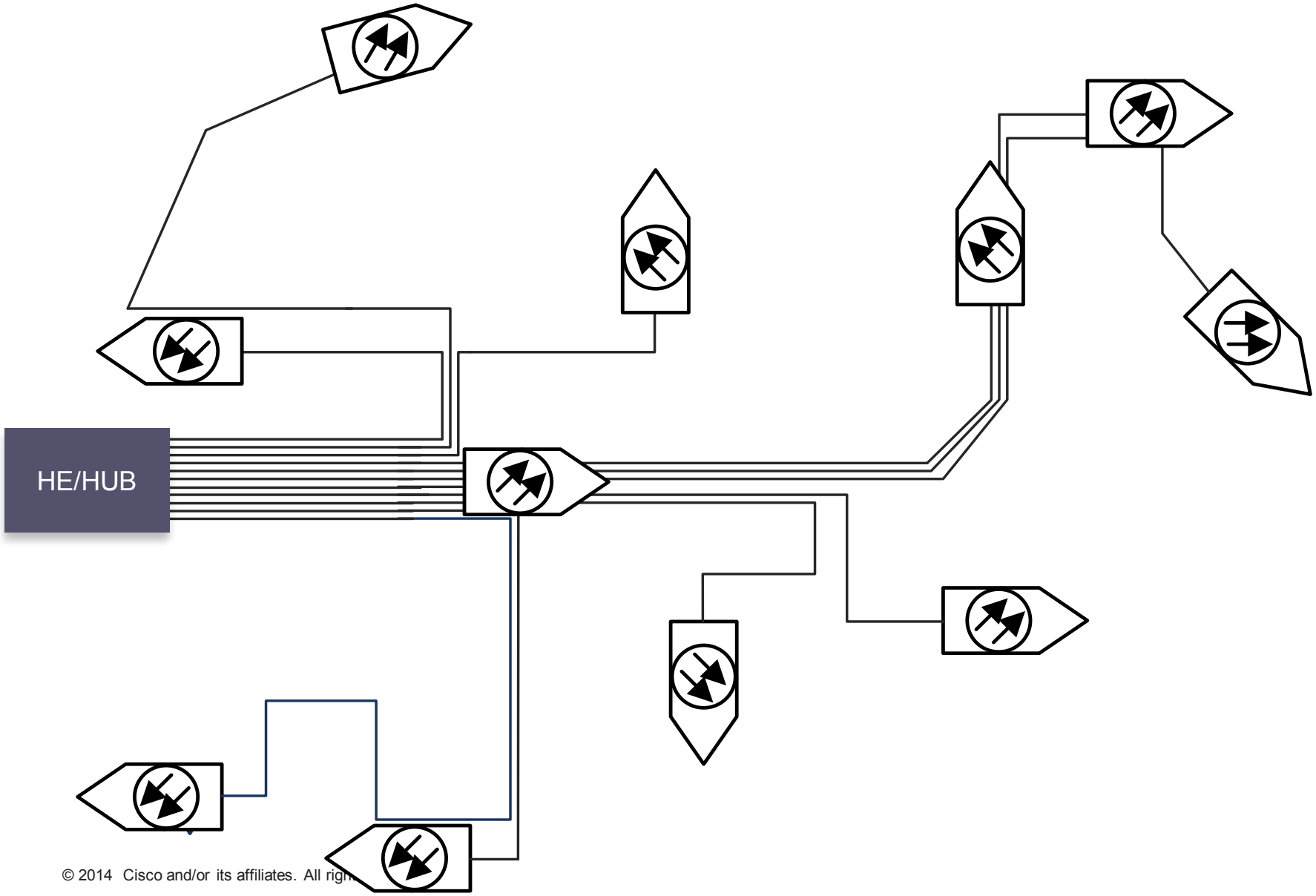
FD Network Modeling

Today HFC – Node plus X Amp Cascade



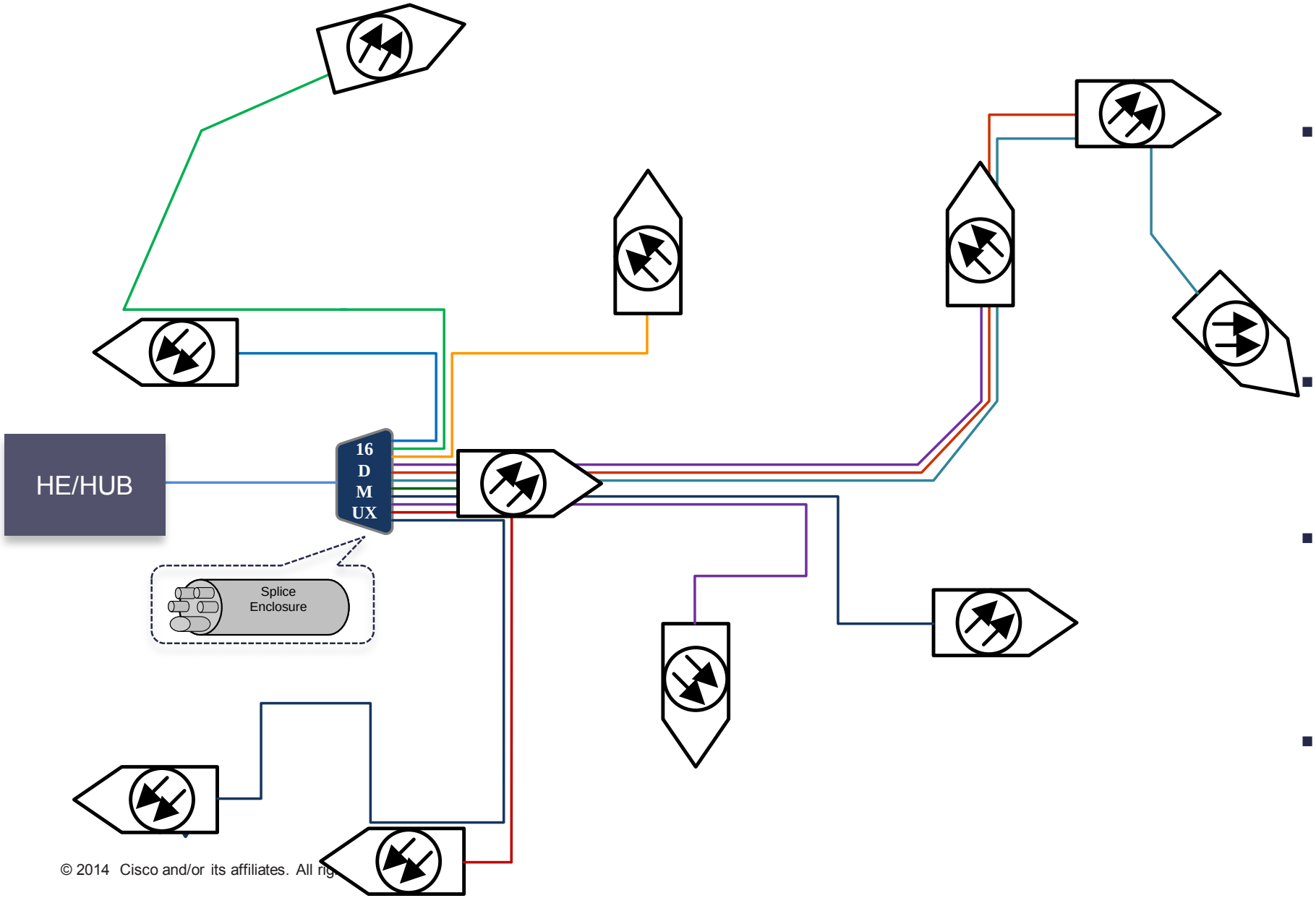
- 1 Node
- 7.49 miles
- 595 homes passed 79 HPM
- 2 power supplies
- 27 RF amplifiers
- 30 total active devices

FD = Increased Nodes = Increased Fiber Demand

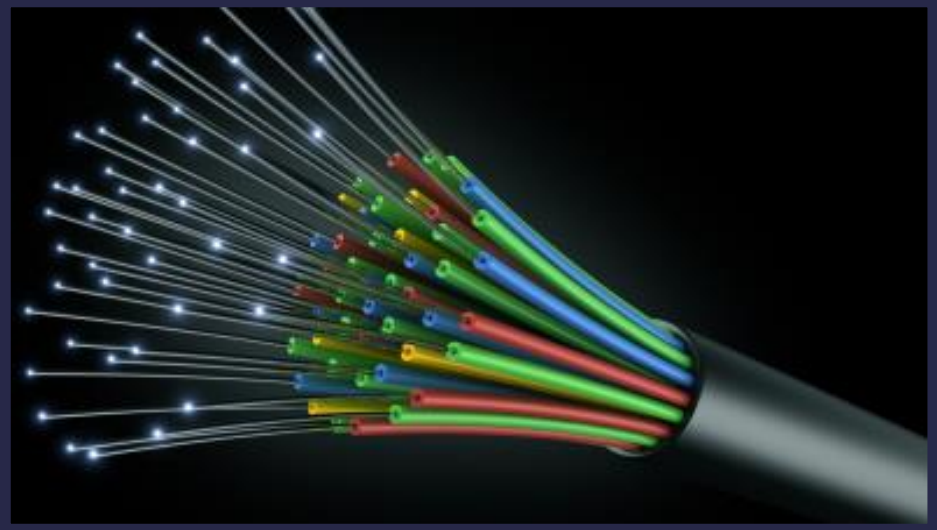


- 1 Node became 11
- Ave 54 homes passed .68 HPM
- 2 power supplies
- 0 RF amplifiers
- 13 total active devices
- Existing node 2 fibers 1 Fwd 1 Rtrn to from HE now needs 22.....or does it?

Sample Fiber Deep Architecture – Forward



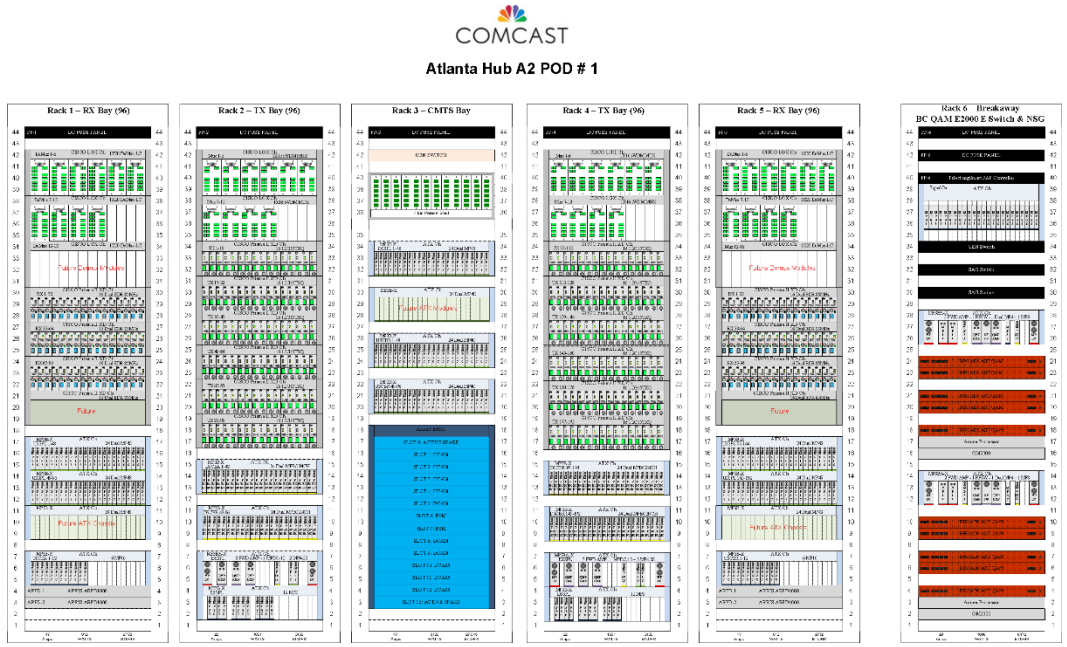
- Full spectrum ITU lasers MUX'd to a single fiber to field enclosure then DMUX'd feeding FD nodes.
- May require construction of fiber from enclosure to new FDNs
- Return mirrors forward, that is it uses dedicated ITU node returns MUXd on a single fiber
- Return concatenation not allowed



POD Overview (Analog)

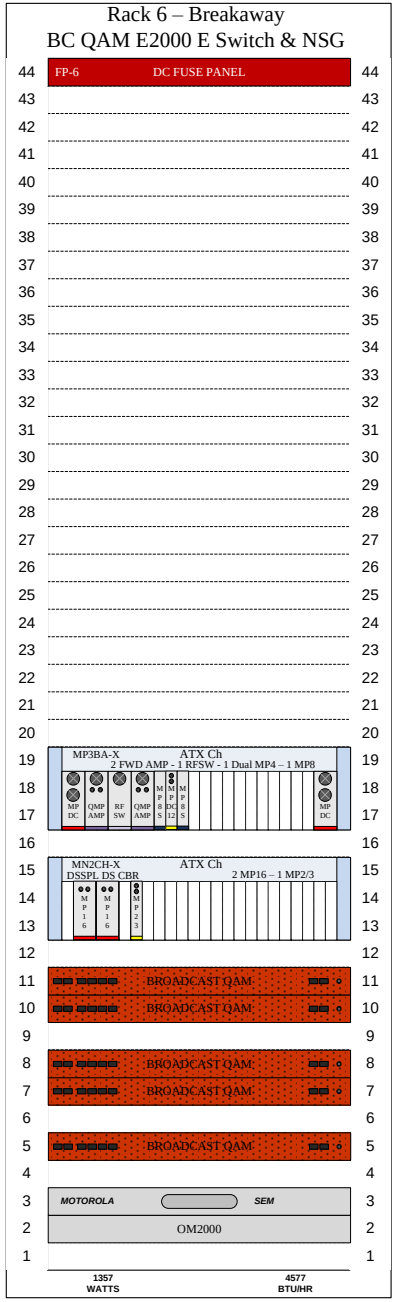
What is a POD

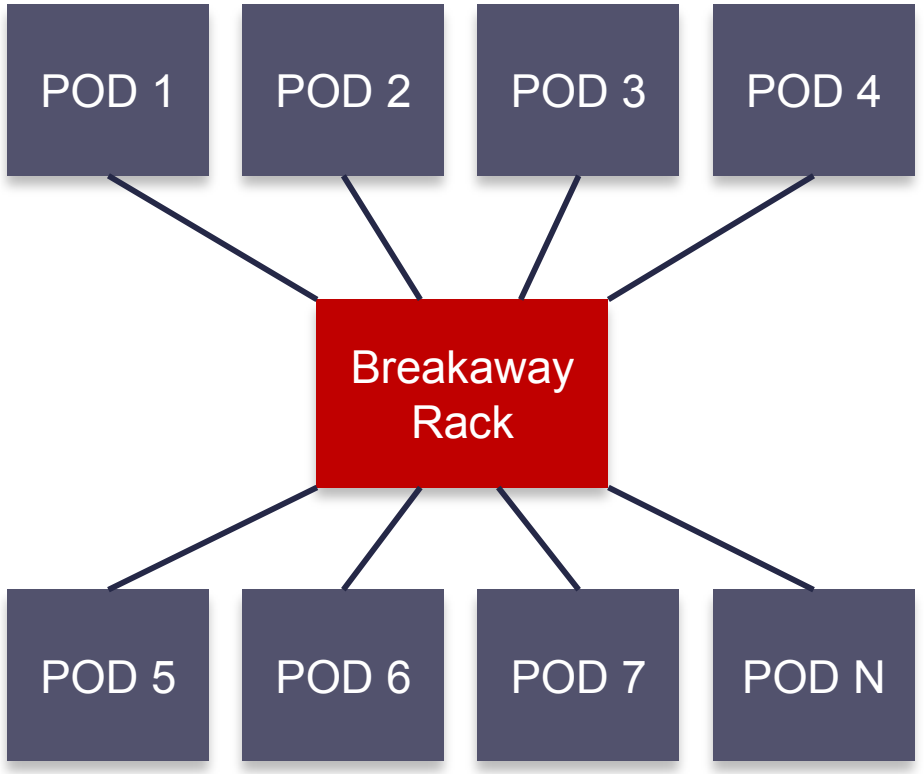
- POD is basically 5 racks of equipment – CMTS, Forward & Return Optics and associated RF splitting combining feeding X number of fiber deep nodes.
- Nodes served from a POD varies depending on vendor CMTS port/service group capacity and HP density
  - Cisco cBR8 56 S/G's POD = 224 to 280 nodes
  - Arris E6000 48 S/G's POD = 192 to 224 nodes
- Driver for POD architecture
  - Standardized architecture
  - Speed deployment process by racking, configuration built off-site then shipped onsite for final assembly
  - Repeatable staging process leads to consistent installations and reduced time on-site



Broadcast Bay

- The Broadcast Bay contains BC QAMs, Forward Amps, RF splitting feeding multiple PODs.
- In non converged VOD markets NSGs added to broadcast bay

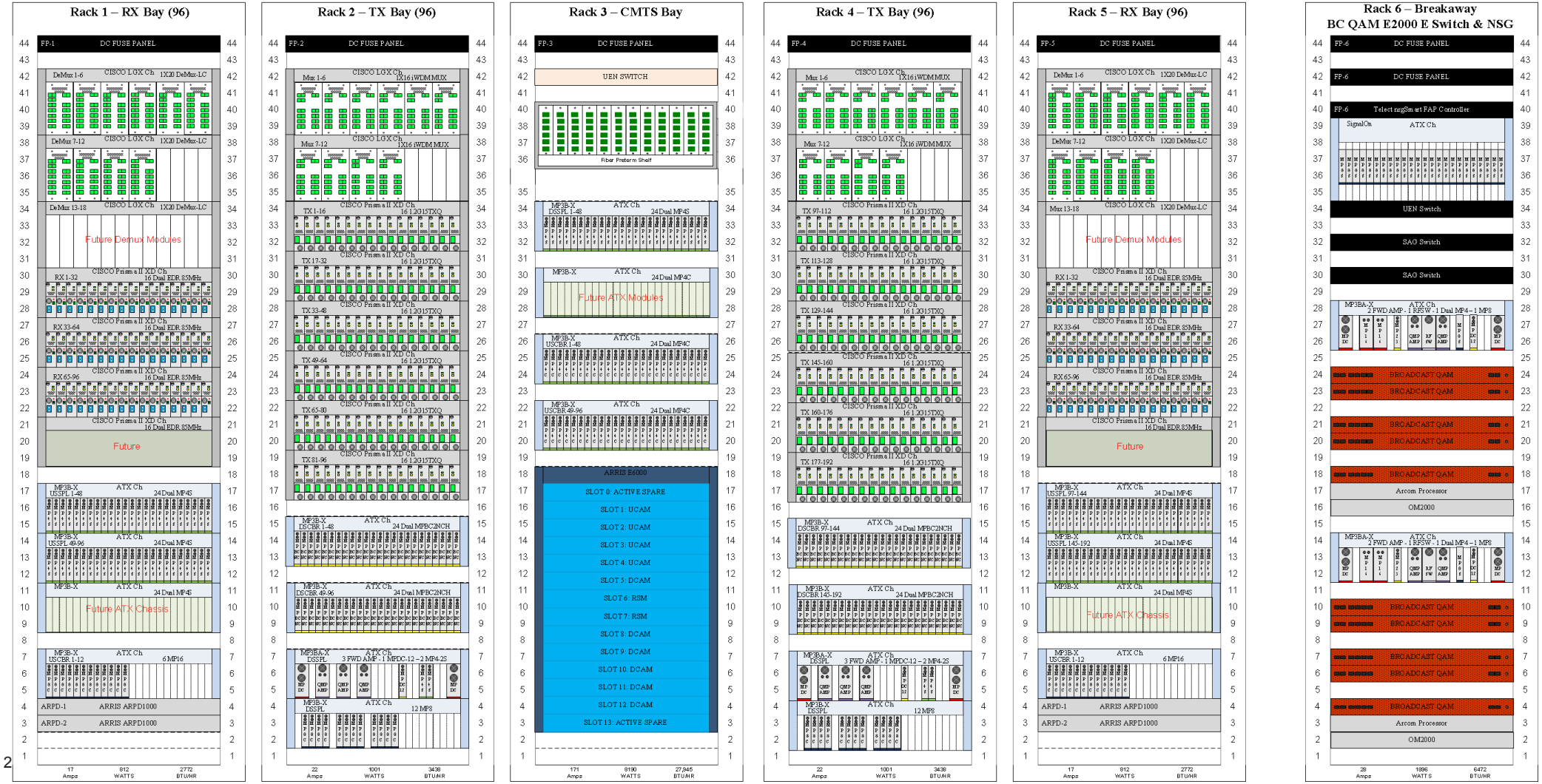




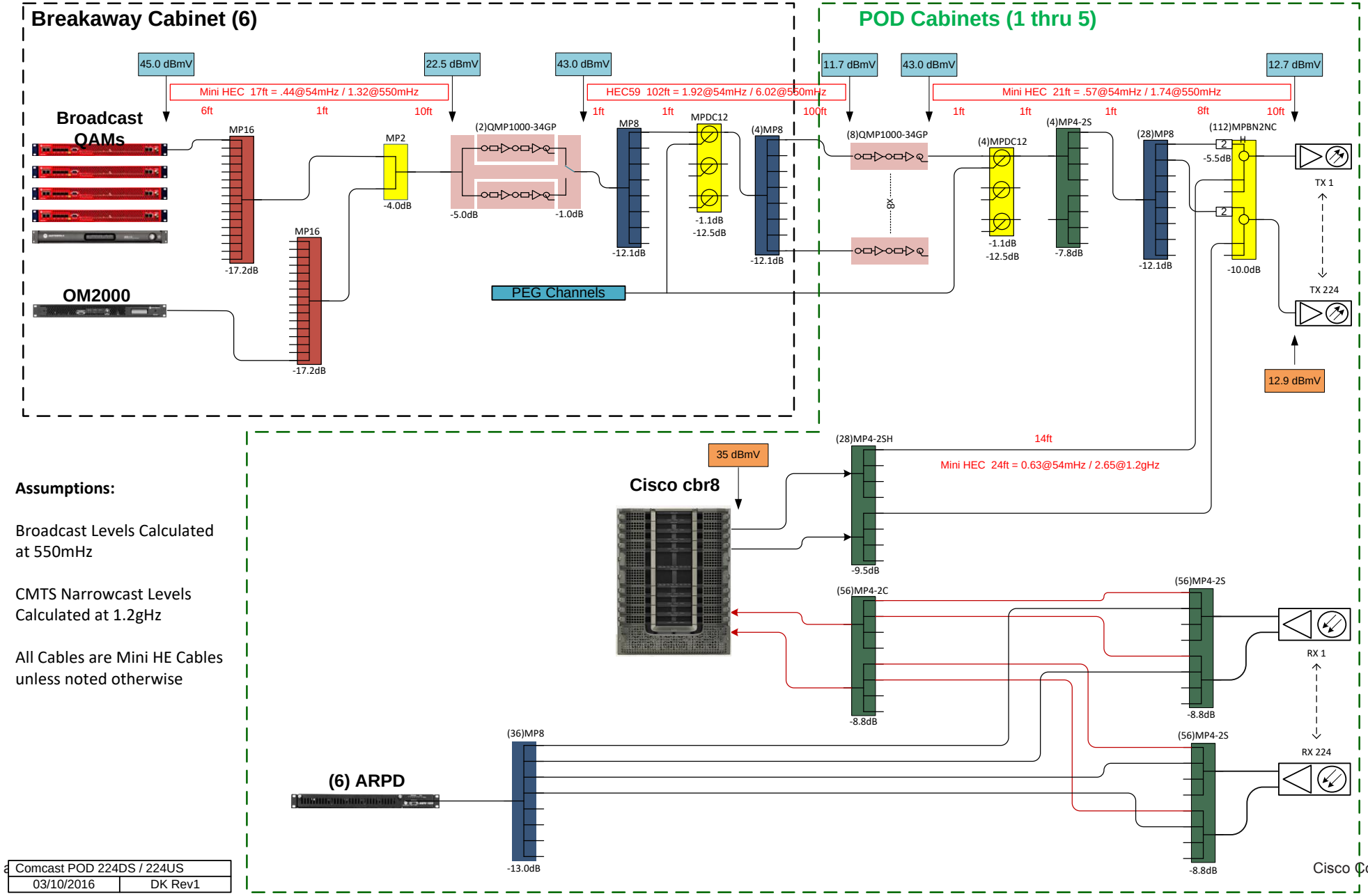
POD with Broadcast or Breakaway Bay

COMCAST

Atlanta Hub A2 POD # 1



cBR-8 224 Node POD Wire Diagram



Assumptions:

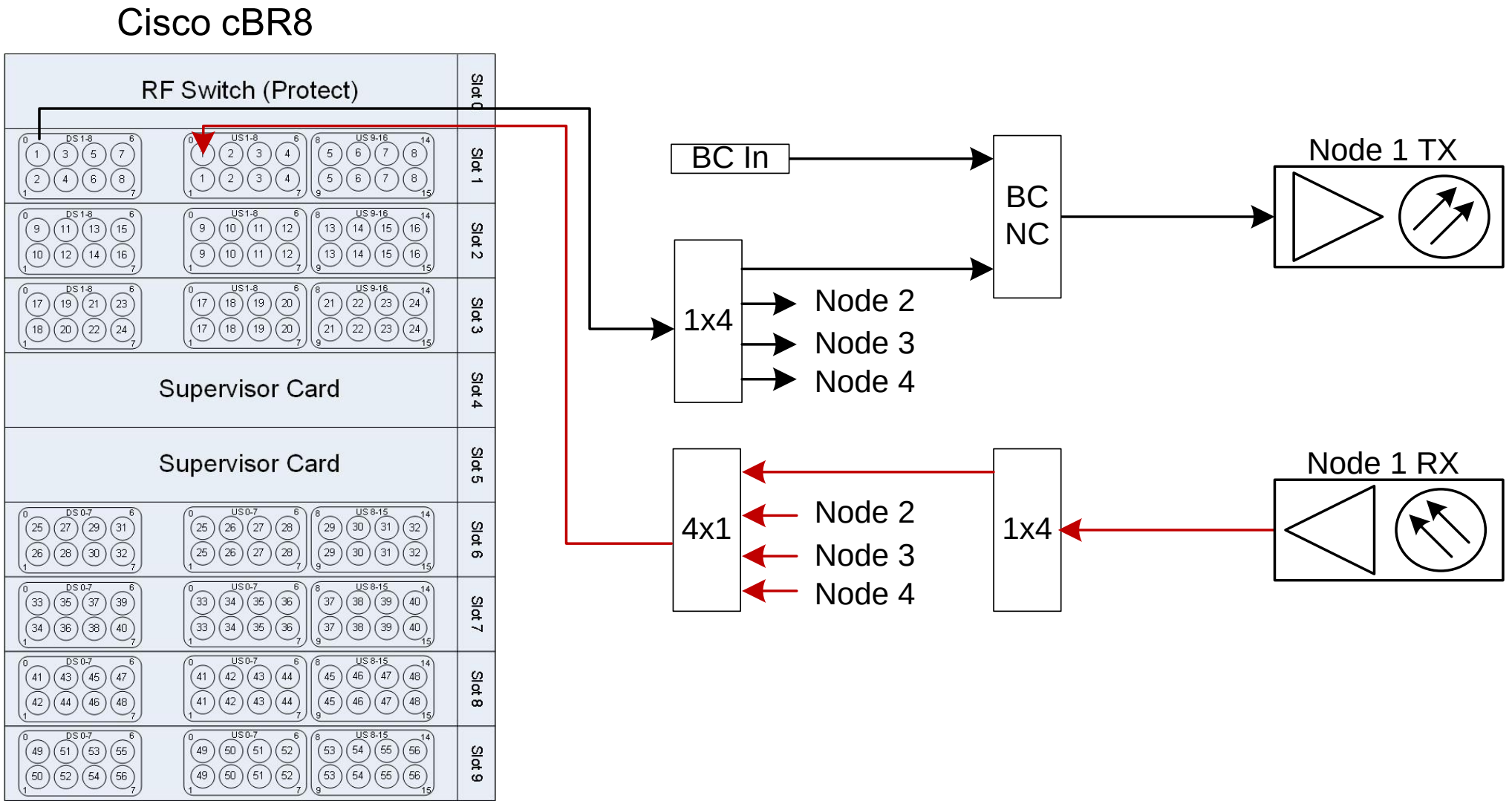
Broadcast Levels Calculated at 550mHz

CMTS Narrowcast Levels Calculated at 1.2gHz

All Cables are Mini HE Cables unless noted otherwise

Comcast POD 224DS / 224US	
03/10/2016	DK Rev1

1:1 SG Map –Dedicated Wavelength Per Node



cBR-8 224 Node POD

Rack 1& 5 Rx Bay

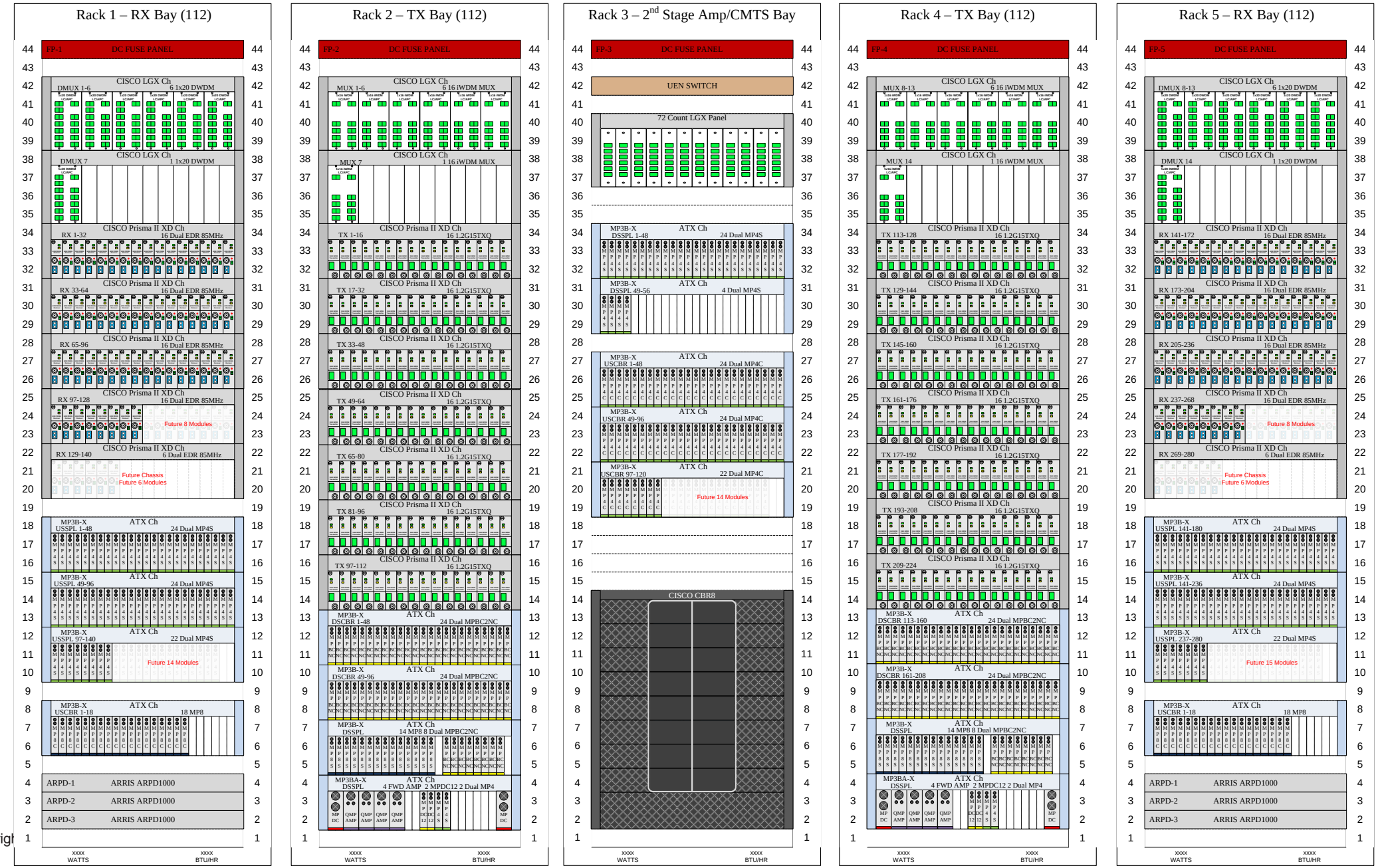
- 7 1x20 2035 DMUX Modules
- 56 Dual EDR RX 112 Node Returns
- 56 Dual MP4 Splitter mods, 18 MP8 combiner mods
- 3 ARPDs

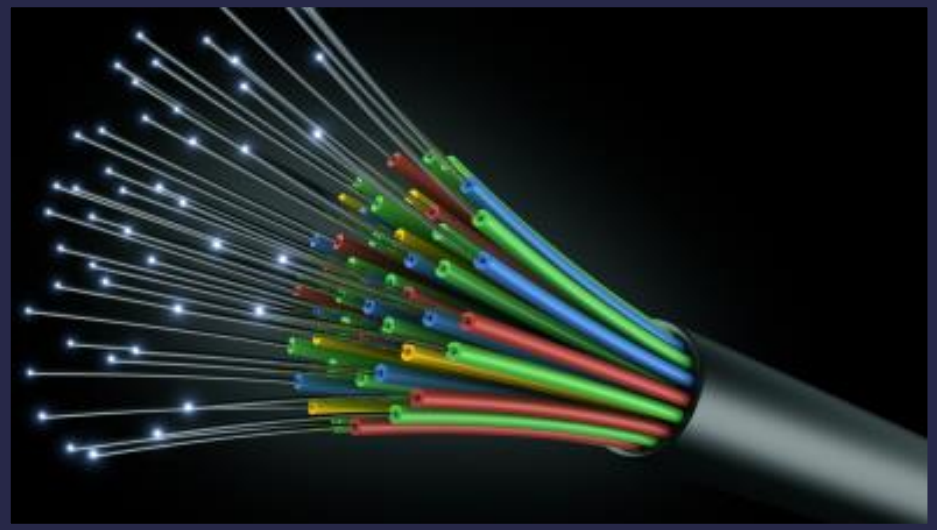
Rack 2&4 TX Bay

- 7 1x16 2062 iWDM Modules
- 112 TX modules
- 56 MP BCNC modules, 14 MP8 splitters, 2 triple MP DC12, 2 dual MP4 and 4 QMP amps

Rack 3 CMTS Bay

- 72 Ct Fiber Patch
- 28 Dual MP4 splitters, 56 Dual MP4 combiner's
- Cisco cbr-8





FD Optical Design

Fiber Deep FLW (Fiber Loss Worksheet)

Fiber Deep Fiber Loss Worksheet

Fiber Sag	1.02
Fiber Storage	1.15
Fiber Tails	150
Version	1.5

Km per Foot	0.0003048
Loss per Km	0.25

Feet to Kilometers Conversion for HE to DeMux			
47013	Feet =	14.330	Km
Kilometers to Feet Conversion			
14.325	Kilometers =	47011	Feet

Feet to Kilometers Conversion			
10000	Feet =	3.048	Km
Kilometers to Feet Conversion			
4.8	Kilometers =	15748	Feet

Field Demux Loss	
1x8	1x16
2.5	3.0

Split Loss
50/50
3.3

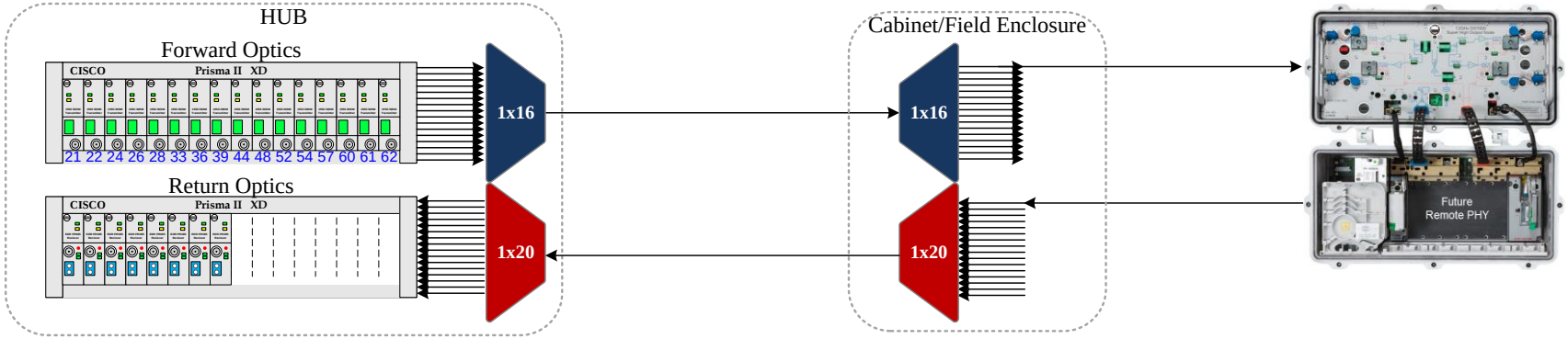
CISCO

Old Node Name	Ports/Mux	ITU #	Transmitter and ITU Ch in Use	Transmitter Number	Return Transmitter ITU Ch.	Receiver Number	Child Node Name	MUX Name	House Counts	Fiber Linear Footage OTN to DeMUX (Parent)	Number of Fiber Segments	Fiber Footage (Sag, Storage, & 1 Tail) HE to DeMUX (Parent)	Fiber Loss HE to Parent Node DeMUX	Linear Footage MUX to Child Node	Number of Fiber Segments	Fiber Footage (Sag, Storage, Tails) DeMUX to Child NODE	Fiber Loss MUX to Child Node	Total Fiber Loss	Vendor Specified Total Optical Power Leaving Hub	Forward Demux	Mux Loss	Atten.	Total Loss - no Splits	HP (Consider Combining HP less than 64)	Manual Selection		Optical Power at Node Receiver	
																									Select Splitter Config	Node Group	No Split	50/50 Split
GAATA2026	1x16	10	Ch 48	10	32	13	A2026	Mux 1.1	53	19,961	8	24,764	1.89	337	1	695	0.053	1.95	7.0	1x16	3.0	3.0	8.0	53	50/50	10	-1.0	-4.3
GAATA2026	1x16	10	Ch 48	10	33	14	A2266	Mux 1.1	63	19,961	11	25,214	1.92	3768	1	4,720	0.360	2.29	7.0	1x16	3.0	3.0	8.3	63	50/50	10	-1.3	-4.6
GAATA2026	1x16	11	Ch 52	11	34	15	A2267	Mux 1.1	97	19,961	11	25,214	1.92	3944	1	4,926	0.375	2.31	7.0	1x16	3.0	3.0	8.3	97	None	11	-1.3	-4.6
GAATA2026	1x16	12	Ch 54	12	35	16	A2268	Mux 1.1	53	19,961	12	25,364	1.93	4193	1	5,218	0.398	2.34	7.0	1x16	3.0	3.0	8.3	53	None	12	-1.3	-4.6
GAATA2026	1x16	13	Ch 57	13	36	17	A2303	Mux 1.1	82	19,961	11	25,214	1.92	3464	1	4,363	0.332	2.27	7.0	1x16	3.0	3.0	8.3	82	None	13	-1.3	-4.6
GAATA2026	1x16	14	Ch 60	14	37	18	A2304	Mux 1.1	72	19,961	11	25,214	1.92	3132	1	3,974	0.303	2.24	7.0	1x16	3.0	3.0	8.2	72	None	14	-1.2	-4.5
GAATA2026	1x16	15	Ch 61	15	38	19	A2305	Mux 1.1	79	19,961	11	25,214	1.92	2642	1	3,399	0.259	2.19	7.0	1x16	3.0	3.0	8.2	79	None	15	-1.2	-4.5
GAATA2026	1x16	16	Ch 62	16	39	20	A2306	Mux 1.1	37	19,961	9	24,914	1.90	1371	1	1,908	0.145	2.06	7.0	1x16	3.0	3.0	8.1	37	50/50	16	-1.1	-4.4
GAATA2026	1x16	16	Ch 62	16	20	21	A2309	Mux 1.1	23	19,961	9	24,914	1.90	1630	1	2,212	0.169	2.08	7.0	1x16	3.0	3.0	8.1	23	50/50	16	-1.1	-4.4
GAATA2026	1x16	1	Ch 21	17	21	22	A2310	Mux 1.1	88	19,961	10	25,064	1.91	2836	1	3,627	0.276	2.20	7.0	1x16	3.0	3.0	8.2	88	None	17	-1.2	-4.5
GAATA2026	1x16	2	Ch 22	18	22	23	A2311	Mux 1.1	121	19,961	10	25,064	1.91	1150	1	1,649	0.126	2.05	7.0	1x16	3.0	3.0	8.0	121	None	18	-1.0	-4.3
GAATA2026	1x16	3	Ch 24	19	23	24	A2312	Mux 1.1	99	19,961	9	24,914	1.90	359	1	721	0.055	1.96	7.0	1x16	3.0	3.0	8.0	99	None	19	-1.0	-4.3
GAATA2026	1x16	4	Ch 26	20	24	25	A2313	Mux 1.1	42	19,961	10	25,064	1.91	1414	1	1,959	0.149	2.07	7.0	1x16	3.0	3.0	8.1	42	50/50	20	-1.1	-4.4
GAATA2026	1x16	4	Ch 26	20	25	26	A2329	Mux 1.1	53	19,961	12	25,364	1.93	3843	1	4,808	0.366	2.31	7.0	1x16	3.0	3.0	8.3	53	50/50	20	-1.3	-4.6
GAATA2026	1x16	5	Ch 28	21	26	27	A2330	Mux 1.1	101	19,961	12	25,364	1.93	3823	1	4,784	0.365	2.31	7.0	1x16	3.0	3.0	8.3	101	None	21	-1.3	-4.6
GAATA2026	1x16	6	Ch 33	22	27	28	A2331	Mux 1.1	50	19,961	11	25,214	1.92	2375	1	3,086	0.235	2.17	7.0	1x16	3.0	3.0	8.2	50	None	22	-1.2	-4.5
GAATA2026	1x16	7	Ch 36	23	28	29	A2332	Mux 1.1	26	19,961	12	25,364	1.93	3749	1	4,698	0.358	2.30	7.0	1x16	3.0	3.0	8.3	26	50/50	23	-1.3	-4.6
GAATA2026	1x16	7	Ch 36	23	29	30	A2333	Mux 1.1	35	19,961	12	25,364	1.93	3590	1	4,511	0.344	2.29	7.0	1x16	3.0	3.0	8.3	35	50/50	23	-1.3	-4.6

Combined Node Group Validation		NCP Information
Node Group	Combined HP	DOCSIS Service Group
13	82	4
14	72	5
15	79	5
16	60	5
17	88	5
18	121	6
19	99	6
20	95	6
21	101	6
22	50	7
23	61	7
24	62	8
25	69	8
26	111	8
27	87	8
28	115	9
29	116	9
30	68	9

Example Optical Budget – Passive

Cisco SE	Chuck Donoghue			LGX	Fiber	Node Link Forward			Fiber	CAS	Node	Total
				16DWDM	Launch				Loss@	16iWDM	dBm	km
Node #	TX Model	TX ITU #	TX Pwr	Loss 3.0	Per ITU dBm	Fiber Ft.	Miles	Kilo-Meters	dB/km 0.23	Loss 3.2	Rec. Pwr.	Primary
Enter Data	Enter Data	Enter Data	Enter Data	Enter Data		Enter Data				Enter Data		
	SQAM-FS	XX	10	3.0	7.0	68,000	12.88	20.7	4.8	3.2	**-1.0**	20.7
	SQAM-FS	XX	10	3.0	7.0	82,000	15.53	25.0	5.8	3.2	**-2.0**	25.0
	SQAM-FS	XX	10	3.0	7.0	97,000	18.37	29.6	6.8	3.2	**-3.0**	29.6
	SQAM-FS	XX	10	3.0	7.0	111,000	21.02	33.8	7.8	3.2	**-4.0**	33.8
	SQAM-FS	XX	10	3.0	7.0	125,000	23.67	38.1	8.8	3.2	**-5.0**	38.1
	SQAM-FS	XX	10	3.0	7.0	140,000	26.52	42.7	9.8	3.2	**-6.0**	42.7
				LGX	Fiber	Node Link Return			Fiber	CAS	EDR	Total
				20DWDM	Launch				Loss@	20DWDM	dBm	km
Node #	TX Model	TX ITU #	TX Pwr	Loss 4.0	Per ITU dBm	Fiber Ft.	Miles	Kilo-Meters	dB/km 0.23	Loss 4.0	Rec. Pwr.	Primary
	EDR	XX	5	4.0	1.0	68,000	12.88	20.7	4.8	4.0	**-7.8**	20.7
	EDR	XX	5	4.0	1.0	82,000	15.53	25.0	5.8	4.0	**-8.8**	25.0
	EDR	XX	5	4.0	1.0	97,000	18.37	29.6	6.8	4.0	**-9.8**	29.6
	EDR	XX	5	4.0	1.0	111,000	21.02	33.8	7.8	4.0	**-10.8**	33.8
	EDR	XX	5	4.0	1.0	125,000	23.67	38.1	8.8	4.0	**-11.8**	38.1
	EDR	XX	5	4.0	1.0	140,000	26.52	42.7	9.8	4.0	**-12.8**	42.7

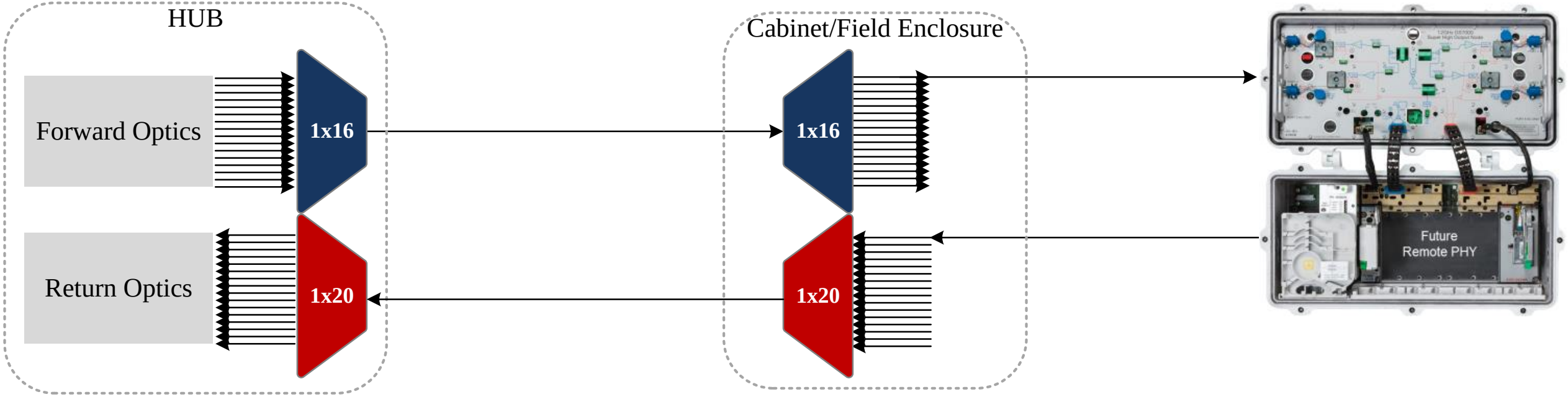


Nodes fed off 1x2 Split reduces link distance to those nodes by approx 15km

Basic FD Design ~ Dedicated Wavelength Per Node

224 POD Config

- 16 Node Config, each node has dedicated forward wavelength
- Smaller node group areas use 1x8
- Dedicated Typically used in high density areas

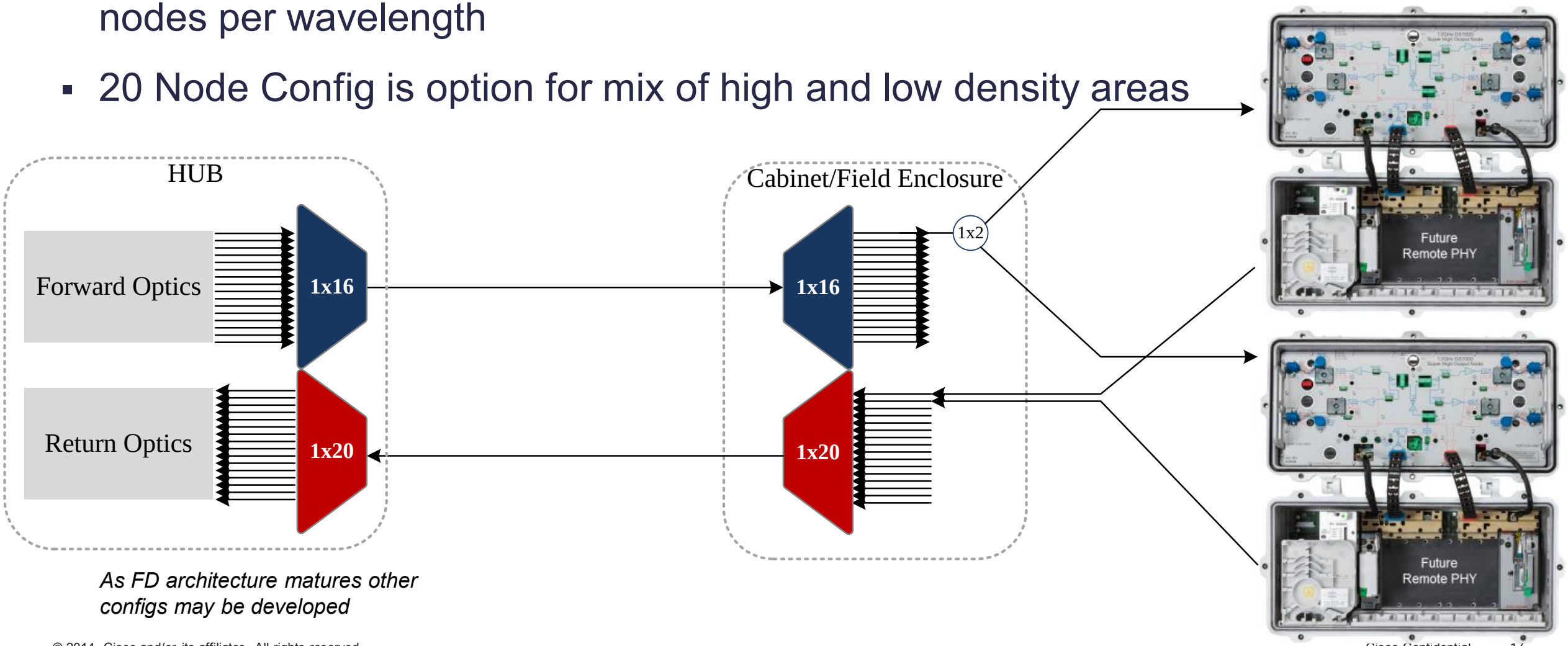


As FD architecture matures other configs may be developed

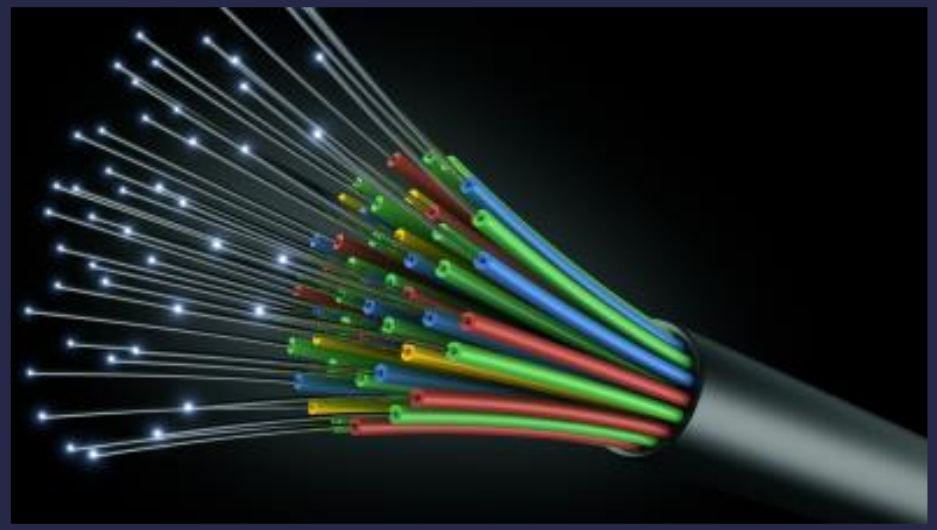
Alternative FD Design ~ Split WL Feeding 2 Nodes

280 POD Config

- 20 Node Config, 25% of forward wavelengths are optical split feeding two nodes per wavelength
- 20 Node Config is option for mix of high and low density areas



As FD architecture matures other configs may be developed



Remote Phy Overview (Digital)

Deployment Scenarios

Our Baseline – Typical Analog FD Architecture

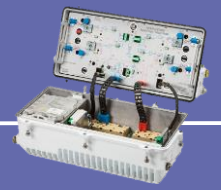
I-CCAP
cBR-8 + HFC Node

RF

Prisma II
Analog optics

1550nm DWDM
(16 wavelengths)

GS7000 Analog FDN



FST Taps

10GE P2P FD Architecture

Distributed Access
cBR-Core + R-PHY Node

10GE

Ethernet
Switch

10 GE link
(DWDM - 40
wavelengths)

GS7000 R-PHY FDN

FST Taps

Protected Transport with Spine Leaf Switch Array 10GE P2P FD Architecture

Centralized Core
cBR-Core + R-PHY Node

10/100GE

Switch Route

100/200
GE

Hub 1

Hub 2

Hub 3

Ethernet
Switch

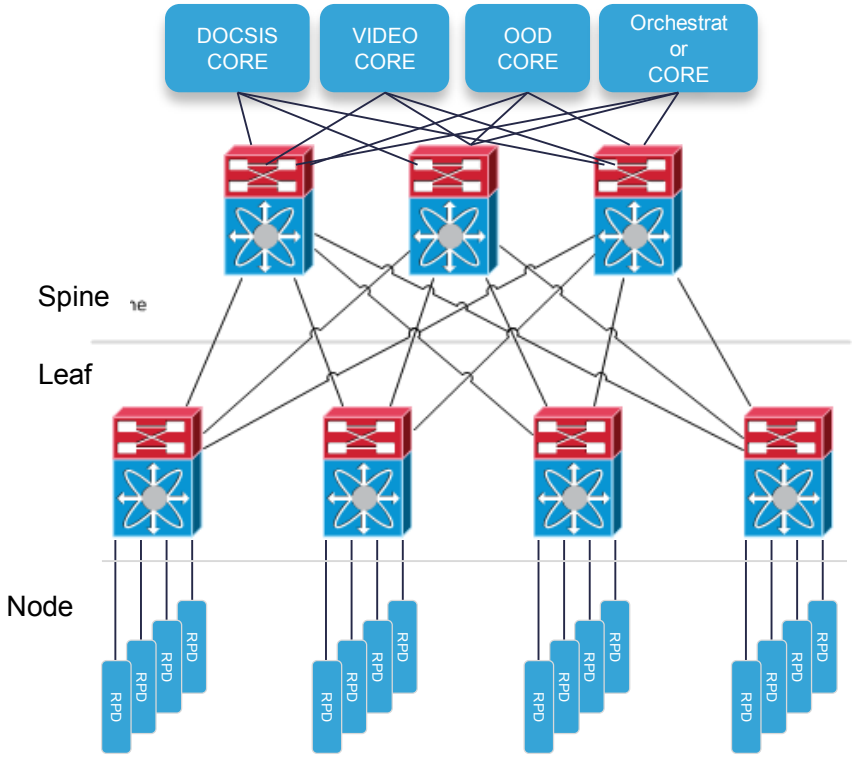
10 GE link
(DWDM - 40
wavelengths)

GS7000 R-PHY FDN

FST Taps

Converged Interconnect Network (CIN) Ethernet Switch Complex “Leaf-Spine Topology”

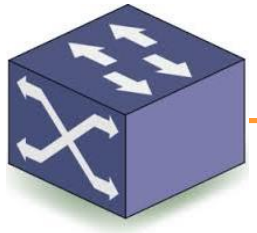
- Creates connectivity between R-PHY cores and RPDs.
- Leaf-spine is a two-layer network topology composed of leaf switches and spine switches.
- The **Spine layer** (made up of switches that perform routing) is the **backbone** of the network, where every Leaf switch is interconnected with each and every Spine switch.
- The **Leaf layer** consists of **access** switches that connect to devices like servers, edge routers and Remote PHY devices.



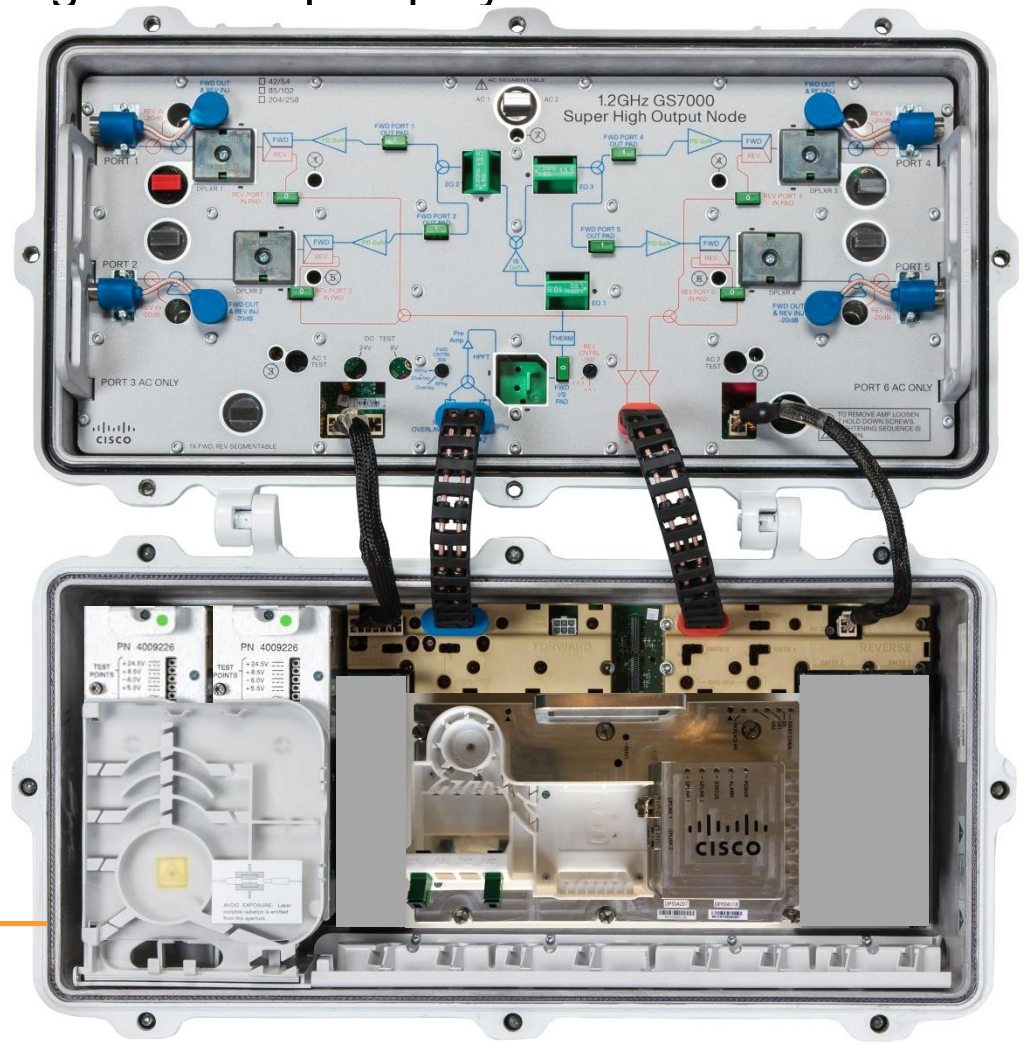
GS7000 1.2GHz Remote PHY Node

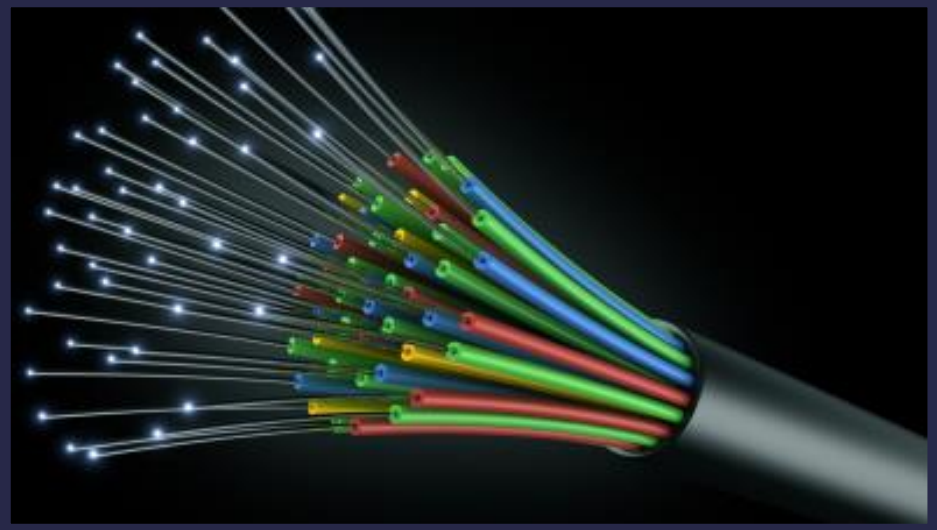
The GS7000 Remote PHY node is a hardened outdoor enclosure for networks tasked with delivering high-speed data, video and voice services over coax. Remote PHY device (RPD) and connects with Core CMTS software to support evolving fiber deep deployments while allowing for future network growth

- The RPD compatible with BAU and FD GS7000 nodes
- Full spectrum 1.2GHz
- Full Video support and overlay option
- Dual 10G Interfaces (Redundancy & Chaining)
- Ethernet Switch embedded
- Remote & Local Configuration & Monitoring
- MACsec supported
- USB Interface
- Auto-recognition
- GEO Tagging for device, Node



10GE





Cisco 1.2GHz HD XD Platform for Fiber Deep Deployments

1.2G Fiber Deep Product Portfolio

SQAM & LRMW TX

SQAM-FS
- Output power = 10dBm
- Supports mix of SC QAMs and OFDM to 1.2G
- ITU 40 and 16 iWDM plans Typical transmit 10-50km

NEW HD LRMW
- Output power = 12.5dBm
- Supports mix of analog, SC QAMs and OFDM to 1.2G
- 16 iWDM plans
- Typical transmit +70km

Enhance Digital Return

- TX/RX supports 85MHz – no hardware change
- Best in industry NPR >55 Peak

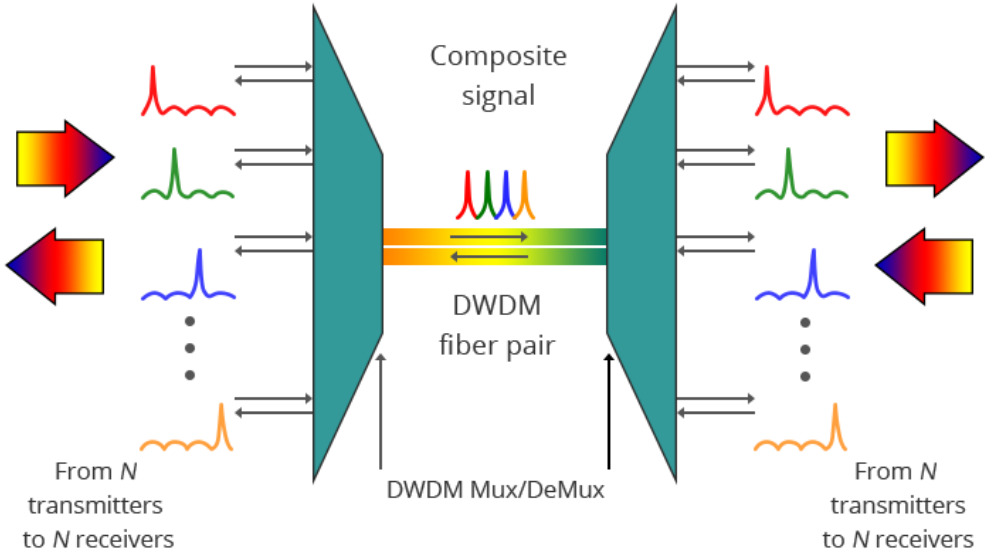
GS7000 FD SHO Node

- Designed for Super High Output Fiber Deep Architectures – 64dBmV output at 1.218GHz
- EDR – Enhanced Digital Return, 85MHz
- Redundant and load sharing Power Supplies
- Supports splits of 42/54 and 85/102
- Hooks for next Gen RPHY

1.25GHz Taps - FST

- 1.25G Full Solutions Tap (FST) and Passives
- Signal conditioning Inverse EQs, Forward EQs & Rev Attn

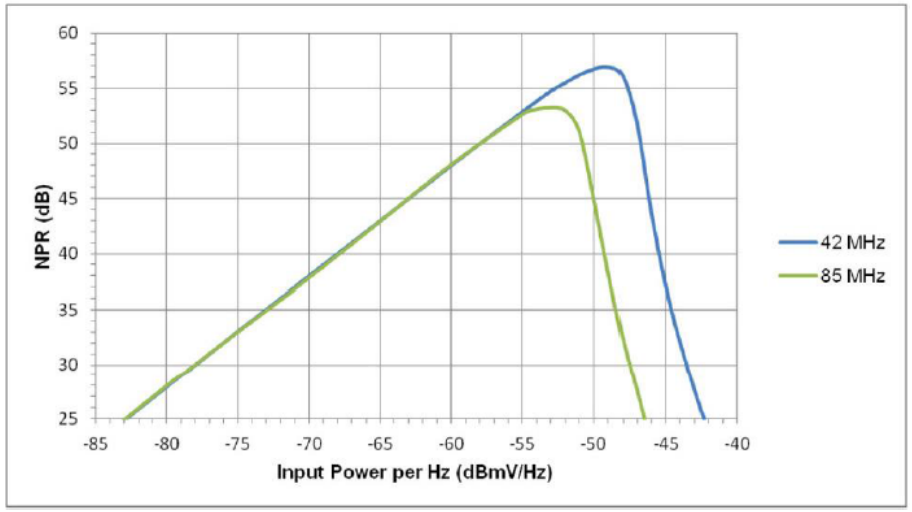
1.2Ghz Full Spectrum Multiwave



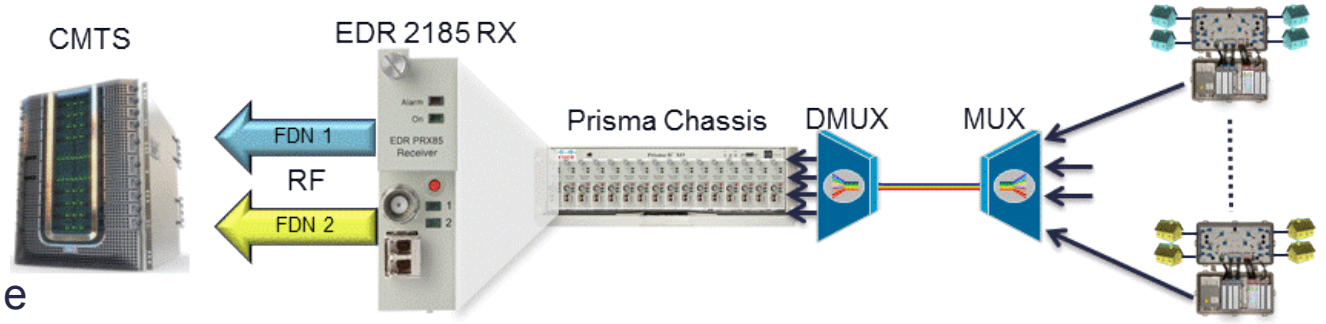
- Full Spectrum Multiwave is a family of intelligent mapped forward linear analog lasers that are muxed on single fiber. The transmitters have a 1.2 GHz passband to permit the inclusion high order modulation types consistent with DOCSIS 3.1
- Intelligent Mapped “iWDM” is a 16 wave plan that is mapped to help mitigate four wave mixing causing performance degradations
- Product Family
  - SQAM-FS 1.2Ghz 10dBm DFB Tx, typical link 10 to 50km
  - LRMW 1.2GHz 12.5dBm ExMod Tx, typical link 50 to 90km
  - 17 & 21 Gain Flat EDFAs, chassis and node based
  - 1x4, 1x8,1x16 Optical passives, LGX and field cassette

Enhanced Digital Return

EDR is a next generation digital return platform expands the functionality of Cisco Nodes by increasing the performance, reach, and efficiency of the reverse path transmissions



- EDR TX Overview
  - Best In Class NPR performance 50 NPR >10dB Dynamic Range
  - Supports D3.1 85MHz upstream bandwidth
  - 45 DWDM &18 CWDM laser options (OPMs)
  - 1:1 and 2:1 Digital TX options (2:1 most common)
- EDR RX Overview
  - Dual module – supports two nodes per module or one 2x seg node
  - Segment node via software from the headend
  - Improved density – 32 RF returns in 3 RU
  - Two Rx OPM options – Up to 30dB budget
  - Embedded in-band monitoring of node TX
  - Fault isolation – minimize node troubleshooting time

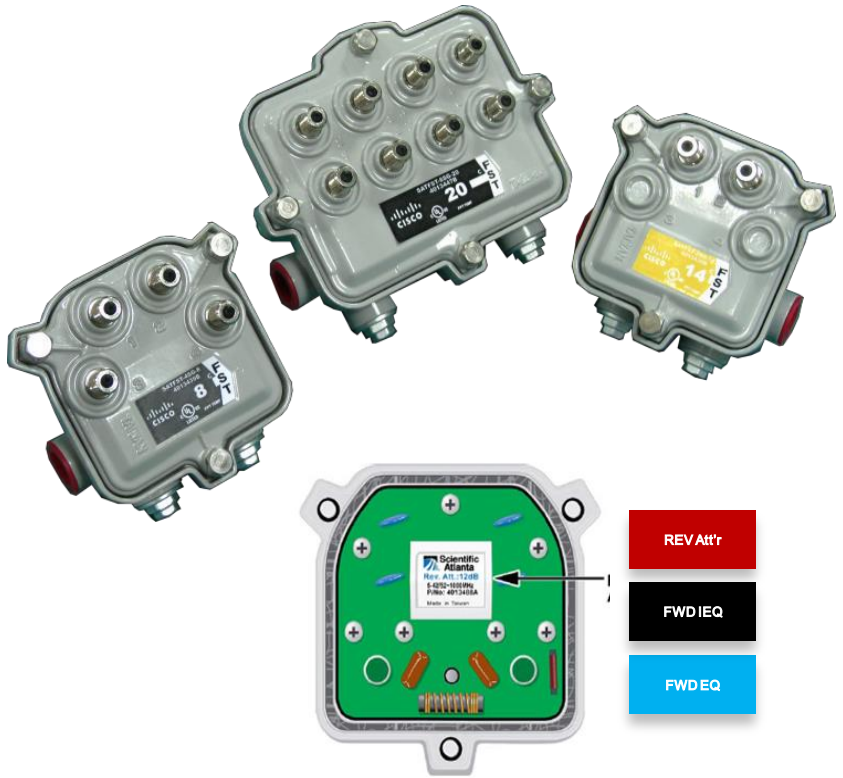


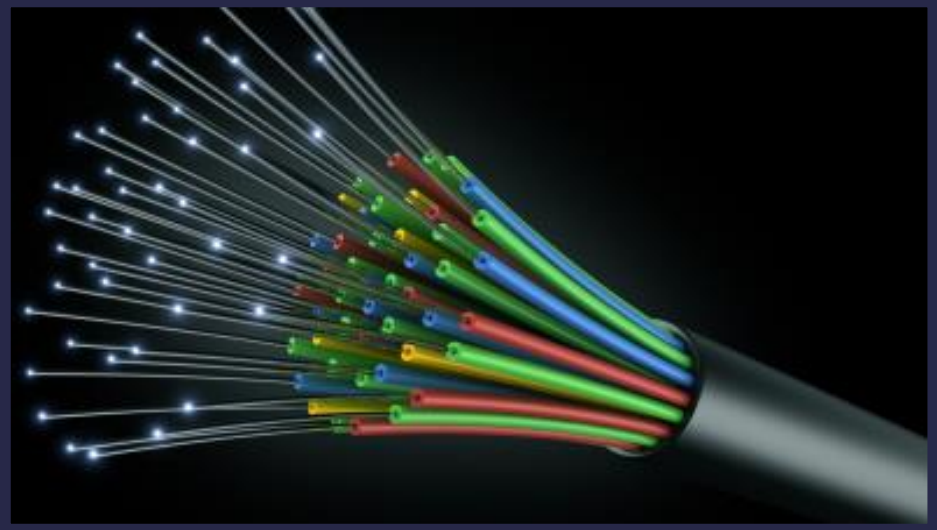
1.25GHz Flexible Solutions Tap (FST)

Equalizing the forward band and controlling ingress and noise with signal conditioning at the tap helps solve these design challenges. Therefore cable equalizer or cable simulator plug-ins are used to maintain forward tilt and return transmission level specifications at all tap locations

Plug-ins

- **Forward Inverse EQs** – used to increase the loss at higher frequency and minimal loss at low frequency. Typically used at tap locations with high level RF signals, closest to nodes/amps
- **Forward EQs** - used to increase the loss at lower frequency and minimal loss at high frequency. Typically used at locations near the end of the feeder line
- **Reverse Attenuator's** – used to increase the reverse path tap loss with minimal forward loss. *Using FEQs reduces need for Rev Attn'r*





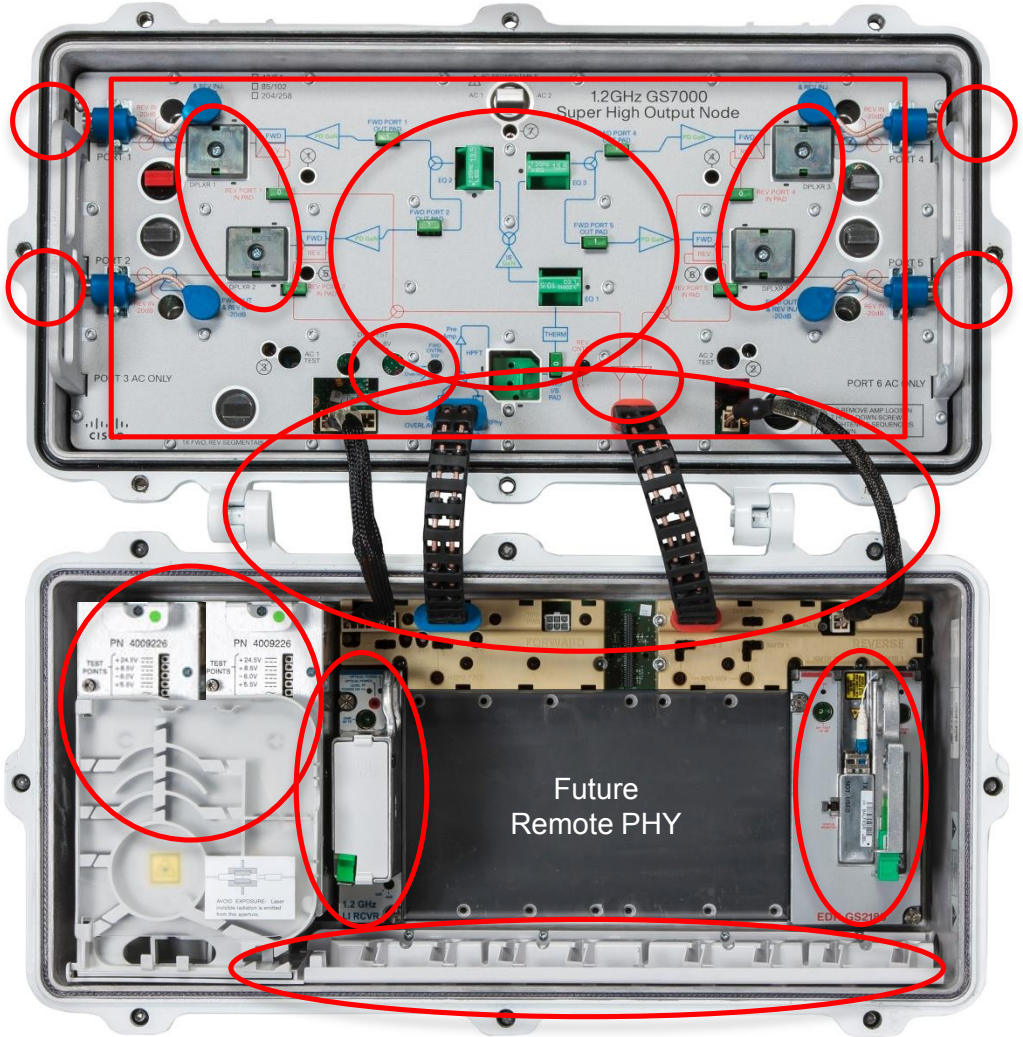
GS7000 Remote Phy Node

GS7000 1.2GHz High Output Fiber Deep Node

GS7000 SHO Node is the latest-generation 1.218GHz optical node platform designed for todays fiber deep node zero architectures and tomorrows next generation technologies such as Remote PHY

Features:

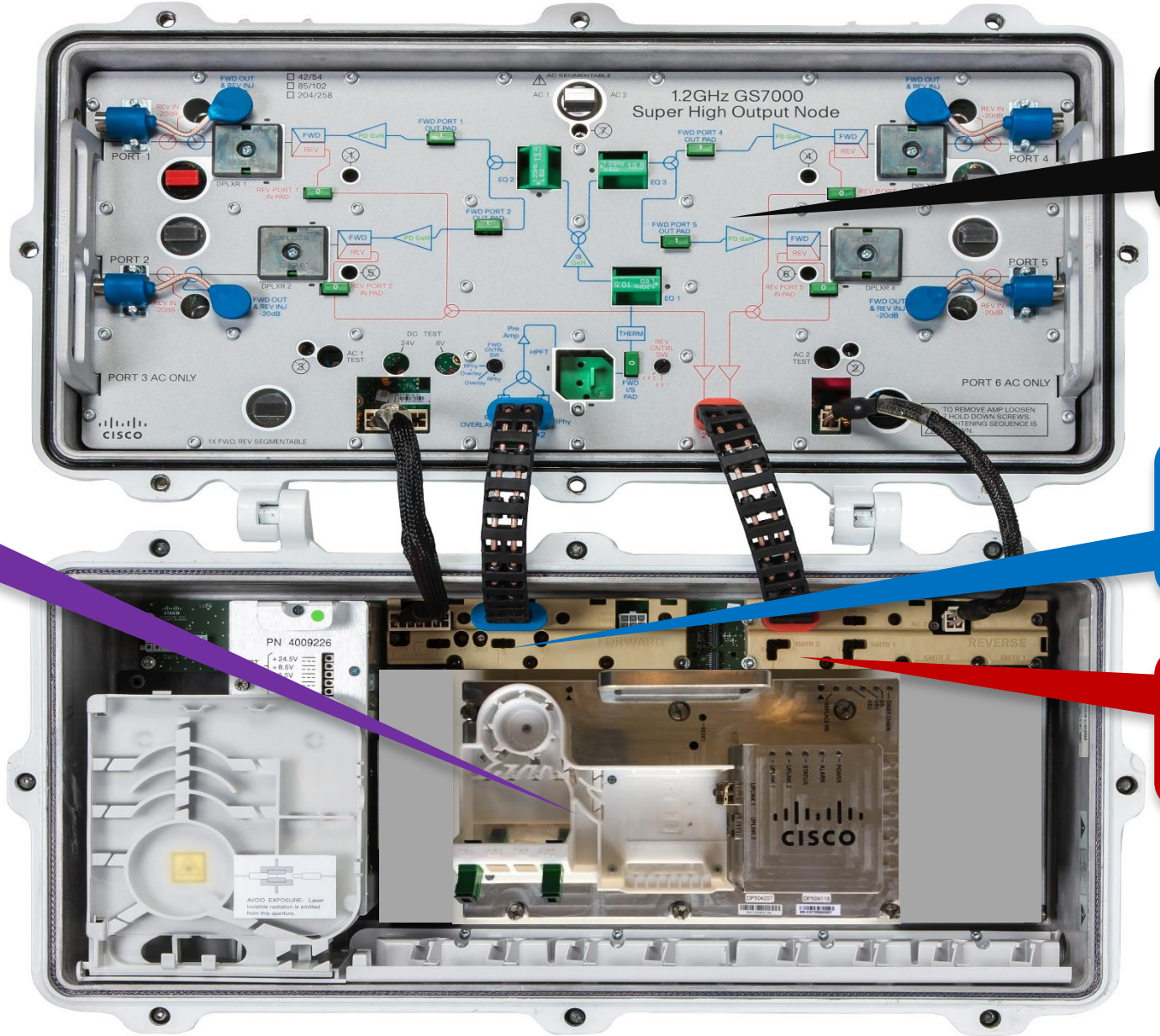
- Easy accessible plug-in diplexers, change freq split in minutes
- Tech friendly forward control switch to change input to launch amp to RX RF (Overlay) or RPHY or RPHY with Overlay
- RF module pre-stuffed at factory with Fwd pads and Eqs, Fwd setup is 1 pad at Rx & 2 pads EDR TX
- Spring-loaded seizure assemblies to allow coaxial connectors to be installed or removed without removing amp module
- Onboard three-state reverse switch (on, off, and 6 dB) allows each reverse input to be isolated for noise and ingress troubleshooting (requires status monitor or local control module)
- Forward and Reverse Path Silk-screened onto module cover



Features:

- Pinch proof cable assembly, never need to add/move for other configurations
- New high efficiency load sharing pwr supply
- 2:1 85MHz Digital TX (EDR), 18 CWDM 45 DWDM OPM wavelengths
- Low Input High Gain Rx -8dBm to -2dBm
- Fiber management tray and connector storage track provides easy access and storage of fiber connectors
- Optional extended fiber tray for optical passives or fiber splices

Node Setup RF Setup



RF module preset at factory. Pads EQs, cabling pre-stuffed

Once RPD provisioning is completed adjust node RF levels

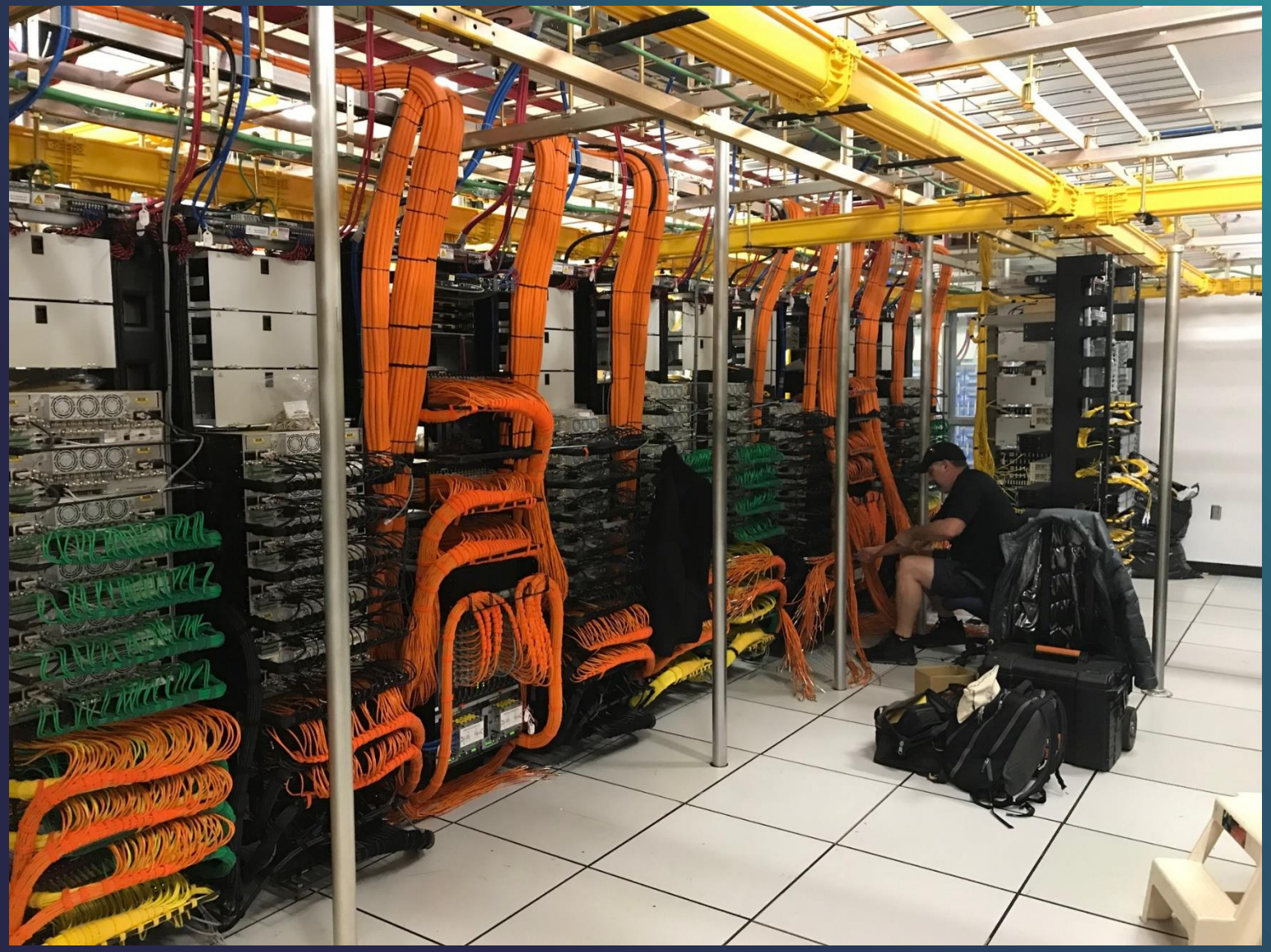
Forward Setup is 1 pad on output of RPD

Return Setup is 1 pad on input of RPD

Thank you.

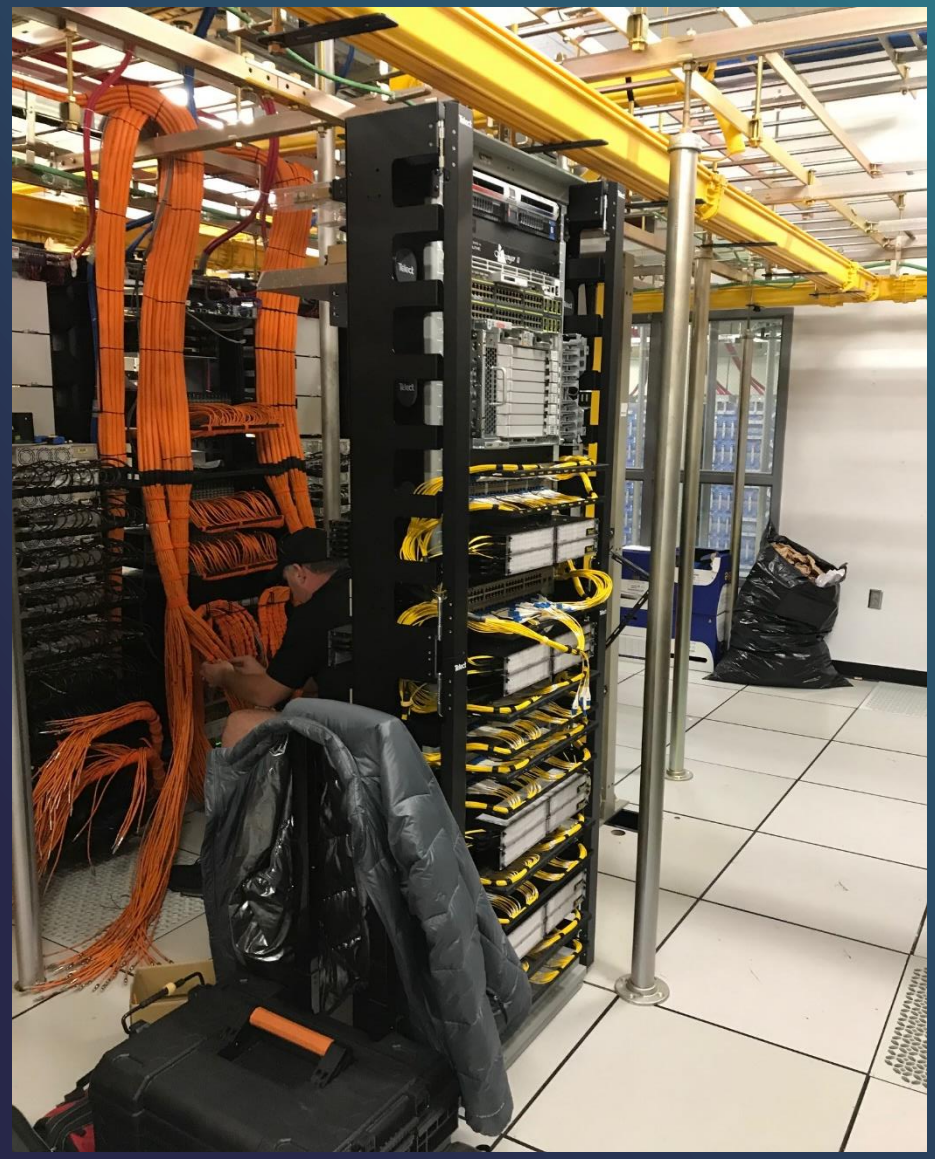
XOC)

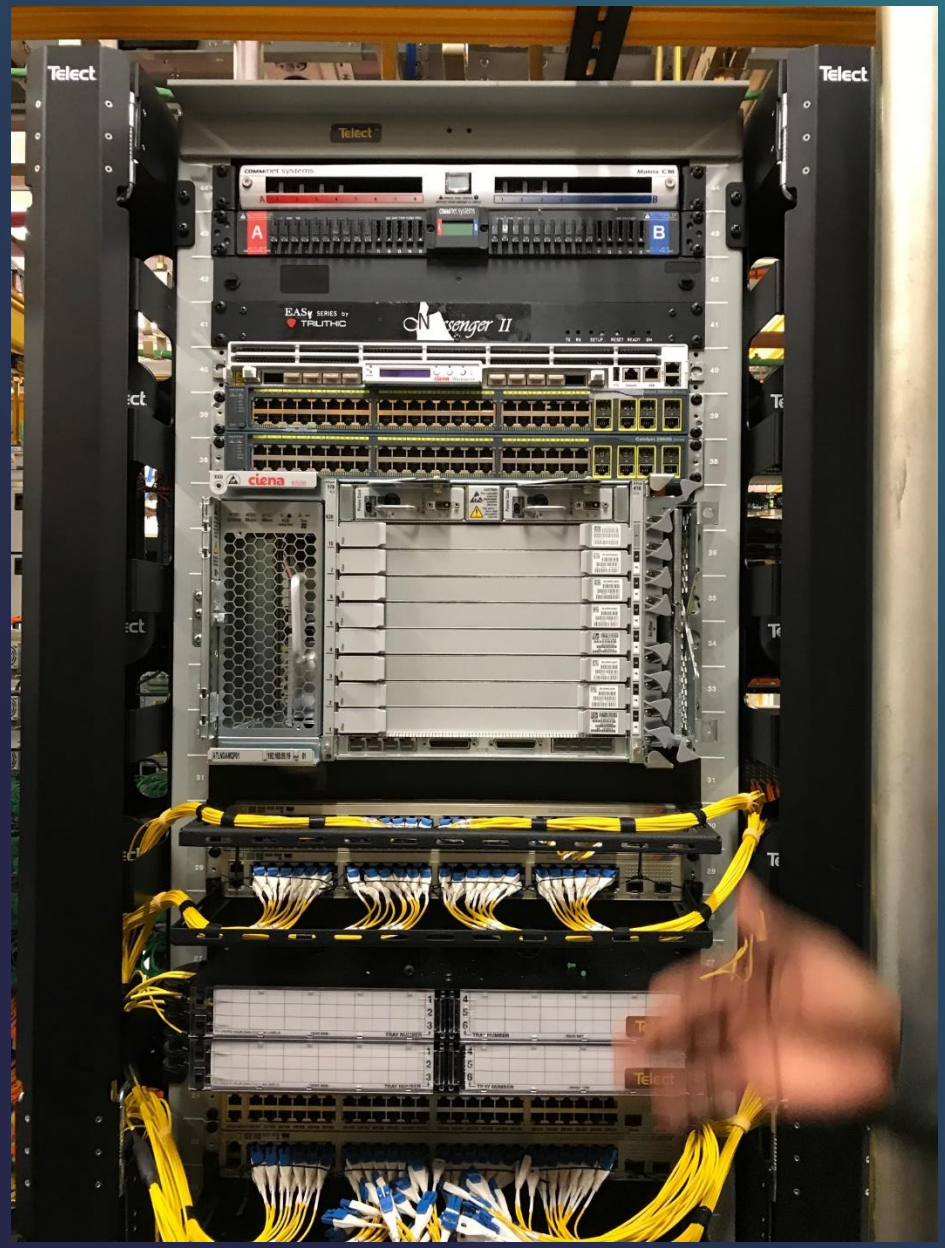
POD Pictures from D9 Hub in Atlanta (XOC)



POD Pictures from D9 Hub in Atlanta (XOC)

Remote Phy POD 1 Rack = 448 Nodes

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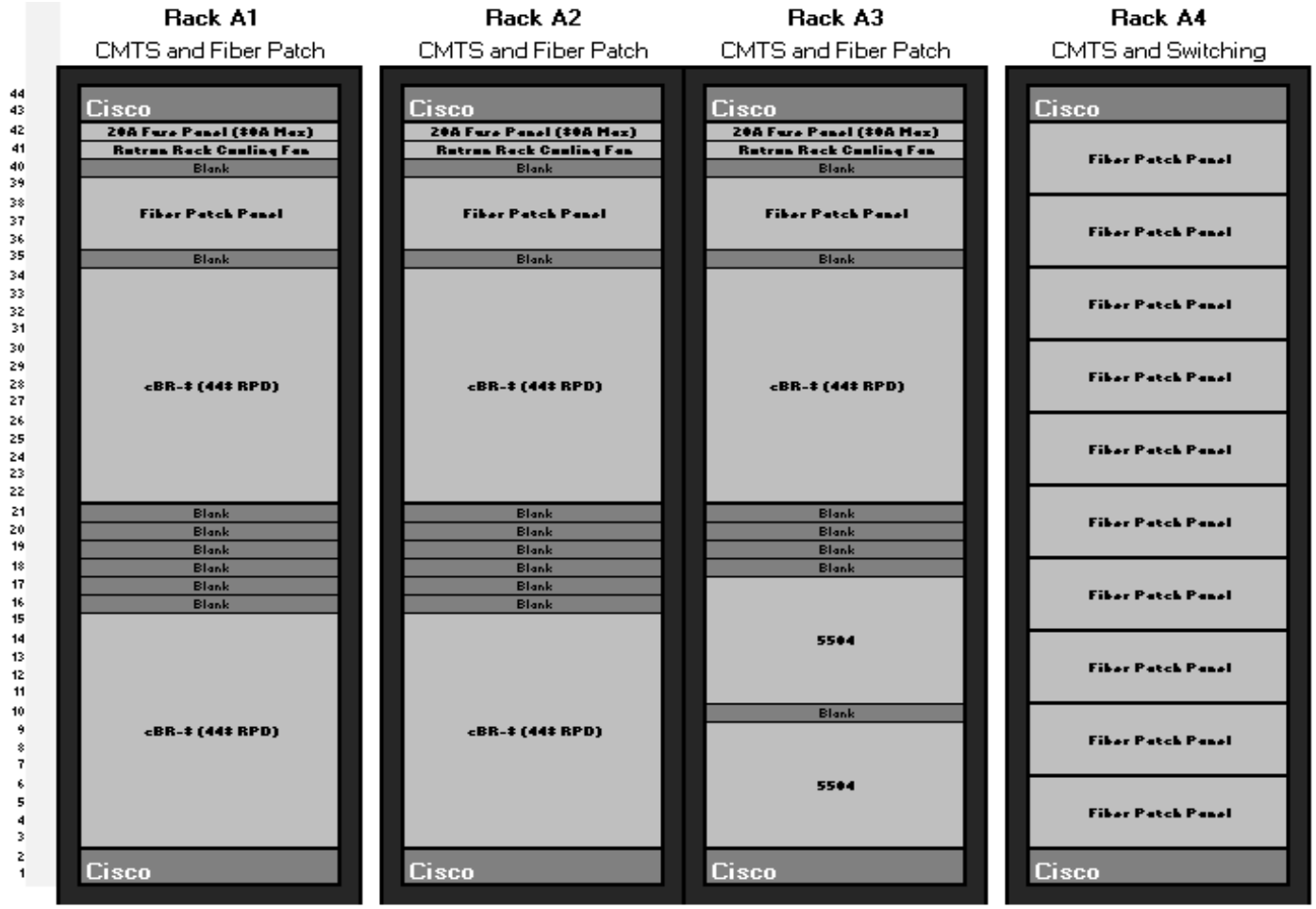
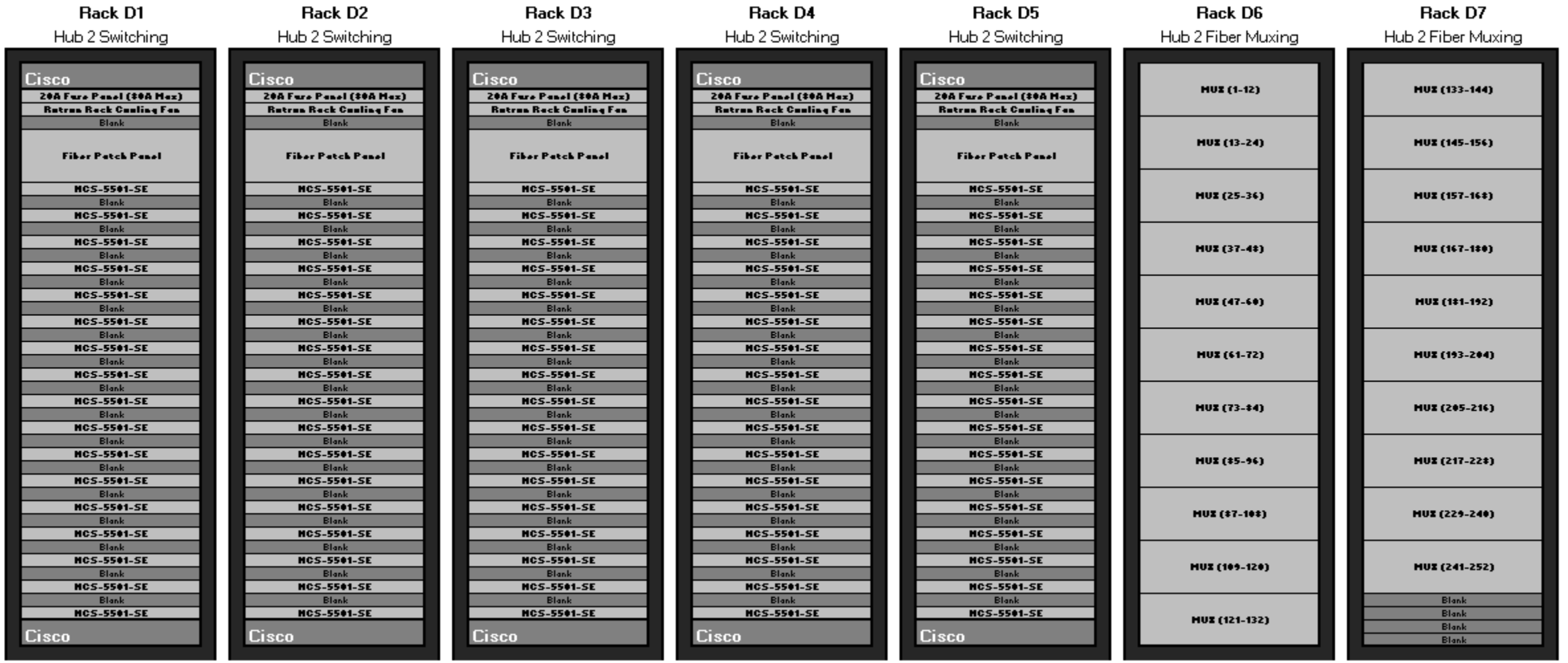
Example Headend Rack Elevation RPHY CORE



2,240 FD RPD Nodes Per 4 Rack POD (See Next Slide for HE 10G P2P)

Example Headend Rack Elevations (10G P2P)



3,376 FD RPD Nodes