Greater Chicago Chapter SCTE

Introduction to FDX and Harmonic nodes

DOCSIS 4.0 is the Technical Standard for a path to 10G

- The latest edition to the DOCSIS standard is DOCSIS 4.0
- This will introduce changes to the PHY and MAC layers of the DOCSIS modem communication system
- The new spec defines two methods for DOCSIS 4.0
  - Frequency Division Duplex (FDD/ESD)
  - Full Duplex (FDX)
- Primary objectives of DOCSIS 4.0
  - ✓ Provide MSOs an HFC path to multi-gigabit symmetric capacity……..by
  - ✓ Addressing long-standing US spectrum allocation limitations…….to
  - ✓ Continue broadband HSD leadership…and
  - ✓ Enable speeds competitive with FTTH

A closer look at DOCSIS 4.0

- DOCSIS 4.0 technology paves the way for the next evolution in broadband over cable's hybrid fiber coax (HFC) networks.
- Offering symmetrical multi-gigabit speeds alongside robust reliability, enhanced security, and minimal latency.
- DOCSIS 4.0 technology can facilitate downstream capacity of up to 10 Gbps and upstream capacity of up to 6 Gbps, enabling seamless provision of multi-gigabit symmetric services across HFC networks.
- As emerging applications, like interactive video conferencing, remote learning, healthcare, IoT, and virtual reality, increasingly rely on higher upstream speeds, the importance of offering symmetric speeds becomes paramount.

Why is DOCSIS 4.0 being considered

- Post-pandemic permanent changes have accelerated the need of new capacity
- Gigabit and Multi-Gigabit symmetric services are emerging
- 10G provides the industry with the tools for Multi-Gig offerings

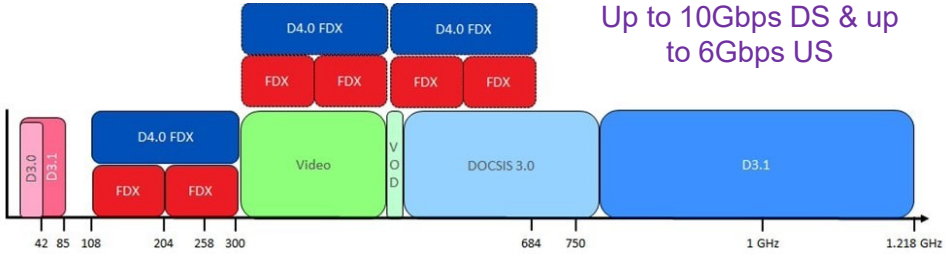
- Today's cable broadband infrastructure can support this new technology, in some cases providing a substantial cost savings to MSOs to re-use existing equipment

- Alongside cost savings, this approach future-proofs the cable networks, establishing a path to state-of-the-art services for the foreseeable future

What is the difference between FDX and ESD/FDD:

FDX

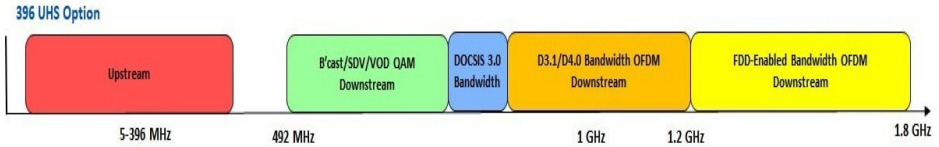
- DOCSIS 4.0 with the Full Duplex improves capacity by FDX transmitting both downstream spectrum and upstream on top of one another. Between the 5-684 / 108-1218 MHz frequency (overlapped). FDX shares the same spectrum, simultaneously, which effectively doubles the spectral efficiency.
- Notably, Full Duplex (FDX) in DOCSIS 4.0 maintains the same downstream spectrum “upper limit” of 1.2 GHz, as in DOCSIS 3.1 (signified by the bright blue box).



Up to 10Gbps DS & up to 6Gbps US

ESD/FDD

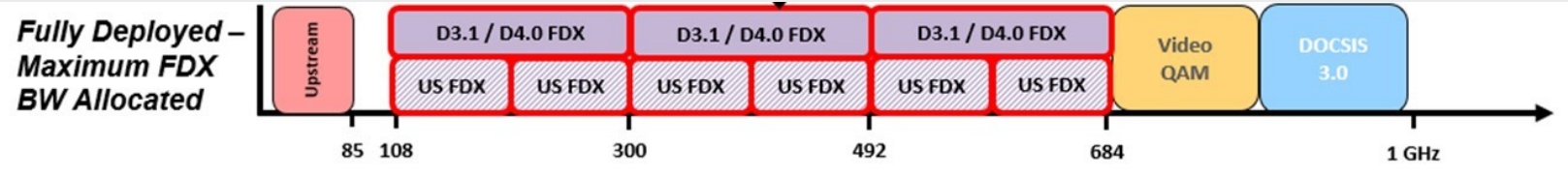
- DOCSIS 4.0 with the enablement of Extended Spectrum DOCSIS (ESD), also known as Frequency Division Duplex (FDD), increases capacity by shifting the downstream spectrum “upper limit” beyond 1.2 GHz, to 1.8 GHz, allowing the upstream spectrum to extend as high as 684 MHz.
- As shown below, the yellow “FDD-Enabled Bandwidth OFDM Downstream” box extends beyond 1.2 GHz frequencies and up to 1.8 GHz frequencies.



Up to 2Gbps symmetrical

A closer look at Full Duplex (FDX) – what's been selected

- This FDX technology is not new and was adopted and enhanced for the DOCSIS plant from telephony and DSL solutions by using a combination of` interference avoidance (sounding) and echo cancellation techniques within the vCMTS level.
- The spectrum allocated for FDX is from 108 MHz to 684 MHz wide.
- This range provided cable modems with a 576 MHz bandwidth so that 3 OFDM channels each at 192 MHz wide will fit.

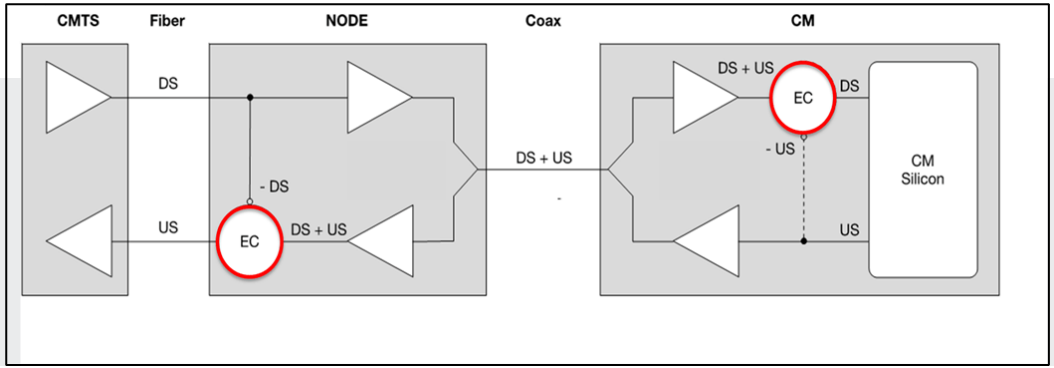


Echo Cancelation

- Similar to telephones which can create echo, RF plant also creates echo which needs to be removed. Echo occurs when the signal coming out from the transmitter, originating from RPD DS re-enters back to the receiver and causes interferences on the signals.

- To avoid this, the vCMTS along with CMs utilize avoidance methods to identify the interference - This avoidance method is called Echo Cancellation (EC).
  - Echo cancelation is a signal-processing operation that subtracts the transmitted signal from the DS signal before it is sent back over the receiver.
  - EC forms a guard around the Tx/Rx paths to block out the signal interferences.

- The process to determine the interference is based on an avoidance strategy in the vCMTS that deals with “unfixable” interference by scheduling the US Tx slots with awareness to not interfere with the local DS listeners.



A few additional details on FDX-

***FDX**, **Full-Duplex DOCSIS**, **D4**, and **DOCSIS 4.0** are all interchangeable!*

Hardware Overview

•**FDX Nodes**: These are still digital nodes (R-PHY) and part of the Distributed Access Architecture (DAA). They have the added capability of using overlapping spectrum for DOCSIS 4.0 applications. The Remote PHY Device (RPD) dictates spectrum usage, whether it be mid-split or FDX.

•**Amplifiers (2025)**: These are mid-split active amplifiers with the added ability to mimic the node capabilities.

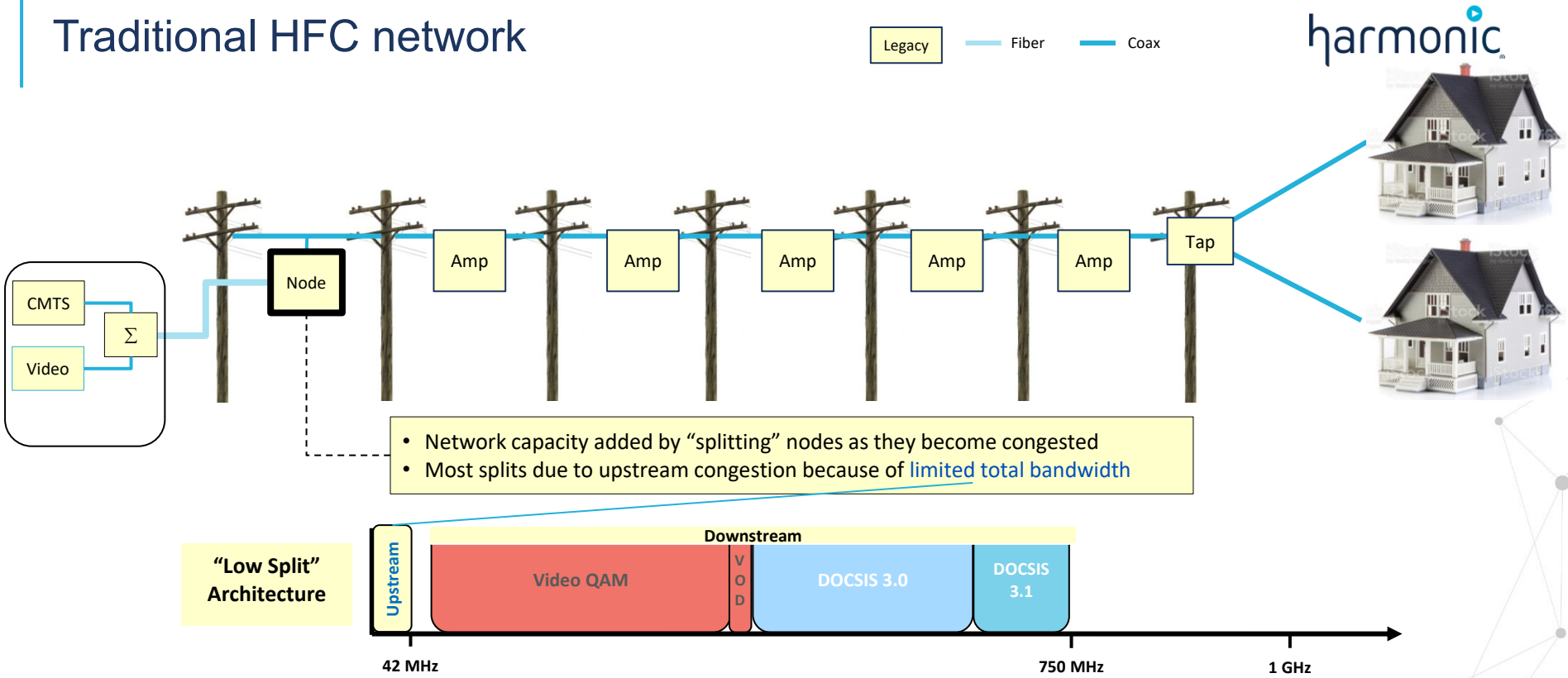
•**Cable Modems**: Equipped with a DOCSIS 4.0 silicon chip, these modems can now transmit an upstream signal in a frequency band previously used exclusively for downstream.

Spectrum Details

•**FDX and Traditional DOCSIS**: FDX (Full Duplex DOCSIS) supplements traditional DOCSIS channel loading methods, including SC-QAMs, OFDMs, and OFDMAs. The key feature of FDX is its ability to overlap the spectrum, enabling multi-gigabit symmetrical service.

•**Required Hardware**: To utilize the FDX spectrum, DOCSIS 4.0 capable hardware is required on both sides of the network, specifically on the node (SoC) and the Customer Premises Equipment (CPE).

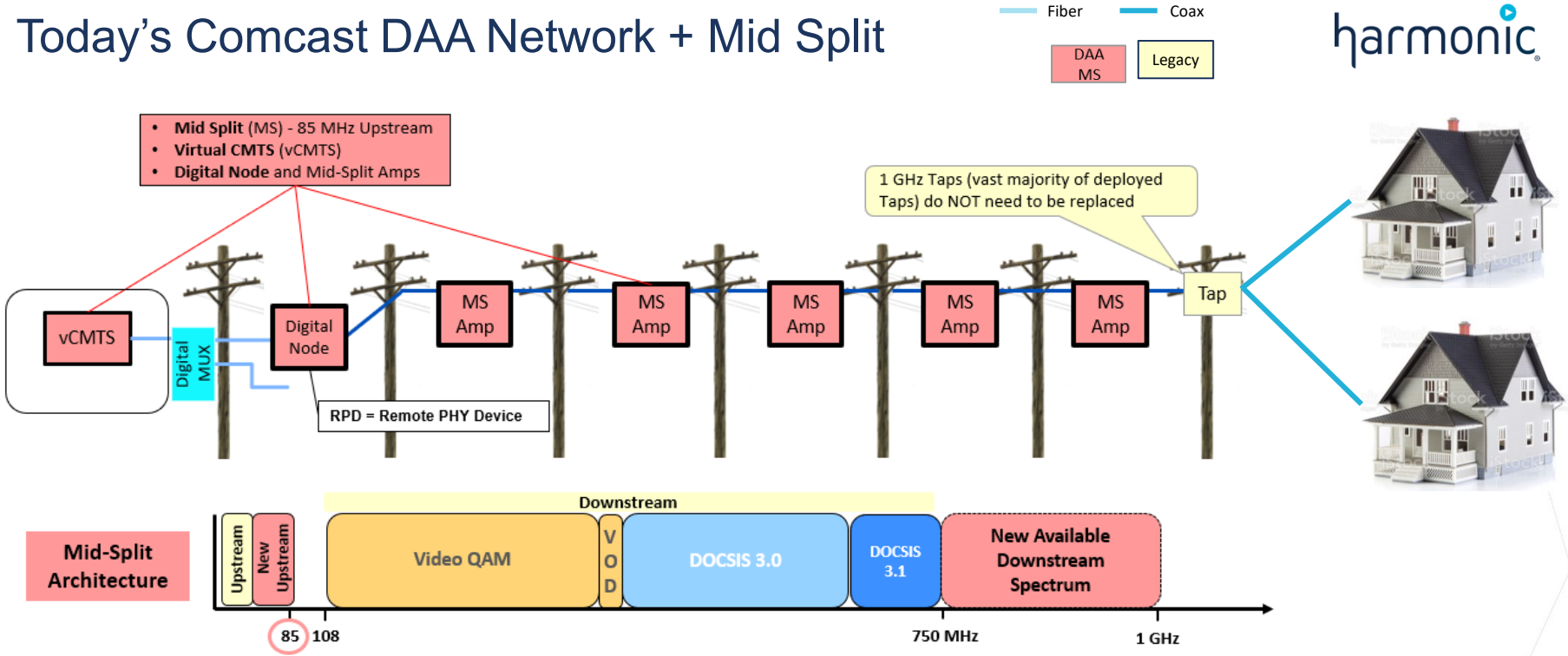
Traditional HFC network



Key Callouts:

- Most of network has been 750 MHz "analog" HFC network, typically with 6 Amplifiers ("N+6") or less
- Upstream speeds limited to **35 Mbps**, and the spectrum is fully utilized by DOCSIS 3.0 SC-QAM signals
- **DOCSIS 3.1** is more efficient than DOCSIS 3.0, enabling higher capacity and speeds downstream and upstream

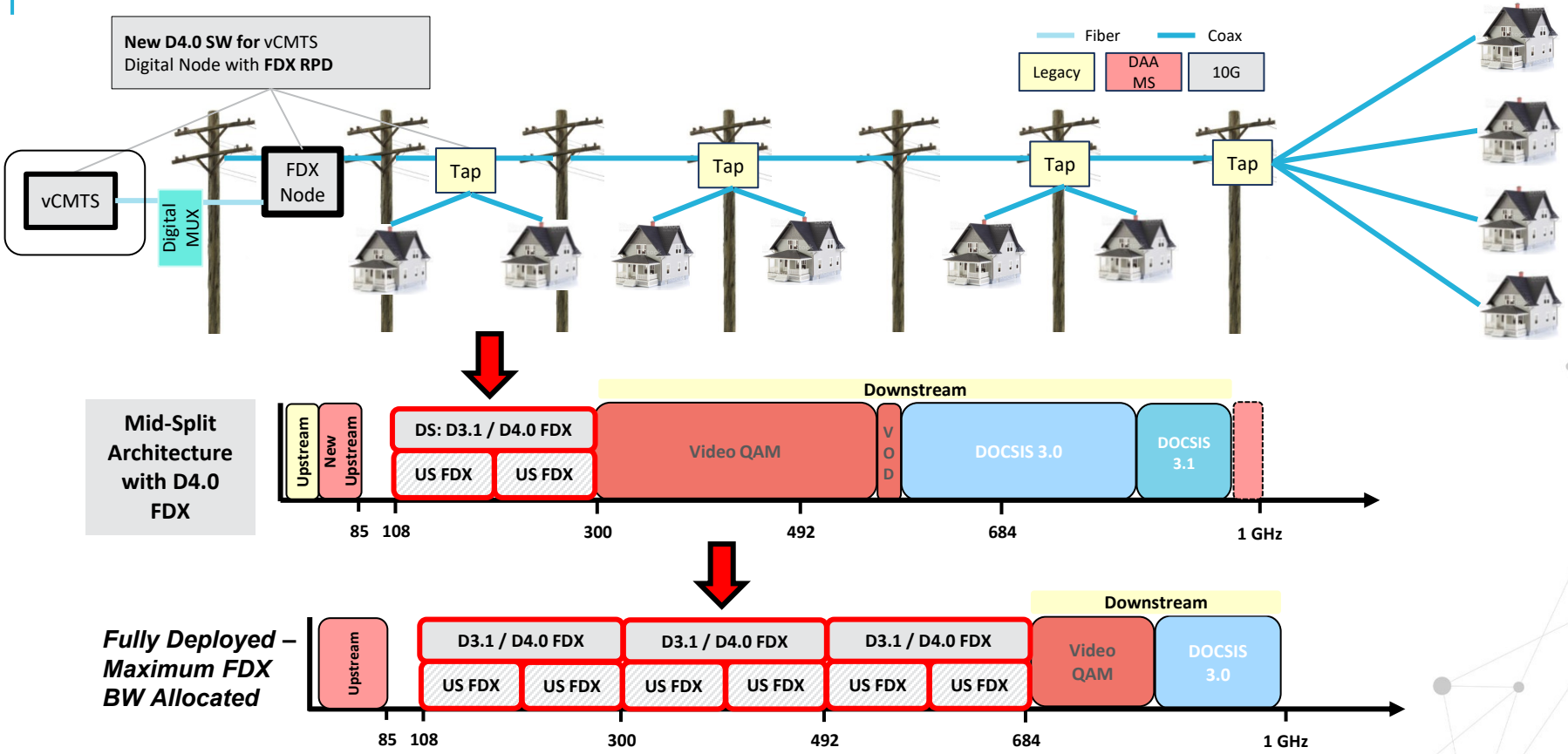
Today's Comcast DAA Network + Mid Split



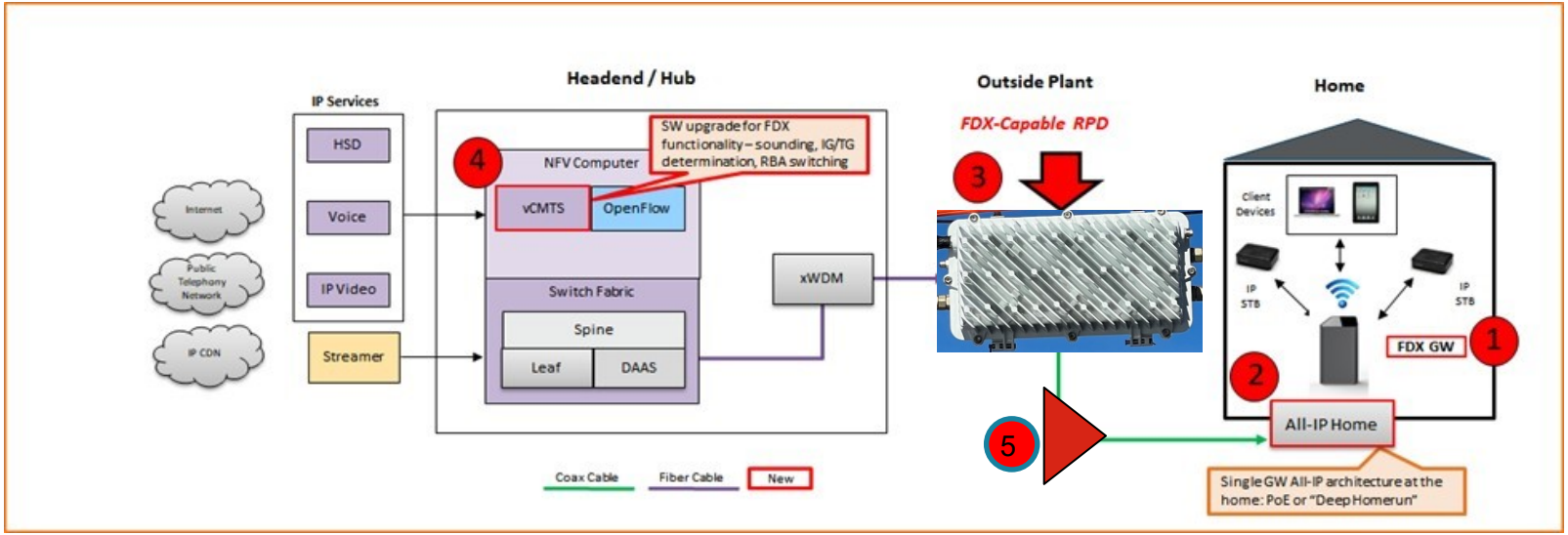
Key Callouts:

- Upstream expanded to 85 MHz and uses DOCSIS 3.1 – increases US **capacity by >4x,** enabling speeds up to **300 Mbps**
- **Long-term upstream traffic growth runway**
- Overall network spectrum extended to at least 1 GHz
- Transformational real-time network and device visibility with DAA and vCMTS, increasing availability and reliability

Initial Migration to Full Duplex will be N+0



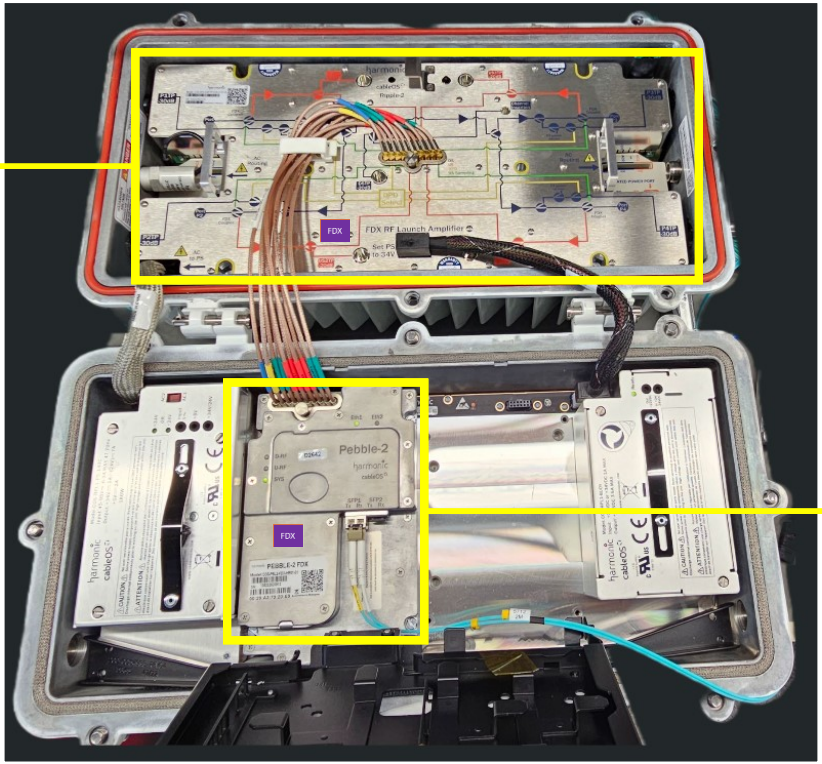
What does an FDX solution look like?



1. In the Home – FDX capable Gateway – New FDX CMs that support D4.0
2. All-IP Home for an FDX customer (only) = No QAM STBs
3. FDX-Capable Harmonic RPD/Node – New RPD and RF tray – module upgrade for R-PHY Nodes
4. vCMTS SW Update that supports D4.0 standard functions and features
5. FDX-Capable Amplifiers by 2025

DOCSIS 4.0 FDX NODE – HARMONIC RIPPLE-2 NODE
2 Key Differences for FDX: RF Tray and RPD

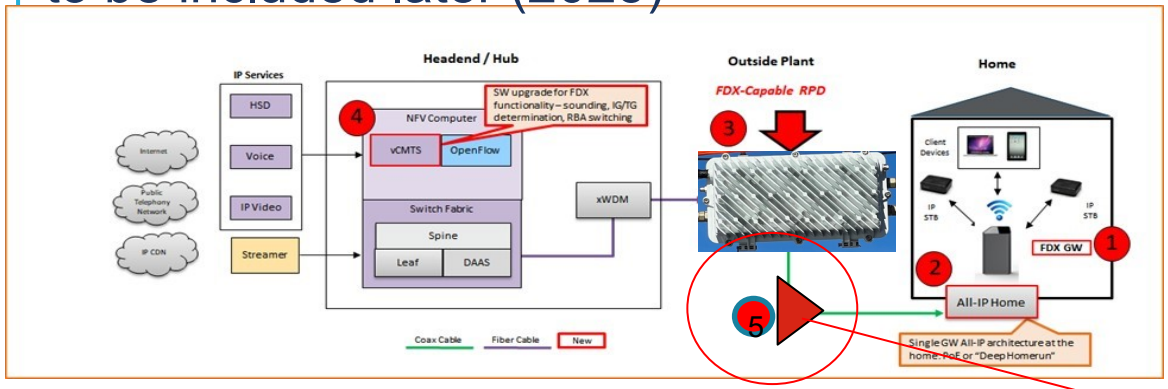
DOCSIS 4.0 FDX RF Tray

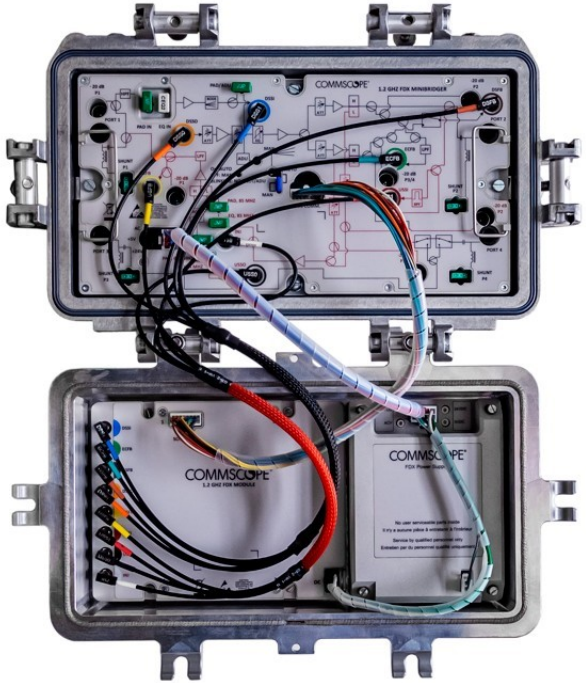


- Common node HW platform in the plant
- Common DAA switched Ethernet-based architecture
- Common virtual CMTS with SW supporting both DOCSIS and PON

DOCSIS 4.0 FDX Remote PHY Device

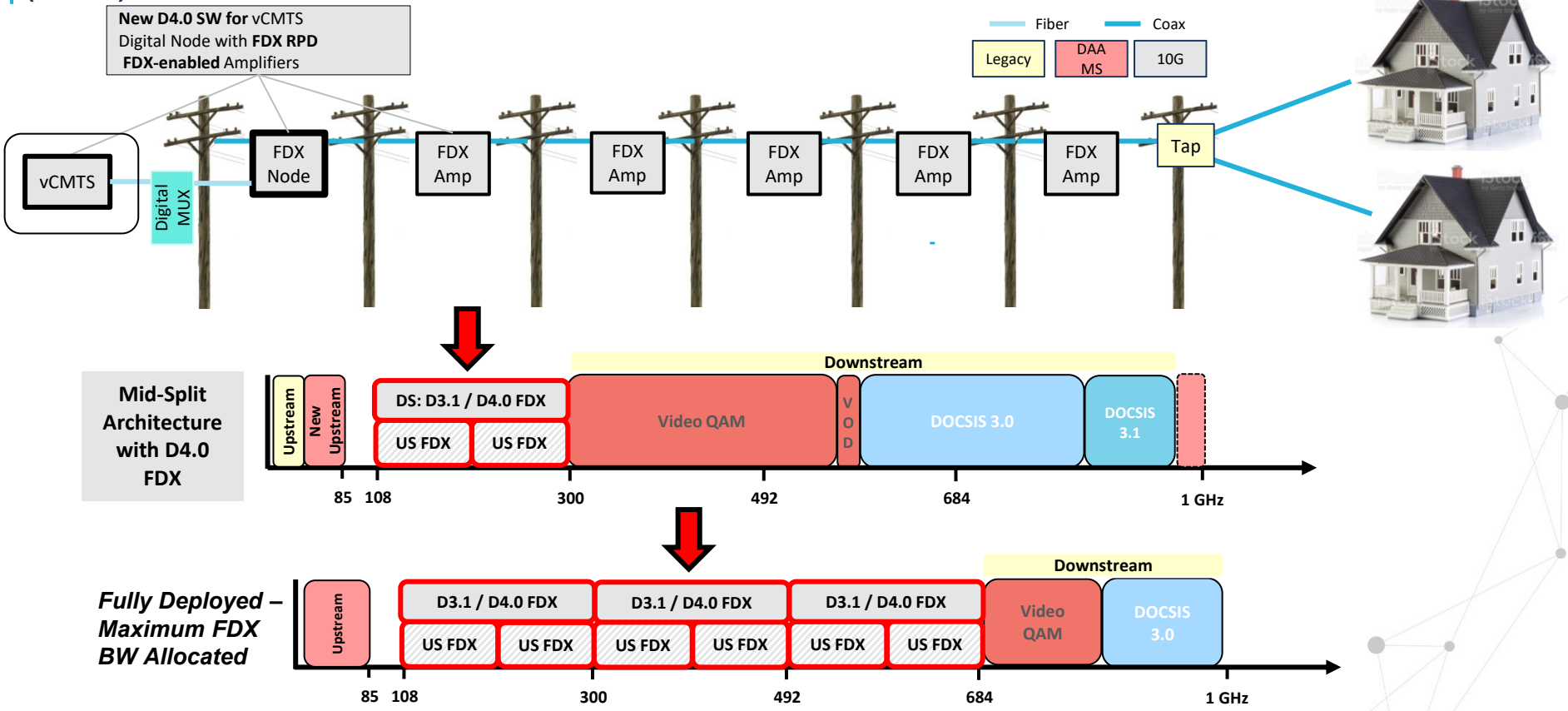
Last piece of the solution will be the FDX Amp – to be included later (2025)





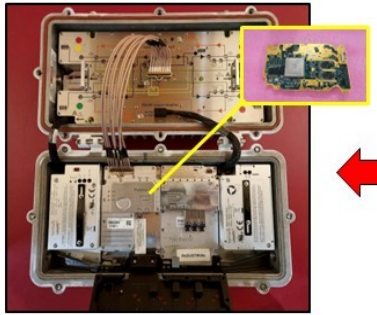
- FDX was originally based on an N+0 architecture only when the standard was developed, now targeting up to N+? architecture
- RF is still not dead!
- Will be utilized for EC & in isolating interference groups in the FDX plant
- SoC/DSP based design for FDX and with an Echo Canceller (same EC as the RPD)
- Streaming telemetry with built in DOCSIS cable modem
  - EC coefficients (channel response), FFTs, levels, transient detection

Tomorrow's Migration to Full Duplex to include FDX Amps (N+x)

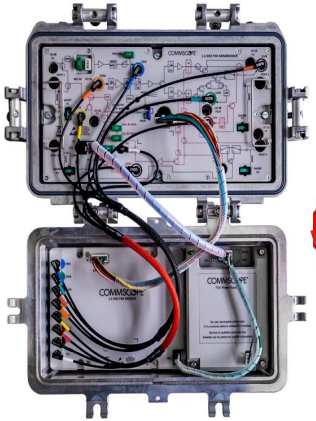


DOCSIS 4.0 FDX N+x Components

vCMTS



FDX Node

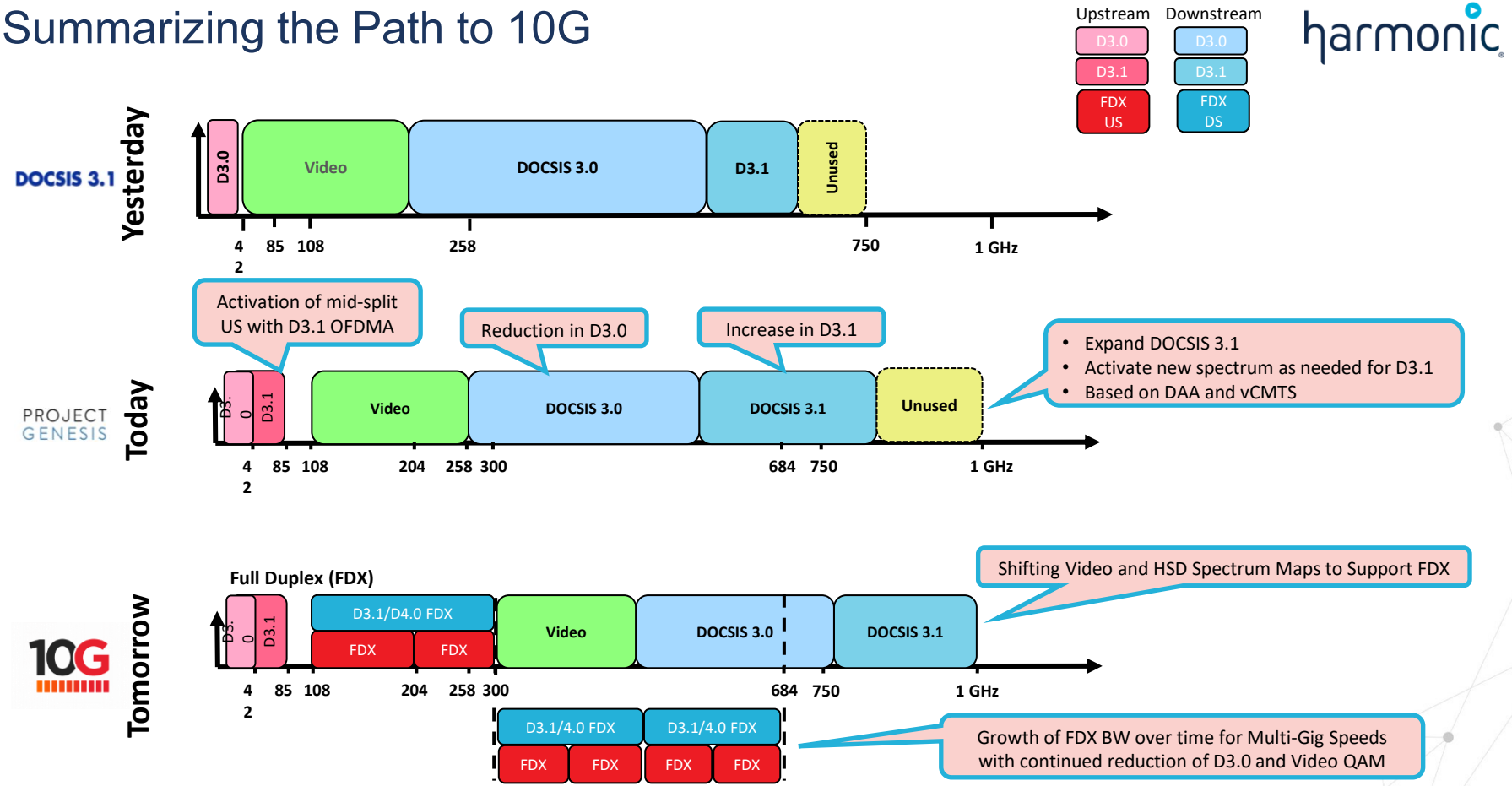


FDX Amplifier

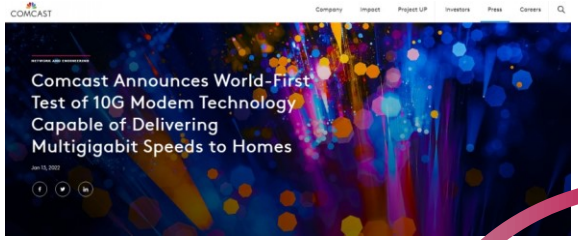
FDX eMTA

D3.1 CPE

Summarizing the Path to 10G



Key milestones for the Path to 10G



Apr 2021

Oct 2021

Jan 2022

Apr 2022

Sept 2022

Dec 2023

2024

MILESTONE

4/21 - Successful test of 1st 10G FDX chip

10/21 - Successful test D4.0 SW upgrade of vCMTS

MILESTONE

1/22 - Successful test of 1st 10G modem chip

4/22 - Successful test of 8Gbps DS / 5Gbps US over live network

MILESTONE

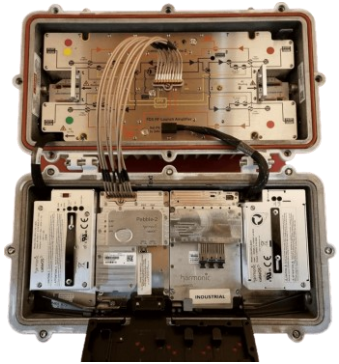
9/22 - Successful test of 10G FDX Amps

12/23 - Launched 1st Live 10G multi-gig nodes in field trials

MILESTONE

First live FDX customers

Summary



- DOCSIS 3.1 is mature, adding advanced features, as millions of D3.1 CPE are deployed
- Post-pandemic permanent changes have accelerated the need of new capacity
- Gigabit and Multi-Gigabit symmetric services are emerging
- DOCSIS 4.0 provides the industry with the tools for Multi-Gig offerings
- DOCSIS 4.0 FDX is actively in development, field trials have been completed, and key trials/launches are happening now!

Hello Chicago!

Introduction to Harmonic nodes

Comcast/Harmonic progression over the years

harmonic

Intro to R-PHY

Remote controls/monitoring & pluggable diplexers

R-PHY & R-OLT
Intro to ePON

Intro to FDX
Symmetrical services

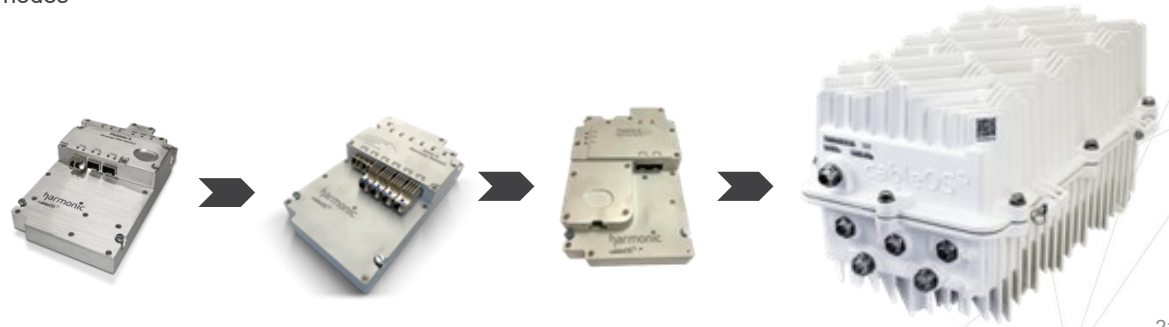
2018
- vCMTS
- WEST & CEN deployed RPL-1 nodes

2021
- West and CEN shifted to RPL+ nodes

2022
- NED started with RPL+ node deployments

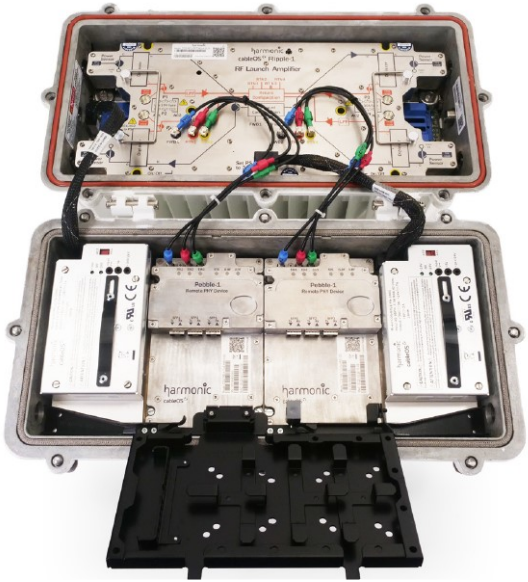
2023
- vCMTS + vBNG
- R-OLT started across all three DIVs

2024
- FDX starting in select markets



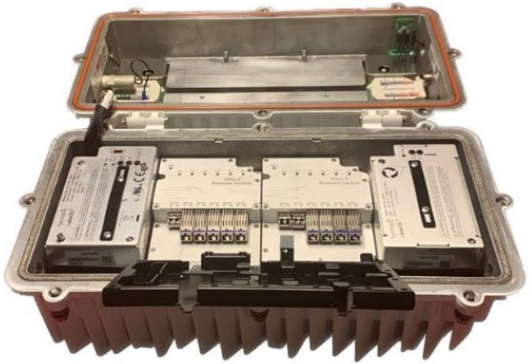
RIPPLE PLATFORM(s) for Comcast DAA

Ripple-1/ Ripple+ RPHY Node

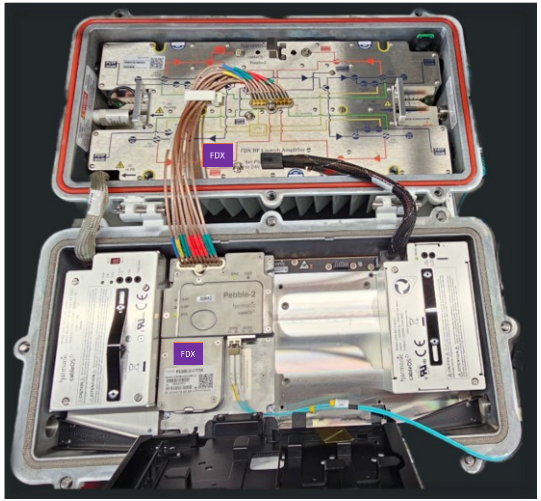


Mid-Split

EPON Ripple+ hRES



Ripple-2 FDX Node

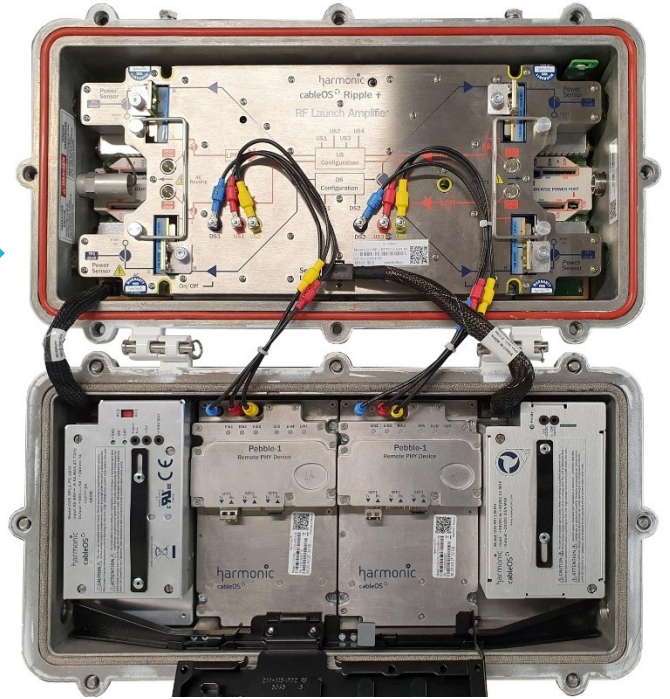


Ripple+ for “Legacy” R-PHY Node Enhancements

Enhancements

- RF Amplifier Tray
  - One tray for all HFC RF Profile needs
  - Pluggable Diplexer Filters
  - Support for Sub Split BAU (Tier 3D), Mid and High Split xNET Tier 1 or 2.
  - Adjust RF Levels and Slope as needed for T2 and T3D deployments – remote controlled
- Enhanced Powering Features
  - AC Boards that supports Dedicated Port Powering
  - Available temporary powering and UPS modules
    - SKIFF and BUOY
- R-PHY Devices
  - Up to two RPDs or any two plug-n-play modules
  - Available Analog Overlay & Channel Insertion options

CableOS Ripple+ R-PHY Node



Harmonic Pebble-1 Features

Cable Labs Remote PHY Compliant

- RF Spec compliant with new DRFI Annex D
- Supports telemetry, FFT, WBFFT and OOB signals

Full DS and US spectrum (5 to 1218 MHz)

- Single DS port with a combination of up to 6x 192 MHz OFDM and 158 SC-QAM
- FD nodes use 1DS x 1US RPD
- Up to Two US ports each with a combination of 2x 96 MHz OFDMA and 12x ATDMA
- BAU nodes use combination of a single RPD for 1x2 or dual RPDs for 2x4 segmentation

Flexible network connectivity

- 3x 10GE SFP+ transceivers / PON ONT
- Supports DWDM 80Km 10GE SFP+

Low power design

- As low as 32 Watts

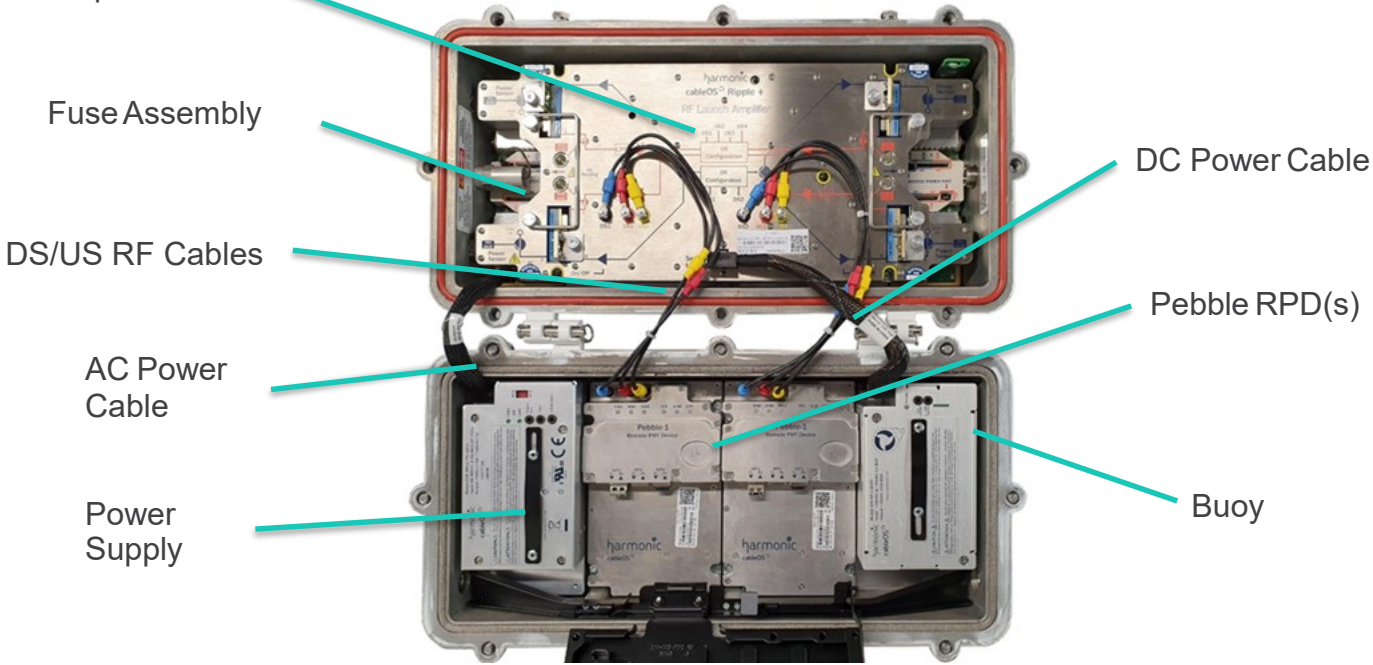
Flexible RF

- Remotely adjustable power level and AGC for temperature compensation
- Configurable DS tilt

AC Boards with SiDactor Surge Protection

- No Seizure screws
- AC connector to SiDactor pluggable board changes gas surge arrestors to dual inline package with pins instead of individual gas surge tubes
- Aux power inputs to AC1 and AC2 buses
- Fuse locations rearranged to allow for Aux ports
- Modified sheet metal and plastic covers to fit new arrangements
- AC connector moved to node lid (PS) to corner of board closest to node lid connector (making room for dedicated power port)

Dual RPD – Tier 2 or Tier 3D BAU node with two 1x2 RPDs

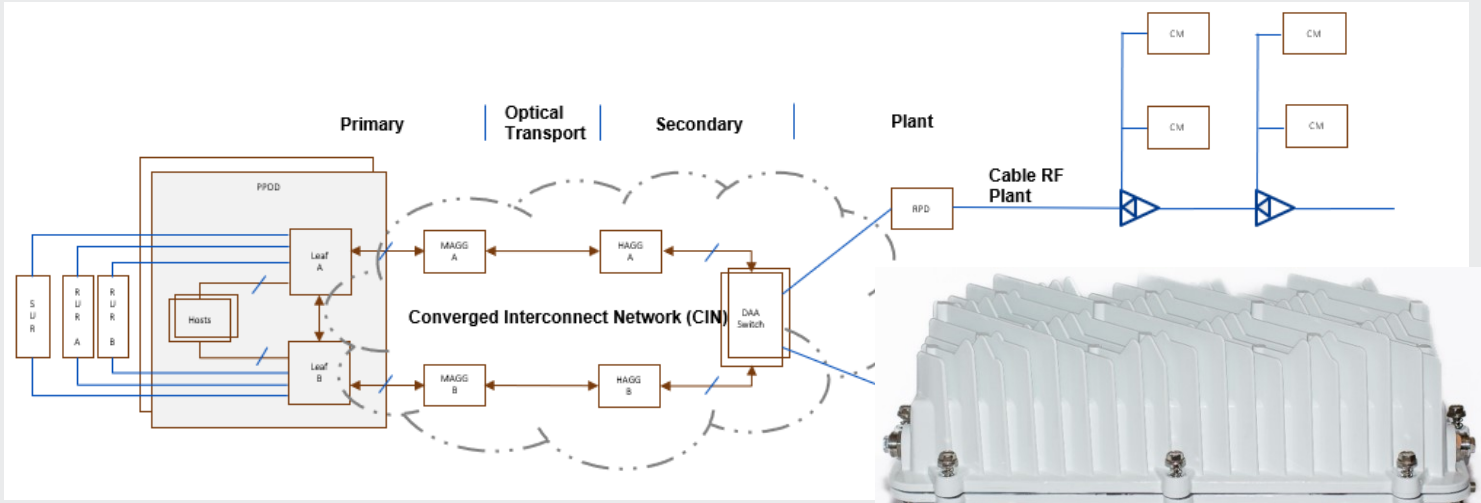


Ripple+: Part breakdown

A-La-Carte ordering:

- Ripple+ Mid Split Node with BUOY
- Pebble-1 1x2 RPD
- A-La-Carte Config:
  - All orders for Mid-Split nodes will follow the below:
    - 1 Node housing
    - 1 or 2 RPDs ordered as needed
    - 1 SFP+ per RPD

DAA/vCMTS topology for R-PHY:



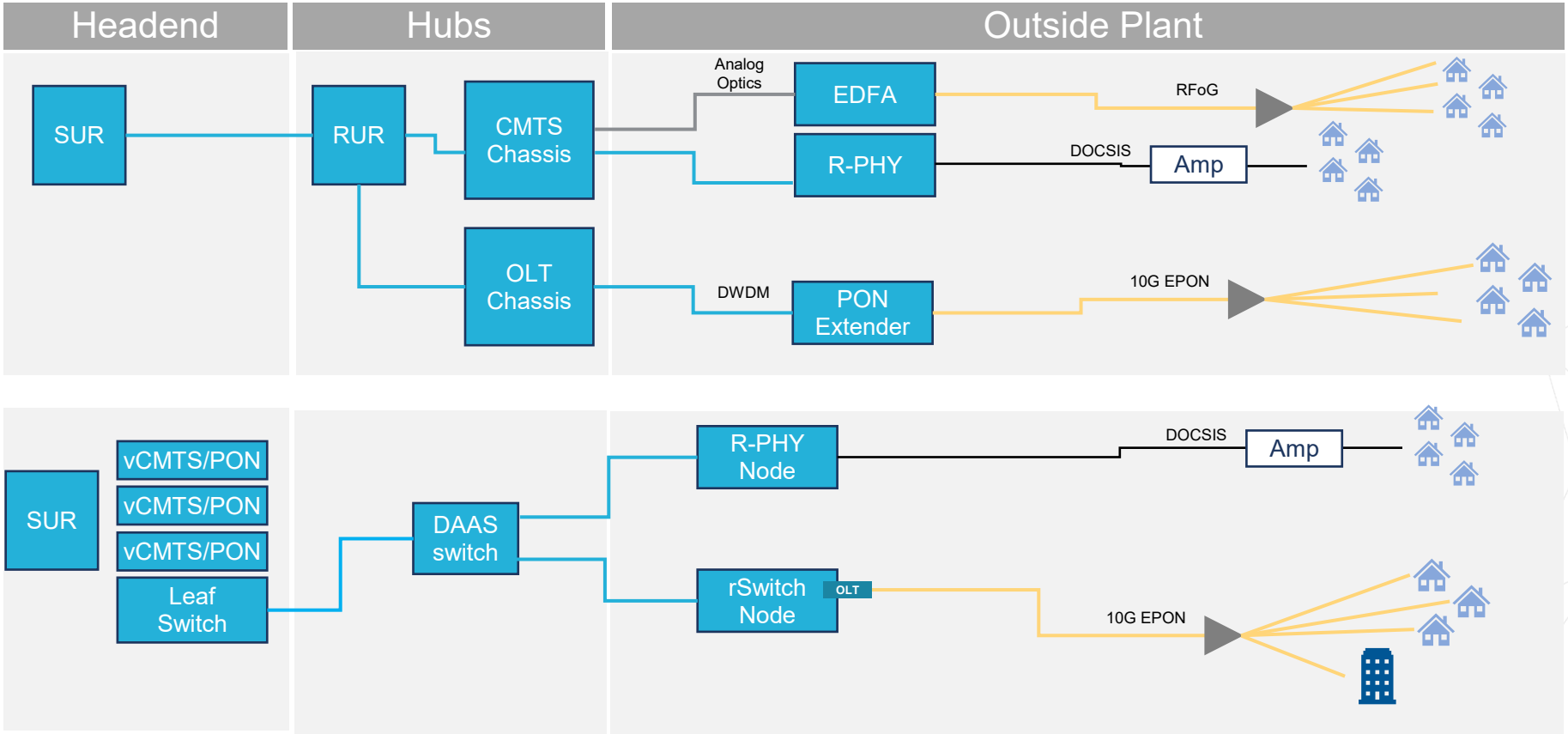
- PPODs, CPODs, Leaf, MAGG, HAGG, and DAAS
- SFP+ type used at the DAAS

Ripple+ R-PHY nodes

What is R-OLT, vBNG, HRES (Harmonic Remote Ethernet Switch) and why?

- The vBNG (virtual Broadband Network Gateway) is replacing the ADTRAN (Sumitomo) OLTs (Optical Line Terminator) and will be a key solution for extending the footprint as part of Remote Optical Line Terminator (R-OLT) initiatives.
- New components include software integration for the vBNG / vOLT in the headends, and new hardware for the Harmonic Jetty Housing, rSwitch (Jetty) & R-OLT (FIN) for the outside plant (OSP). More to follow on the new hardware in this training deck.
- The purpose of this R-OLT solution is to extend the vCMTS architecture deeper into the Comcast HFC plant, creating increased opportunities for existing access solutions.
- This R-OLT solution will implement new access services, while providing consistent environment implementation, and reuse of common functional components.

Legacy vs New PON architecture



Next Generation Comcast EPON

1. Jetty R-OLT Housing

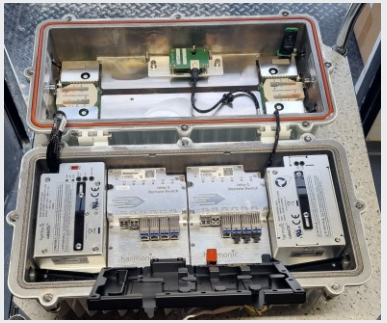
1. The Jetty Housing is the same Harmonic node housing that is deployed in DAA RPD deployments and includes the buoy module to increase the holdup time for the power pack.
2. The housing is powered from a network power supply and 80W of power dissipation should be designed to accommodate a fully loaded housing.

2. Jetty-1 Remote Switch (rSwitch)

1. The Jetty-1 is a remote switch that connects to the DAAS switch through a standard 10G DWDM link.
2. The Jetty-1 has six SFP+ ports, two designated as uplink ports and 4 OLT ports.

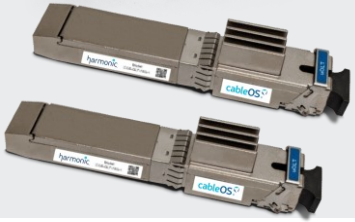
3. Fin-1 R-OLT pluggable

1. The Fin-1 enables simple plug-and-play 10G PON capability from rSwitch.
2. The use of up to four Fin-1's per Jetty-1 will be acceptable in the Comcast EPON deployment
3. Cannot be plugged directly into DAAS



Jetty-1 R-OLT Housing

Jetty-1 rSWITCH



Fin-1 EPON R-OLT

rSWITCH and R-OLT

Comcast port deployment scenario:

- 1 Ethernet + 1 to 2 PON ports per Jetty-1
- Will support 2x Ethernet + up to 4x PON ports per Jetty-1

Maximum Power consumption

- Jetty-1 (without SFP power) <15W
- SFP+, 10 Gbps, 80 km, DWDM <2W
- Fin – 1 <2.5W
- Maximum power at 60 deg C:
  - 1x Jetty-1, 2x 80km DWDM SFP+, and 4x Fin is <30 watts

Jetty-1
rSWITCH

Fin-1
EPON R-OLT

Fin-1 REMOTE OLT

Fin-1 is a 10G Optical Line Terminal (OLT) in an SFP+ compliant package

Specially designed for deployment in Jetty remote devices

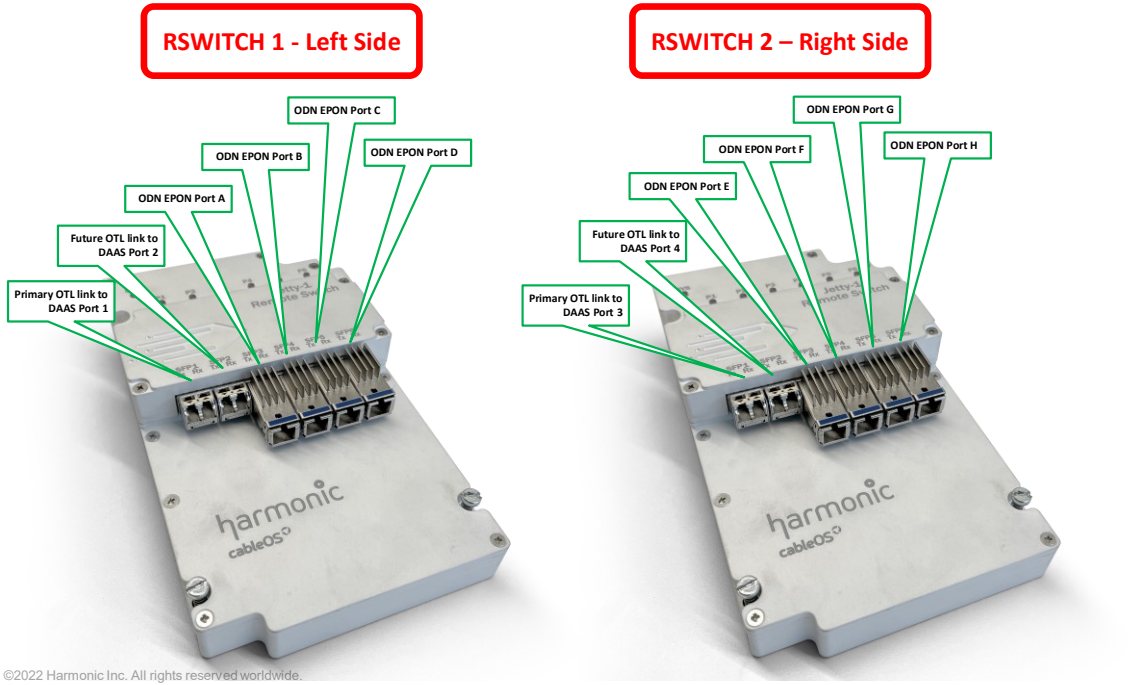
Fin-1 supports

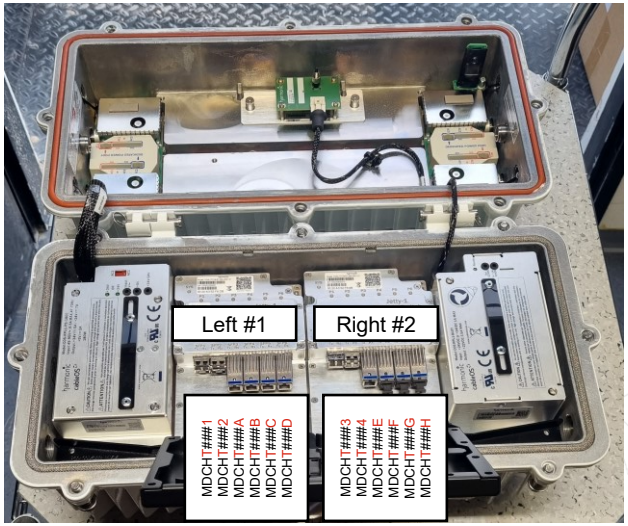
- XGS-PON or 10G-EPON protocols
- Performs all PON MAC layer functionality
- Split 1:128 for 5 km distance
  - Up to 80 km from DAAS to Jetty with up to 5 km additional
  - 128 max subscribers
- Typical Wavelengths 1577nm Tx and 1270nm Rx
- Tx levels will range from +3 to +6dBm
- Rx levels can be from -5 to -28dBm
  - Check Comcast design specs for recommended values

Description	I-Temp
Deployment	Outdoor Node or Cabinet
Optic Class	“N0” / PR10+
Distance	1:128 @ 5 km
Temp	-40 to 85° C
Power	2.2W / 2.8W
Part Number	COS-FIN1-10-I-E1

Jetty-1 Remote Switch SFP+ and R-OLT Installation

- Comcast has very specific requirements on the rSWITCH(Jetty) port usage
- The first Jetty (rSWITCH) should always be installed in the left side of the lid
- Installations of the Fins (R-OLTs) should always be Left to Right
- DAAS connectivity is provided by the **Furthest Left** port on the rSWITCH



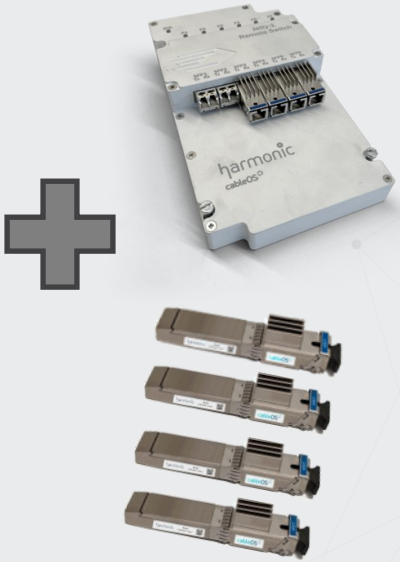


R-OLT/Jetty node: Part numbers and CIFAs

A-La-Carte ordering:

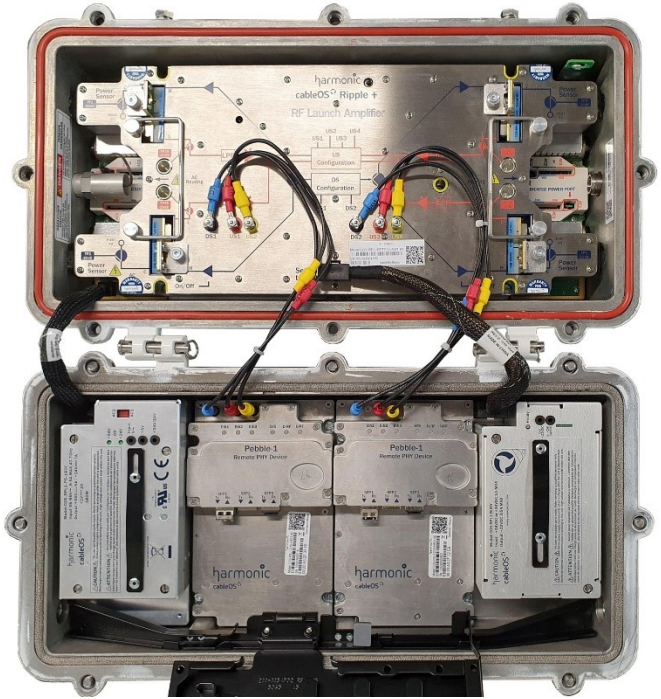
- Jetty Housing configured for rSwitch
- Jetty remote Switch
- Remote OLT (FIN)

- A-La-Carte Config:
  - All orders for R-OLT will follow the below:
  - 1 Node Housing
  - 1 or 2 Jetty rSwitch
  - 1-4 FINs per rSwitch
  - 1 SFP+ per rSwitch

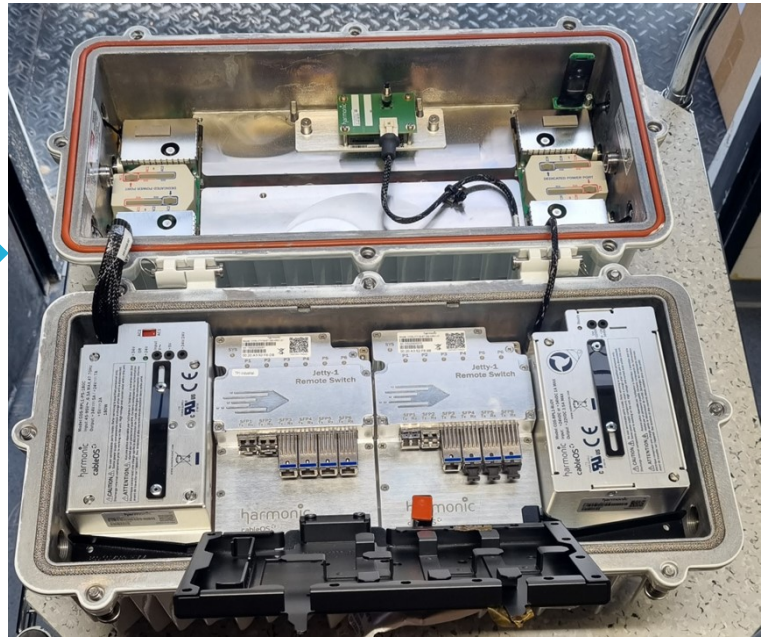


Ripple+ R-PHY Node and HRES R-OLT Node: Two node types for legacy R-PHY launches & R-OLT

R-PHY Node



R-OLT Node



R-OLT network utilizes the same vCMTS (R-PHY) topology:

Ripple+ R-PHY nodes

- Same PPODs, Leaf, MAGG, HAGG, and DAAS
- Same SFP+ type used at the DAAS
- Existing PPODs support vBNG

Jetty R-OLT nodes

Here comes the RIPPLE-2 FDX NODE

Next Gen Design:

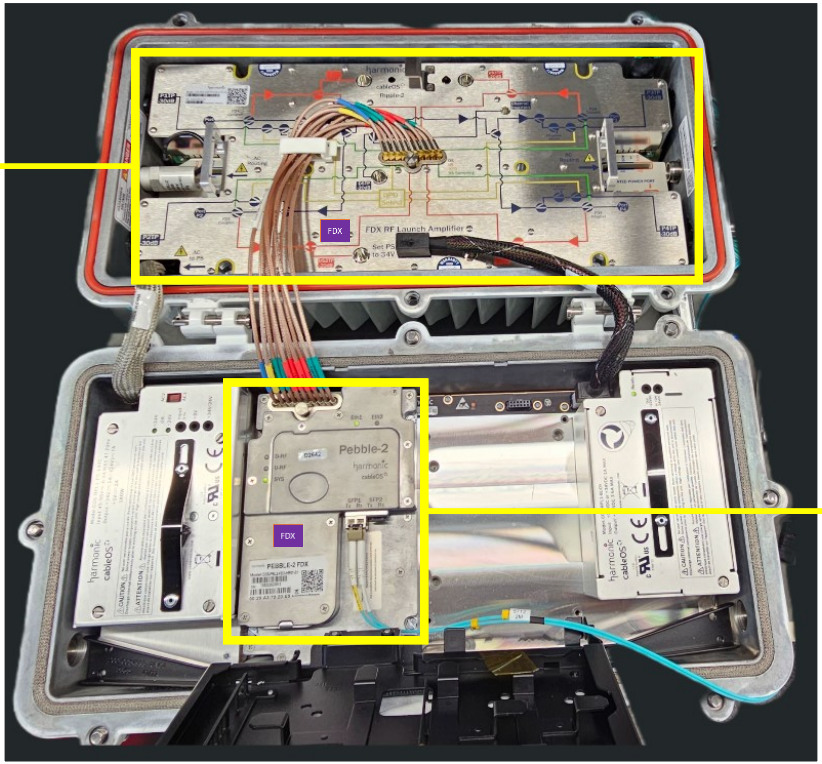
- The **Ripple-2** is the next-generation Remote PHY/FDX node, requiring an FDX capable RF Tray and single Pebble-2 FDX RPD. Two key changes to the node that will address D3.1 and D4.0 demands.

Key Enhancements:

- **Flexibility**: Enables unparalleled flexibility to support D3.1 RPHY and D4.0 FDX
- **Low power**: Advanced power management technology reduces node power requirements to offer the most power-efficient device in the industry
  - (SW enhancements such as Digital Pre-Distortion (DPD) and vBias for reduced power consumption)
- **Modular form factor**: The Pebble-2 Remote PHY Device (RPD) is compatible with the Pebble-1 DAAS platform and provides a growth path for existing nodes
- **Full (Ultra) DS and US Spectrum**: RPD supports up to 1.8 GHz in several configurations
- **Upgrade path to Full Duplex (FDX)**: Install in RPHY D3.1 (mid-split) today and ready for Full Duplex D4.0 once vCMTS is ready

DOCSIS 4.0 FDX NODE – HARMONIC RIPPLE-2 NODE
2 Key Differences for FDX: RF Tray and RPD

DOCSIS 4.0 FDX
RF Tray



DOCSIS 4.0 FDX
Remote PHY Device

DOCSIS 4.0 FDX NODE – HARMONIC RIPPLE-2 NODE

LAYING THE GROUNDWORK FOR THE HARMONIC RIPPLE NODES:

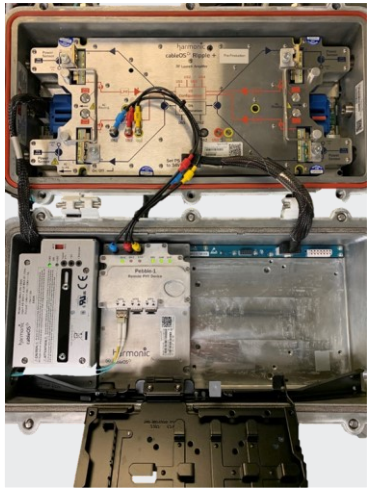
The Ripple-2 uses the same power packs and buoys as the previous generation nodes.

However, Ripple-1 and Ripple+ RF trays and RPDs **cannot** mix with Ripple-2 RF trays and RPDs.

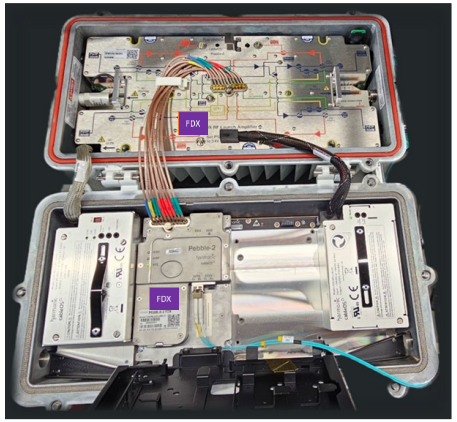
(This is mechanically impossible as the RF cables are entirely different.)

The goal is to keep all Ripple-1 and Ripple+ trays and Pebble-1 RPDs together and then to keep all Ripple-2 trays and Pebble-2 RPDs together.

Ripple-1* / Gen1
1x2 RPD
(Dual 1x2 option)

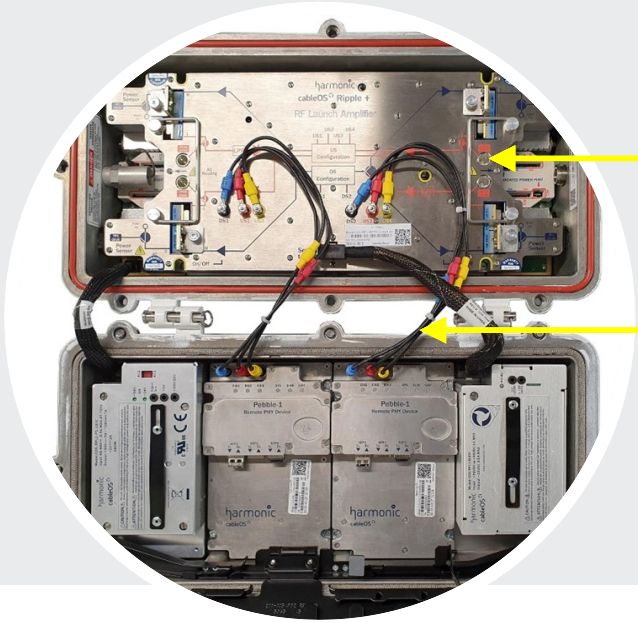


Ripple-2 / Gen2
(with FDX)



DIFFERENTIATING THE GEN1: RIPPLE-1, RIPPLE+ 1X2 & GEN2: RIPPLE-2 FDX

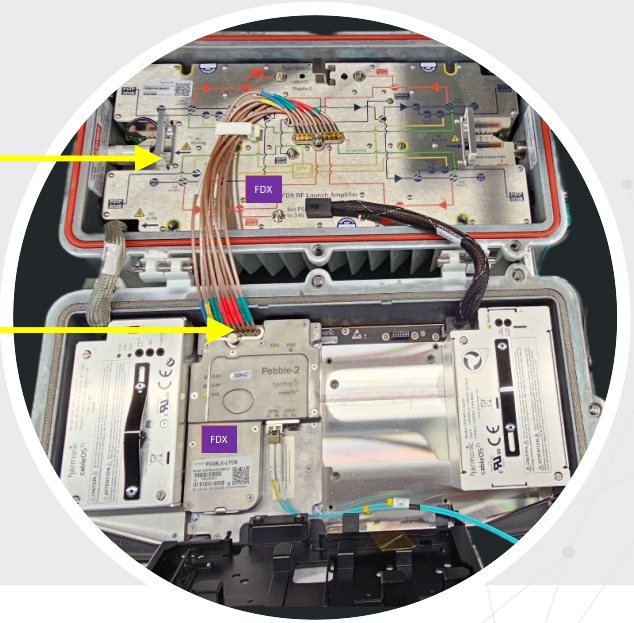
Gen1 Ripple-1/Ripple+ with Pebble-1(1x2)



Different RF trays
Ripple-1 vs Ripple-2

Different RF cables
Pebble-1 vs Pebble-2

Gen2 Ripple-2 with Pebble-2 (FDX)



HARMONIC RIPPLE-2 FEATURES

Full DOCSIS 3.1 / 4.0 FDX support

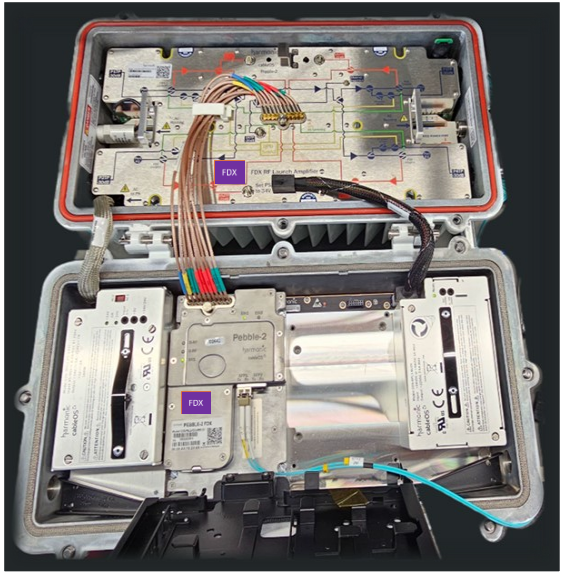
Full FDX band: D4.0 108-684 MHz / D3.1 5-85 MHz, 108-1218 MHz

Modular RF launch amplifier
- 4 high-output ports (64 dBmV/channel analog equivalent)
- Remote controlled output level, slope, and US attenuation

Modular single or dual advanced Power Supplies
- Supports two power sources and flexible power passing
- Available Dedicated Power Port, BUOY, and SKIFF

One Pebble-2 RPD
- Remotely configured node segmentation
- Supports up to 1DS x 2US with FDX RPD
- Built-in Local Channel Insertion (mid-2024)

Remotely configurable for easy installation and setup
- The only plug-ins are power-pass configuration fuses
- Simplifies install, module replacement, and allows for quick setup



HARMONIC PEBBLE-2 FEATURES

Cable Labs Remote PHY Compliant
- RF Spec compliant with new DRFI Annex D
- Supports telemetry, FFT, WBFFT, PNM, and OOB signals

Full DS and US spectrum (5 to 1218 MHz)
- Supports 1x2 for PHY and 1x1 for FDX
- Single DS port with a combination of up to (6) 192 MHz OFDM and (158) SC-QAMs
- Up to (2) US ports, each with a combination of (2) 96 MHz OFDMA and (12) SC-QAMs

Flexible network connectivity
- (2) 10GE SFP+ transceivers
- Supports DWDM 80 km 10GE SFP+

Low power design
- As low as 44 watts w/2 SFP+ devices

Flexible RF
- Remotely adjustable power level and AGC for temperature compensation
- Configurable DS tilt

R-PHY, R-OLT, and now FDX network utilizes the same vCMTS topology:

Ripple+ R-PHY & FDX nodes

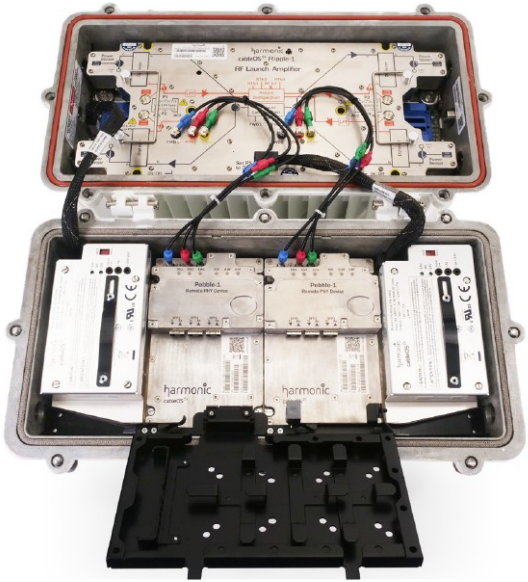
- Same PPODs, Leaf, MAGG, HAGG, and DAAS
- Same SFP+ type used at the DAAS
- v3.0 and above PPODs support FDX

Jetty R-OLT nodes

RIPPLE PLATFORM(s) serving 3 technologies in the DAA network

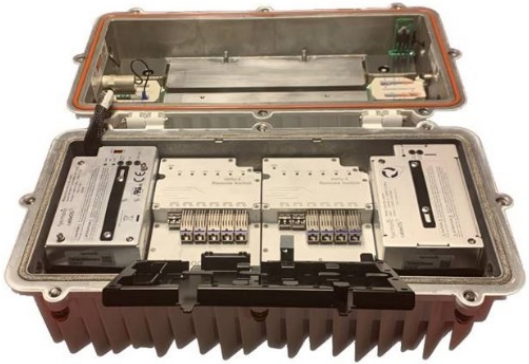
harmonic

Ripple-1/ Ripple+ RPHY Node

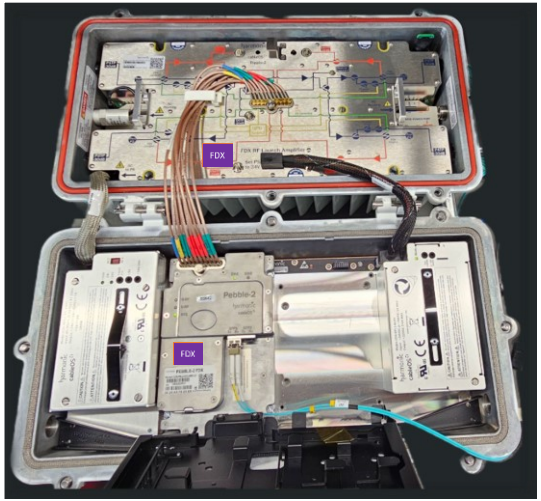


Mid-Split

EPON Ripple+ hRES



Ripple-2 FDX Node



PEBBLE INSIDE HARMONIC and other **NODES**

Ripple

Reef-1

Wave

Oyster

Pebble inside

NC 4000

Raft

GS7000

GAP (Future)

OM4100/4120

Node Installation

Strand Mount Installation

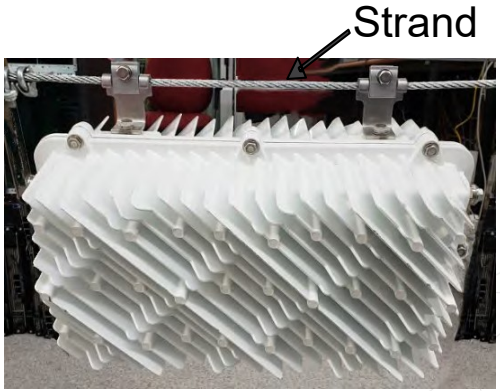
Guidelines

- Follow Comcast processes for typical node installation according to Comcast construction splicing standards
  - Located in the Standards Portal or VOX
- The minimum strand diameter should be 5/16 inch

Installation

- Loosen the strand clamp bolts
- Lift the housing and slip the strand clamps over the strand
- Finger-tighten the clamp bolts to allow movement of the housing as needed to install the coaxial cable and connectors.
  - Secure once cables are in place
- Use a ½-inch torque wrench to tighten/loosen the strand clamp bolt
  - Tighten bolts to 5 to 8 ft-lbs

Strand Cable Clamps and Bolts



Pedestal Mount Installation

Guidelines

- Follow Comcast processes for typical node installation according to Comcast construction splicing standards
  - Located in the Standards Portal or VOX

Installation

- Secure the node to the pedestal mounting bar with the strand clamp bolts
- Loosen the strand clamp bolts
- Lift the housing and slip the strand clamps over the strand
- Finger-tighten the clamp bolts to allow movement of the housing as needed to install the coaxial cable and connectors
  - Secure once cables are in place
- Use a ½-inch torque wrench to tighten/loosen the strand clamp bolts
  - Tighten bolts 5 to 8 ft-lbs

Strand Cable Clamps and Bolts

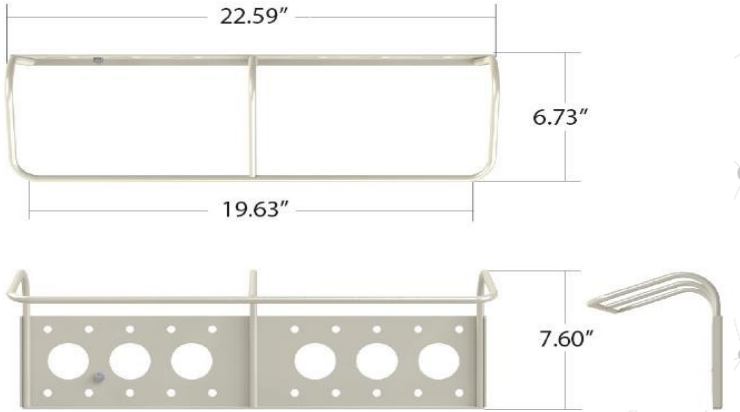
Wall Mount Installation

Guidelines

- Follow Comcast processes for typical node installation according to Comcast construction splicing standards.
- For wall mount deployments common in MDUs, the PPC wall bracket can be used to mount the housing to the wall

Installation

- Loosen the strand clamp bolts
- Lift the housing and slip the strand clamps over the strand
- Finger-tighten the clamp bolts to allow movement of the housing as needed to install the coaxial cable and connectors.
  - Secure once cables are in place
- Use a ½-inch torque wrench to tighten/loosen the strand clamp bolts.
  - Tighten bolts 5 to 8 ft-lbs

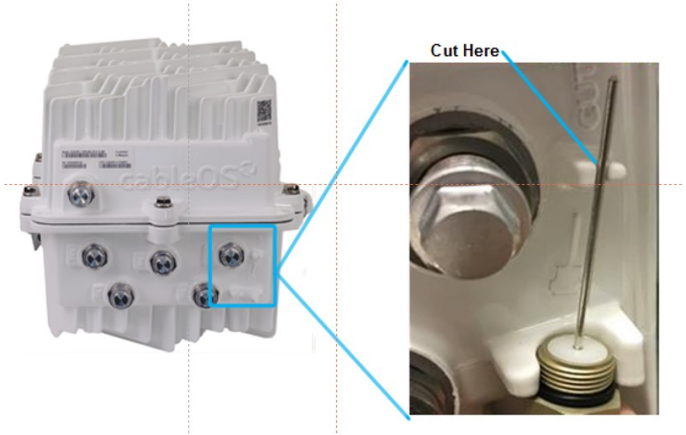


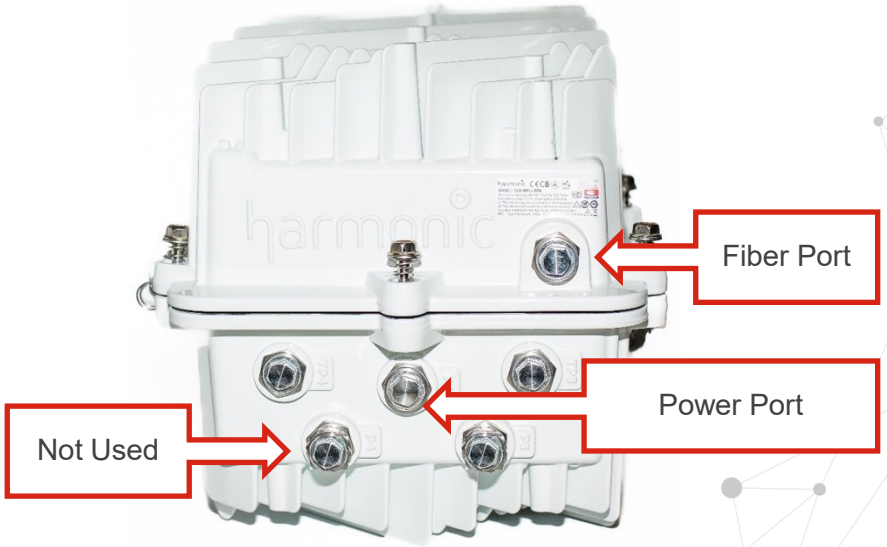
Manufacturer	CIFA NUMBER	Part Number	Description
PPC	94262	22-2019-0036-011-001	Kit, Wall Mountable Node Strand Bracket

Hardened Remote Ethernet Switch node

Each Jetty-1 housing has:

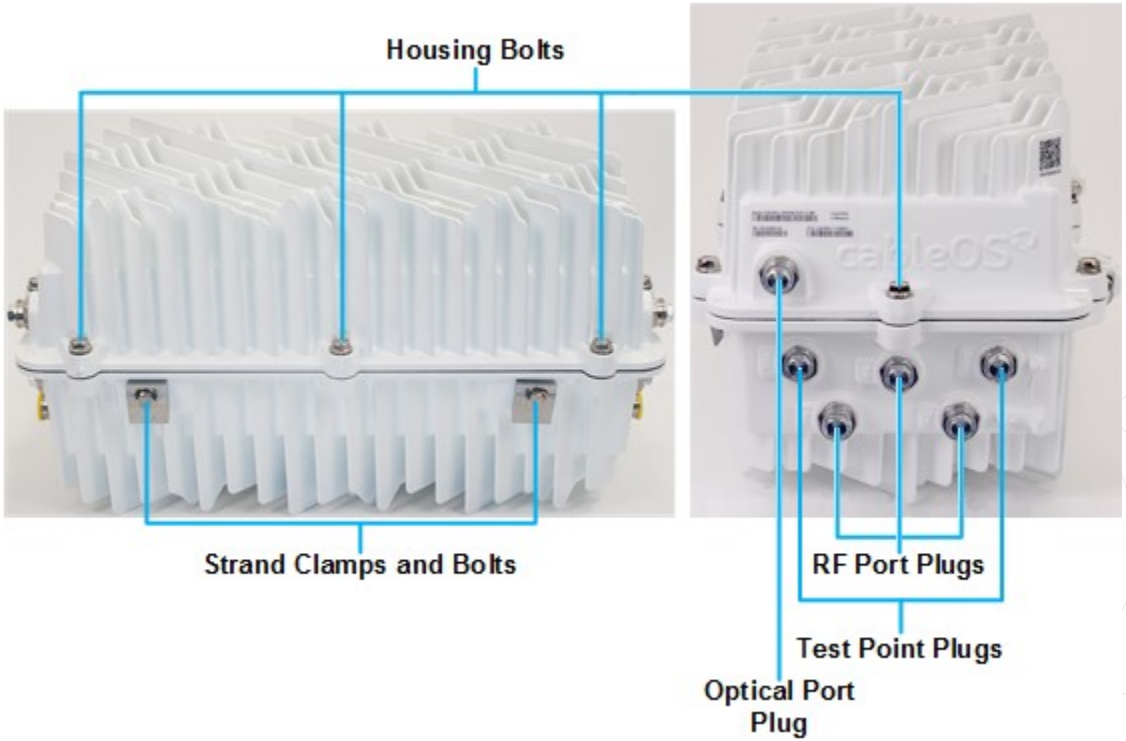
- 2 Ports (P5/P6, one on each side of the base) used for Dedicated Port Power
- 2 fiber ports (one on each side of the lid) used for node fiber cable installation
- All port plugs: 8-10 ft-lbs for permanent installation





RF Ports for R-PHY nodes

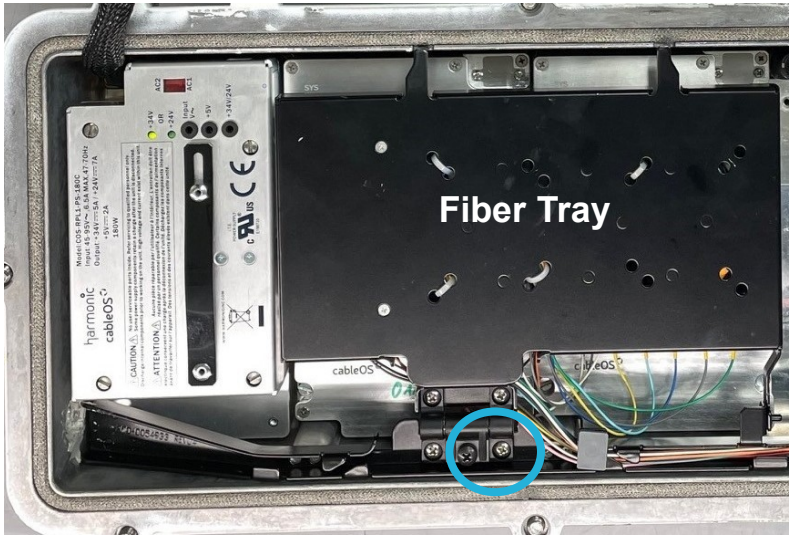
- **Each Ripple+ has:**
  - 2 RF output ports with respective FWD test points (TPs) on each side, P1, P2, P3, & P4.
  - 2 Additional ports to be used for Dedicated Port Power or Local Channel Insertion (P5 & P6)
  - 1 fiber port mounted for IP network on each side of the Ripple lid
  - Test points (TPs) are attenuated -20 dB
    - (RTN TPs are located internally on the RF Amp.)
  - All port plugs: 8-10 ft-lbs for permanent installation.

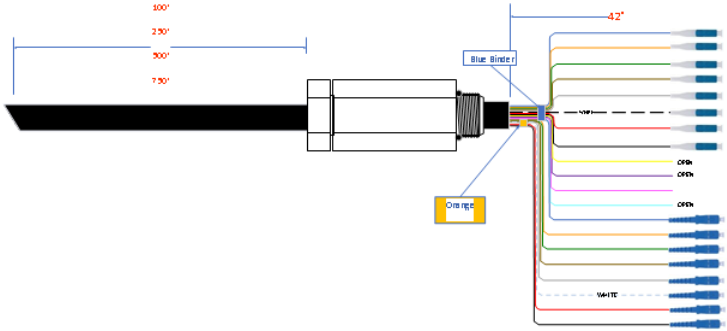


Fiber Tray

The node housing supports 2 fiber entry (either side of the lid)

- Fiber tray has an adjustable **tension screw**
- NEW Fiber tray designed for 8 + 8 Service Cable
- Parking lots for unused LC and SC connectors





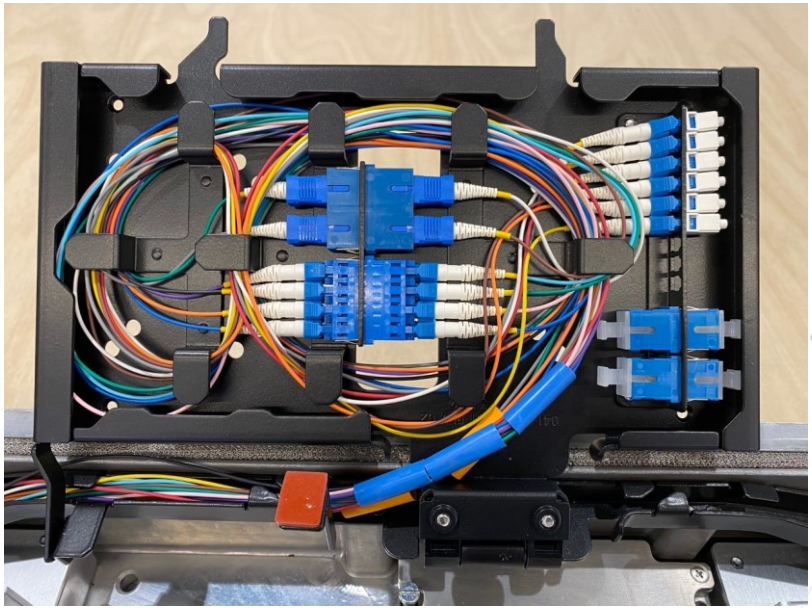
The housing for the R-OLT required a unique node service cable to establish fiber connectivity and the development of a new cable specification for R-OLT deployments. This cable accommodates either a single or dual rSWITCH configuration. The cable has eight (8) LC/UPC for the OTL (transport) side and eight (8) SC/UPC for the ODN (PON) side.

Manufacturer	CIFA Number	Part Number	Description
AFL	305785	CS018284-0250FT	ROLT 8 LCUPC & 8 SCUPC Armored 250' w/ 8 Dark

Installing the Fiber

Follow the service cable instructions for securing to the housing

- Select the lid housing port and remove the port plug
- Feed the optical connectors through the entry port one at a time; when all have been inserted, even them up, and pull them through until the adapter is flush with the housing
- Separate the active connectors from the spares, route the spares through the fiber tray and into the spare connector plate
- Route the active fibers to the Jetty(s) allowing enough slack for tray opening/closing

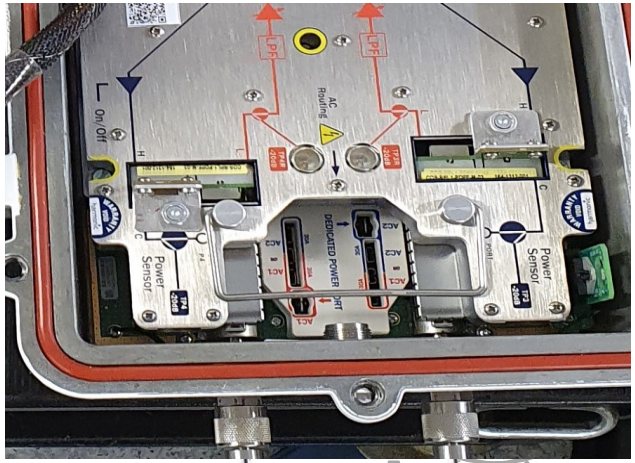


Connecting the coaxial cables/stingers

Coaxial stinger installation

- Insert the stingers into the RF ports
- Screw the stingers to the ports per manufacturer's recommendation
- No stinger seizure screws on the AC seizure boards
- Follow normal procedures for heat shrink tube and other weather proofing materials according to Comcast construction splicing standards.

Note: Standards available in Comcast Standards Portal



Alternate Powering Solutions & UPS Back Up

SKIFF

- Provides temporary powering via integrated “F” connector
- Used for maintenance, cut-ins, and any other temp powering use cases
- Same mechanical footprint as existing Ripple-1 Power Pack
- DOES NOT POWER PLANT only NODE

BUOY

- Maintenance-free capacitor-based UPS unit
- Looks like a power pack and plugs in the second PP slot
- Keeps the RPD afloat for a few seconds during short power interruptions, the RF module is not kept alive during this time
- Must be removed to use the SKIFF, does not reboot the RPD during removal or insertion

LEDs – RPD Operational Status

At bootup all three LEDs rotate across the row of LEDs until the Pebble completes download of all files

3 LEDs (SYS, D-RF, U-RF) provide Pebble operational status.

- System (SYS) LED
- D-RF (Downstream) LED: Green
- U-RF (Upstream) LED: Green

3 LEDs (Eth1, Eth2, Eth3)
provide link status for SFP1, SFP2, SFP3 respectively

- Steady Green = good link status
- Blinks Green when traffic exists
- No LED – fault, consult XOC for possible configuration or optical related issue

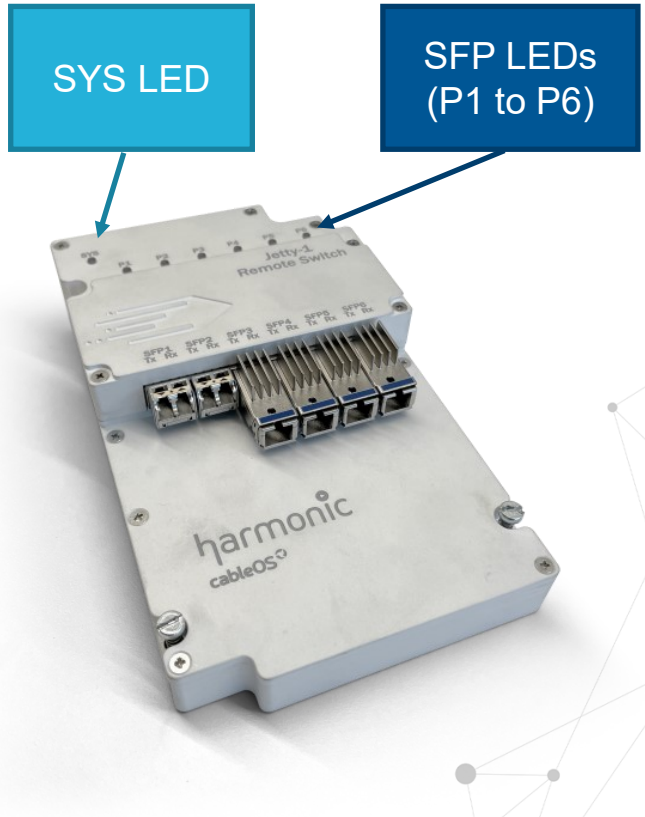
Jetty-1 Remote Switch LEDs

- Two LEDs: SYS and P1 through P6 to provide Jetty operation status
- System (SYS) LED:

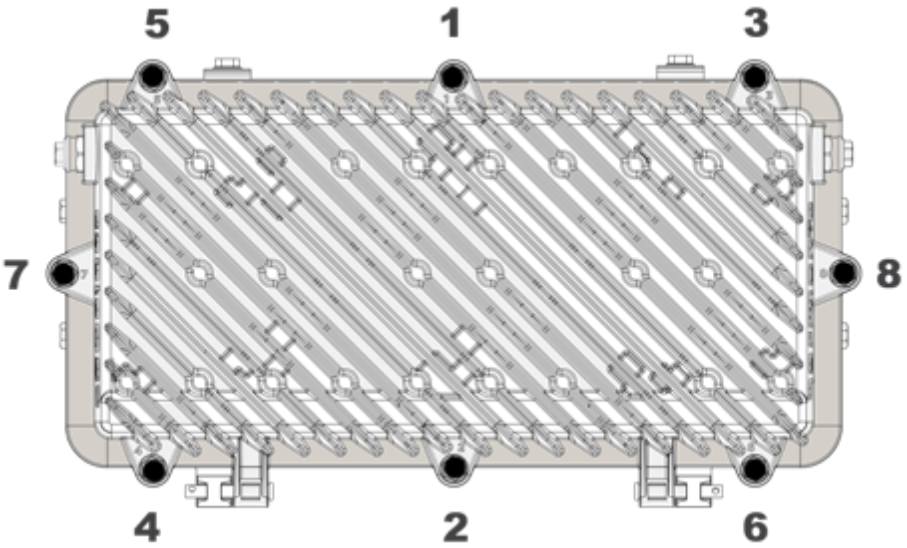
LED Color and/or Pattern	State Indicated	Meaning/Remedial Action
Green, 2 Hz flashing	Power-on, initializing.	
Green, steady	System status is good. Connections are good.	Functioning normally.
Red, steady	System fault.	Device cannot initialize.

- SFP Port LEDs (P1 to P6 used for SFP+ and FIN-1(R-OLTs):
  - Tunable or Fixed channel 10G SFP+ for SFP1 slot 1 and slot 2 for future use.
  - FIN-1(R-OLT) plugs into slots **3** through **6**

LED Color and/or Pattern	State Indicated	Meaning/Remedial Action
Green, steady	SFP connected.	Ethernet port is operational.
Green, flashing, 2Hz	Low bit rate.	
Green, flashing, 4Hz	High bit rate.	



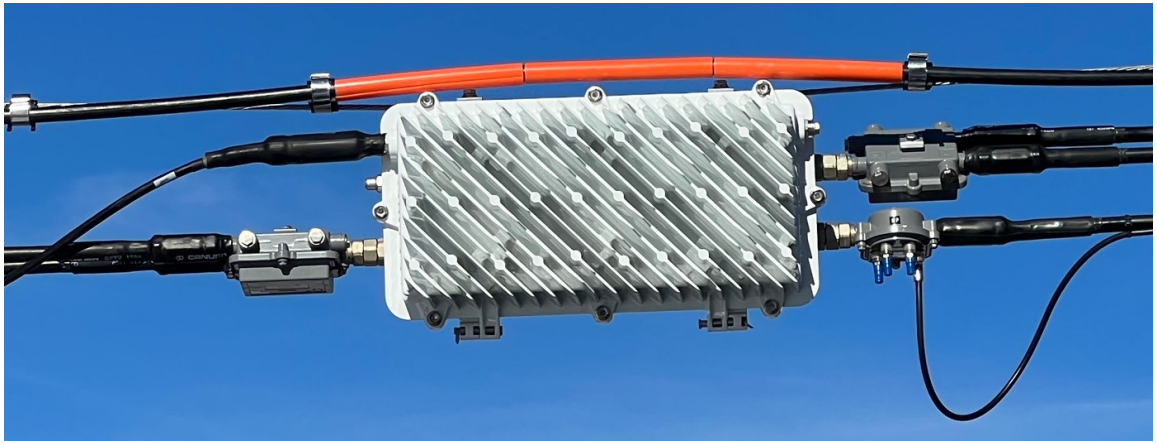
Closing the Ripple-1 housing



- Close the lid until the base and lid flanges align taking care that no cables are pinched between the flanges.
- Tighten the housing bolts in the prescribed **order of 1-8** shown on the lid flange
- Torque the bolts in order 8 to 10 ft.-lbs
- Failure to properly torque will result in water ingress

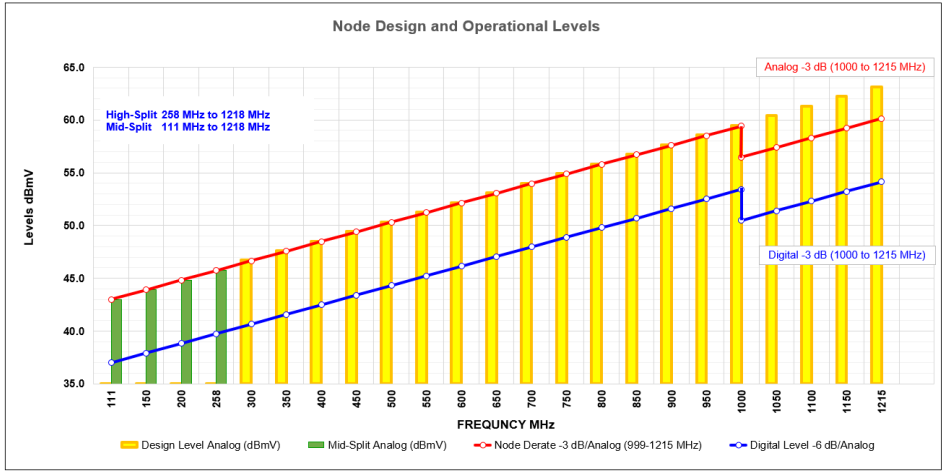
Recommendation for weatherproofing the housing

- Improve field installation processes to reduce the likelihood of humidity and casual water
- Close node housing bolts and torque to 8-10 ft-lbs
- Make sure that all port plugs are installed and properly tightened to 5-8 ft-lbs
- Apply heat shrink to all RF ports and the fiber service cable adapter
- The example to the right is a good representation of the fiber service adapter with heat shrink
- It is recommended to take the heat shrink as close to the node housing as possible to increase heat shrink seal reliability even more
- Recommend tenting for installations during inclement weather to minimize casual water

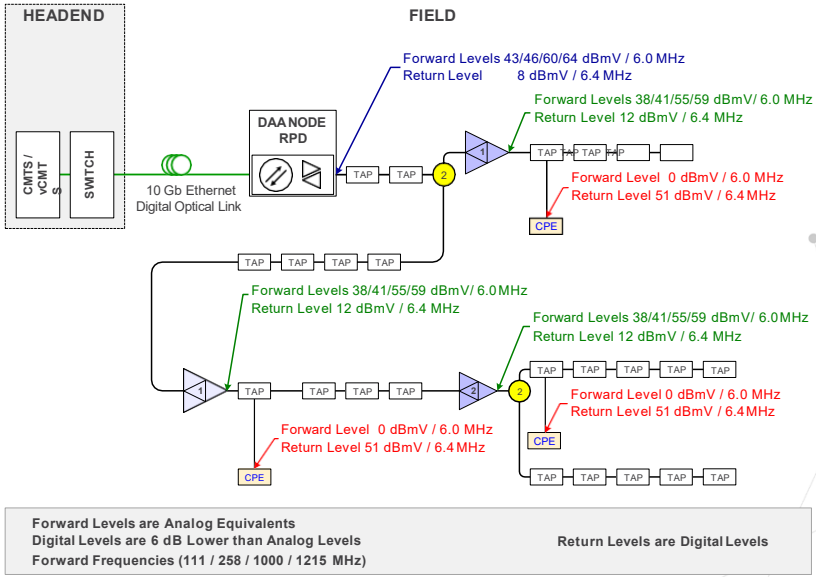


Node Provisioning

xNET 3.0 Standard DS Node Operational Levels



MHz	111	150	200	258	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1215
Design Level Analog (dBmV)	43	44	45	46	47	48	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
Operational Node Derate -3 dB/Analog (999-1215 MHz)	43	44	45	46	47	48	48	49	50	51	52	53	54	55	56	57	58	59	57	58	59	60	61
Operational Digital Level -6 dB/Analog	37	38	39	40	41	42	42	43	44	45	46	47	48	49	50	51	52	53	54	51	52	53	54



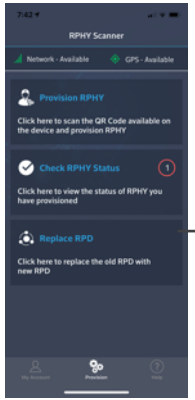
Operational RF Levels

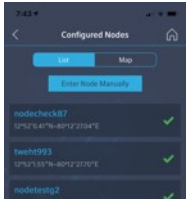
- Tier 1, FD, N+0 will be configuration file based – no in App changes
- Tier 2 & Tier 3: Match existing DS design levels for the specific node location using App
  - Nominal forward (DS)
    - Node output:
      - Setup for existing node location levels extrapolating the tilt up to 999MHz (111-999 MHz)
      - Range supported:
        - Output: 42 - 58 dBmV/6MHz @1218 MHz
          - 55 dBmV @ 1002MHz
        - Tilt: 10 - 22 dB (111-1218 MHz)
          - 16 dB 102-1002 MHz
  - Nominal return (US)
    - Node input: ~18 dBmV/6.4MHz, 0 dB tilt (5 – 85 MHz)
    - RPD input range
      - 0 - 40 dBmV/6.4MHz, 0 dB tilt (5 – 85 MHz)

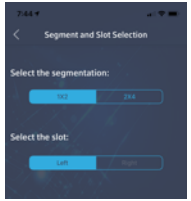
RPD Config Standards

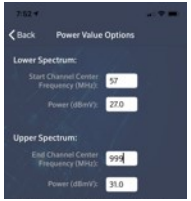
DS x US	RPD	RPD DS to RF Ports	RPD US Port to RF Port
1x1 (all FD node types)	Left / Slot-1	RPD (Left/Slot-1) DS port is forwarded to Ripple Ports P1, P2, P3, P4	Ripple port P1, P2, P3, P4 is configured to RPD (Left/Slot-1) US1
1x2	Left / Slot-1	RPD (Left/Slot-1) DS port is forwarded to Ripple Ports P1, P2, P3, P4	Ripple port P1 & P2 is configured to RPD (Left/Slot-1) US1 Port Ripple port P3 & P4 is configured to RPD (Left/Slot-1) US2 Port
2x4: Left/Slot-1	Left / Slot-1	RPD (Left/Slot-1) DS port is forwarded to Ripple Ports P1 & P2	Ripple Port P1 is configured to RPD (Left/Slot-1) US1 Port Ripple Port P2 is configured to RPD (Left/Slot-1) US2 Port
2x4: Right/Slot-2	Right / Slot- 2	RPD (Right/Slot-2) DS port is forwarded to Ripple Ports P3 & P4	Ripple Port P3 is configured to RPD (Right/Slot-2) US1 Port Ripple Port P4 is configured to RPD (Right/Slot-2) US2 Port

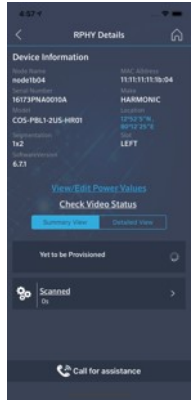
R-PHY scanner App Provisioning Flow











Note: Material for review of the R-PHY Node Comcast hand-held field app is available on Comcast ULearn

Step:1 End User Action: upon opening the scanner app, the end user will select “Provision RPhy”
Step:2 End User Action: scans the QR code on the RPD
Step:3 End User Action: Selects RPD from the list or manually enters the node name
Step:4 End User Action: Clicks 1x2 for node segmentation. By default, 1x2 will select the left slot position
Step:5 End User Action: Adds power value options
Step:6 End User Action: User can view RPhy details to gain access into the latest provisional status

Node Troubleshooting – Basic Building Blocks

Power

- Single Power Pack per node
- Converts AC input to DC output for modules
- Requires 45 VAC minimum to work
- Design 50 VAC minimum
- Are there temporary power sources in the power network?

RF

- RFP Output/Input correct – test probes
- RFP Tight?
- Mini Coax from RPD to RF amplifier or Combining board loose, damaged or kinked?

Light

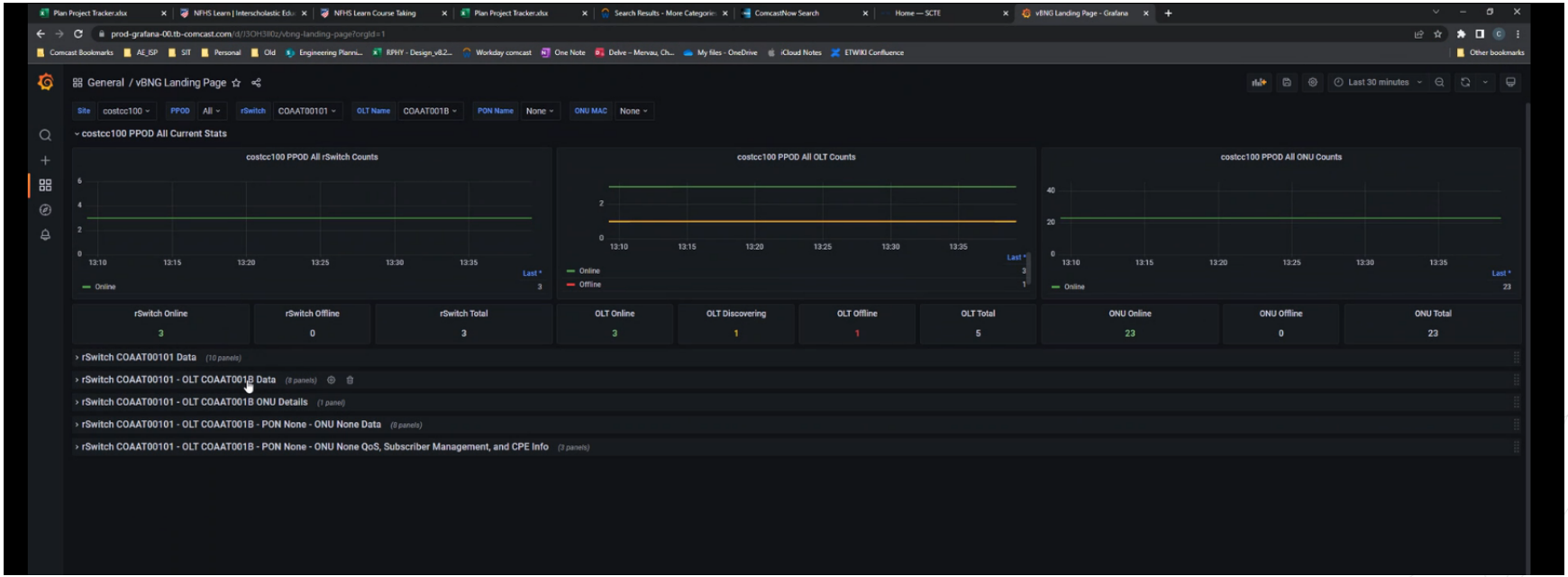
- Input levels (-10 to -27 dBm)
- Node Cable kinked or damaged?
- Fibers damaged or bent to tight?
- Correct wavelength for SFP+?

Housing

- Mechanical damage?
- Lid closed and torqued properly
- Port caps replaced and snug
- Node cable heat shrunk
- RF Cables tightened, and heat shrunk

Troubleshooting and monitoring

- Troubleshooting will take place at the AC/DC side, optics, and HW components
- Verify power, LEDs, and light levels
- Grafana offers monitoring capability at the RPD, rSwitch, OLT, and ONU levels
- If you're unable to resolve any HW issues, call the service desk through the scanner application and DAA will assist



TECHNICAL ASSISTANCE

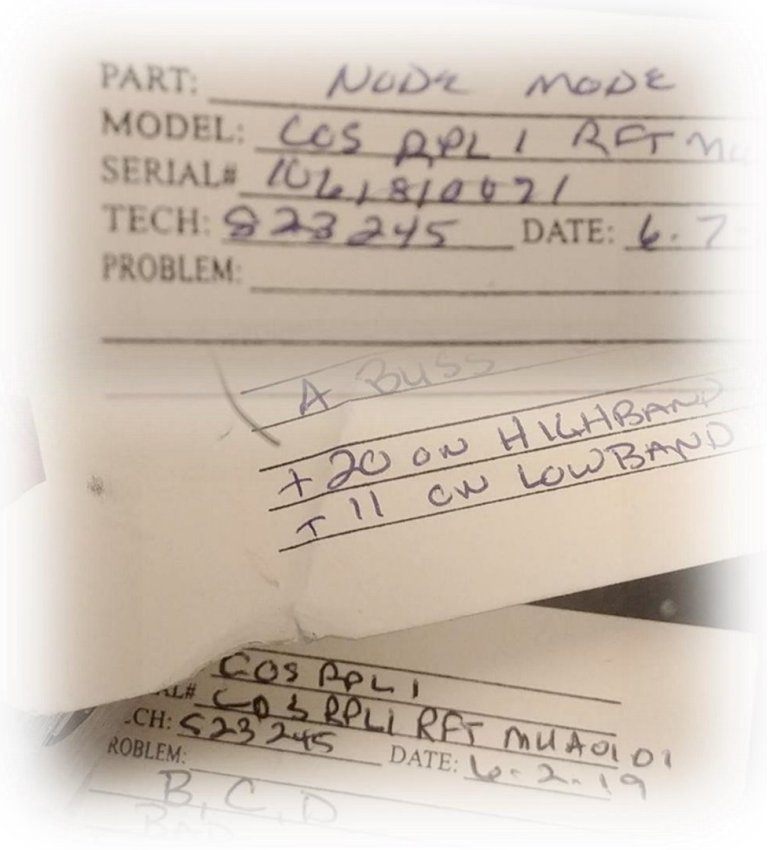
FOR FIELD REPLACED UNITS THAT ARE SWAPPED OUT IN THE FIELD W/O INVOLVING TAC

Please contact your regional Harmonic Account Manager/Sales Director so RMA can be created

FNS – Fiber Node Services is also available for all RMA support

- Regional pickups and milk runs can be worked out directly with FNS
- FNS point of contact:
  Steve Chew
  steve@fibernode.com
  (765)-524-1611

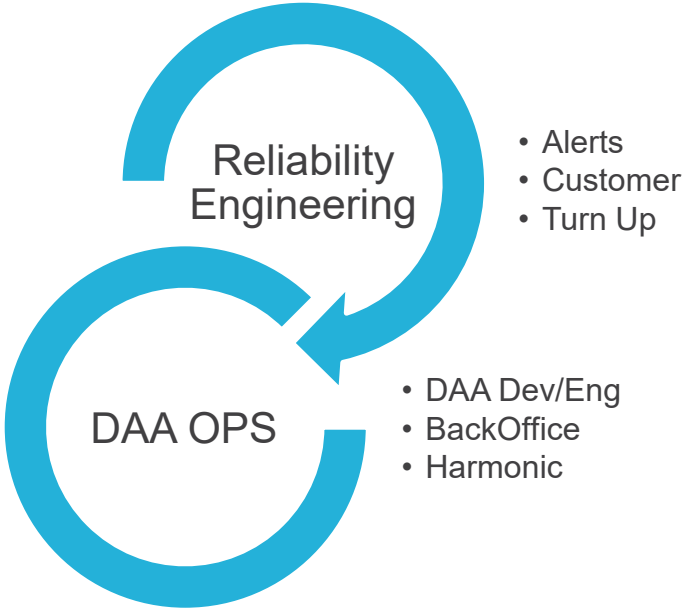
Please use service tags to provide details of the failure and attach to the module



Technical Assistance

Escalation Path

1) HFC/XOC
    1) Platform_RF_Access@comcast.com
    2) 1-267-260-3464
2) DAA Operations Desk:
    1) 24x7, On call rotation
    2) DAA_Support_Desk@comcast.com
3) Microsoft Teams Channel
    1) **platform_RE_Access**



Thank you

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(215) 280 3700

Special thank you to Rob Howald for his collaboration on this deck!