Cable's Changing Landscape

Emerging Technologies in Today's Networks

SCTE Chicago 9/25/19

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New Acronyms

RPD: Remote PHY Device

Note: Not to be confused with Return Path Demodulator that was also referred to as an RPD and has since been replaced with the Advanced Return Path Demodulator (ARPD).

CCAP: Converged Cable Access Platform

- Current architecture which brings DOCSIS and video modulation into a single converged chassis. Provides space savings as well as simplification of wiring.

DAA: Distributed Access Architecture

- New approach distributing signals throughout the network. QAM modulation/demodulation for DOCSIS and video is moved deeper into the network (formerly node location). This approach lessens space, power and HVAC demands at hub location. A significant improvement in signal quality will be realized.

FDX: Full Duplex

- Not a new term to communications, but a new approach being explored in DOCSIS 3.1. In this scheme, upstream and downstream signals share the DOCSIS channel and can enable dynamic configuration of upstream and downstream capacity.

New Acronyms

GCP: Generic Control Protocol

Generic Control Plane Protocol (GCP) is used to pass configuration between cores (principal and auxiliary) and RPDs.

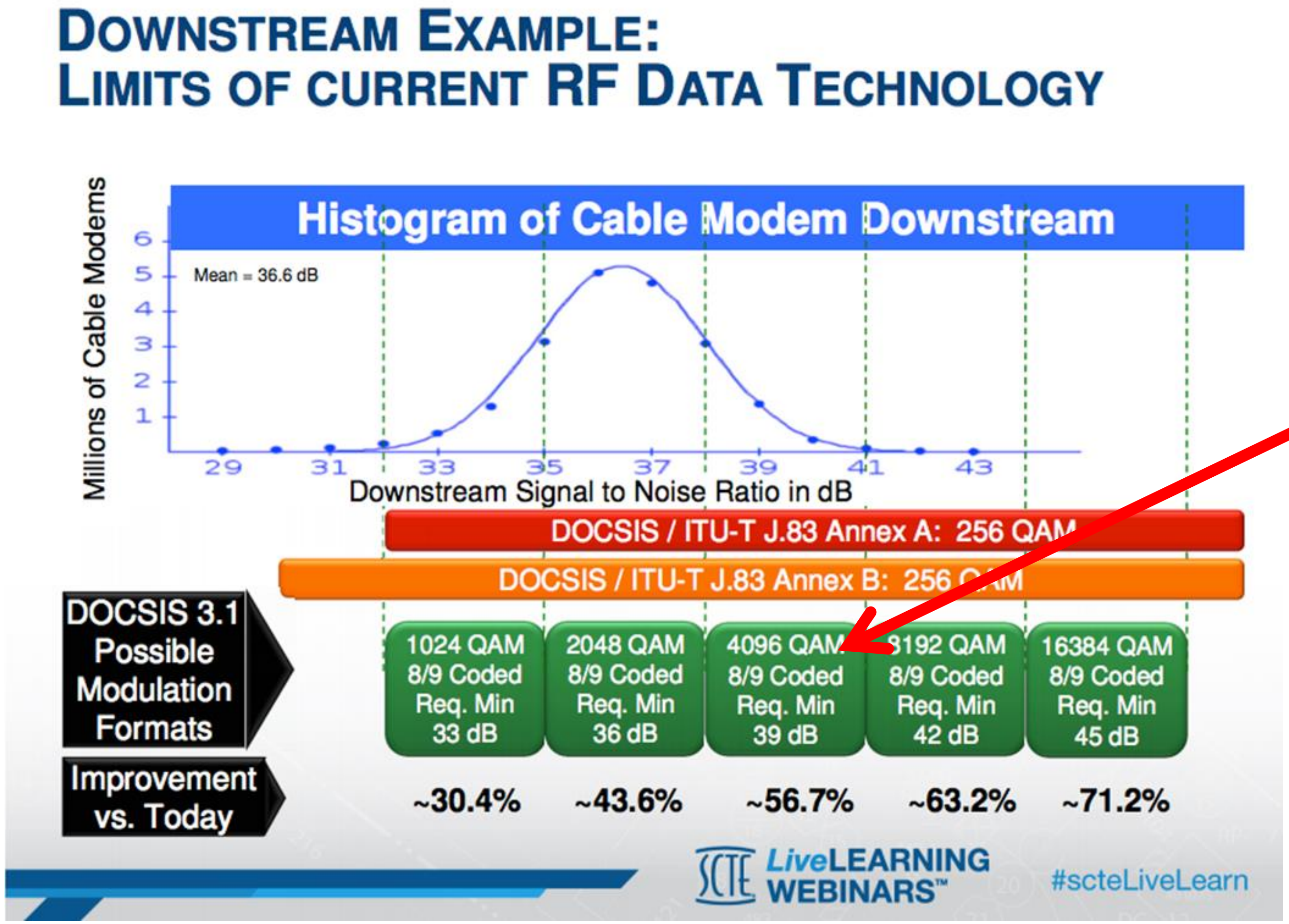
CIN: Converged Interconnect Network

Data network architecture interconnecting various servers (DOCSIS, video, etc.) to the RPD.

IEEE 1588 PTP: Precision Time Protocol

- A protocol to establish a “grandmaster clock” and maintain synchronization with various slave clocks distributed along a network which is spread physically over a large geographic area.

Why is Remote PHY important to DOCSIS 3.1?



Existing plant conditions are not quite good enough to support 4096QAM

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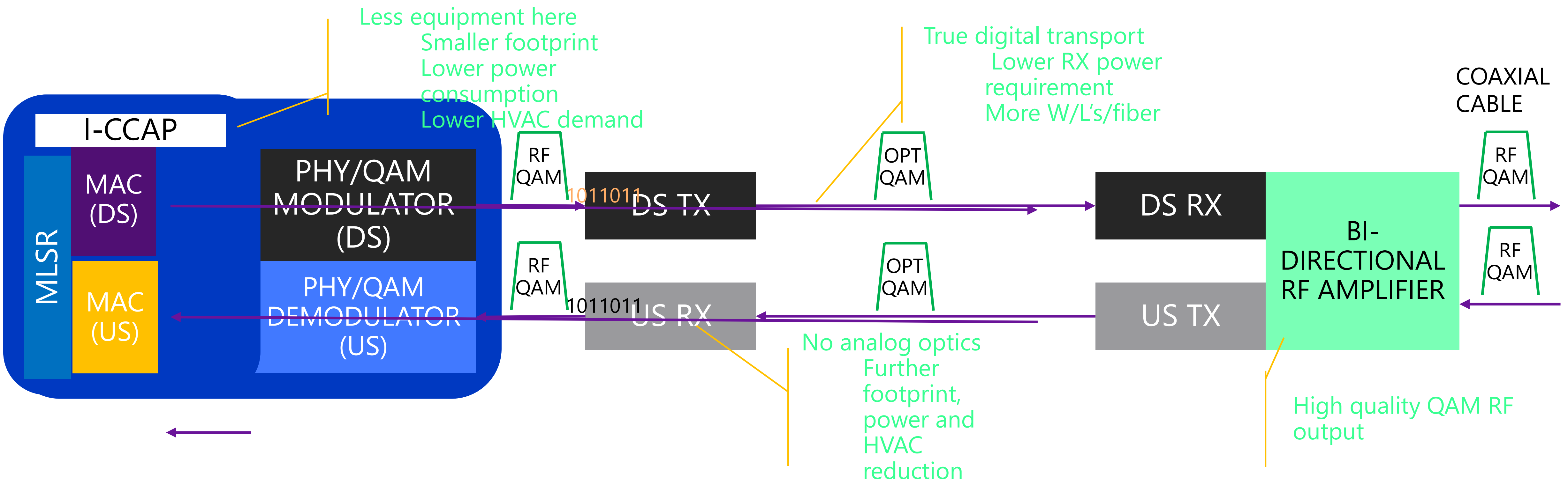
What is Remote PHY?



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Additional reasons for Remote PHY:

Higher bit-rates for DOCSIS 3.1: If the DOCSIS 3.1 PHY is located in the optical node, then:

-Transmission impairments from the optical path and the laser and receiver are removed

-Thus allowing DOCSIS 3.1 to operate at one or two higher levels of modulation.

-Customer can hopefully see a 10% to 20% increase in throughput for a given spectrum.

Longer reach: Analog fiber cannot reach as far as switched digital fiber network allowing deeper fiber deployments.

Scaling: R-PHY allows the vCMTS chassis to **scale down** as well as **scale up**

Scale UP: Higher Service Group(SG) density per chassis

Multiple RPDs per SG: Better utilization of SG processing power for nodes with sparse subscriber penetration

Scale DOWN: A centralized vCMTS Core can serve nodes from multiple smaller hubs; removes the need for dedicated equipment per hub.

Why Remote PHY?

DAA with Remote-PHY in the Node

- Save space and power in the HE
- Mining the coax _ extending its life
    - Bypass the "weakest link" -analog fiber- by using digital
    - Bring Headend performance to the Node
        - **45-47 dB MER at the Node**
    - Digital Optics Long Distance capabilities
    - Performance at the Node Independent of Distance
- More wavelengths – more capacity - on the fiber
    - **>> 40 λ's**
    - **Potential: 80 km 10G Tunable DWDM SFP+ , 50 GHz spacing for 90-100 channels/fiber**

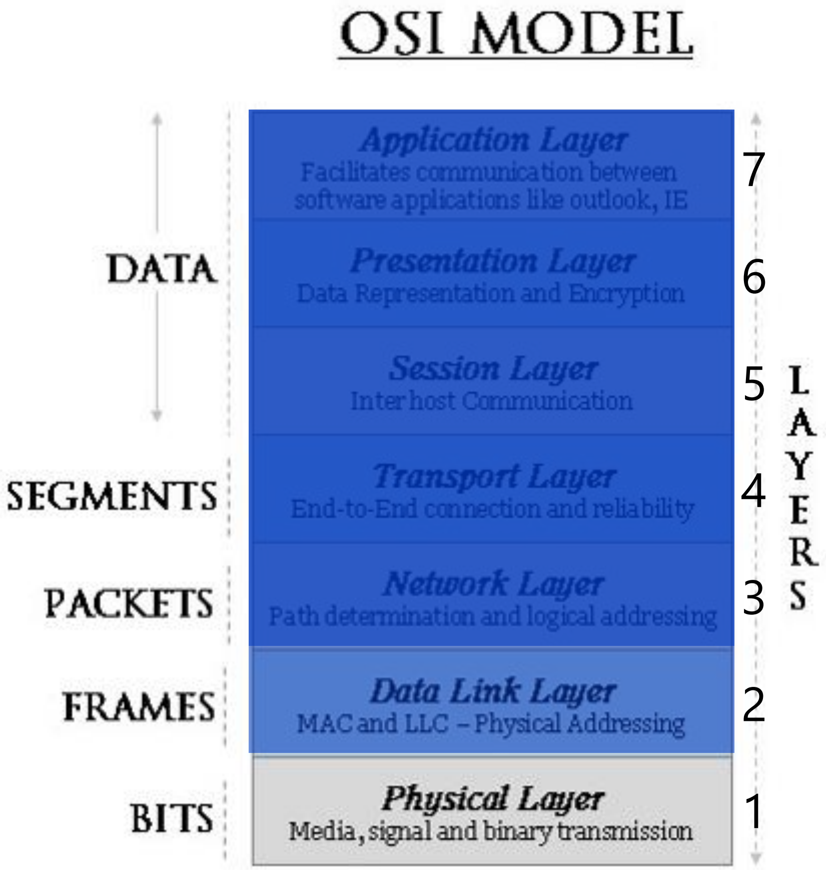
Fiber Deep

- Only one active location between HE and subscribers
- "Easy" system upgrades from the Node only, only where needed, per Node segment

Remote PHY applications

- Downstream R-PHY – Edge QAM moved to the Node, digital HE to the Node
- Remote upstream Receiver – Move CMTS burst receiver to the Node, payload data only to the HE
- FDX – Full Duplex – CommScope developing
    - High-speed bi-directional symmetrical on passive coax

A Step into Layer 2 of the OSI Model



Historically, CATV outside plant techs were dealing with Layer 1 only

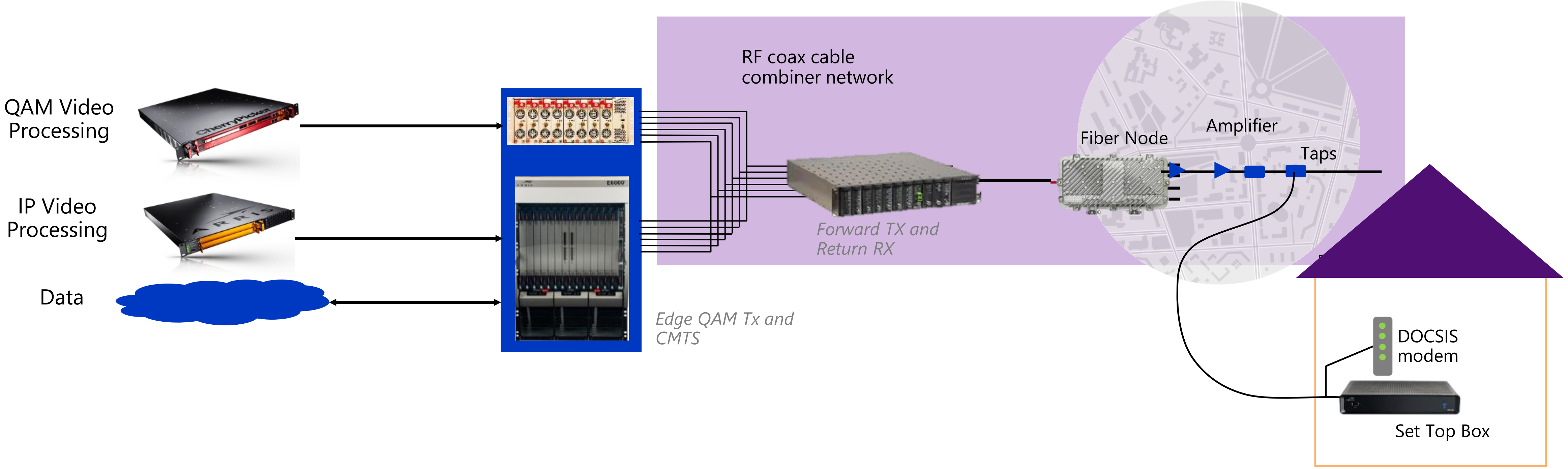
- Layer 1 involves the physical communications medium only
  - Fiber
  - Nodes
  - Coax
  - Amplifiers
  - Passives

Signal levels were measured, signal quality evaluated, but there was little or no effort to actually interpret the actual information being transported

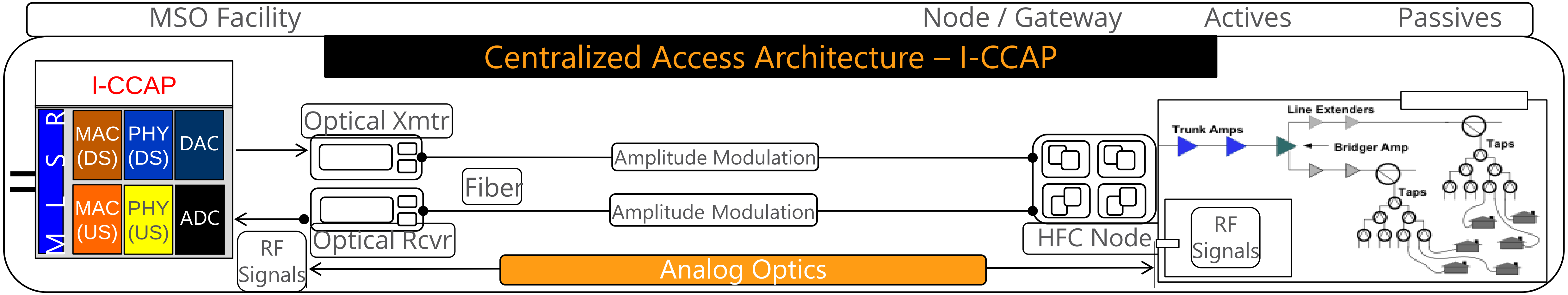
With R-PHY, there will be a need to know how to understand some of the exchanges between the I-CCAP core and the R-PHY device

- That moves us also into Layer 2

CURRENT ACCESS NETWORK –

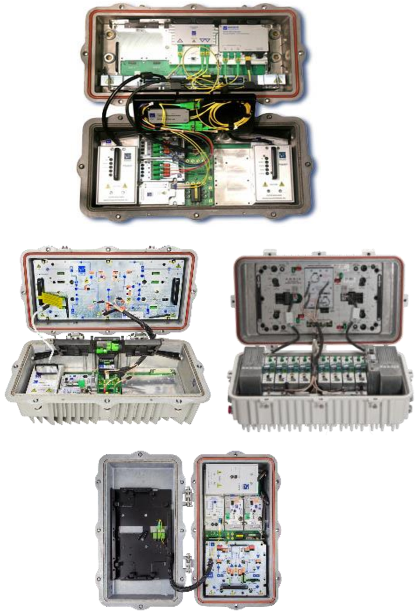


Centralized & Distributed HFC Access Architectures



CMTS-ICCAP Edge QAM

Forward TX and Return RX

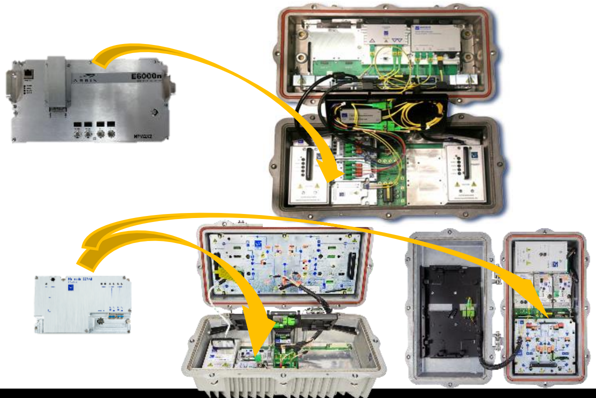


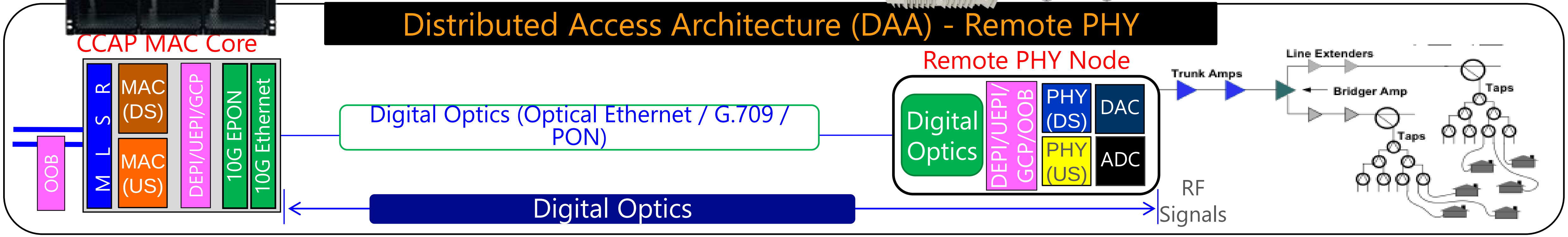
Nodes

Centralized & Distributed HFC Access Architectures

MSO Facility	Node / Gateway	Actives	Passives

10GbE Switch





- <u>Nodes</u>
- OM6000
- NC4000/2000

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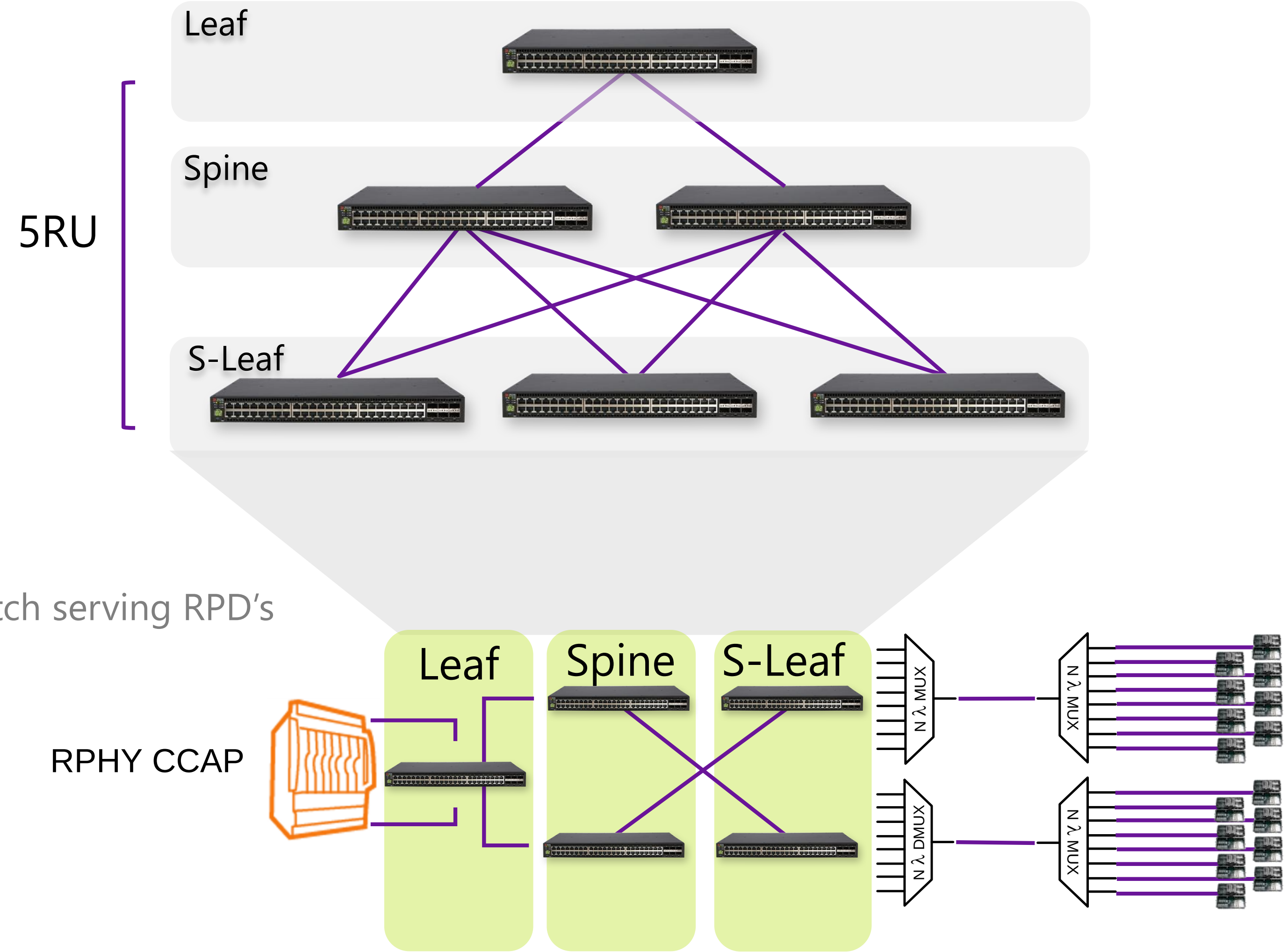
Closer Look at Ethernet Fabrics

Converged Interconnect Network "CIN"

- Topology
  - Layer 2 and or Layer 3
  - Physical & Logical Mesh
  - Options for Fabric Networks
- Roles of Leaf, Spine, S-Leaf
  - Leaf terminates edges into Mesh
  - Spine is a the backbone of Mesh
  - S-Leaf – a MACSEC implementation Leaf Switch serving RPD's
- Authentication
  - S-Leaf is a NAS
  - NAS in a Controller
- Discovery for RPD to CORE
  - DHCP Based
    - Relay in the S-Leaf
    - Relay in a Controller



CIN Fabrics Enable Consolidation of all Remotes :
Remote PHY, Remote MAC, Wireless and Remote OLT PON Services

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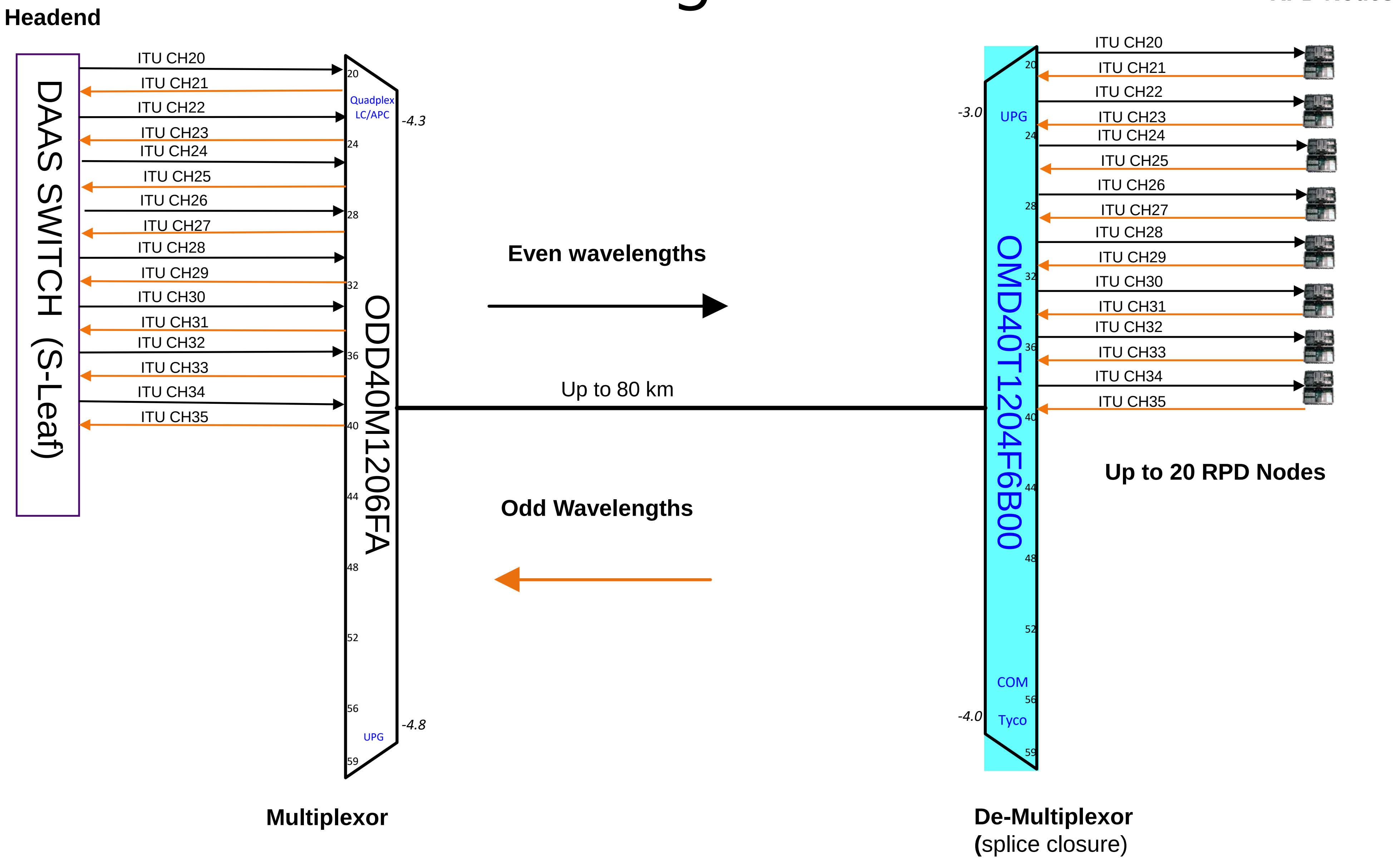
Timing is Critical

- With I-CCAP all of the timing was in that box in the Headend. The node did not require a timing signal

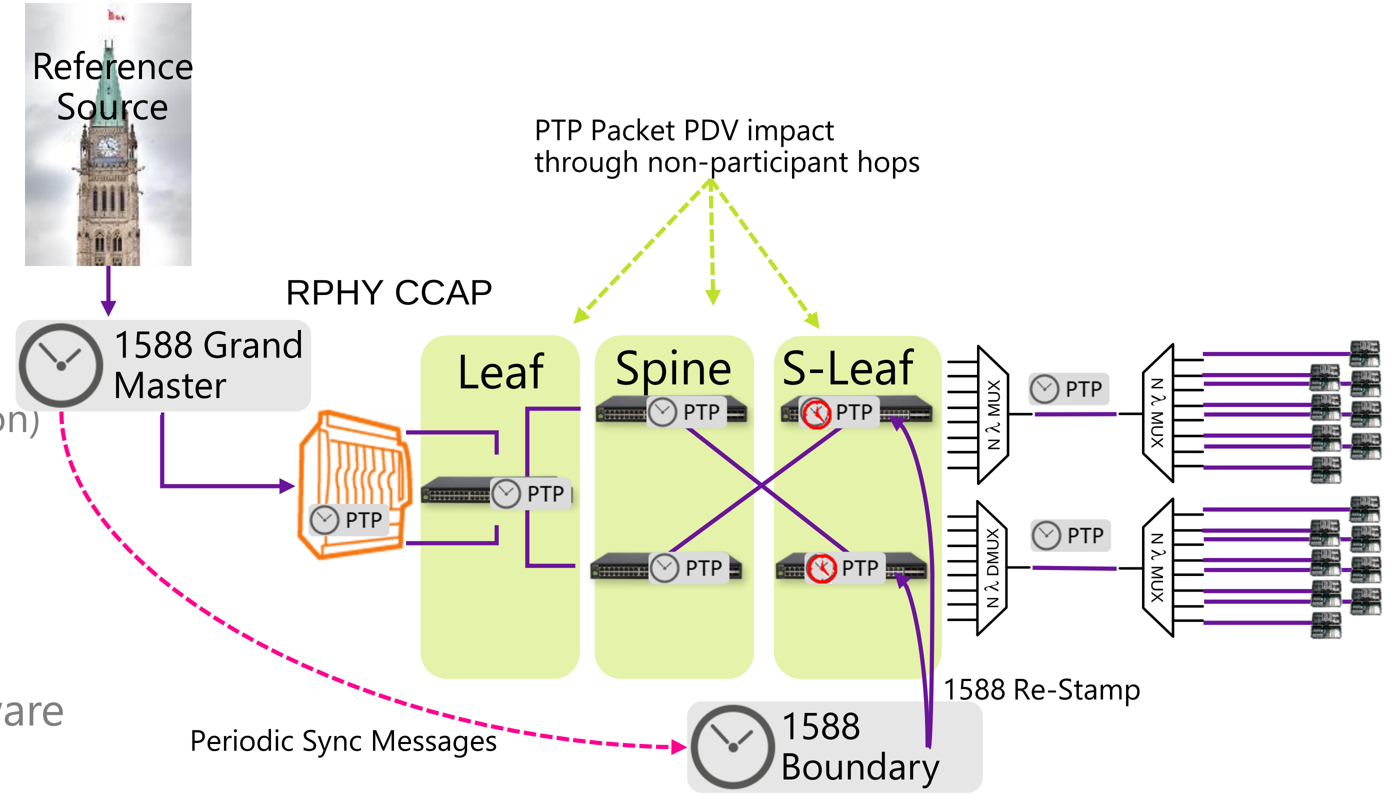
- With Remote PHY we are taking some of the hardware from the Headend and moving it to the Node .

- It is important to have precise timing between the Node and Headend so that DOCSIS and Video services flow correctly

DWDM Single Fiber Solution



Remote PHY Timing Dependencies



Remote PHY Timing

- IEEE 1588 Precision Time Protocol (PTP).
- Types of Clocks.
  - Grandmaster Clock (Ultimate Source)
  - Boundary Clock (Slave to Grandmaster)
  - Transparent Clock (Independent Compensation)
- Packet Delay Variation (PDV) is critical

Both CCAP Core and RPD

- OC slaves to an external Grand Master.

The network path

- Between the GM and Core/RPD is 1588 unaware (not a BC nor a TC)

Max of ~2-3 hops (1588 unaware) between the GM and Core/RPD

The 1588 packets must be placed in the highest QoS flow (e.g. DSCP value of 46) in order to maintain reasonable PDV.

For routed L3 networks, it is a must to ensure that the forward and reverse paths have similar delays between each slave and its master (GM or BC) to ensure accurate 1588 delay calculation.

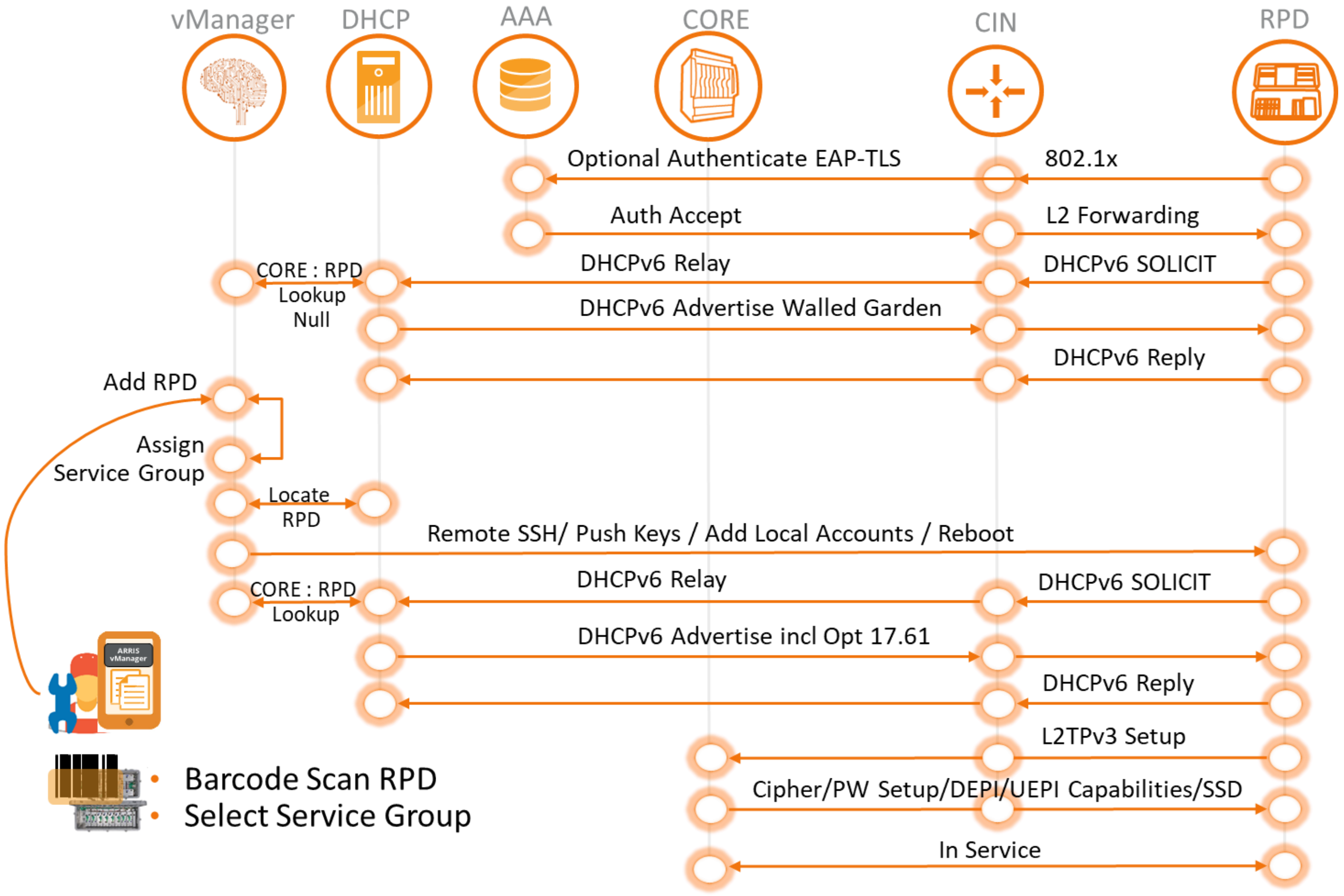
Some RPHY Drawbacks

- Not everything about RPHY is positive. There are a few things that will appear as "negatives".
  - Boot process takes about 5 minutes
    - When an RPD goes down, the entire onboarding process must occur. That will take as much as 5 minutes
  - Firmware updates will need applied
    - Schedule in maintenance window
    - Will require reboot
  - Field troubleshooting is limited
    - Only optical level, voltages and LED status are field checkable. If those parameters are OK, then either provisioning is incorrect or device is bad. (Great opportunity for finger-pointing)

Onboarding RPD Process Flow

Power on to In Service

- RPD authentication at the Network
- Discovery of Principle & AUX Cores via DHCP
- L2TPv3 Tunnel
    - Setup to CORE(s)
    - Authentication
    - Encryption
    - Pseudo wires for DEPI and UEPI and OOB paths
- In Service



Example of successful GCPP(Generic Control Protocol Principal) Core Initialization overview

RPD powers up

1. RPD gets its IPv6 Address and Principal CCAP core address from DHCP server
2. RPD Connects to TOD server
3. RPD sends TCP SYN to Principal CCAP core to see if it is there
4. If RPD gets a response it sends a GCPP NOTIFY to Principal CCAP core announcing it is alive
5. If the RPD is in Principal core's config it sends it EDS that includes:

   - read request for RPD capabilities
   - write request for CCAP core capabilities
   - write request for software version RPD should be at (if RPD is NOT at this version is will do a Secure Software Download. *If software is upgraded RPD will reboot.*

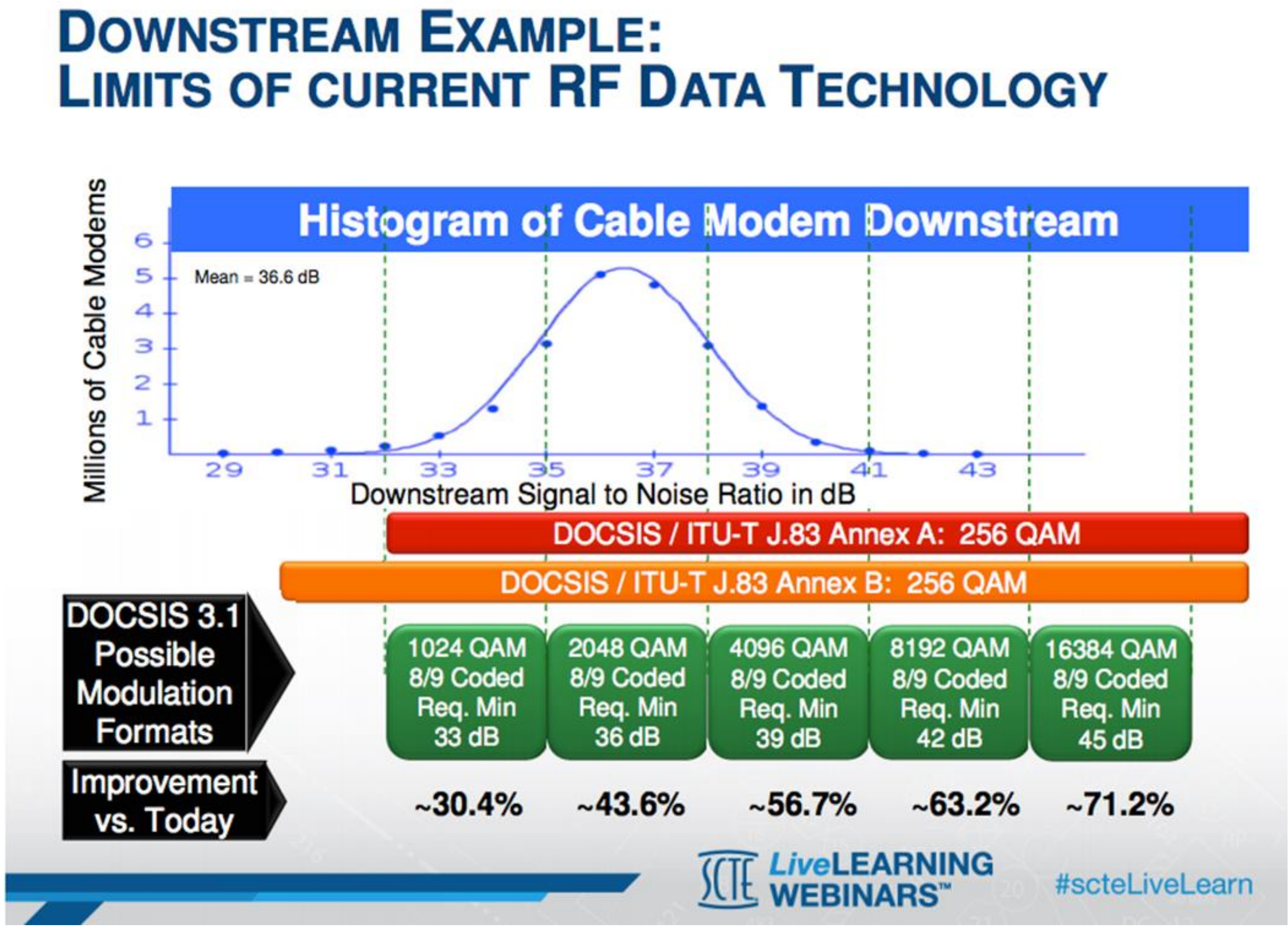
6. Principal CCAP core will then send the RPD the IP address of the Grand Master Clock (PTP)
7. Principal CCAP core can send down OOB, Dedicated Tone and other channel configuration
8. Principal CCAP core will then send down aux core table listing the aux cores
9. Principal CCAP core send downs initial configuration complete
10. Principal CCAP core sends down move to operational
11. The RPD sends the aux cores a NOTIFY with a cold reset status and a startup notification
12. The RPD sends the Principal core a NOTIFY with a state of 6 indicating "powered up"
13. The RPD starts to receive its configuration information from the aux cores (DOCSIS, video,…).
14. The RPD sends the AUX core a NOTIFY with a state of 6 indicating "powered up"
15. The RPD sends the Principal core a NOTIFY it is connected to the AUX Core
16. The RPD sends the Principal and AUX cores a NOTIFIES indicating PTP lock status and when locked

So What's Gained in RPHY?

- Headend-to-node fibers become more efficient
  - More wavelengths can be used
  - Greater distances can be traversed
- Signal quality is substantially improved
  - 45-47dB MER performance at the node
- Data throughput can be increased
  - Using OFDM and higher order QAM modulation in the OFDM, capacity can increase
- Need for additional brick-and-mortar infrastructure is reduced
  - Traditional node splits using more analog optics are eliminated
  - Power and HVAC in hubs does not have to scale

Improving Throughput

If we go Node + 0, then 16384 QAM is theoretically possible



Moving into the Future of DOCSIS

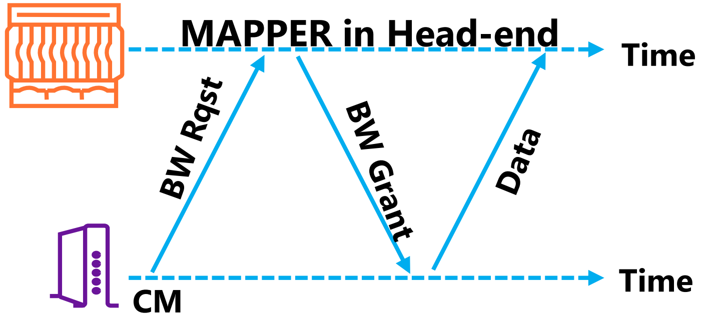
Major Problems Coming to DOCSIS & HFC In Near Future… With Some Possible Solutions

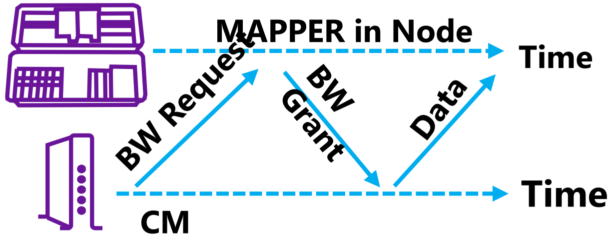
Issue #1: Upstream BW Capacity will need to grow in the next 2-3 years

- Increased DOCSIS 3.1 US OFDMA deployments
- **Dynamic FDX for Node+0**
- **Dynamic FDX w/ FDX Amplifiers for Node+X**
- **US Extended Spectrum DOCSIS (aka Ultra-High-Split) with existing DS Spectrum (w/ existing Taps) for Node+0 or Node+X**

Issue #2: US Latency Issues will need to be addressed in the next 2-6 years

- Low-Latency DOCSIS concepts
- MAPPER in RPHY Node
- RMD (MAPPER in RMD Node)
- RMC (MAPPER in RMC Node)





Issue #3: DS BW Capacity will need to grow in the next 5-10 years

- Increased DOCSIS 3.1 US OFDMA deployments
- **Extended Spectrum DOCSIS (DS Spectrum growing beyond capacity of existing Taps) w/ Static FDX for Node+0 or Node+X**
- **Extended Spectrum DOCSIS (DS Spectrum growing beyond capacity of existing Taps) w/ Dynamic FDX for Node+0 or Node+X**

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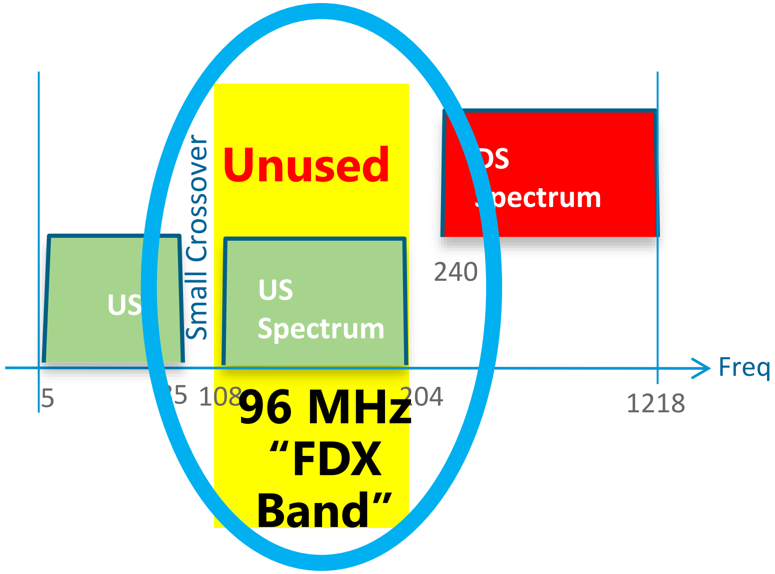
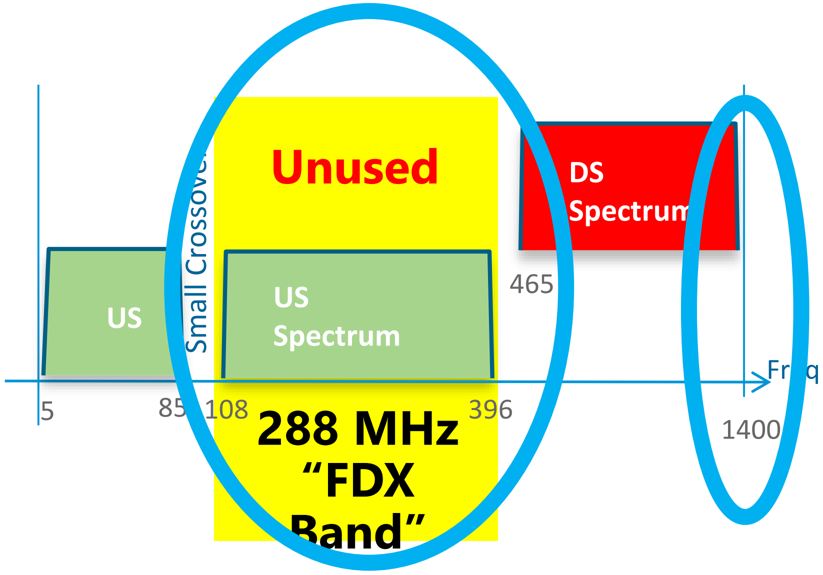
Start with Ext. Spectrum DOCSIS & Add FDX Later (to increase US BW Capacity)

When At Node+X (X>0)



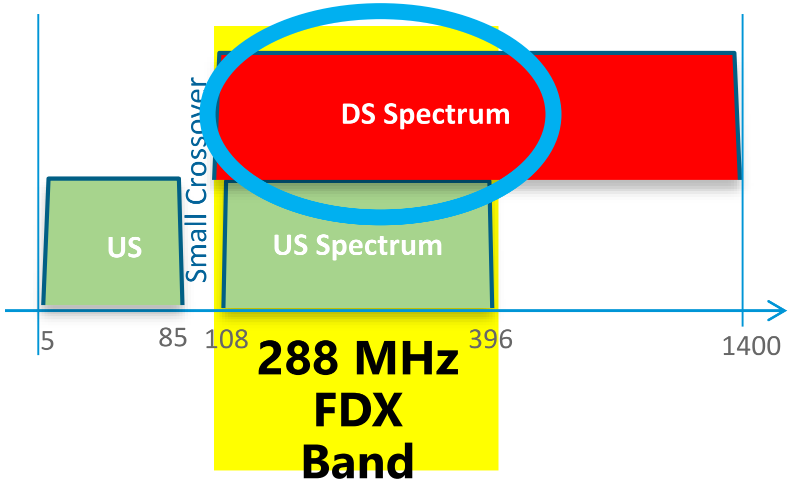
- Upstream: 176 MHz
  -> 1496 Mbps
- Downstream: 978 MHz
  -> 8313 Mbps

When At Node+X (X>0)



- Upstream: 368 MHz
  -> 3128 Mbps
- Downstream: 935 MHz
  -> 7947 Mbps

When We Arrive At Node+0



- Upstream: 368 MHz
  -> 3128 Mbps
- Downstream: 2892 MHz
  -> 11,900 Mbps

- Both paths end up at the same end-point
- The same DOCSIS chip-sets can potentially be used for both paths

So What is FDX?

We currently use FDM (Frequency Division Multiplexing) to provide for bi-directional signals

5-42 or 5-85MHz Upstream

54 or 105 and higher for downstream

FDX (Full Duplex or DOCSIS 4.0) changes all that

We will communicate in both directions on the same wire at the same frequencies

HOW CAN THAT HAPPEN?????

FDX at a high level

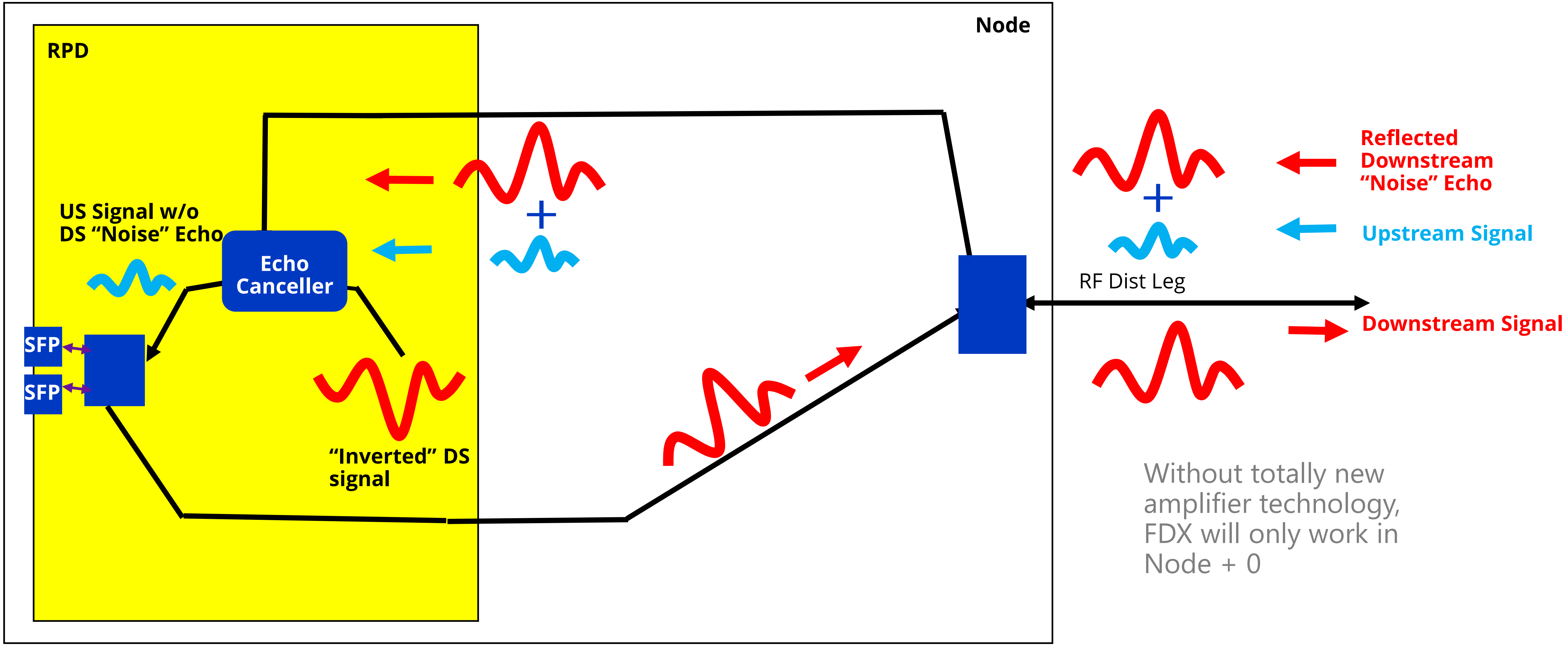
Let’s make an audio analogy:

If one Person 1 yells “Hello” from one end of a quiet field to Person 2 at the other end, and Person 2 yells “Hi” afterward, they most likely will hear each other.

If they speak simultaneously, they will not hear each other because their own voice will drown out the other’s.

If each could cancel his own voice out from his ears, then he should be able to hear the other voice.

Handling Noise at the Node (FDX Node Echo Cancellation) (greatly simplified… must cancel the DS "Noise" in the Lower-Power US Signal)



Without totally new amplifier technology, FDX will only work in Node + 0

Will This Work?

Speaking from a purely technical perspective, absolutely

Like most other new concepts, the biggest hurdle is making it practical from an economical standpoint

Since echo cancellation will be complex and costly, it will most likely be used at the RPD and not in the cable modems.

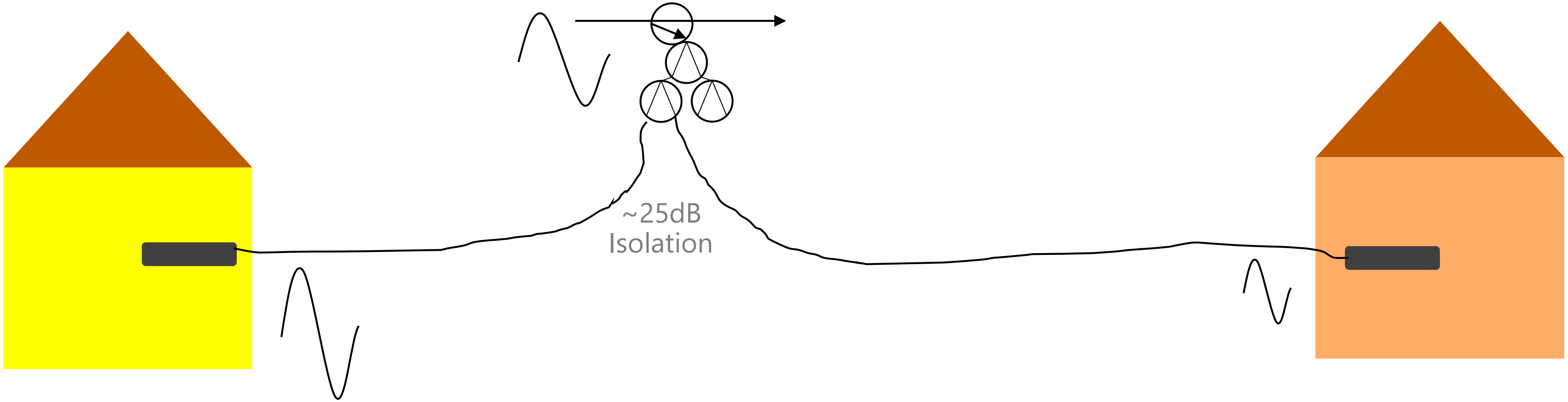
That implies that an RPD can talk to one modem and listen to another simultaneously on the same frequency

Since CM's will not have echo cancellation, they will not receive and transmit simultaneously

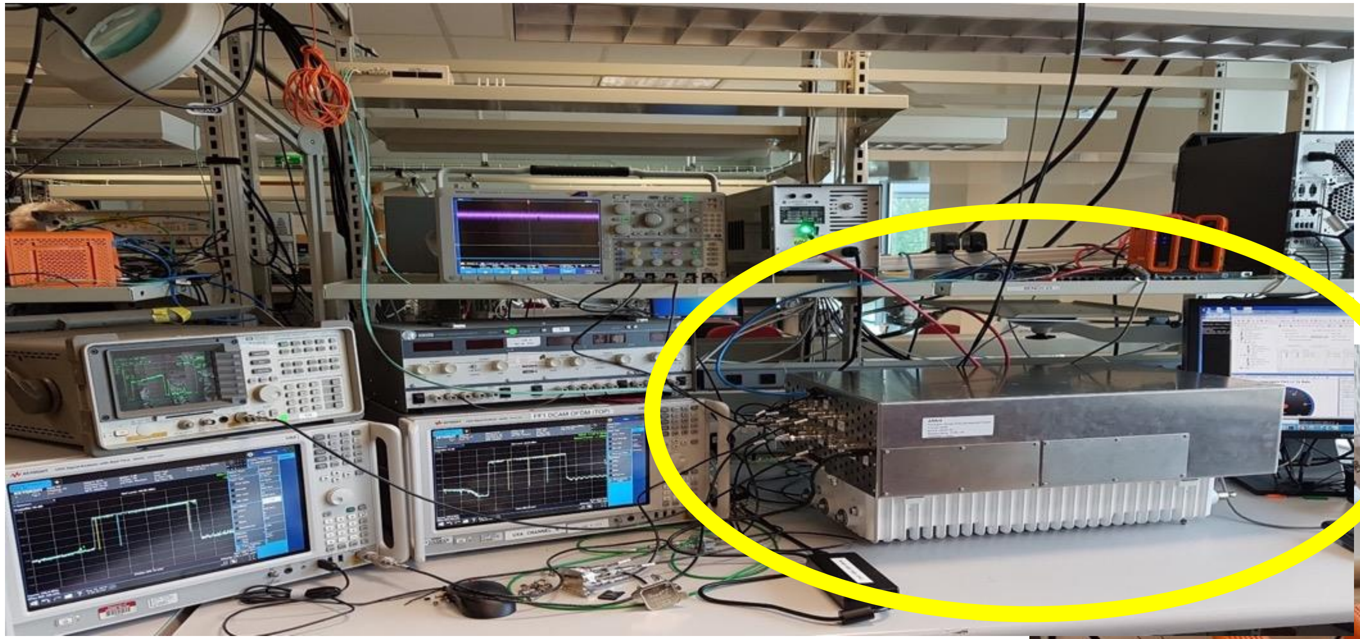
Other FDX Gotcha’s

A transmitting modem may interfere with a neighboring modem trying to receive on the same frequency

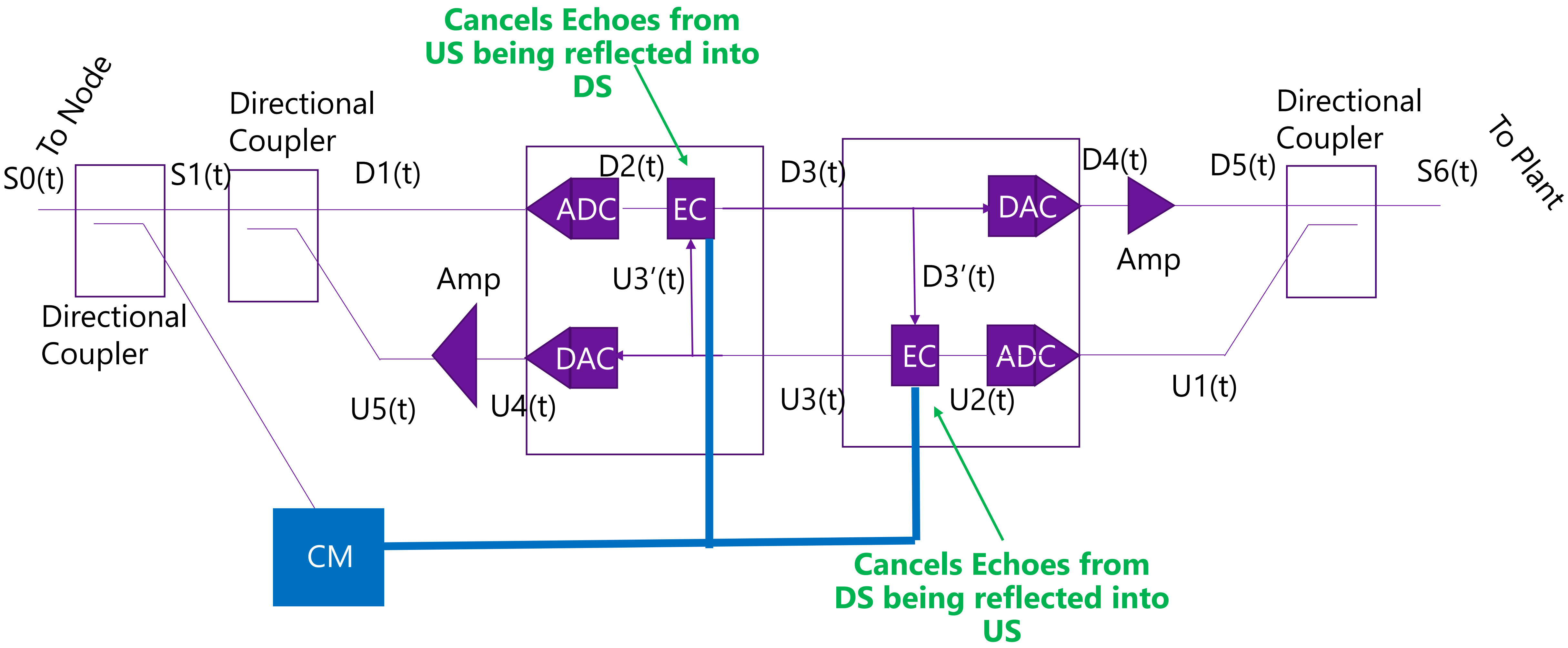
- This is a function of the isolation between tap ports
- FDX CM’s will generate “sounding” signals that will identify potential interfering modems
- These modems will be placed in “interference groups”
- Modems in a specific IG will not transmit and receive simultaneously on the same frequency



Is FDX Real? Yes…The ARRIS "Franken-Node" & FDX-like Test CMs exist… Developed for FDX Field Trial Testing that began in November 2018 at Comcast

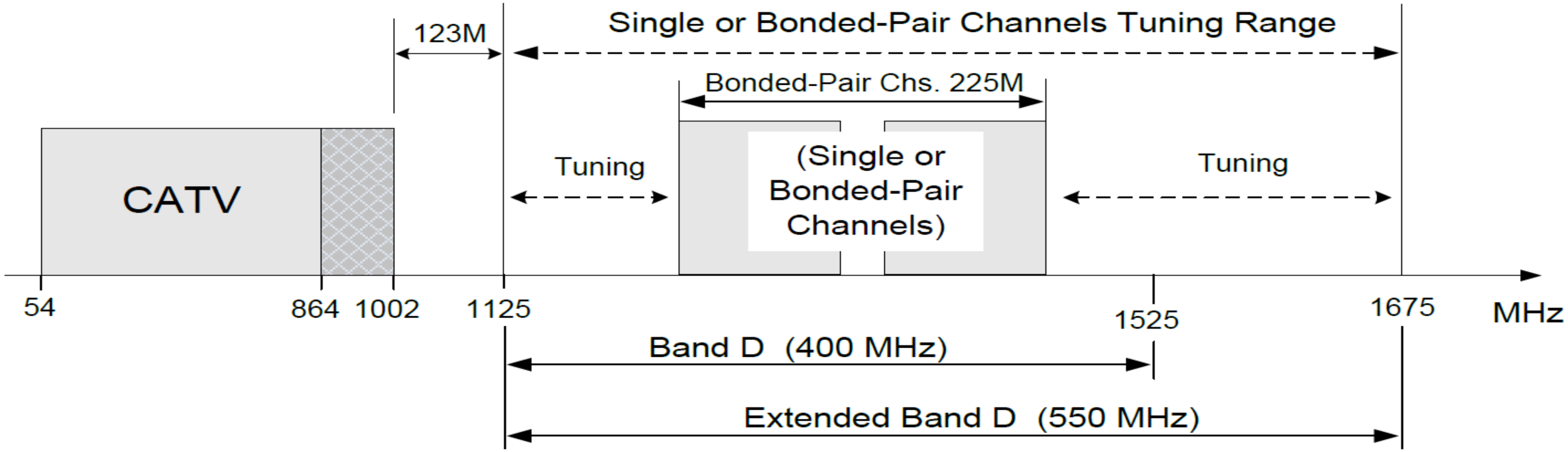


Full-Duplex FDX Amplifier Proposal



Moving Past 1GHz

Extending the Spectrum

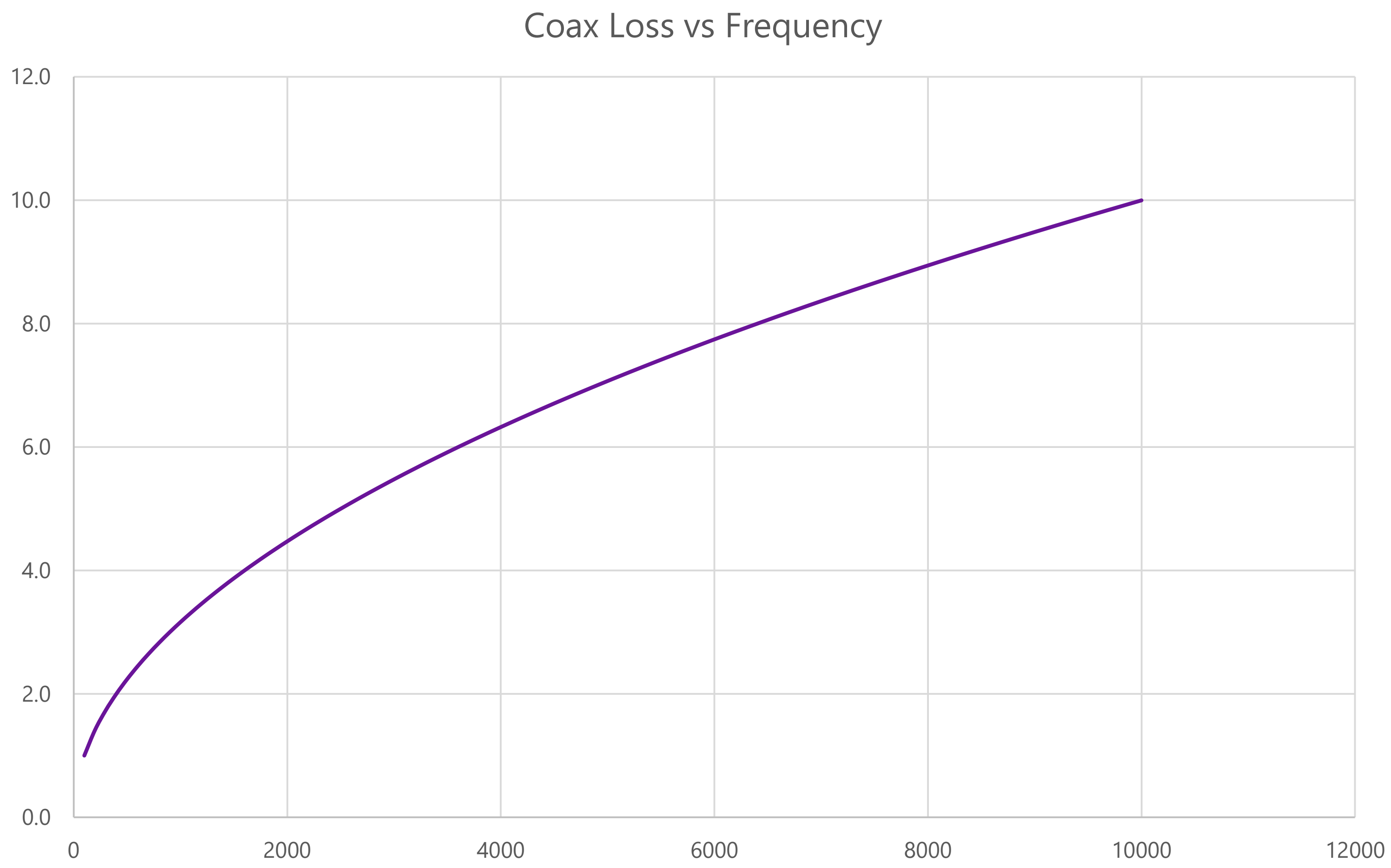


The move to 1.2GHz is in many cases complicated my in-home MoCA devices

There is already a significant push to go beyond 1.2GHz.

Some technologists are predicting 3GHz in the next decade

Extending the Spectrum



- The immediate thought on extending the spectrum goes to the increased loss of the coax
- 1dB of cable at 100 MHz is 5.5dB at 3GHz
- Some consider the practical limit of coax to be 10GHz
- That would mean 1dB of cable at 100MHz becomes 10dB at 10GHz

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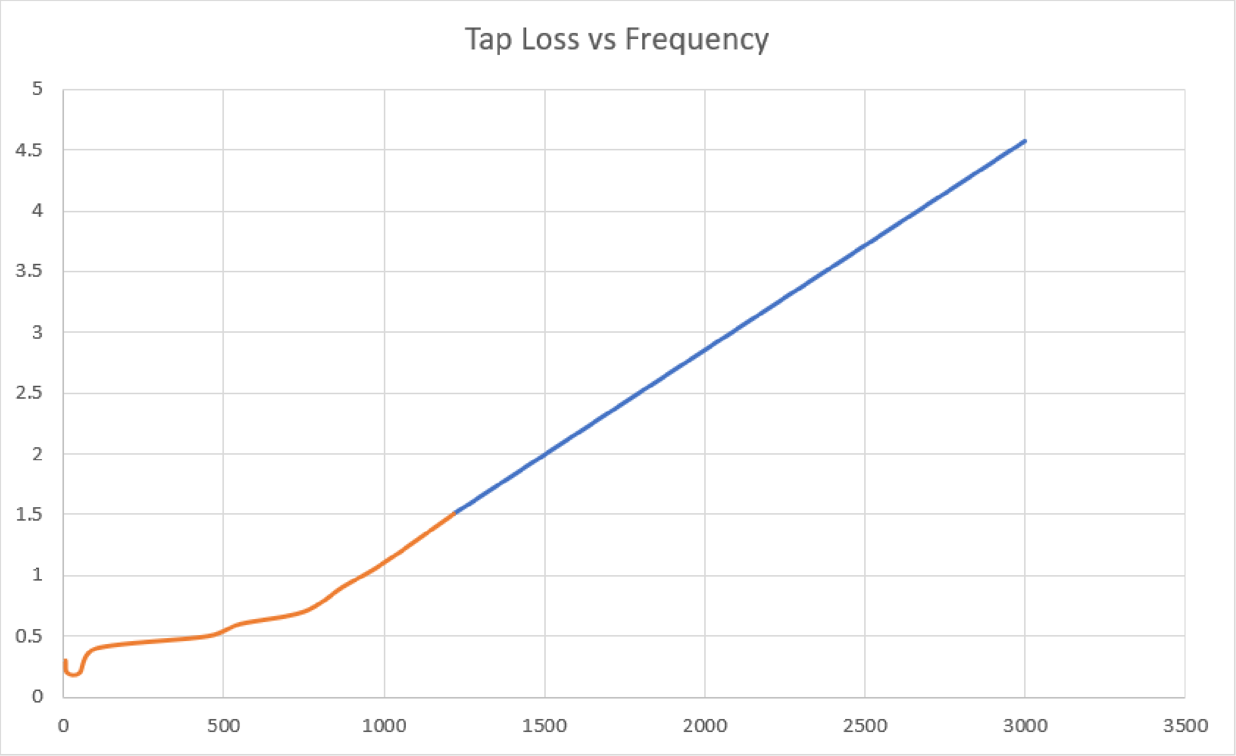
Extending the Spectrum

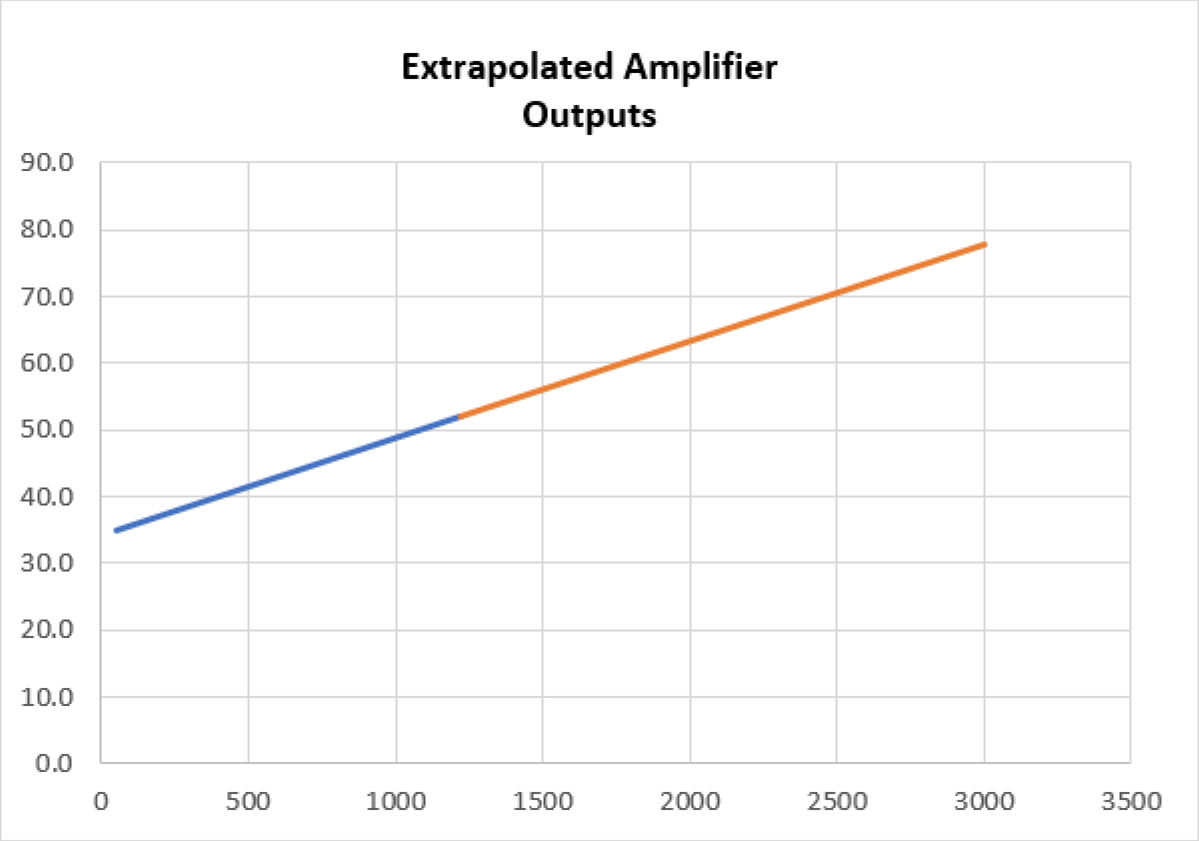
- Other considerations are passive devices
- New 1.2GHz passives were just released in the past couple of years
- RF efficiency of passives decreases as bandwidth increases
- Broadened spectrum will share space with many new potential ingress sources



Extending the Spectrum

Amplifier bandwidth expansion brings more challenges

- If we adopt the traditional approach of extrapolating the RF levels linearly, the 3GHz. Output level will be 78dBmV (virtual, 72dBmV true QAM)
- With such high levels and more signals being amplified, distortion performance will be a true challenge
- AC power consumption will also increase



Without a doubt, the wizards of cable will be thinking this through carefully. We may see some new and creative solutions on the horizon.

Summary

FDX focuses on US BW & is being developed for the ~2020 time-frame…

FDX w/ FDX Amplifiers is the "Holy Grail" for BW efficiency… But FDX may only work for Node+0 (unless cheap & low-power FDX Amps can be created)

Extended Spectrum DOCSIS focuses on DS BW & US BW. CableLabs committee should produce a spec quickly for products in the early 2020's

Extended Spectrum DOCSIS seems to be simpler & less risky to many MSOs

Different MSOs will likely choose different paths

The marriage of FDX & Ext. Spec. DOCSIS may be a marriage made in heaven for the Cable Industry

- ➢ Permits optimal use of the spectrum for both US & DS
- ➢ Permits operators to work well in Node+0 & Node+X environment
- ➢ Gives operators options in how to evolve their networks
- ➢ Improves Economies of Scale for chip & system developers of the Cable Industry

Starts to converge the many diverging solutions being considered by operators

Any Questions?

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