Remote PHY Fundamentals & Strategy

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Agenda

- The Basic Business Case
- RPHY Fundamentals
- RPHY Strategy
- RPHY Latency

The Basic Business Case for Remote PHY

Challenge: CCAP Scaling for Fiber Deep

Fiber Deep simplified example

- Node size moves from 500 HHP to 50 HHP
- 10x the nodes needed and 10x the number of I-CCAP (12x-18x typical)

Operational challenges

- Not enough room in the hub for 10x I-CCAP
- Not enough power in the hub for 10x I-CCAP

Business challenges

- MSO ARPU is the same. MSOs will not pay 10x for CMTS
- Vendors cannot sell CMTS for 1/10 the price

Can the CMTS scale to 10x the port density without 1/10 the cost?

Solution: Remote PHY

CCAP Core

RPD:
Remote PHY Device

The CCAP RF port density is limited by its physical front panel capacity

By separating the ports from the CCAP, the port connectivity and the remaining CMTS Core capacity can scale separately.

- Ports == connectivity
- Core == capacity

Customers can optimize connectivity vs capacity

Example

Classic I-CCAP system

- Say it has 50 RF Ports with a total of 100 Gbps capacity
- Optimal for 50 ports, 2 to 10 Gbps/port (1x to 5x over-subscription)

New RPHY System

- 500 Remote PHY 1 Gbps ports would require one 100 Gbps core (5x)

Note that a 500 HHP N+5 plant and a 50 HHP N+0 plant have the same number of subscribers and traffic load at cutover time.

- More RPHY Cores can be deployed for capacity as needed over time

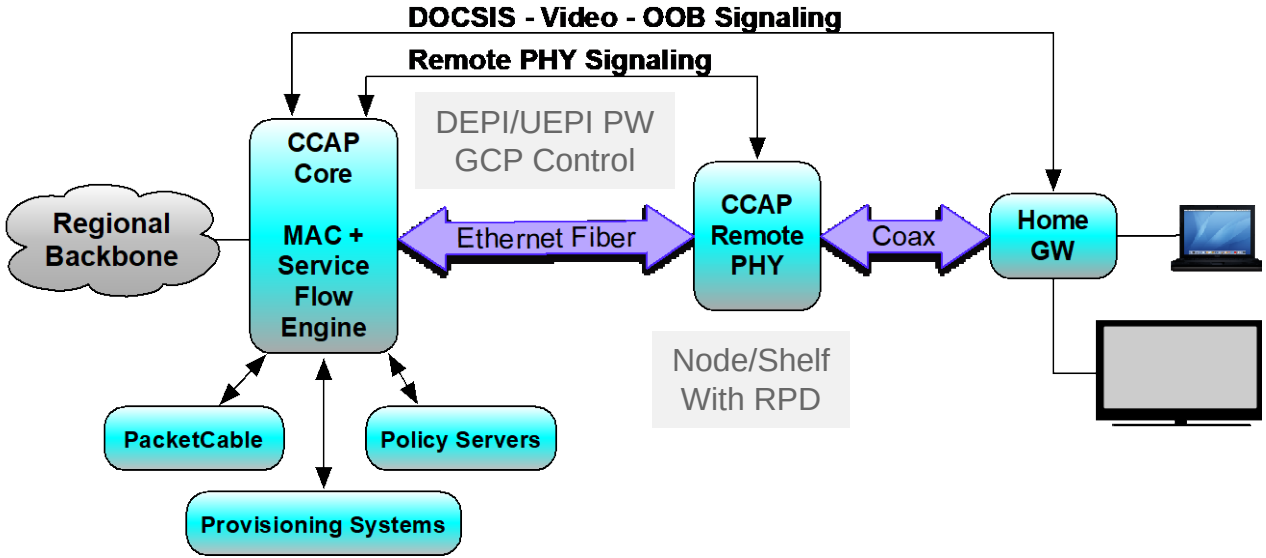
Remote PHY Fundamentals

History

DMPI	M-CMTS	R-PHY
2001	2005	2015

- DMPI (DOCSIS MAC-PHY Interface) was an ASIC-to-ASIC interface and was included in 2001.
- M-CMTS (Modular CMTS) introduced DEPI as a CMTS-to-EQAM interface in 2005. DEPI was an evolution of DMPI but now over IP. DEPI and UEPI (unpublished) became the new ASIC-to-ASIC i/f over 10 Gbps Ethernet.
- R-PHY added enhancements to DEPI and UEPI and re-published under the spec names R-DEPI and R-UEPI. GCP which was already in use as a module interface was published as the RPD configuration interface.

Remote PHY Architecture



- The Remote PHY Device (RPD) is a pseudowire (PW) attached L1 gateway.
- Remote PHY implies centralized software. DOCSIS signaling is CMTS core to CM. RPHY signaling is limited to PHY timing, configuration and control.

Pseudowires

A pseudowire (PW) is an emulation of a wired connection over a packet network

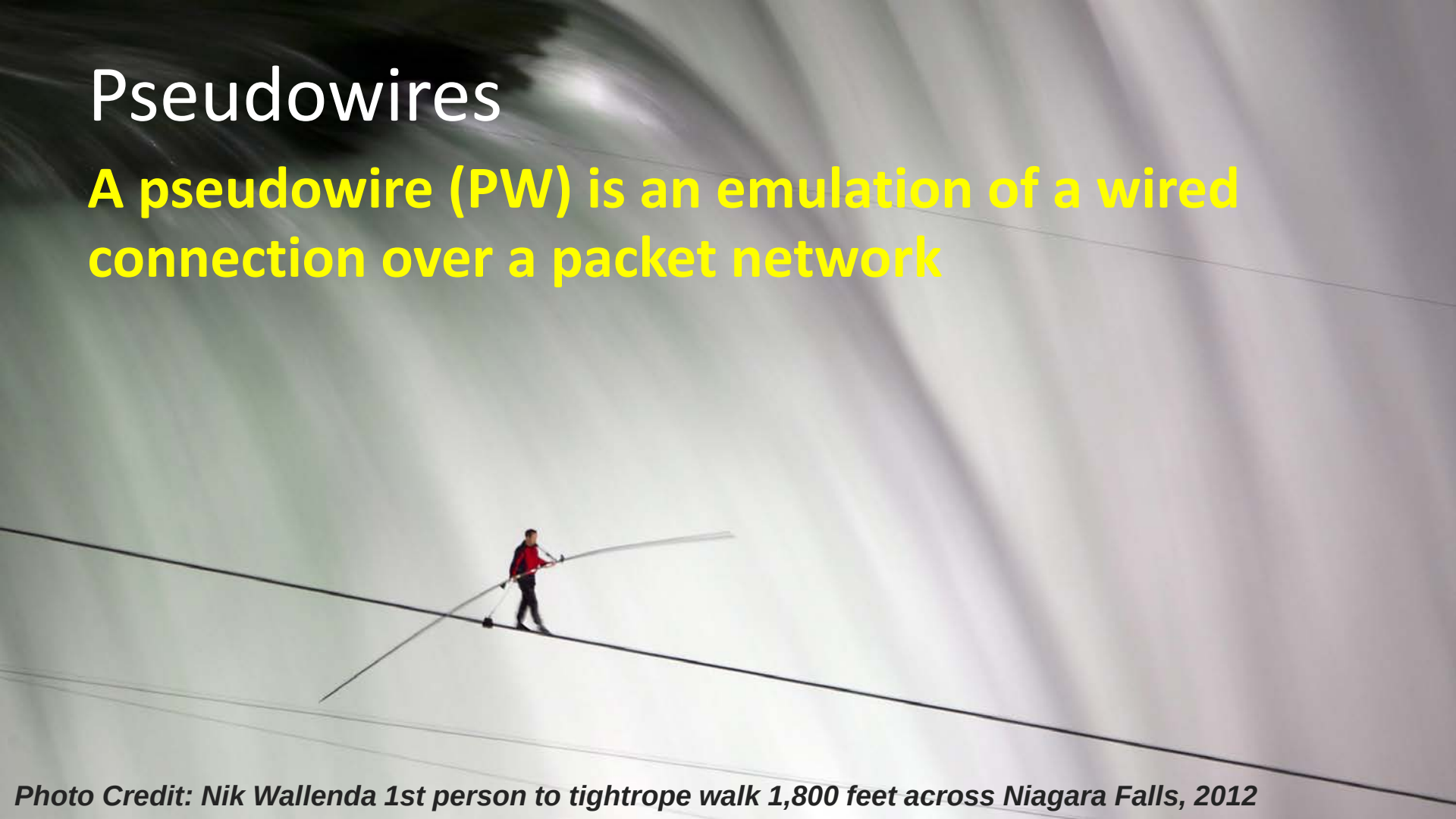
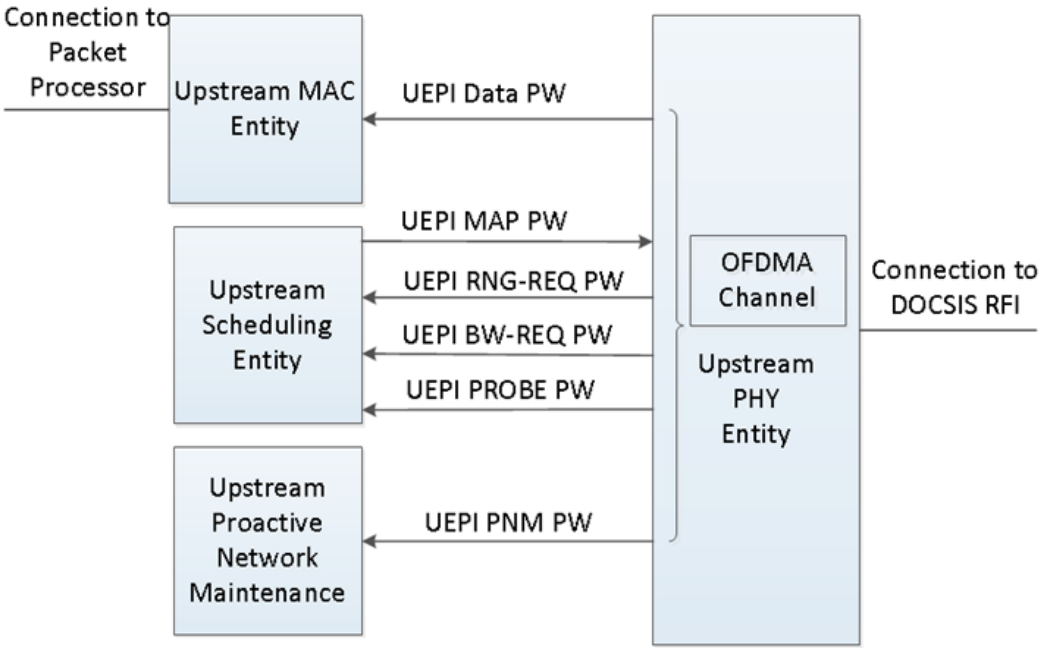


Photo Credit: Nik Wallenda 1st person to tightrope walk 1,800 feet across Niagara Falls, 2012

R-DEPI & R-UEPI

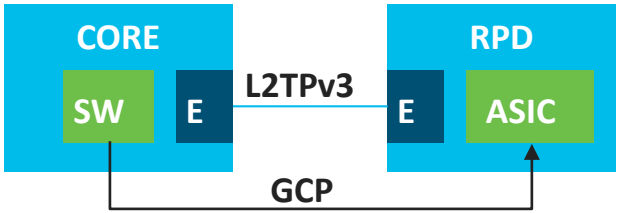
- Remote Downstream/Upstream External PHY Interface
- RPHY uses L2TPv3 as a pseudowire because L2TPv3 is designed for an IP network and it has both a data plane and control plane.
  - L2TPv3 manages the network connection to the RPD
- DEPI/UEPI is a DOCSIS frame with header and trailer
  - PSP (Packet Streaming Protocol) allows packets with concatenation.
  - MPT (MPEG Transport) allows for MPEG-TS
  - Separate PW for REQ, MAP,

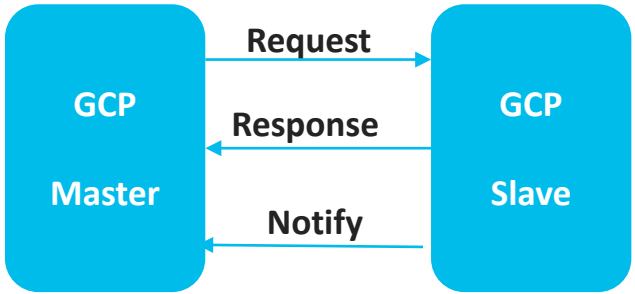
UEPI Scheduler PWs



- To minimize upstream latency and jitter, all scheduling activity are on separate PWs.
- This allows higher QoS treatment for scheduling on the IP network.

GCP – Generic Control Plane





GCP was written for RPHY

GCP sits above a transport like TCP

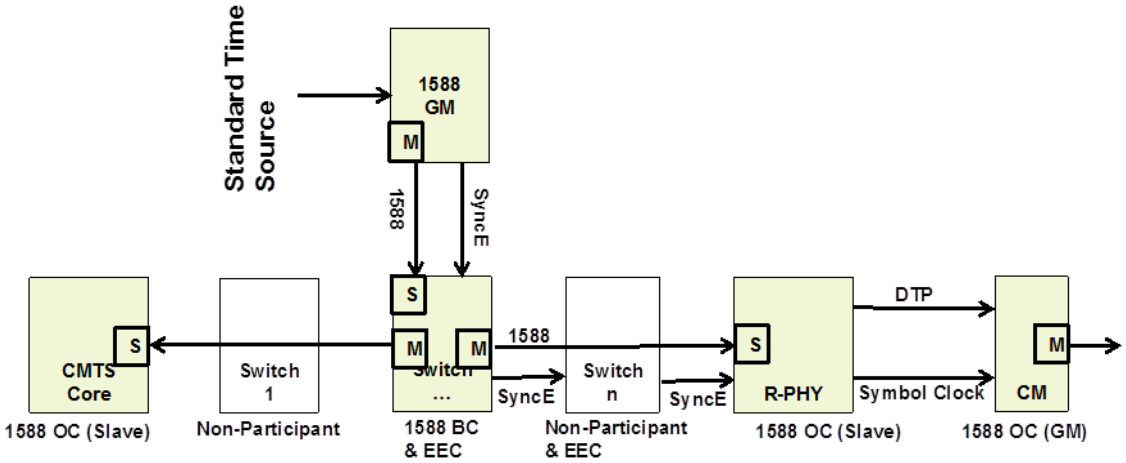
GCP manages the initialization and operation of the RPD

GCP master can RW. GCP slave can notify.

GCP can carry any data structures,

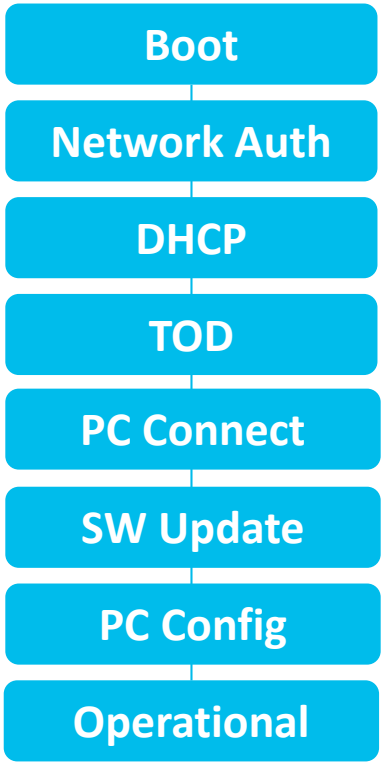
- TLVs can be borrowed from other specs or be specific to RPHY
- The UCD message is borrowed from the DOCSIS spec and used.

R-DTI



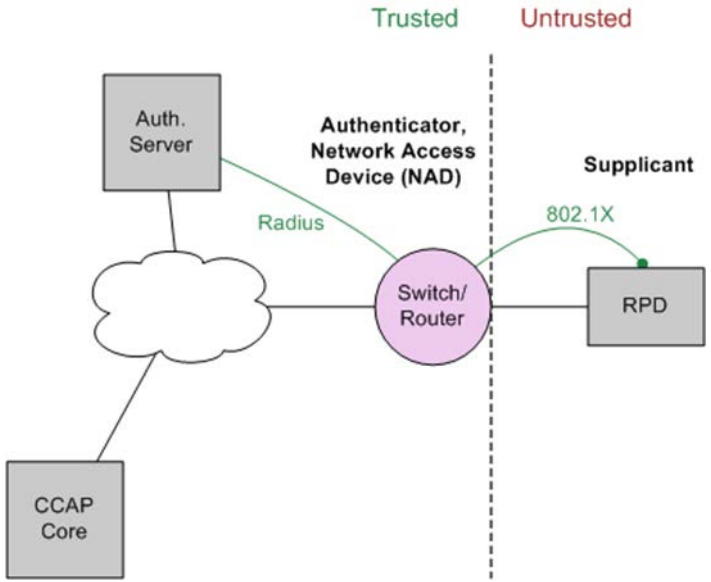
- R-DTI (remote DOCSIS Timing Protocol)
  - Unrelated to the original DTI from M-CMTS
- CCAP Core and RPD are synchronized with 1588
  - Precision PHY timing is between RPD and CM
  - Timing between Core and RPD/CM is for MAC US Scheduler. Less precision needed.

RPD Boot Process



- The RPD will boots up internally
- 802.1X certificated-based network authentication
- DHCP to get an IP address, TOD server, PC server
- Time of Day from TOD server
- Connects to Principal Core (PC) w/wo authentication
- PC points to secure SW download (SSD) server
- PC configures RPD.

Network Authentication

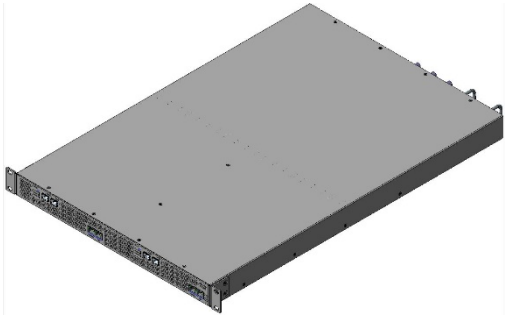


- RPHY allows for the RPD to exist in untrusted territory.
  - Hub is considered trusted
- RPD authenticates to the network and optionally to the CCAP Core.
- This use of 802.1X can be extended to any network element that will be on the CIN network.

Types of RPD Products

GS7000 RPD

- 1x2. No HA.
- Deep Fiber



Fixed Shelf

- 1RU 6x12. No HA.
- Small hub

High Density Shelf

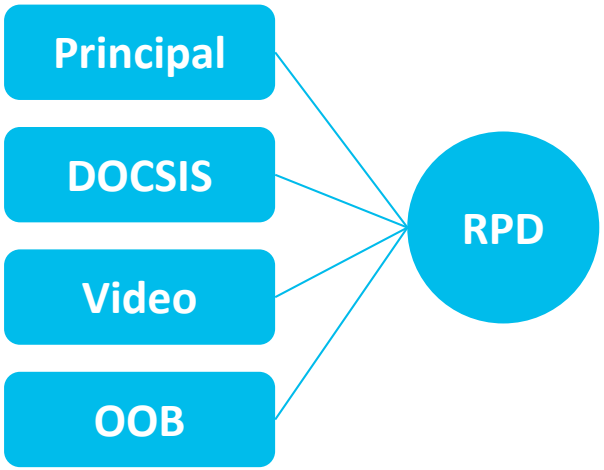
- 7RU 72SG 12+1 HA.
- Medium to large hub

OpenRPD – Open Source SW for R-PHY

- Cisco contributed RPD SW into an open-source at CableLabs.
- Drives full interoperability.
  - Any RPD with any CCAP Core.
  - 100% of the node vendors, no DOCSIS experience required.
- This enables and accelerates the Remote PHY market.
- New development model for cable.

Core and RPD Connecrtivity

Multiple Cores Connect to Each RPD

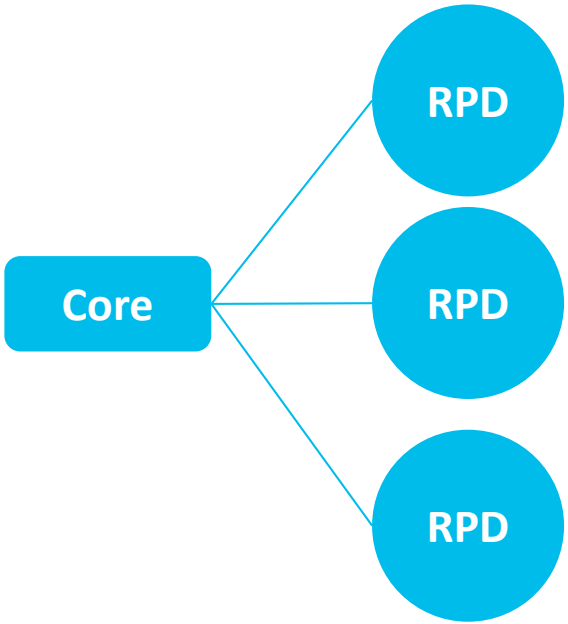


In a simple case, one CCAP chassis contains all core types.

There are multiple possible core types

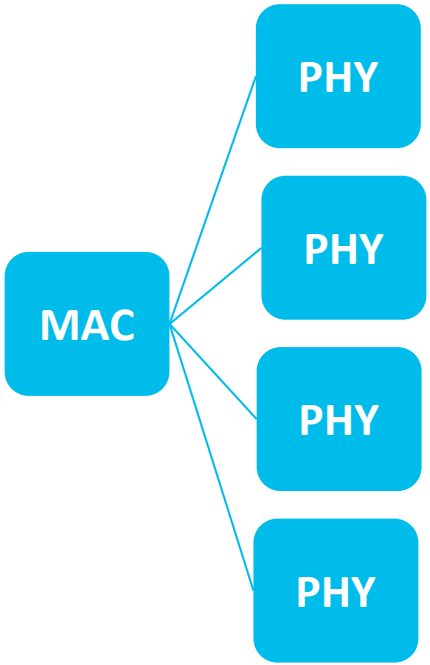
- Principle Core
- DOCSIS Core
- Broadcast Video Core
- Switched Digital Video Core
- VOD Video Core
- OOB 55-1 Core
- OOB 55-2 Core
- NDR/NDF Core
- Spectrum management and test cores.

One Core Connects to Many RPDs



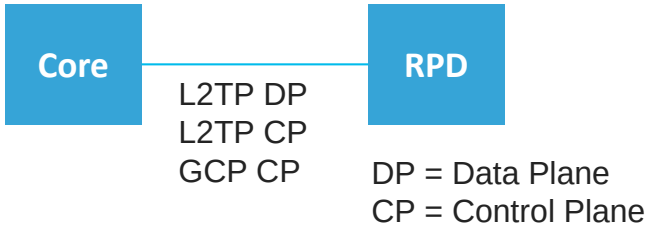
- Each core connects to multiple RPDs
  - Each core type (DOCSIS vs Video) may service a different number of RPDs
- RPD resource assignment may change over time.
  - Newer RPDs with additional capabilities must mix with old ones.
- The MAC instance in the Core must match the PHY instance in the RPD.
  - A Core product may have multiple MAC instances
  - A RPD product may have multiple PHY instances

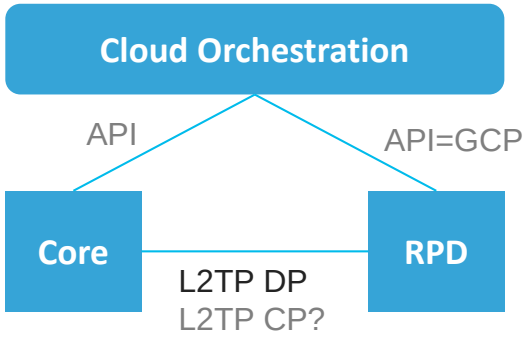
Virtual Splitting and Combining



- One MAC domain, N PHY interfaces
- Multicast in the downstream
- Multiple PW in the US with one scheduler
- Reduces CMTS resources by combining capacity.
- Good first step with deep fiber
  - Increases CMTS scaling
  - Decrease investment cost
  - Upgradable later to full BW without a truck roll

Automation





- The original RPHY architecture was peer-to-peer and designed to work with a physical core and no cloud.
- Eventually, the RPD and Core can be completely configured from the cloud and the core can be physical or virtual.
- RPHY currently has a hybrid architecture called GCPP with cloud orchestration, cloud cores, physical cores and support for legacy video cores.

Remote PHY Strategy

Port Scaling

Connectivity vs Capacity

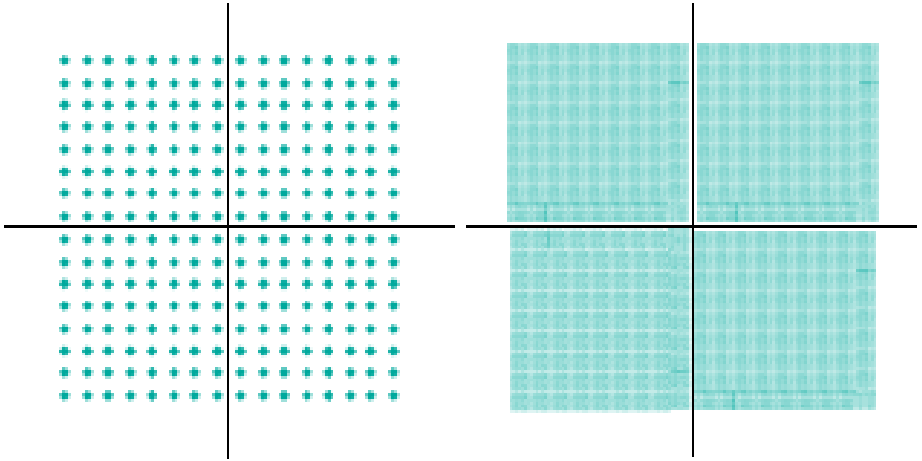
Allows10x the port density without 10x the core capacity

Better RF

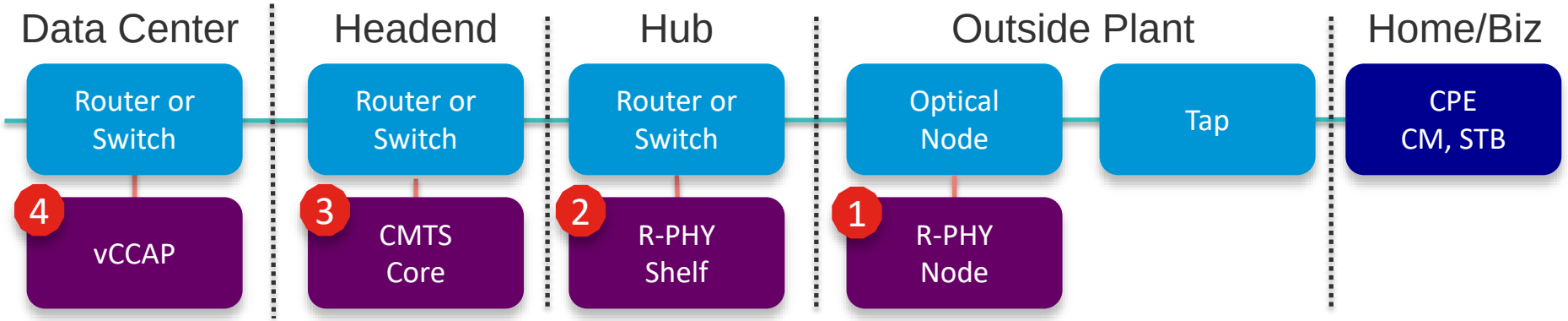
By moving the RF from the hub to the node,

- the MER performance is improved
- The dynamic range and any distortion of the optical path is eliminated

So higher RF modulations are possible.



Remote PHY Deployment Scenarios



1. Deep Fiber
2. Configurable CMTS
3. Hub Site Consolidation
4. True Virtual/Cloud CCAP

Only R-PHY technology can span these markets

Digital Optics

One of the biggest impacts of RPHY is the conversion of HFC from analog optics to digital optics

Ethernet over Fiber

- 10G DWDM
- Coherent 100G - 200G optics
- P2P, Ring, Daisy Chain

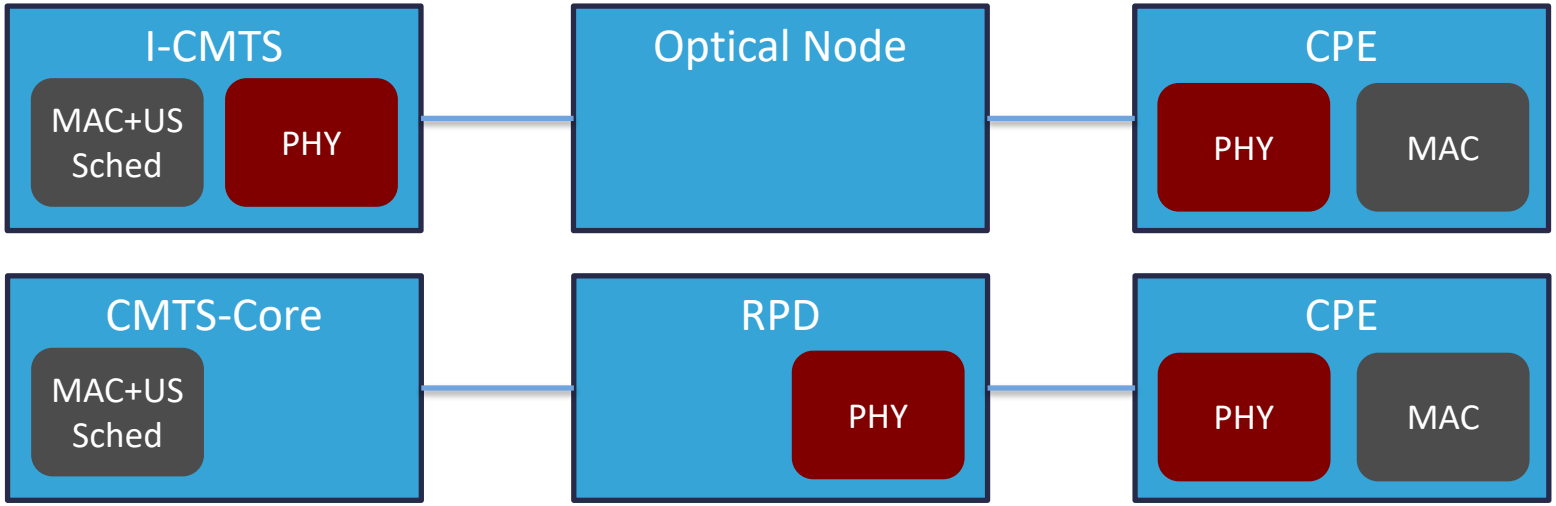
Hub is now Ethernet Switches

Advantages

- Lower cost optics
- Lower plant maintenance costs
- Longer distances
- More wavelengths
- Simpler plant design rules
- Multiple Nodes per wavelength
- HFC becomes an IP network
- Shared fiber infrastructure for Residential & commercial.
- Investment supports future PON and FTTH.

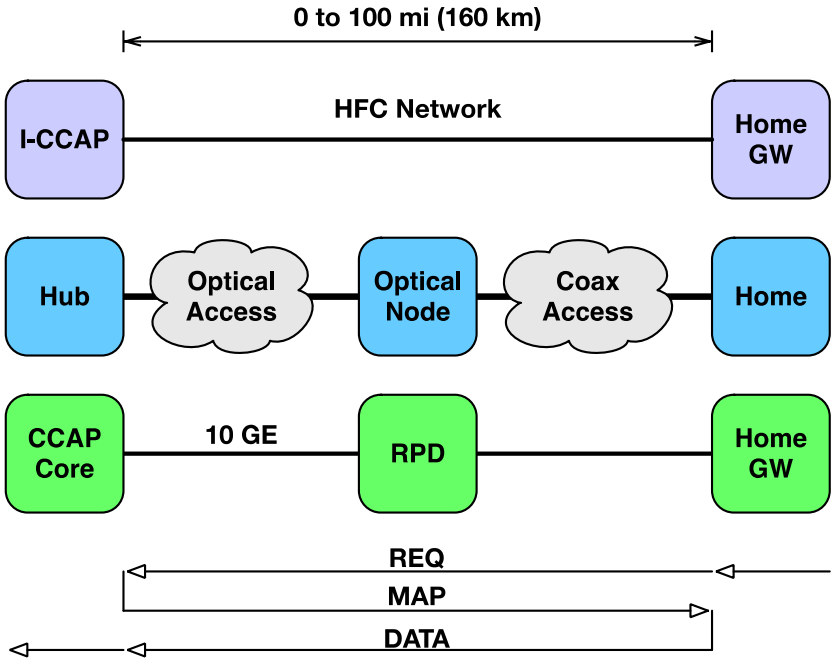
Remote PHY Latency

Location of US Scheduler



- PHY Moves but scheduler for R-PHY is in the same place as I-CMTS
- REQ and GNT (MAP) have high network priority and thus low latency & jitter.

REQ-GNT Latency for < 100 miles



RPD = Remote PHY Device

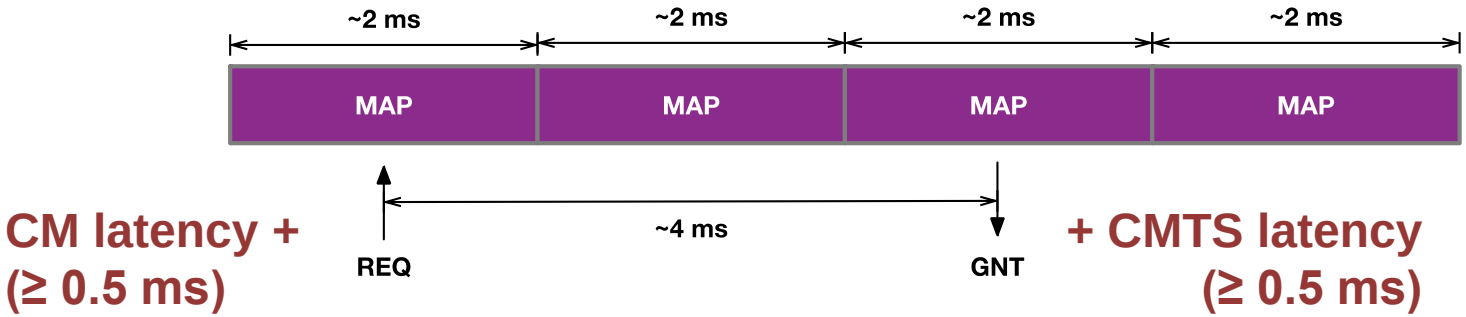
I-CMTS and R-PHY have the same circuit design and the same REQ-GNT delay

- REQ and MAP have QoS to minimize network jitter.

I-CMTS and R-PHY have near equivalent DS and US latencies

- Added latency is 0 to 1 MAP intervals.
- observed 0.5 ms extra avg.

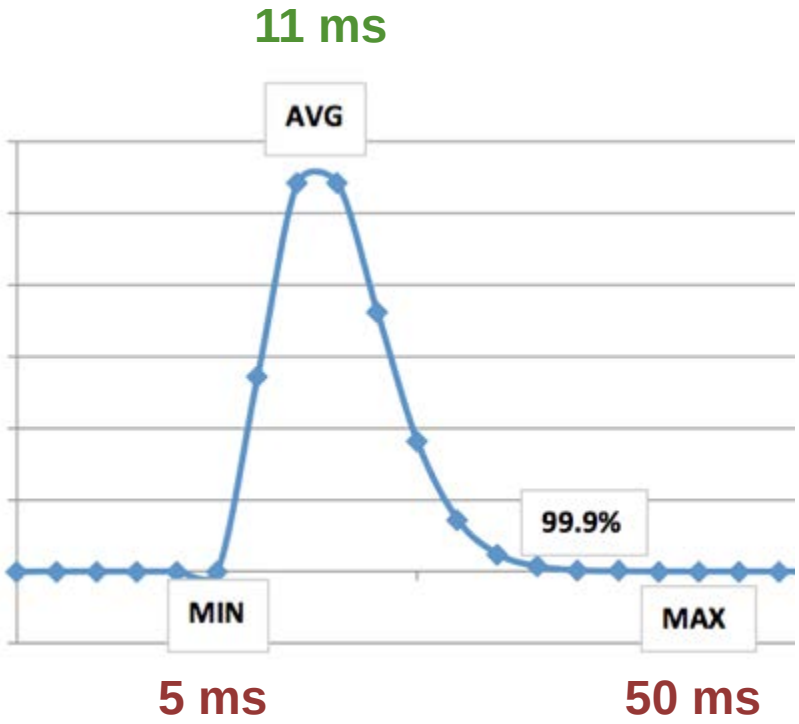
DOCSIS Minimum Upstream Latency



The minimum US latency is ~5 ms (measured value)

- Reactive Granting – REQ followed by a GNT
- Latencies in systems < 100 miles are dominated by MAP duration, MAP advance time, packet buffering and reassembly, rather than the plant distance.
- 0.4 ms (D3.1) or 0.8 ms (D3.0) REQ-GNT delay.

DOCSIS 3.0 Upstream Latency



- There is a min, avg and max.
- DOCSIS latency increases as the system buffers fill.
  - Simultaneous arrival of packets at CMs.
  - REQ back-offs
  - Piggy backing only kicks in under heavy loads
- DOCSIS is latency tolerant.

Tested at 10%, 50% and 90% loading with multiple CMs.

Location of US Scheduler

A centralized scheduler:

- Works, simpler, more scalable (say for FDX), and has nearly the same performance as I-CMTS for <100 miles
- Allows for better interoperability

The R-PHY Specification allows the scheduler to be centralized or remote.

- See R-PHY System Spec, Appendix B.2
- Remote scheduling is allowed for potential future optimization (if needed for >> 100 miles)


CISCO