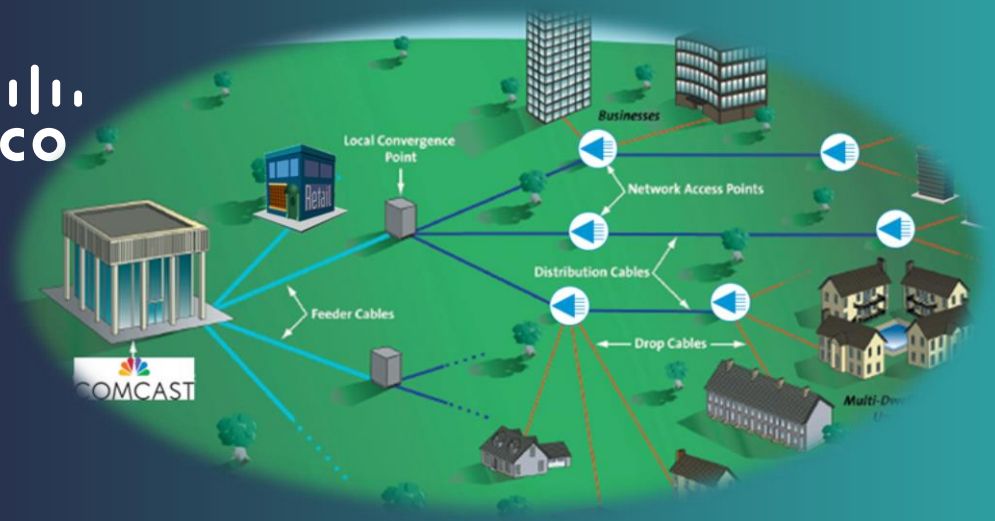

Fiber Deep Access Technologies "The Road From HFC to IP"

SCTE Golden Gate Chapter June 18th 2015

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Setting Expectations
What We're Going To Talk About

- Provide a **basic high level overview of fiber based technologies** and solutions for the cable MSO access network with a focus on fiber conservation, taking fiber deeper and the industries migration from HFC to DFC (IP)
- Each solution comes with it's own set of complexities and limitations and some are not fully baked. For this discussion and due to time restraints we'll TRY to stay out of weeds and keep discussion at a high level

Agenda

- Drivers for Fiber Deep
- What is Fiber Deep
- Fiber Hurdles
- Linear Optics Solutions for Fiber Deep
- Full Spectrum Multiwave
  - What Is FS MW
  - Multiwave Examples
  - MW Recap
- Radio Frequency Over Glass
  - What is RFoG
  - RFoG Examples
  - RFoG Recap
- Digital Optics Solutions
- Remote PHY – Road to IP
  - Need for Digital Fiber
  - R-PHY Vision
  - R-PHY Use Cases
  - R-PHY Recap
- PON The End Game
  - High Level Overview
  - Technologies & Topologies
  - Node PON Overlay Example
- Fiber Deep Architecture Summary
- Wrap Up Q&A

Disclaimer

* Things change quickly, this is a best attempt to provide a general overview; I may not have the most current information
* Nothing is absolute in this space and few approaches are mutually exclusive
* My opinions may “POP IN” from time to time

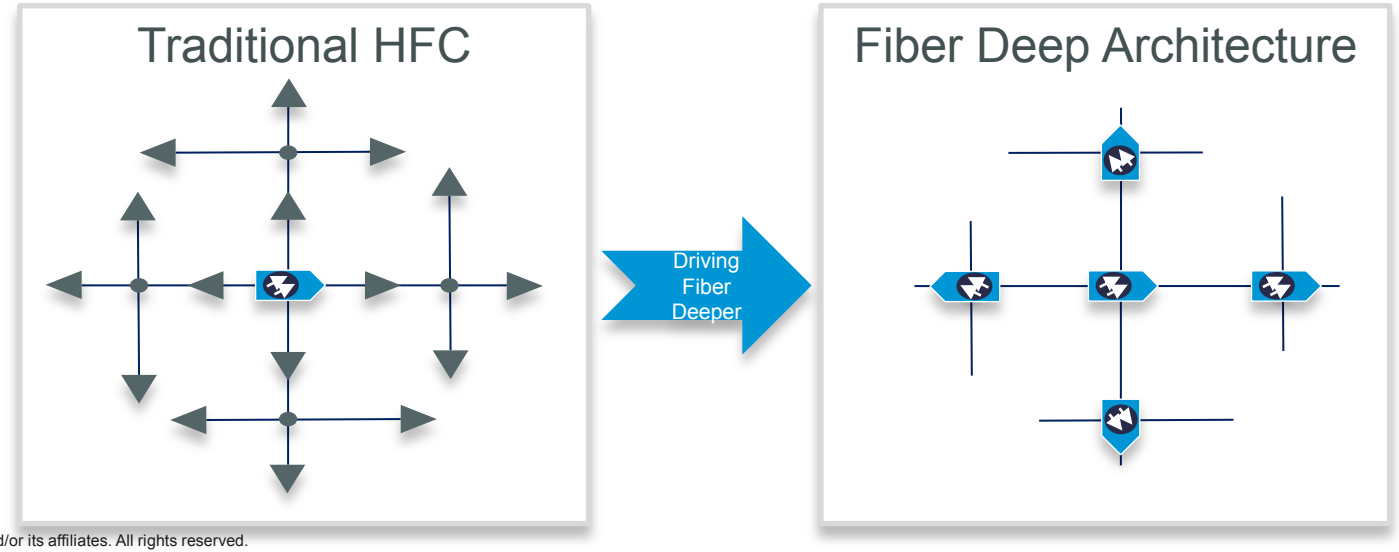
Drivers for Fiber Deep

- Competition
  - ✓ Telcos
  - ✓ Municipals
  - ✓ Cable
  - ✓ Competitive(Google Fiber)
  - ✓ Developer/ Integrator
- Lower OpEX
  - ✓ Reduction in plant actives
  - ✓ Reduction of field power supplys
  - ✓ Reduction in truck rolls

- Performance
  - ✓ Improved Market Health
  - ✓ Increased bandwidth to expand service offerings
    - More Available Content
    - HDTV Introduction
    - Internet (HSD)
    - VOD
    - IP Video
  - ✓ Improved network reliability

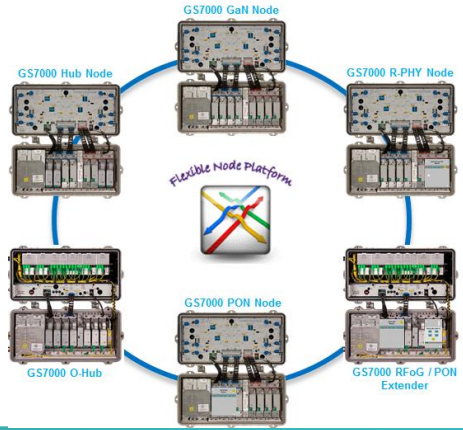
Fiber Deep

- Fiber Deep often referred as Node + O is an HFC architecture that extends the fiber deeper into the network, typically within a few hundred feet of the subscribers' homes, the optical-to-electrical conversion of downstream signals occurs much closer to subscribers' homes, which eliminates/reduces the requirement of RF amplifiers



Fiber Deep Benefits

- With the length of the coaxial cable runs shortened this reduces the size of node service areas, it in turn results in…..
  - Increased bandwidth to expand service offerings
  - Reduced OpEX with regards to operators' power supplies and maintenance costs, including troubleshooting and annual maintenance
  - Reduction/elimination of RF amplifiers provides higher network availability and improved network performance
  - Provides migration path to FTTH or xPON architectures
  - Uses flexible Nodes as platforms providing migration path to…..
    - Multiwave Extension
    - RFoG
    - Remote PHY
    - EPON/GPON



Fiber Deep Hurdle

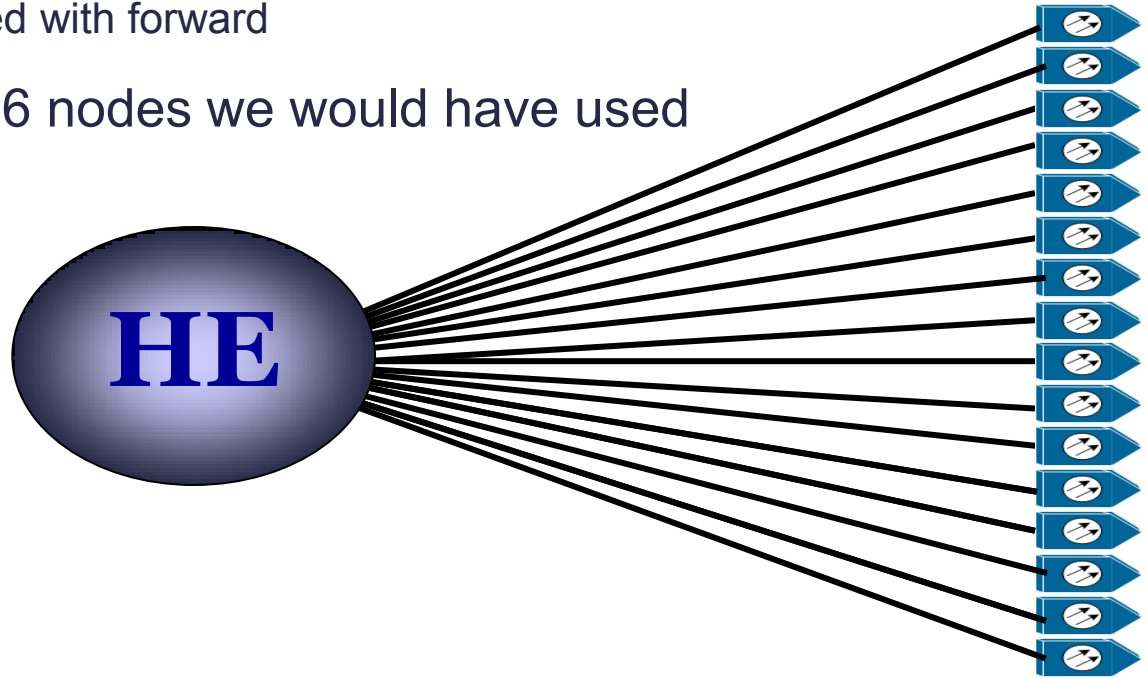
- Regardless if planning for fiber deep node zero or adding nodes for node plus X cascade the common hurdle to overcome is “Increased Fiber Demand”

How do you feed more nodes with less or equal number of fibers

Technology !!!!!

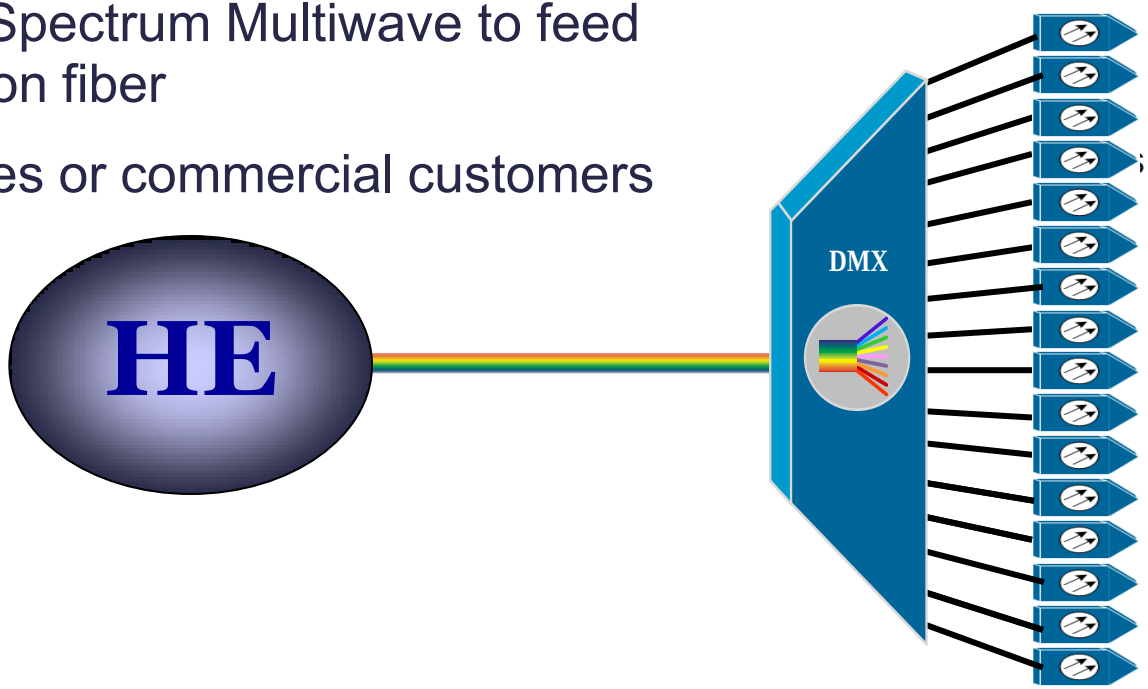
Yesterdays Practice for Feeding Nodes

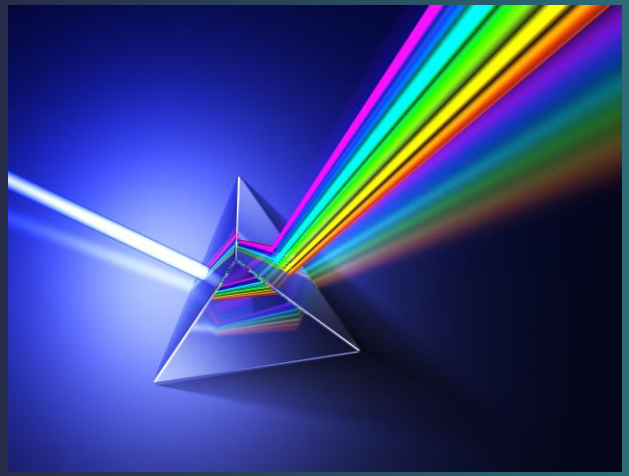
- Each node had 1310 downstream 1310 upstream
  - Occasionally 1550 return muxed with forward
- If we assume a cluster of 16 nodes we would have used 16 to 32 fibers
- What if you need to add or segment nodes and fiber starved?



Todays Practice for Feeding Nodes

- Fiber is a BIG pipe we should be taking advantage of with WDM technology like Full Spectrum Multiwave to feed multiple nodes over common fiber
- Frees up fiber for new nodes or commercial customers

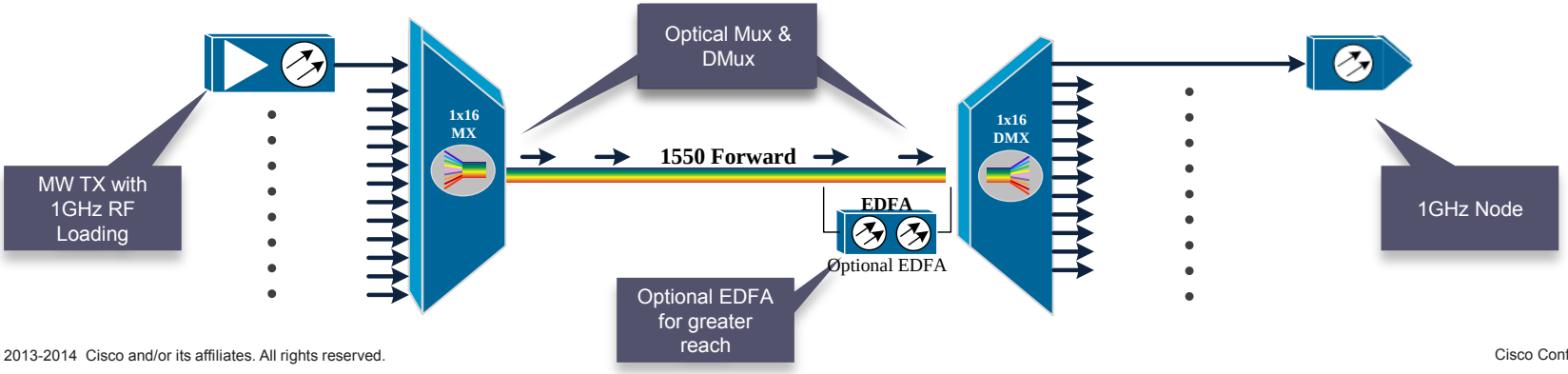




Full Spectrum Multiwave

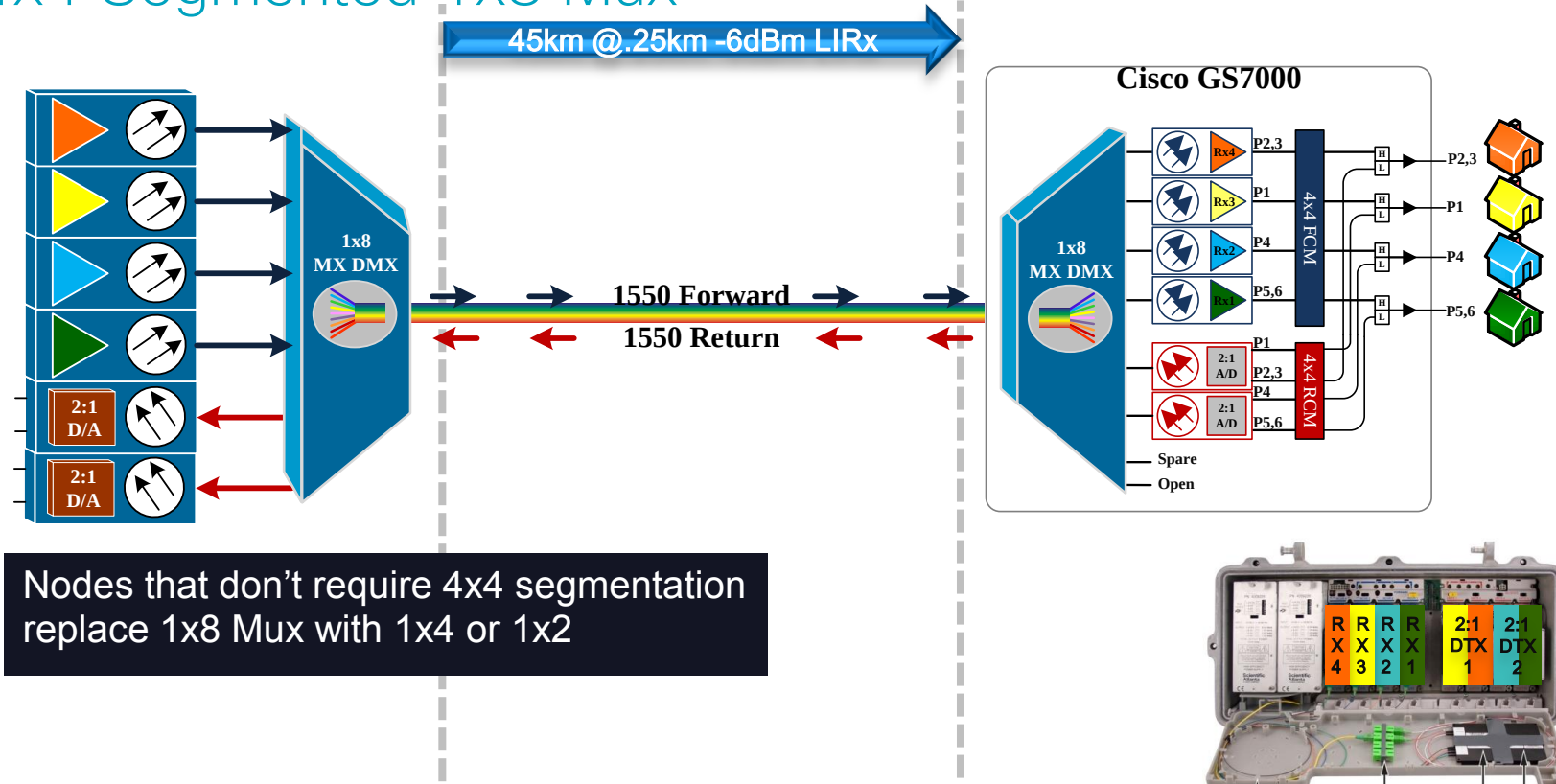
What is Full Spectrum Multiwave

- Full Spectrum Multiwave is an analog optics technology of channelized lasers (typically in the C-Band) that can be muxed to a single fiber feeding a cluster of nodes
- Cisco solution uses standard grid wavelengths following International Telecommunications Union (ITU) that are channel mapped to mitigate four wave mixing
- Solution Consist of.....



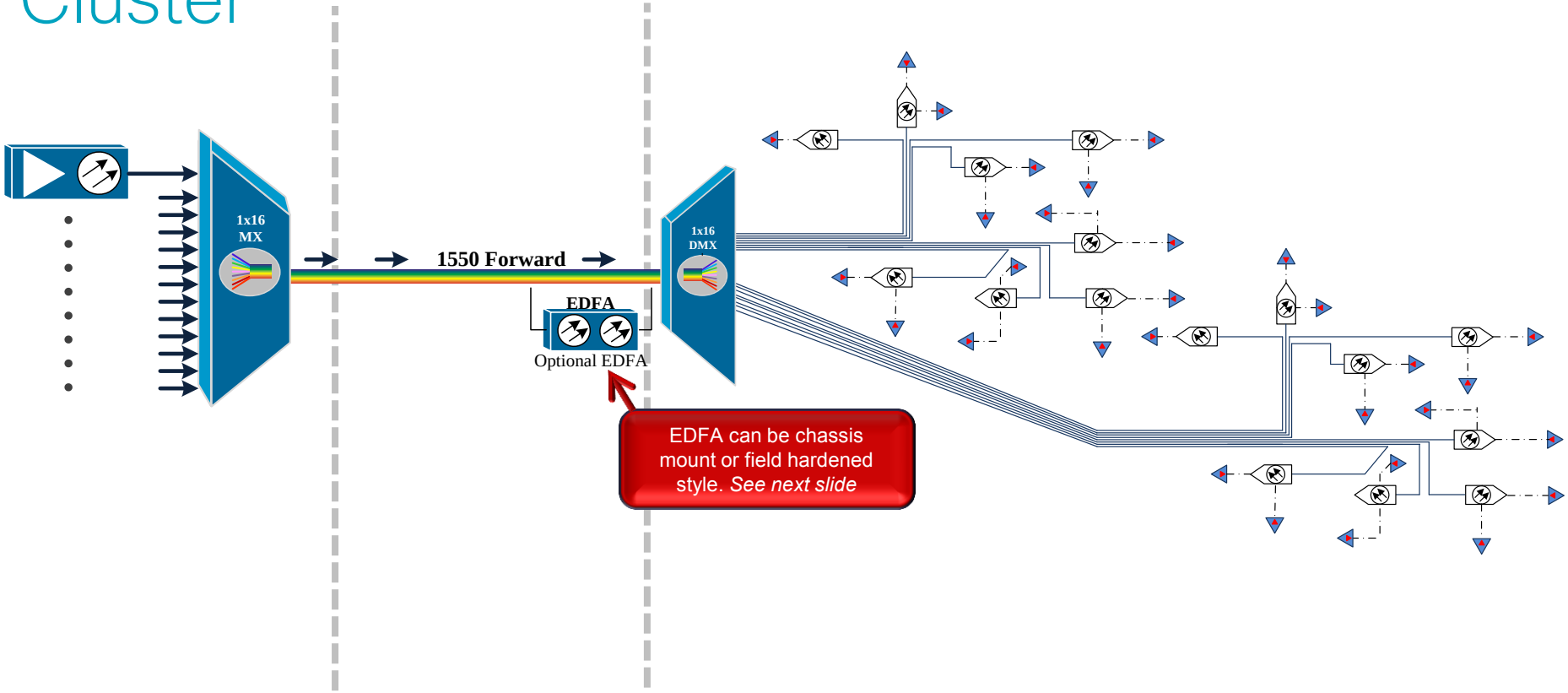
P2P Single Fiber to Node

4x4 Segmented 1x8 Mux



Nodes that don't require 4x4 segmentation replace 1x8 Mux with 1x4 or 1x2

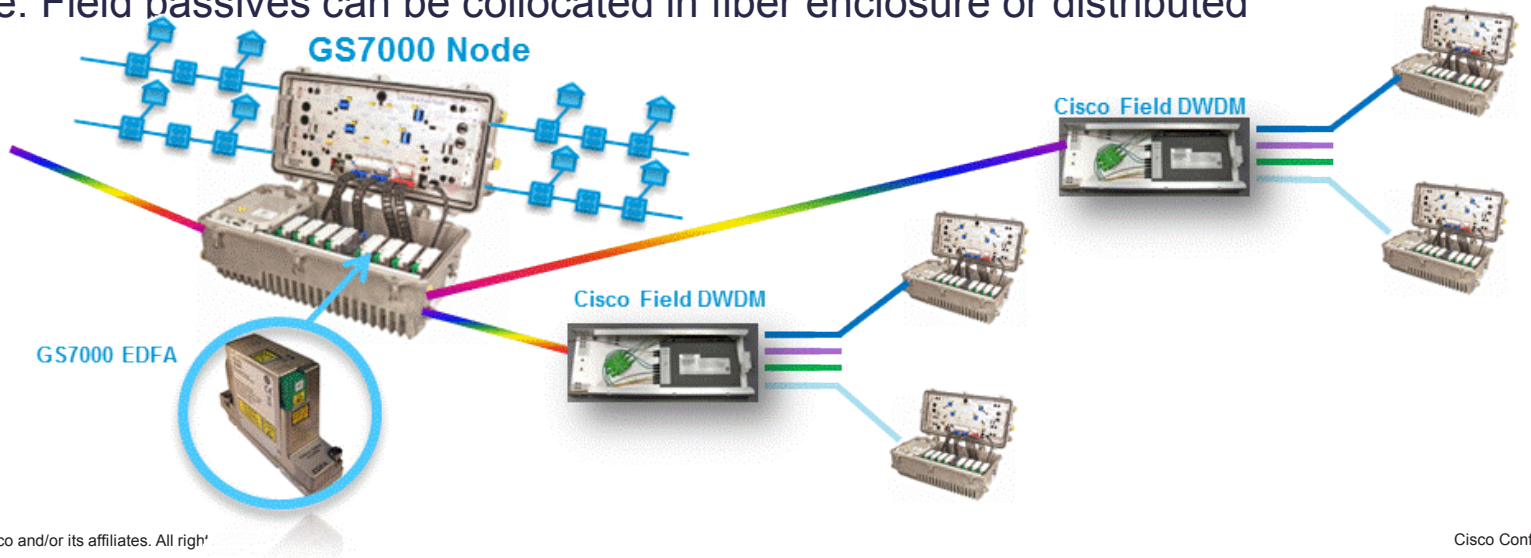
P2MP Single Fiber to DMX Feeding Node Cluster



HFC Node with EDFA

Full Spectrum Multiwave are received in GS7000 node housed with EDFA module for signal amplification. The amplified wavelengths are routed to field hardened DWDM passive, the DMUX wavelengths feed the local node (node with EDFA) and 1xN area nodes

- ✓ Applications: Plant extensions, Fiber Deep, MetroE.....typical application feed 8 to 16 node pocket
- ✓ Note: Field passives can be collocated in fiber enclosure or distributed

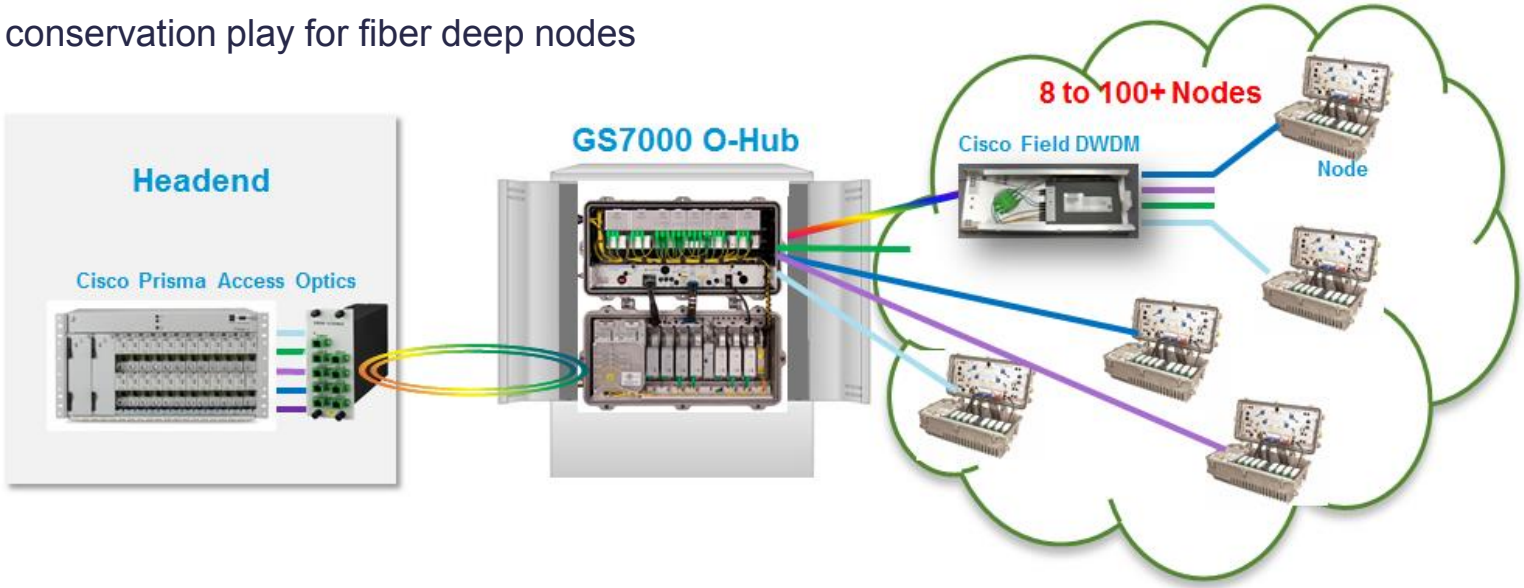


Optical Hub – Full Spectrum Extender

The O-Hub platform is a strand mountable field hardened “node style” housing that incorporates EDFAs, protection switches and optical passives

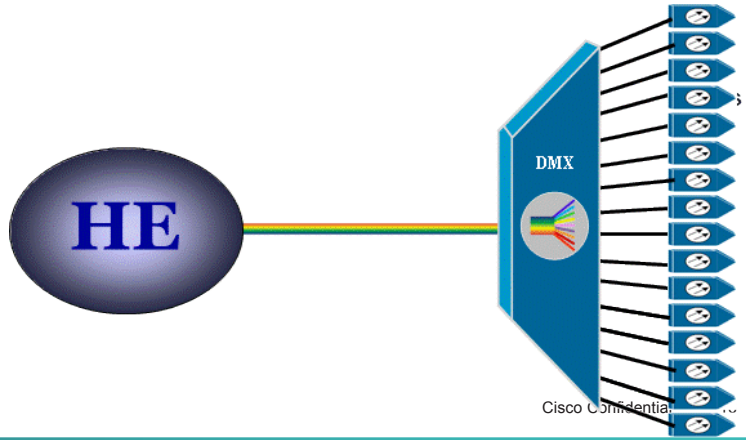
Application:

- ✓ Extended range solution expanding footprint of HFC plant to those areas outside of footprint of brick and mortar facility
- ✓ Fiber conservation play for fiber deep nodes



Full Spectrum Multiwave Recap / Takeaways

- Fiber is BIG FAT PIPE that should be taken advantage of…..stop the 1310 nonsense
- FS Multiwave enables fiber deep architecture allowing deployment of additional nodes with reduced dependency of costly fiber overlash
- MW frees up fibers for new commercial customers $$$$$$$$
- Multiple TX options depending on analog/QAM loading and link distance
- MW can be amplified with EDFA to extend reach, indoor chassis mount and field hardened versions



Q&A

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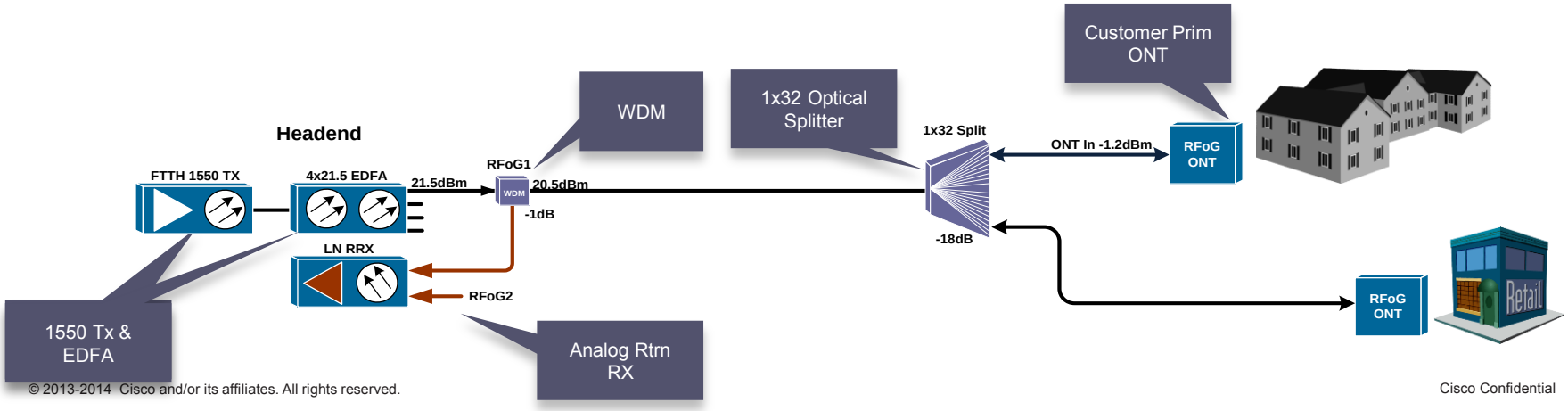
RFoG Its Big F and Little C

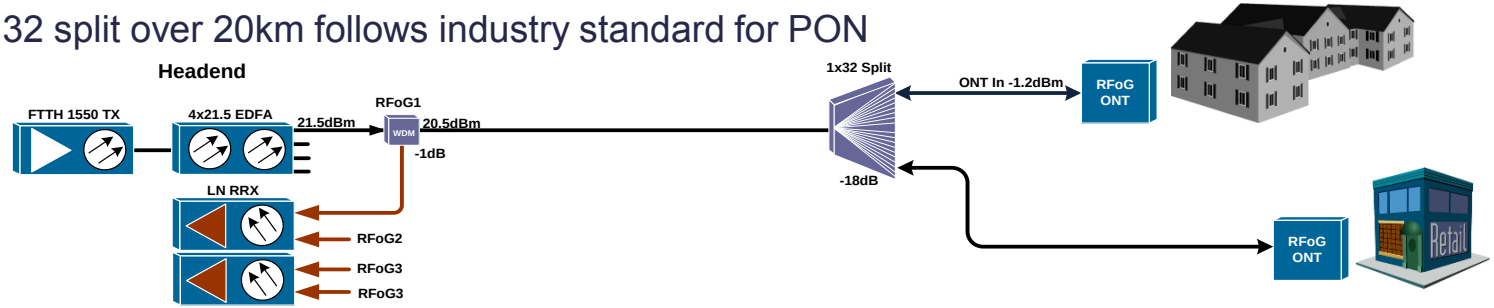
RFoG – Radio Frequency over Glass

- RFoG is an analog optics technology that transmits RF over fiber, instead of coaxial cable to a terminating unit (ONU/ONT) deployed at the customers premises
- DS & US transmission use different wavelengths to share the same fiber, typically 1550 DS 1610 US is used enabling overlay of xPON
- Solution Consist of.....

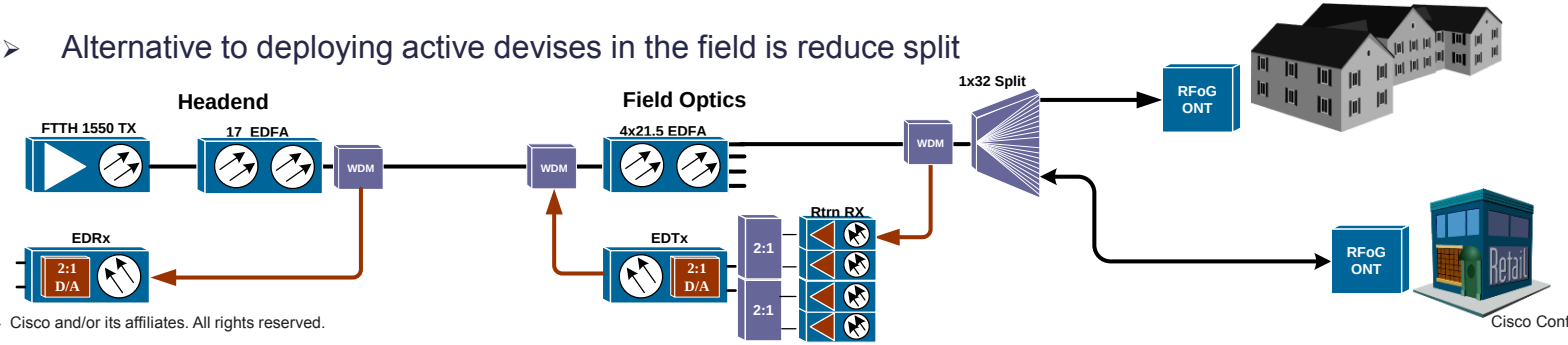


Two Architecture Types Deployed
Passive & Hybrid

- Passive is typically 1x32 split over 20km link – no active devices in the plant
- 32 split over 20km follows industry standard for PON

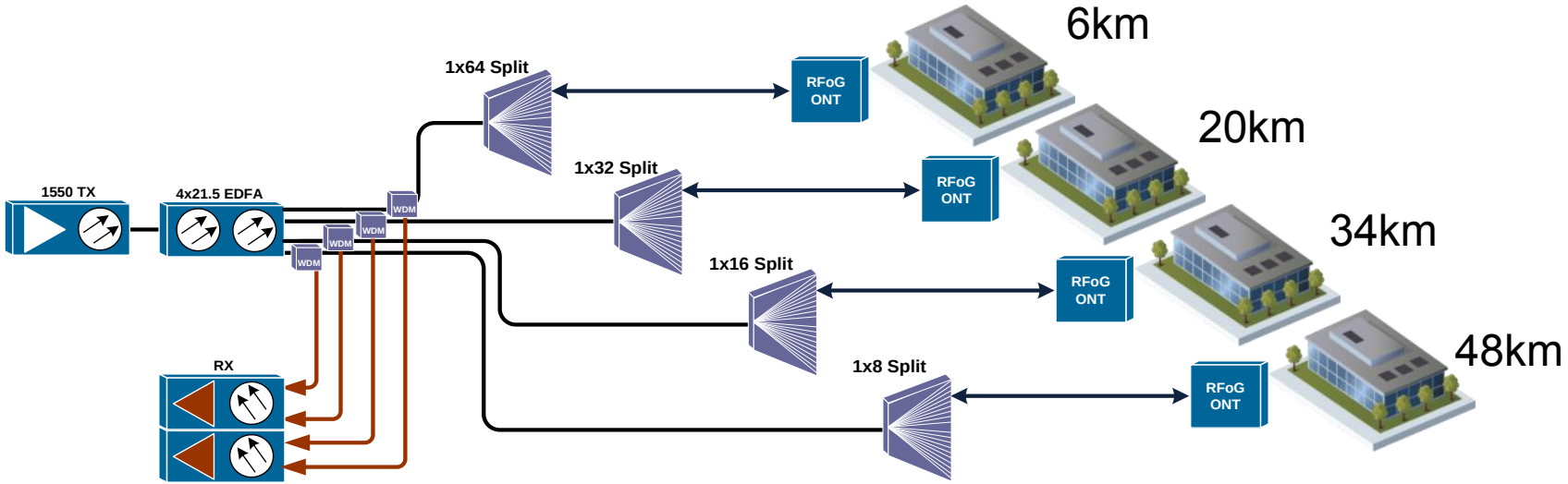


- Hybrid RFoG is when active field optics (EDFA, return Rx/Tx) are used to extend reach or conserve fiber
  - Alternative to deploying active devises in the field is reduce split

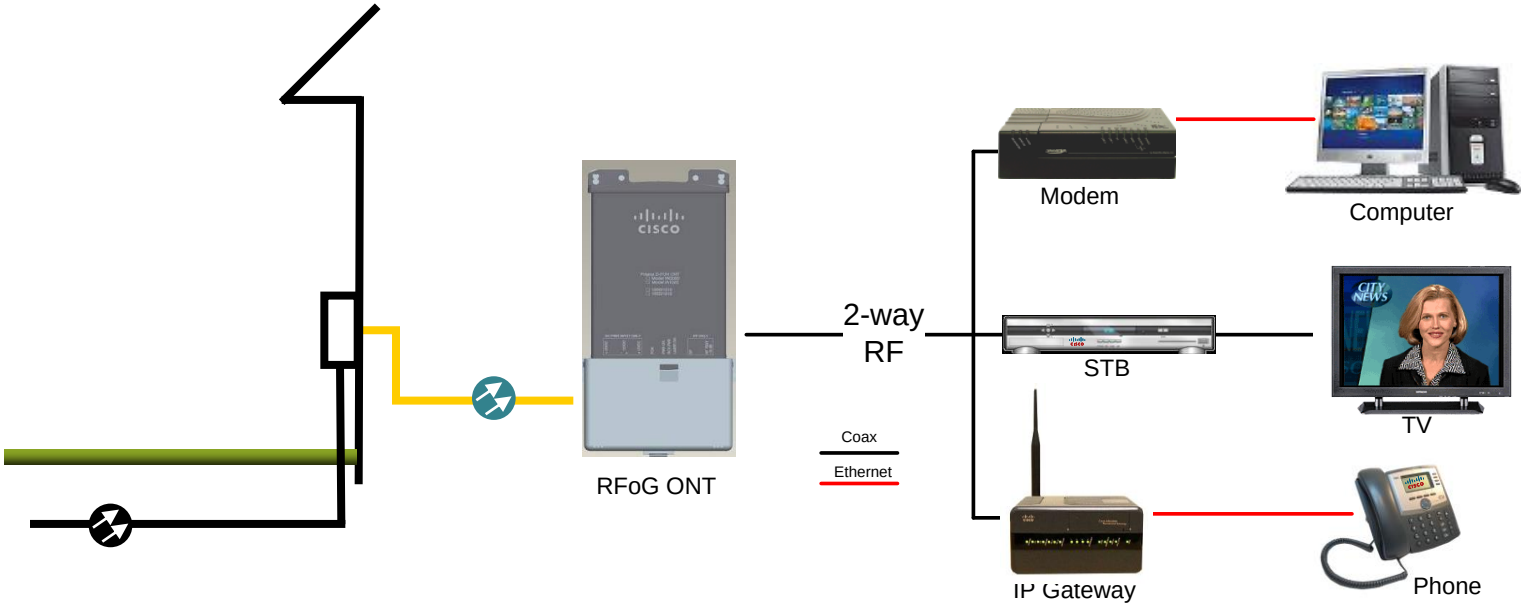


Alterative Split Ratio & Reach

- An alternative to placing active device in the field to reach those customers that are beyond a standard 20km 32 split is decrease split ratio inversely if distance is short you can increase split

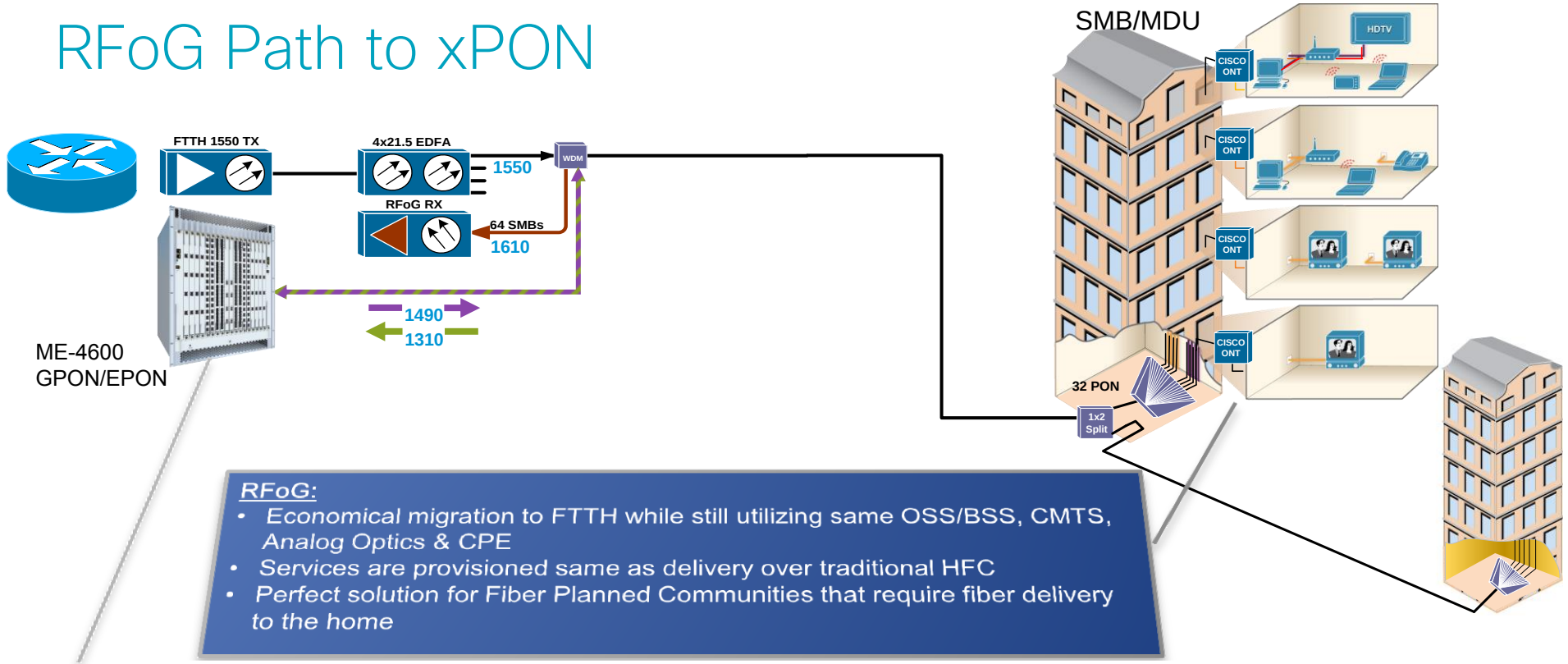


At The Customer Prim



- MSO may be able to dictate communication closet requirements to home builder
- Ideal solution would have:
  - AC outlet
  - Coax, Cat 5 & twisted pair cable stubbed to closet
  - Space for ONT, necessary splitters, cable modem & possibly a wireless router

RFoG Path to xPON



RFoG:

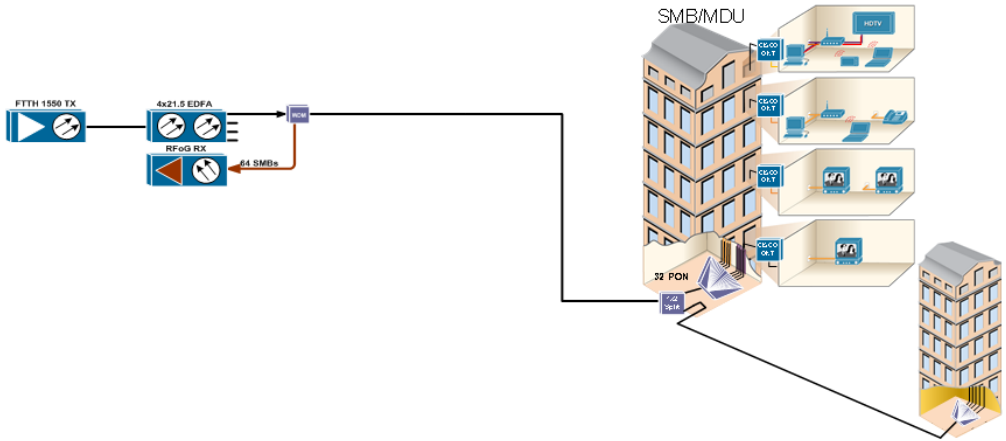
- *Economical migration to FTTH while still utilizing same OSS/BSS, CMTS, Analog Optics & CPE*
- *Services are provisioned same as delivery over traditional HFC*
- *Perfect solution for Fiber Planned Communities that require fiber delivery to the home*

GPON/EPON:

- *Ultimate access solution for IP Services providing unlimited bandwidth, high SLA and scalability such as Commercial and Macro Cell Backhaul*
- *Obvious residential migration (from RFoG) as IP Services and CPE devices inhabit the majority of households*

RFoG Recap / Takeaways

- RFoG is HFC with a Big FIBER and small COAX.
- RFoG leverages existing HE (OSS, BSS, CMTS, VOD servers, etc.)
- RFoG is a logical step for cable MSO on their way to PON
- RFoG uses 1550 DS 1610 US can coexist on same fiber with future xPON



Q&A

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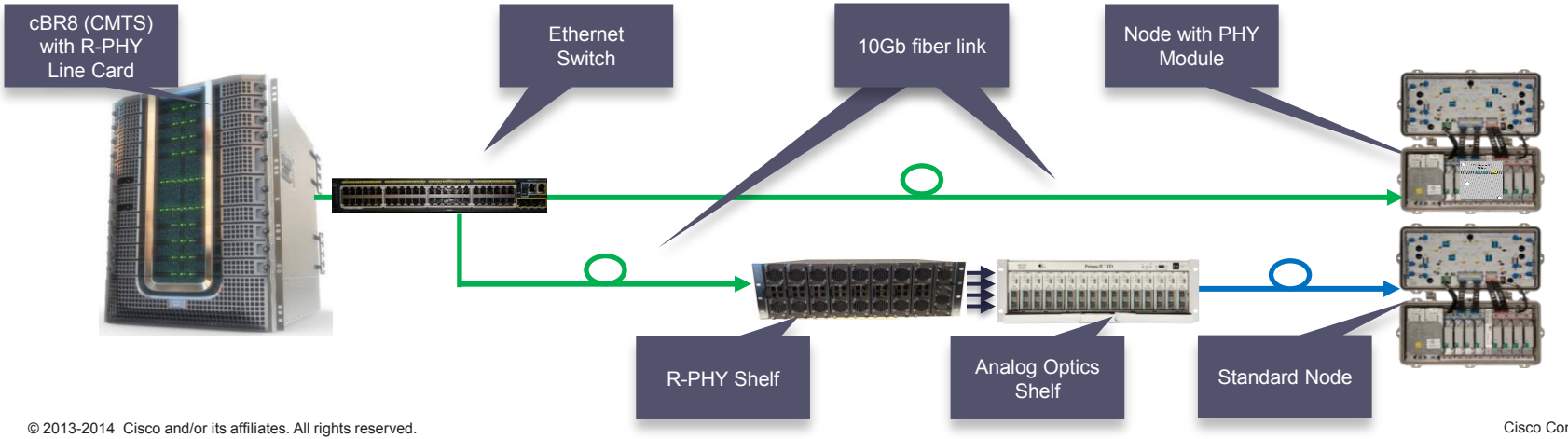
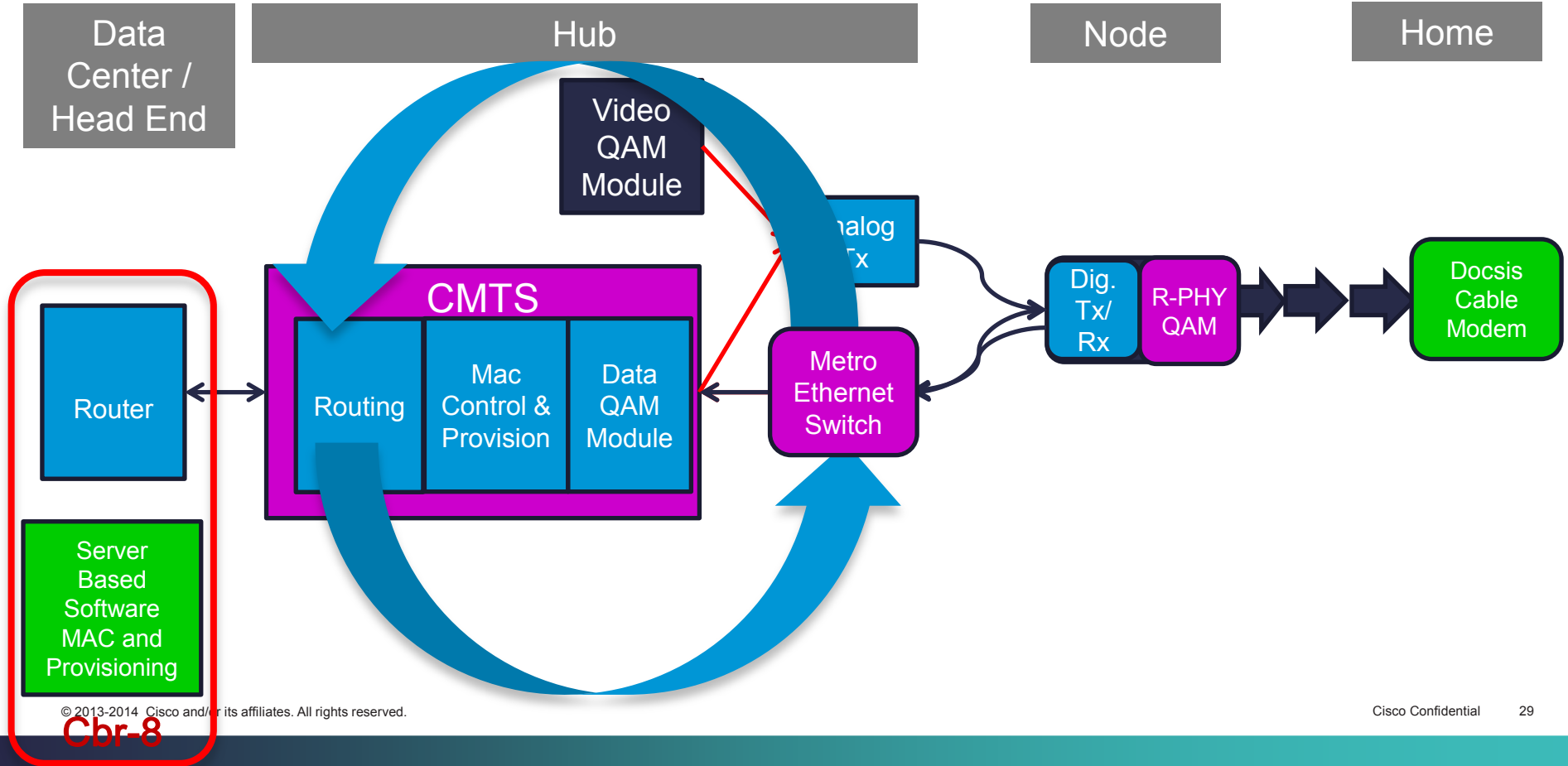
Remote PHY “The Road From HFC to IP” Next Gen Fiber Deep Access Technology

What is Remote PHY

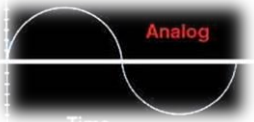
- R-PHY is a technique consisting of distributing the physical layer (RF Mod/Demod) into the HFC network (in the Node or PHY shelf).
- Removing the PHY from the CMTS (CCAP Core) makes it possible to eliminate the analog laser in the HE and converting it to digital fiber Ethernet link



Cisco's Remote PHY Vision



Linear HFC Digital HFC Advantages Disadvantages

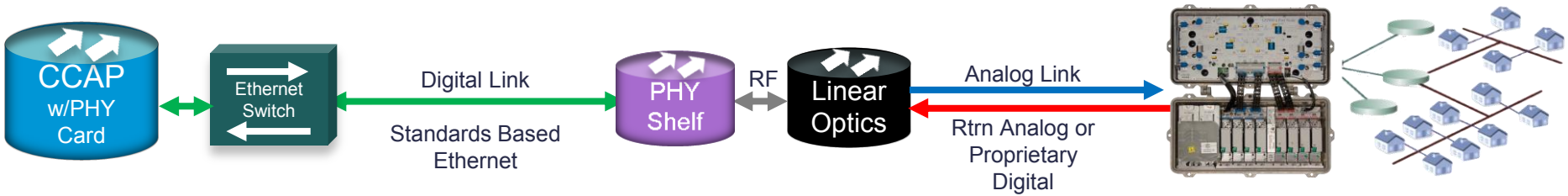


- **The advantages of Linear HFC are**:
  1. It does not “touch the bits”. A linear HFC access network is a simple pipe which does not reformat data and is modulation agnostic
  2. It works. It supports the full service requirement of the cable operator
  3. It is inexpensive
- **The disadvantages of Linear HFC are**:
  1. It is distance limited,100km links are challenging
  2. The linear optics system requires link optimization
  3. Linear optics restricted to 16ish wavelengths per fiber
  4. Its usage is generally restricted to CATV spectrum
  5. It introduces noise that limits achievable SNR

- **The advantages of Digital HFC are**:
  1. Digital Fiber can travel longer distances >1000kms
  2. Removing Mod/Demod hardware from the CMTS reduces energy and heat loading in HE/Hubs
  3. Digital fiber supports more wavelengths (80+) per fiber
  4. OPEX are lower – link optimization not required
  5. Optical noise contribution to SNR is eliminated, as a result a remote QAM placed after fiber link can run at higher order of modulation “4096 QAM”
- **The disadvantages of Digital HFC are:**
  1. An access network which “touches the bits, unlike the “passive pipe” of linear
  2. The need for a more sophisticated optical node that can do digital to analog conversion

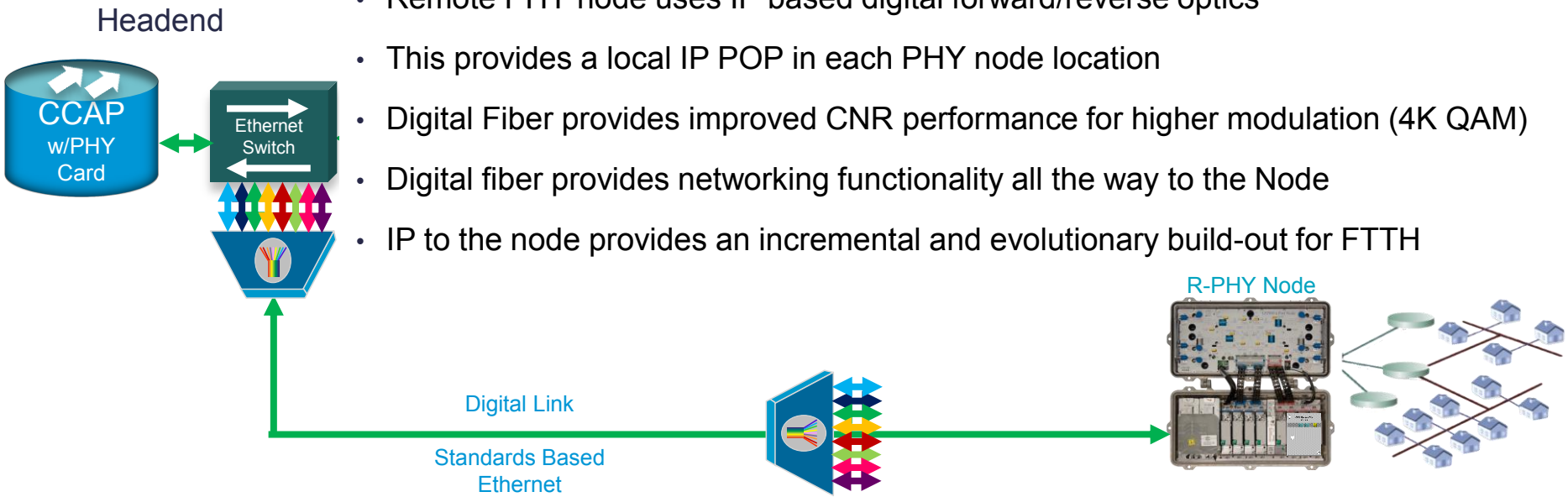
Remote PHY Shelf Example
HE to HUB/OTN Linear Optics to Digital Optics Upgrade

- Remote PHY shelf allows you to increase the density of Service Groups on your CMTS
- Allows convergence of several small hubs to optimize the CMTS capacity
- Reduces hub rack space and energy requirements
- Replaces HE to Hub linear fiber link with Digital fiber transport provides improved performance and scalability

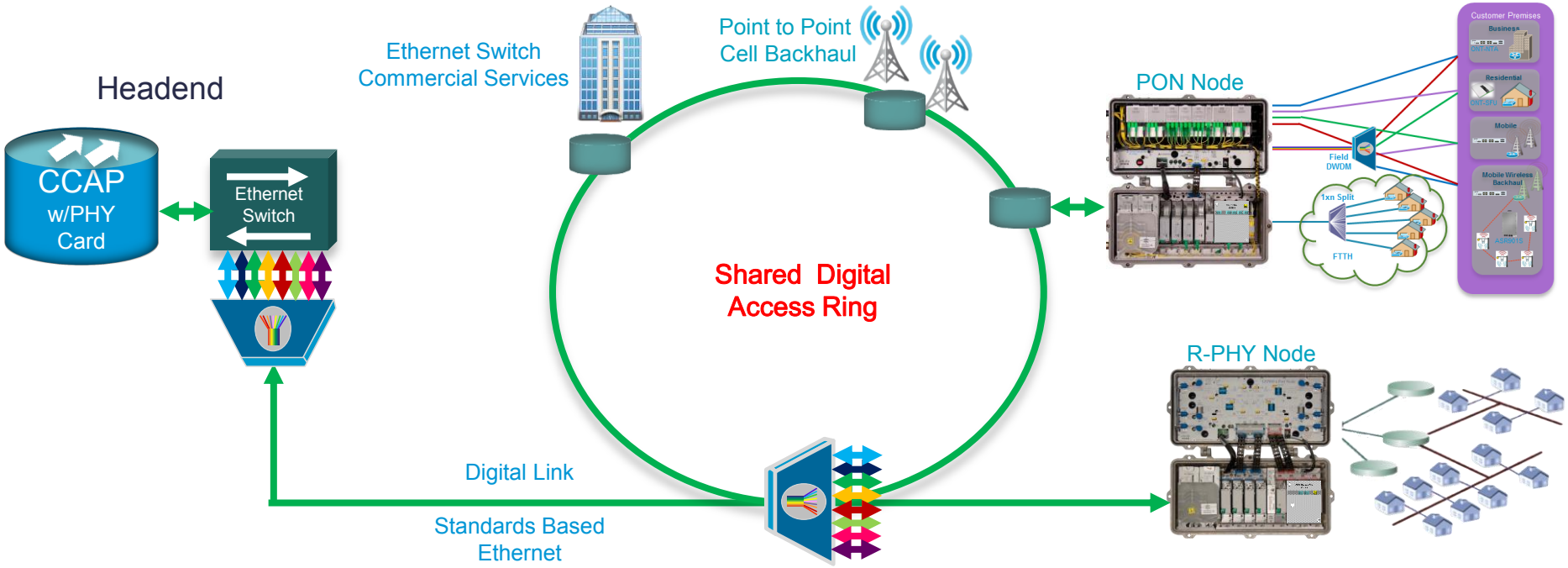


Remote PHY Node Example
Digital to the Node / Node Becomes IP POP

- Remote PHY node uses IP based digital forward/reverse optics
- This provides a local IP POP in each PHY node location
- Digital Fiber provides improved CNR performance for higher modulation (4K QAM)
- Digital fiber provides networking functionality all the way to the Node
- IP to the node provides an incremental and evolutionary build-out for FTTH

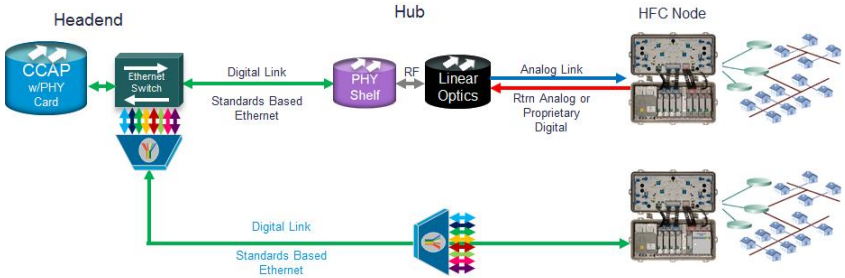


R-PHY Common Architecture for Residential and Commercial Customers



Remote PHY Recap / Takeaways

- Implementation of Remote PHY will integrate seamlessly into your existing HFC architecture
- R-PHY enables “Digital Fiber Deep”, opening up new monetization opportunities for new customers
- R-PHY saves on Hub Space / Power / HVAC Savings – Green Initiative
  - Trade HVAC costs for cooling fins on a pole…
  - Consolidate hubs
  - Reduce HE/Hub space
- R-PHY Fiber Savings / Fiber Management
  - More wavelengths per fiber
  - Make fiber network more manageable
  - Converge commercial Ethernet fiber with Access Fiber
  - Improves performance, enables 1024 to 4096 QAM
  - Creates the ability for traditional node become a Multi-Access Platform



Q&A

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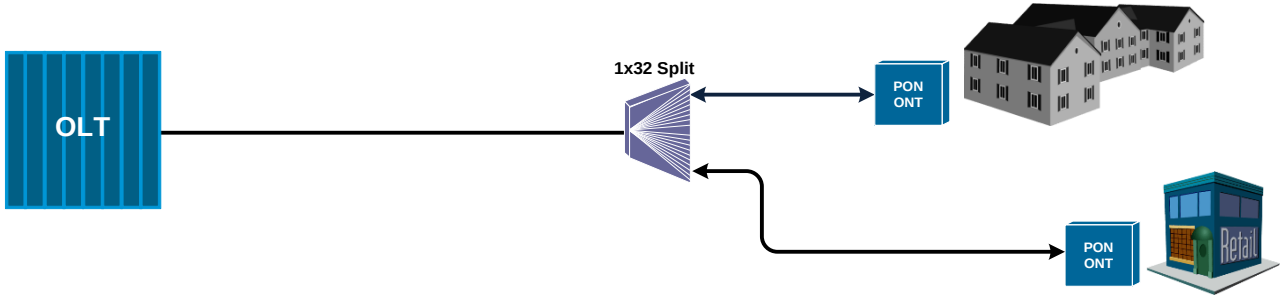
PON FTTx “The End Game”

FTTX Terminology

- FTTx is possibly the most non-descriptive acronym in telecom history. It includes nearly all networks that exist today (even wireless networks require fiber at some point). However, for our purposes there are two categories of FTTx:

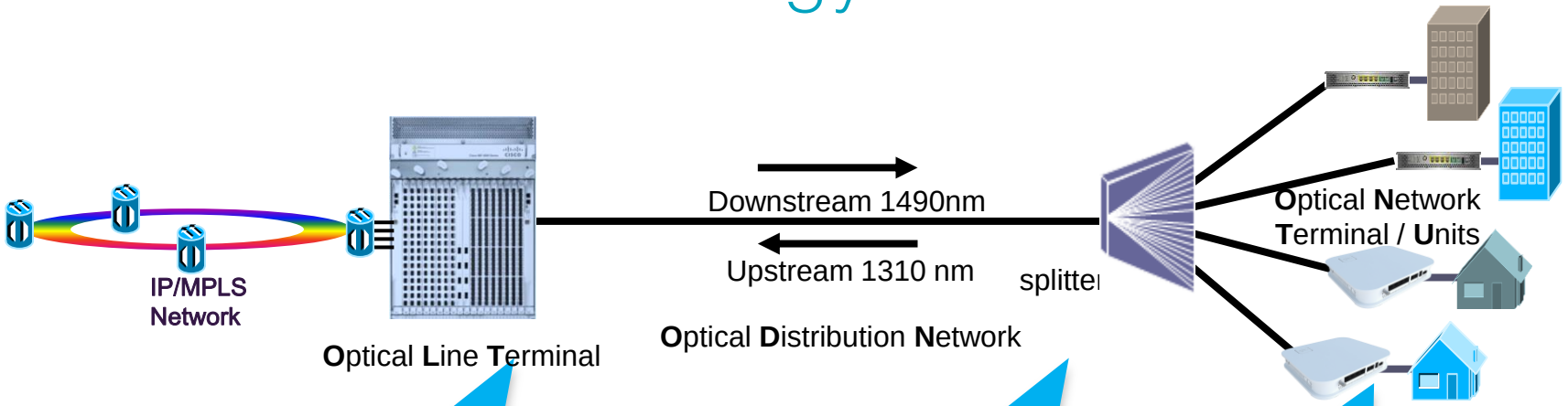
1. **Uninterrupted fiber connection all the way to the customer**
   - Fiber to the Business (FTTB)
   - Fiber to the Home (FTTH), popularized by FTTH Council
   - Fiber to the Premise (FTTP), popularized by Verizon
   - Point-to-Point FTTH (P2P), also called E-FTTH (Ethernet)
2. **Fiber in the network**
   - Fiber to the Node (also FTTN)
   - Fiber to the Neighborhood (FTTN)
   - Fiber to the Curb (FTTC)
   - Fiber to the Cabinet (also FTTC)

What is PON



- A PON architecture consists of a single feeder fiber that is passively split (typically serving 32 homes)
- The forward transmission is shared among the subscribers
- The reverse traffic is combined from the subscribers to the single feeder fiber
- PON systems are typically a TDMA system designed to activate / deactivate the subscriber reverse traffic to avoid optical collisions

Basic PON Terminology



OLT – optical line terminal

- **Tx (1490nm)**
- **Rx (1310nm)**
- **Provides IP data**
- **Voice can pass thru**
- **IP video can pass thru**

ODN – Optical Distribution Network (ODN).

- **The ODN connects the OLT and ONTs/ONUs near or at user homes by using optical fibers and splitters.**

ONT – optical network termination

- **Subscriber O-E end point**
- **Can be located in NID**
- **Can be located indoors**

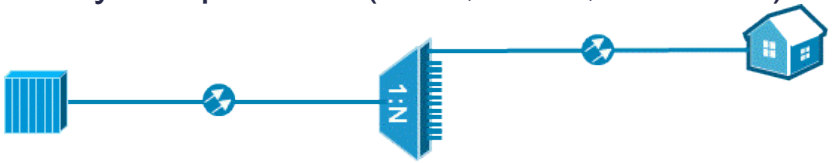
ONU – optical network unit

- **Another name for ONT**

PON Technologies

GPON is an ITU standard and is an evolution of the BPON standard. It supports higher rates, enhanced security, and choice of Layer 2 protocol (ATM, GEM, Ethernet)

- GPON 2.5Gbps DS 1Gbps US
- NGPON1 10Gbps DS 2.5Gbps US

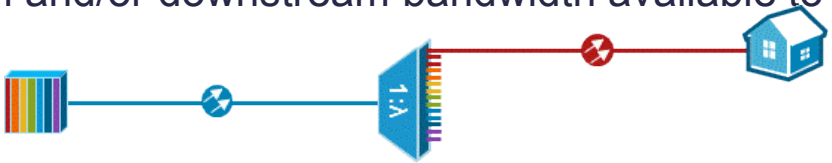


EPON or GEPON is an IEEE standard for using Ethernet for packet data.

- EPON 1Gbps DS 1Gbps US
- 10GE-PON 10Gbps DS 10Gbps US

WDM-PON (NG-PON2) is a type of passive optical networking that uses multiple optical wavelengths to increase the upstream and/or downstream bandwidth available to end users

- NGPON2 40Gbps DS 10Gbps US



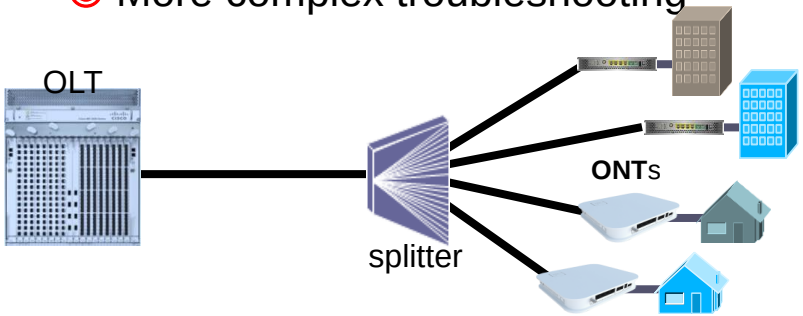
Cisco ME4600 Multiservice Platform Supports All The Above Technologies

FTTH / FTTB Fiber Topologies

Two Choices for Optical Fiber Access Topologies

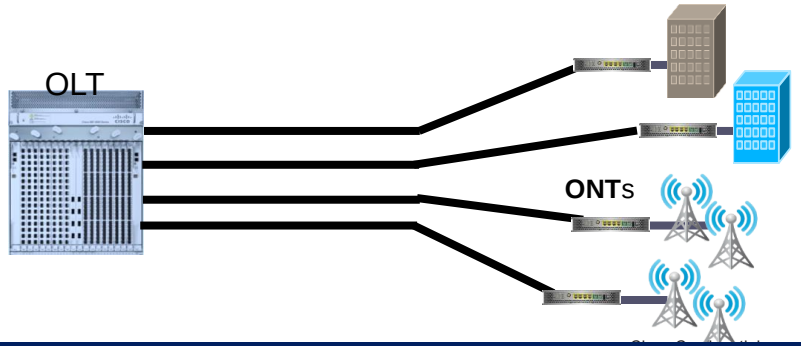
Passive Optical Network (PON)

- Point to multipoint (P2MP) uses optical splitter – shared network
- Ex: GPON, GEPON
  - ☺ Lower CAPEX
  - ☺ Lower power consumption
  - ☺ Less CO rack space needed
  - ☹ Asymmetric BW split
  - ☹ More complex troubleshooting



Point to Point Network (P2P)

- Also called Ethernet – FTTH
- One fiber per subscriber
  - ☺ Easier BW upgrades
  - ☺ Easier unbundling
  - ☹ More space needed at CO for distribution frames
  - ☹ More fiber duct utilization

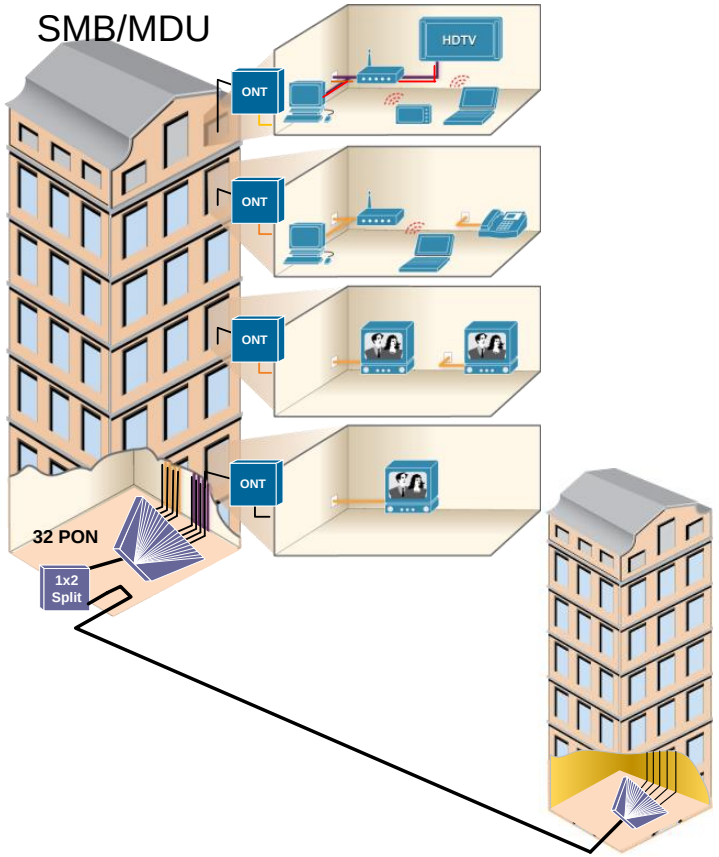


OLT can be hardened unit installed in outdoor cabinet or can be node based unit

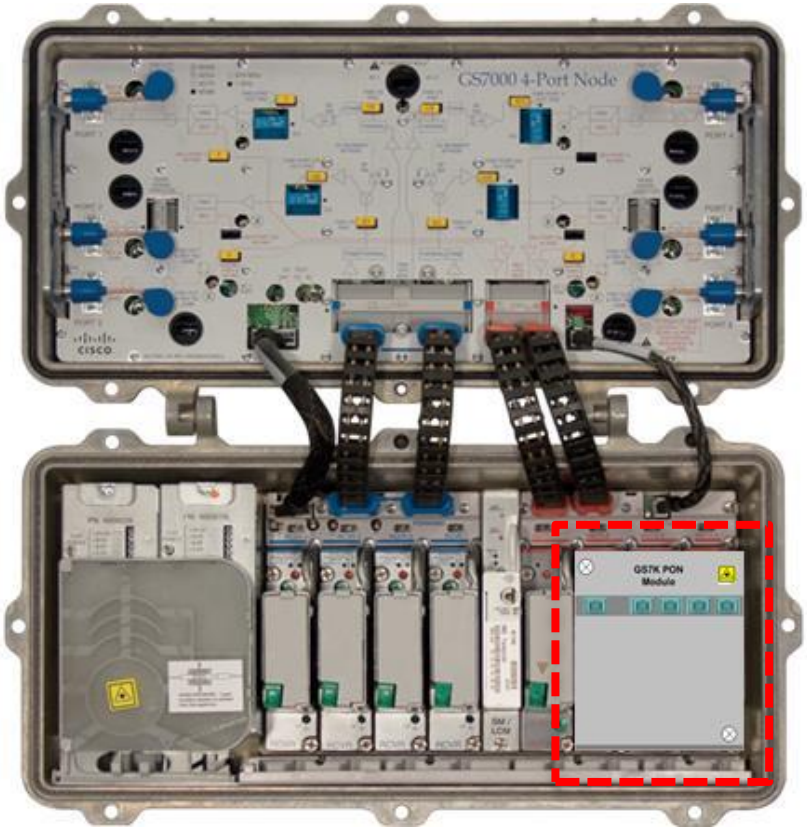
PON Challenges & Deployment Example

PON Has It Challenges

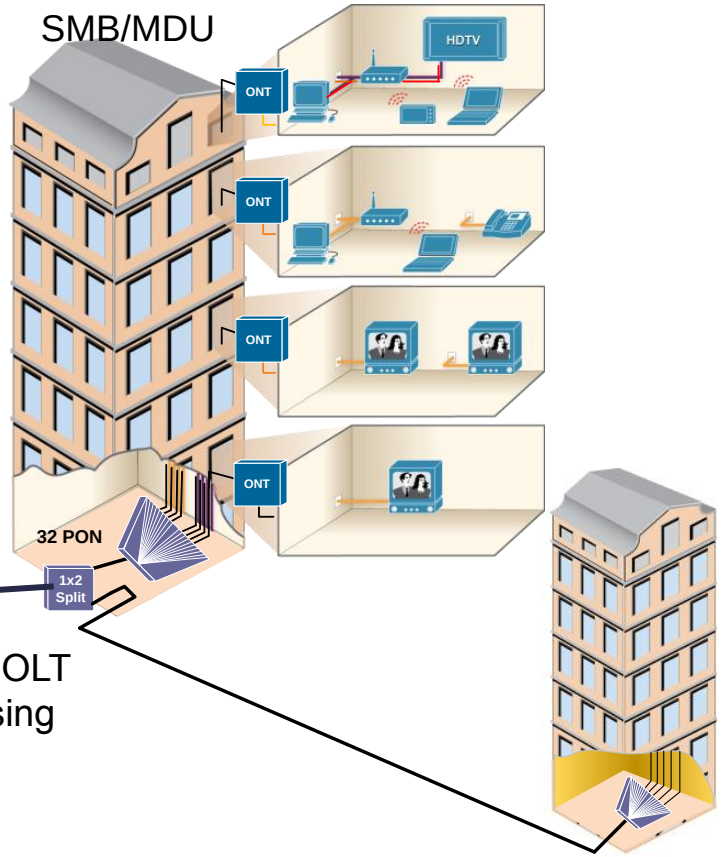
- Requires 1 fiber per 1x32 split – what if you have a 500HP MDU to build a PON network. 500/32 = 16 fibers
- Typical reach is 20kms – what if you have the 16 fibers BUT the MDU is beyond 20km



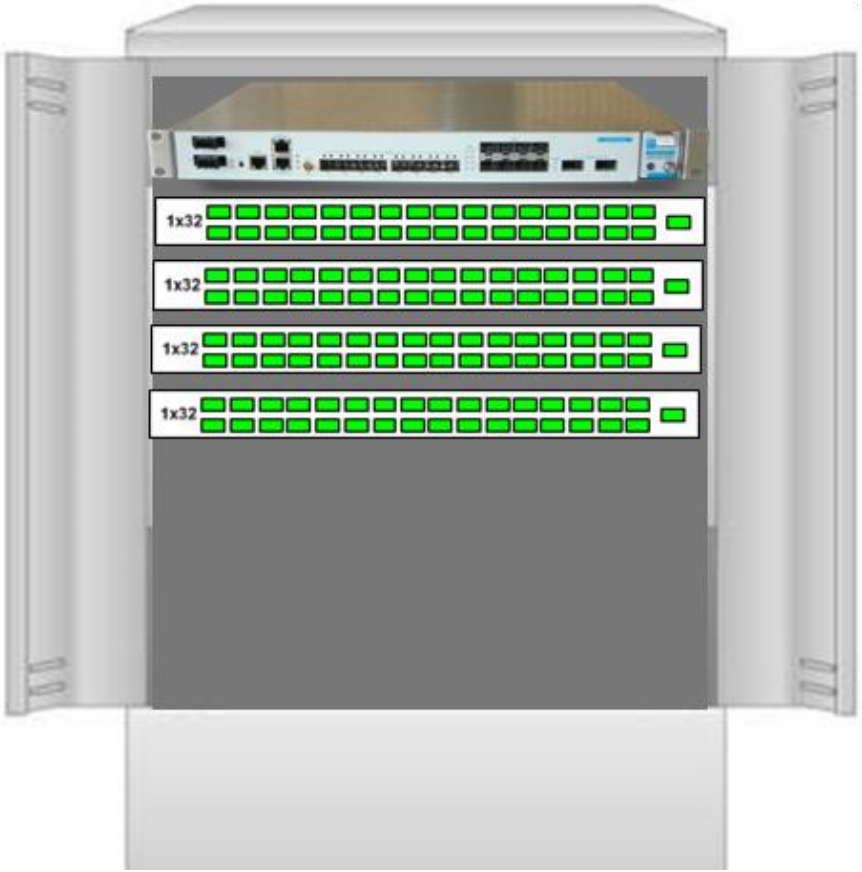
Overcoming Challenges

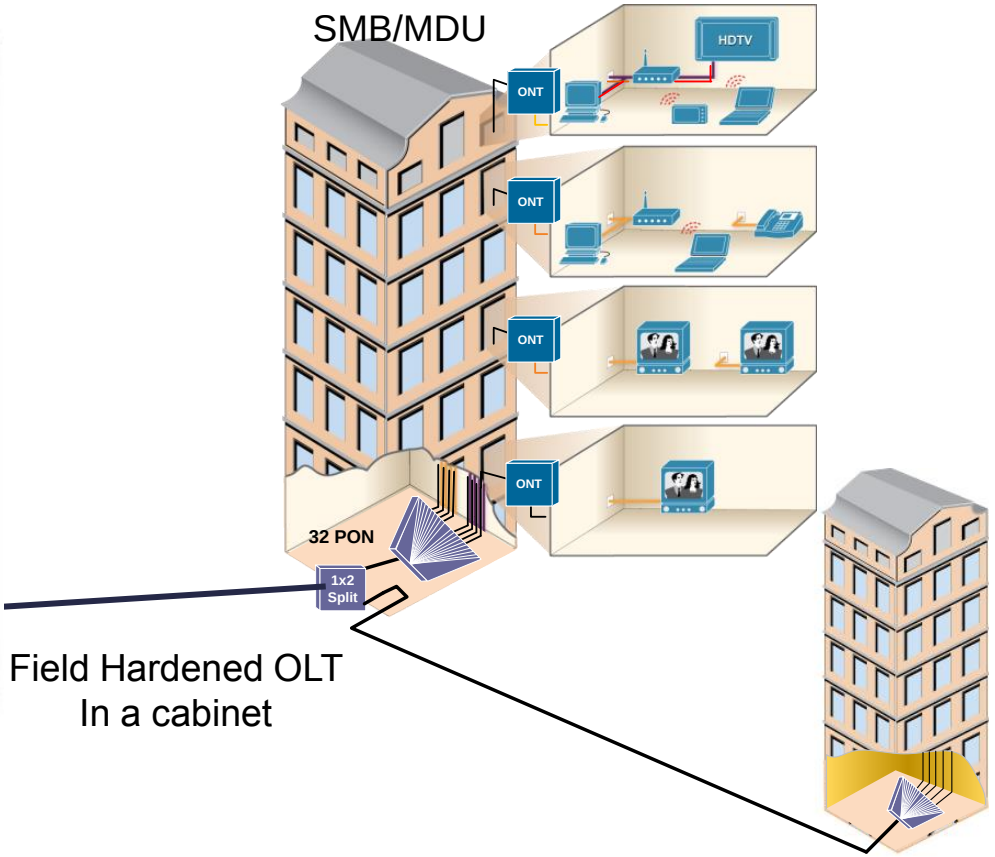


Field Hardened OLT
In a Node housing



Overcoming Challenges

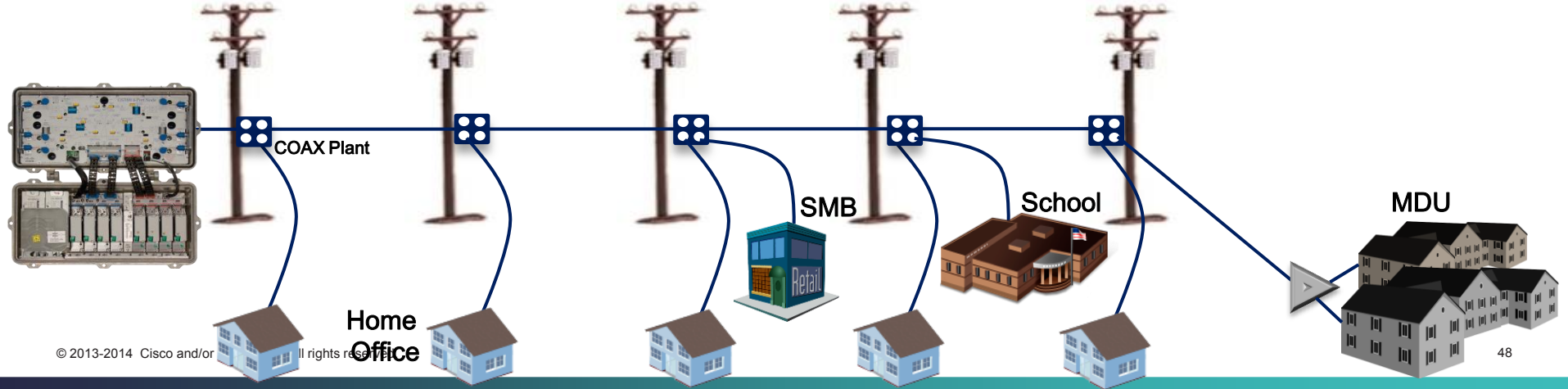




Field Hardened OLT
In a cabinet

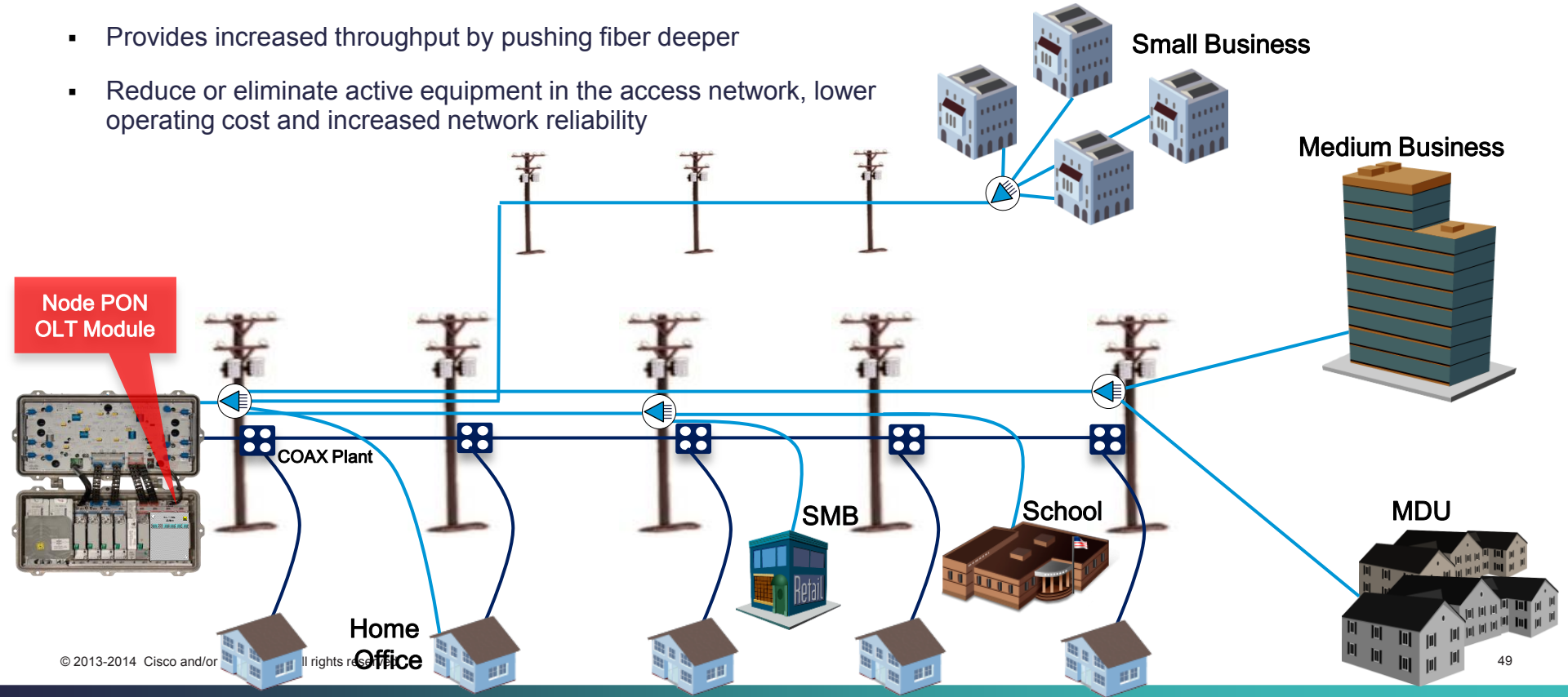
Typical COAX Plant

- Typical coax plant feeds residential and the occasional SMB, School or MDU.
- Service providers face challenges to support SMB while leveraging existing investments in infrastructure while increasing capacity.
- Issues feeding bulk accounts and small to medium business with residential cable customers
  - ✓ Large bulk accounts can be problematic with ingress on the plant
  - ✓ Throughput can be slowed

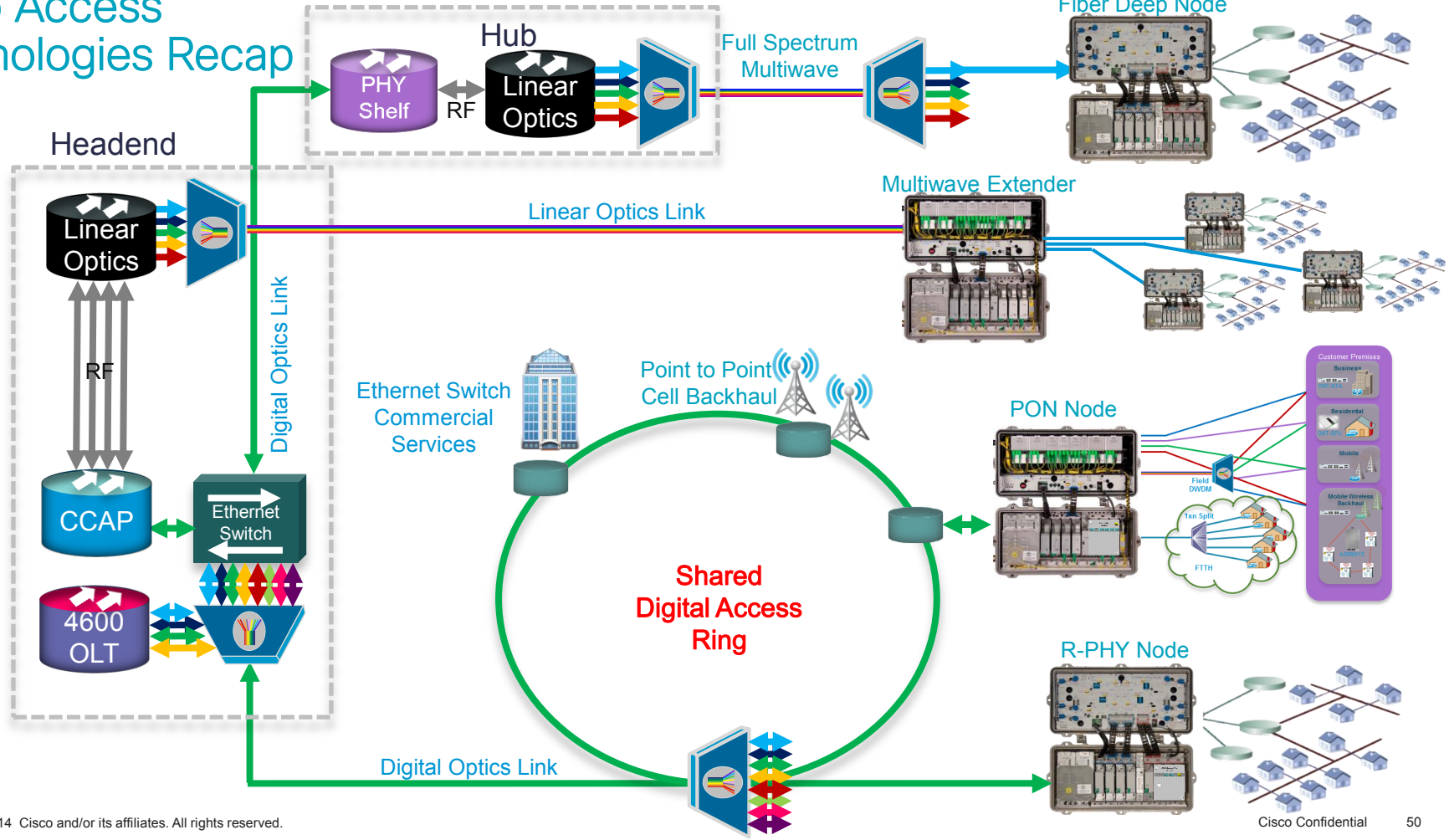


PON Solutions Allow….

- Better balance node serving area by offloading SMB/MDU or high-end resi DOCSIS users to IP fiber based PON
- Provides increased throughput by pushing fiber deeper
- Reduce or eliminate active equipment in the access network, lower operating cost and increased network reliability



Cisco Access Technologies Recap



Q&A

CISCO

Thank you.