# Super-PON

## Scale Fully Passive Optical Access Networks to Longer Reaches and to a Significantly Higher Number of Subscribers

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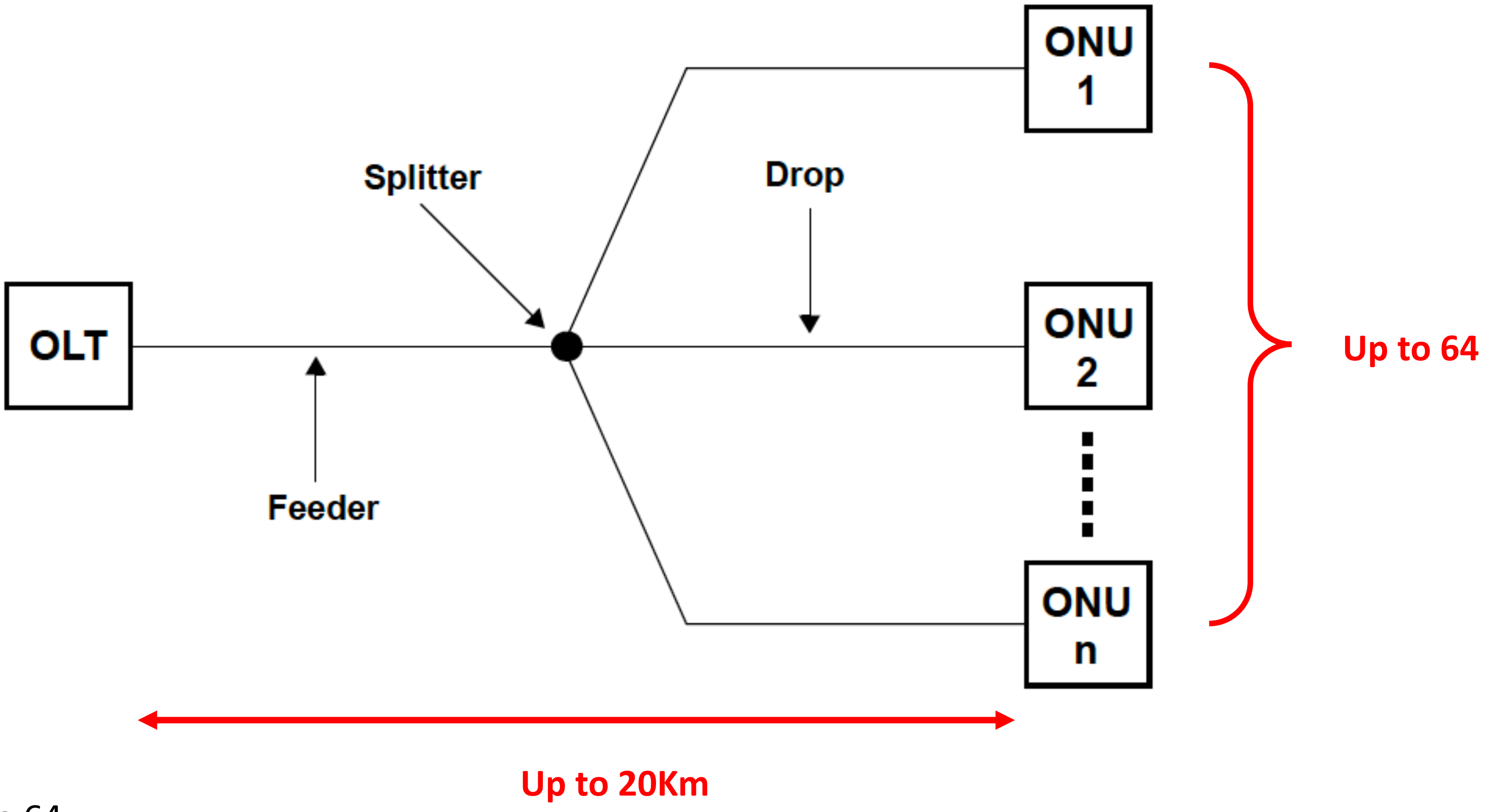
Joy Jiang

# Agenda

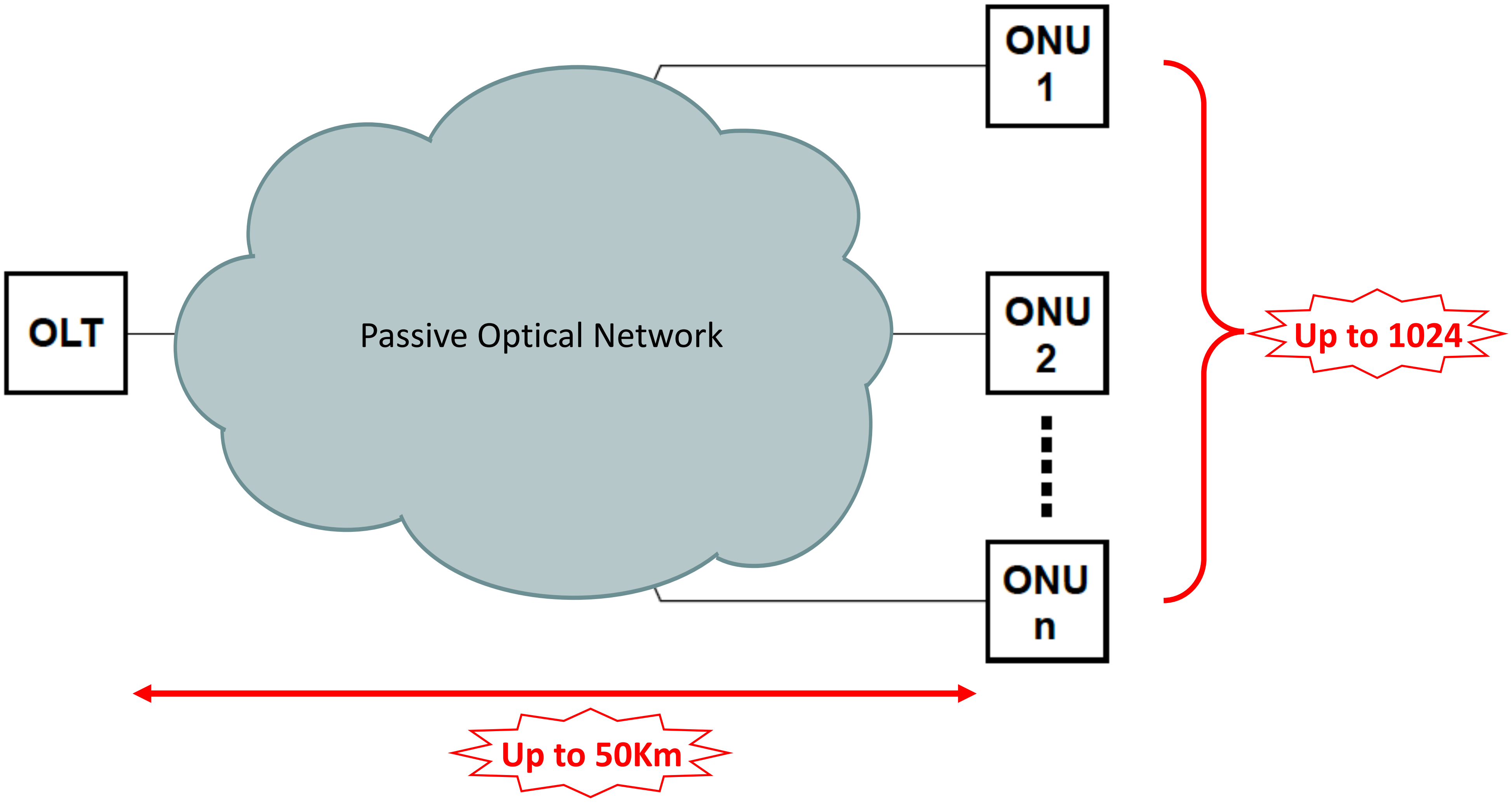
- Super-PON Idea
- Why Super-PON?
- Super-PON PMD

# IEEE 802.3 EPON Architecture




IEEE 802.3 Clause 64

# Super-PON Scalability



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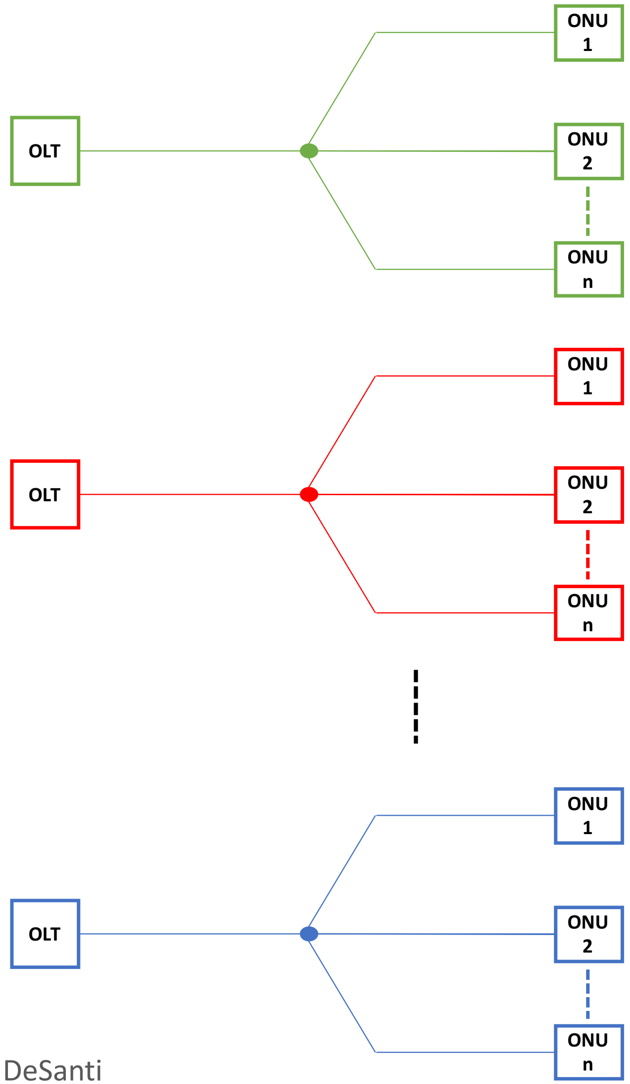
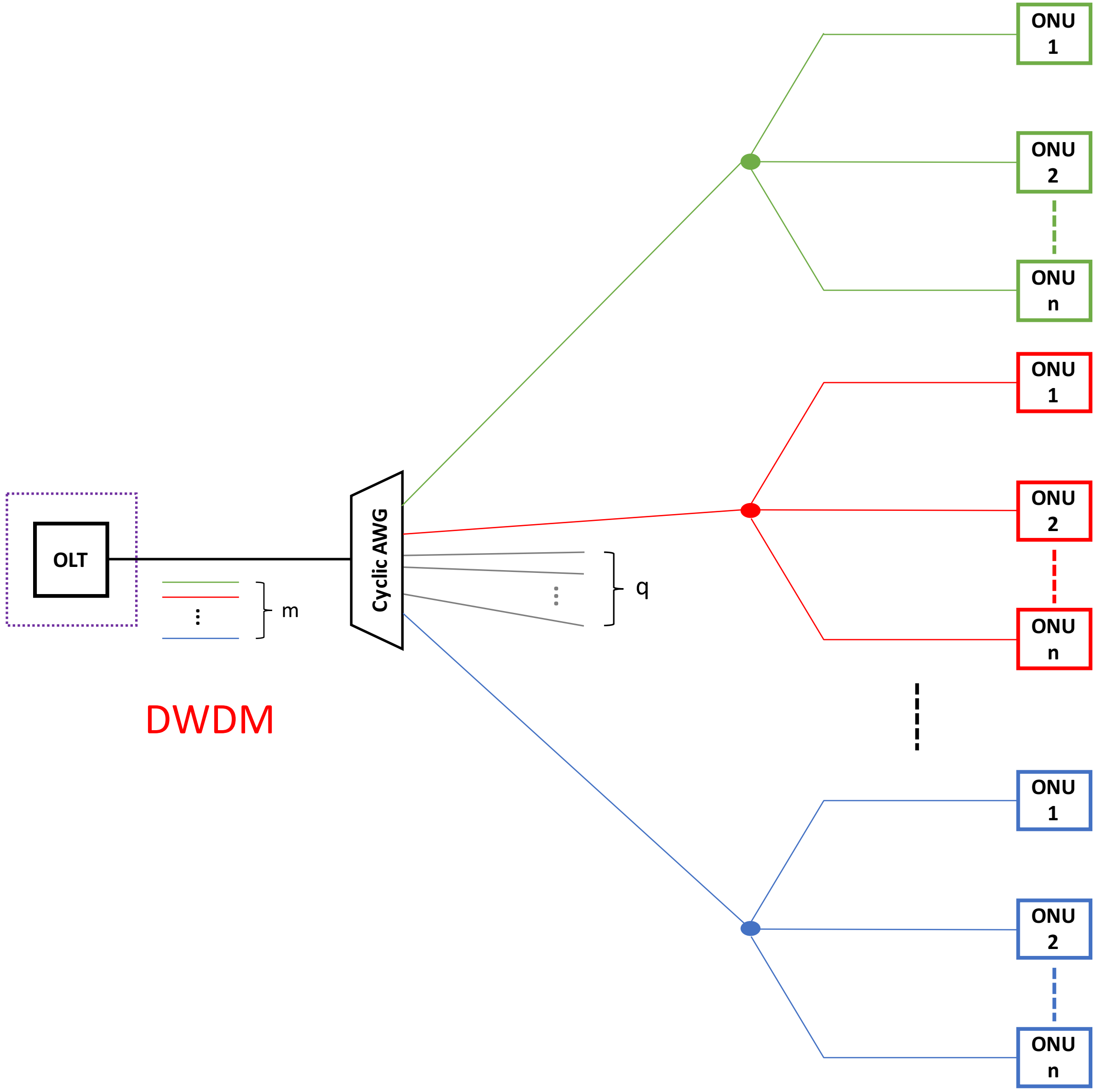
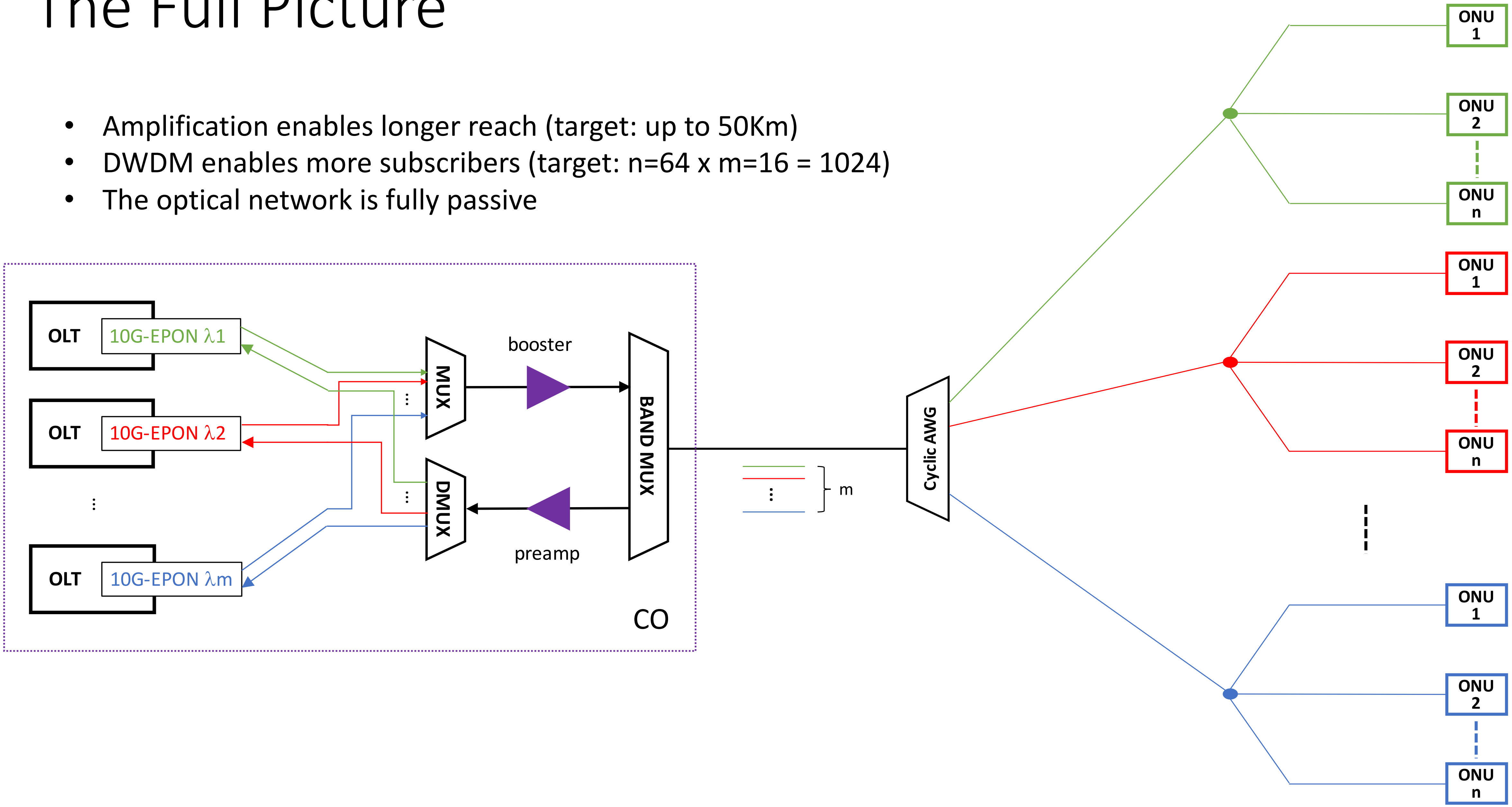



# …To Here

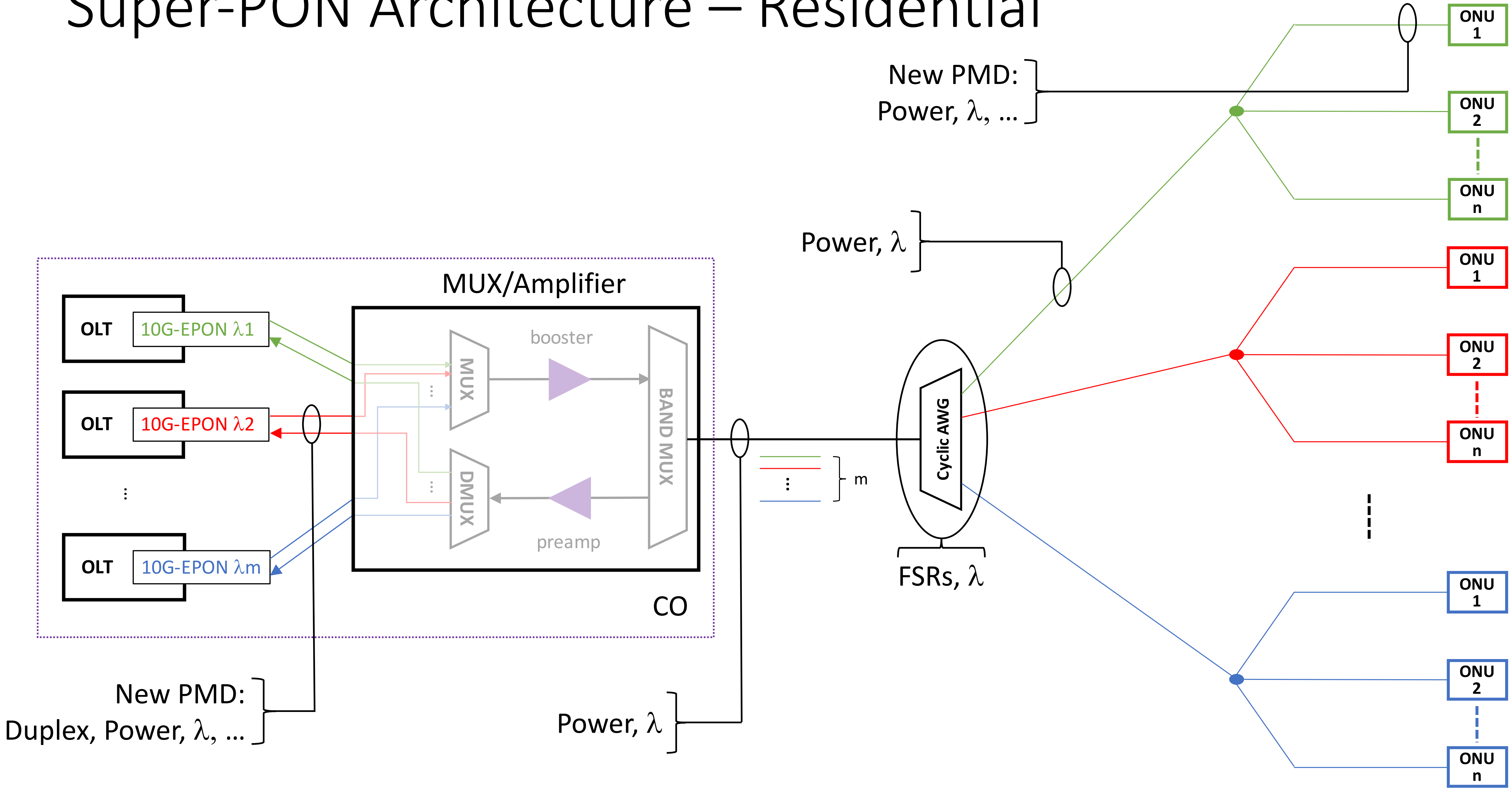


# The Full Picture

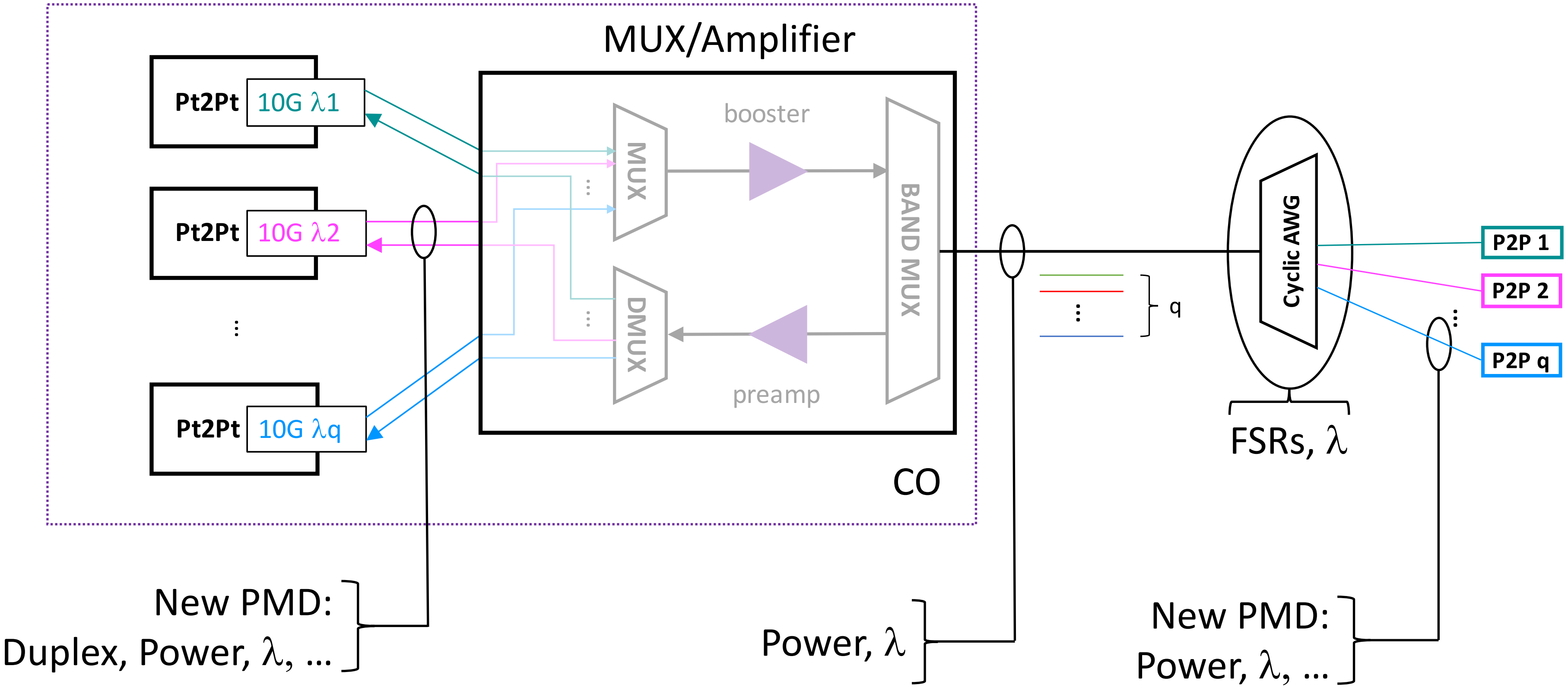
- Amplification enables longer reach (target: up to 50Km)
- DWDM enables more subscribers (target: n=64 x m=16 = 1024)
- The optical network is fully passive



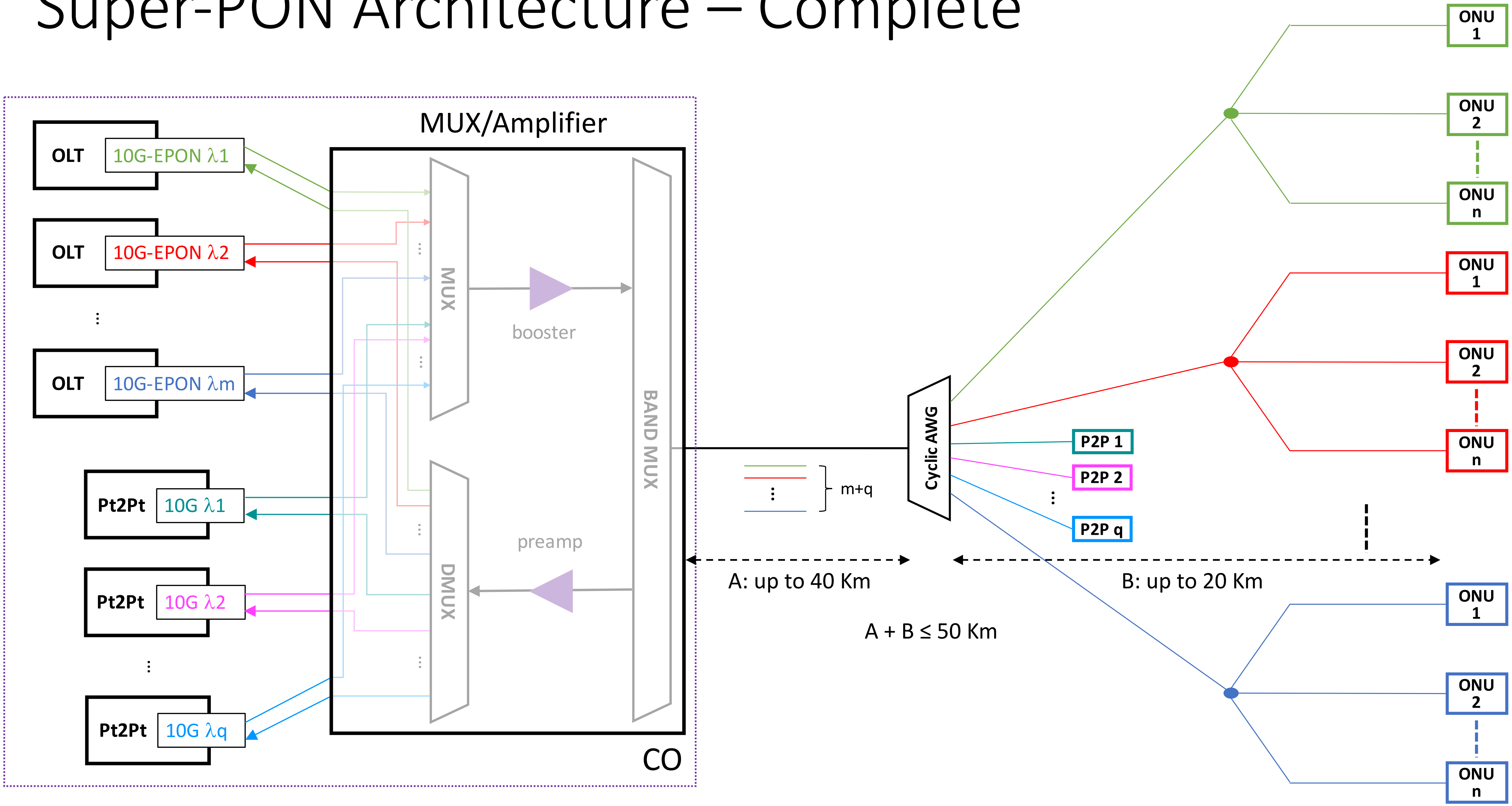
# Super-PON Architecture – Residential



# Super-PON Architecture – Point to Point Support



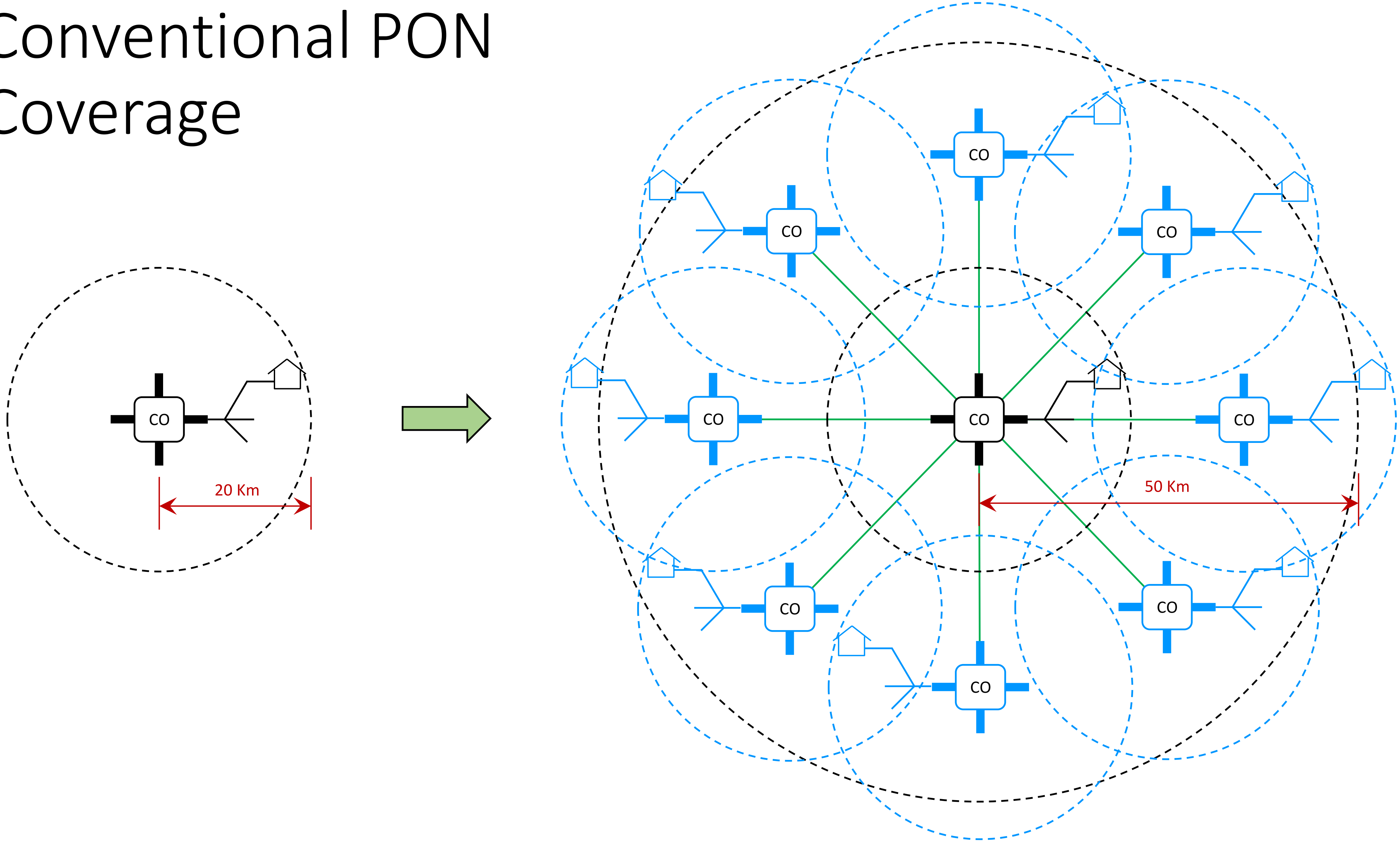
# Super-PON Architecture – Complete



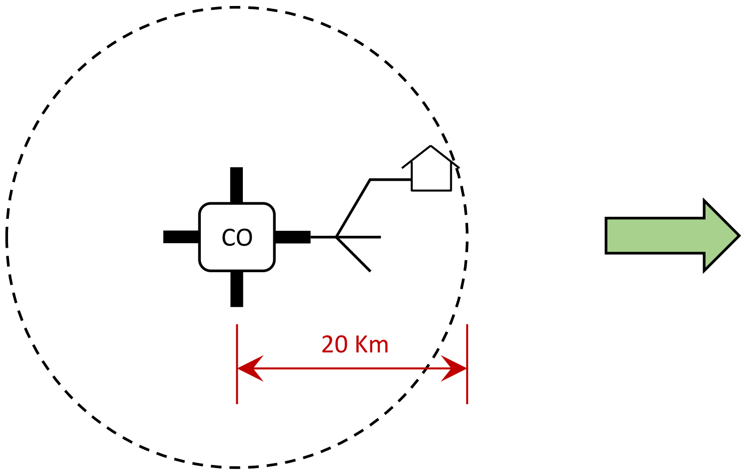
# Agenda

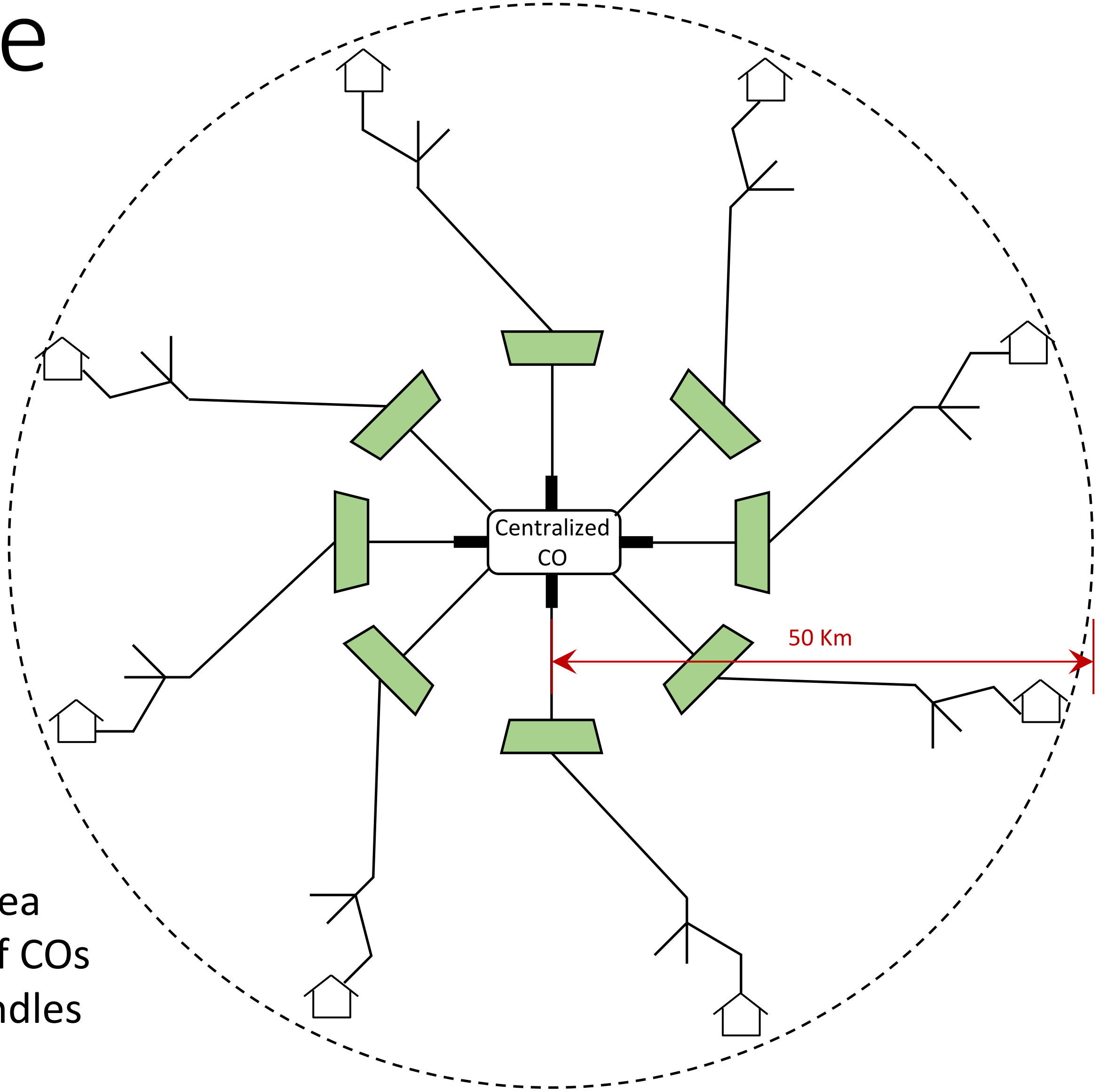
- Super-PON Idea
- Why Super-PON?
- Super-PON PMD

# Conventional PON Coverage



# Super-PON Coverage

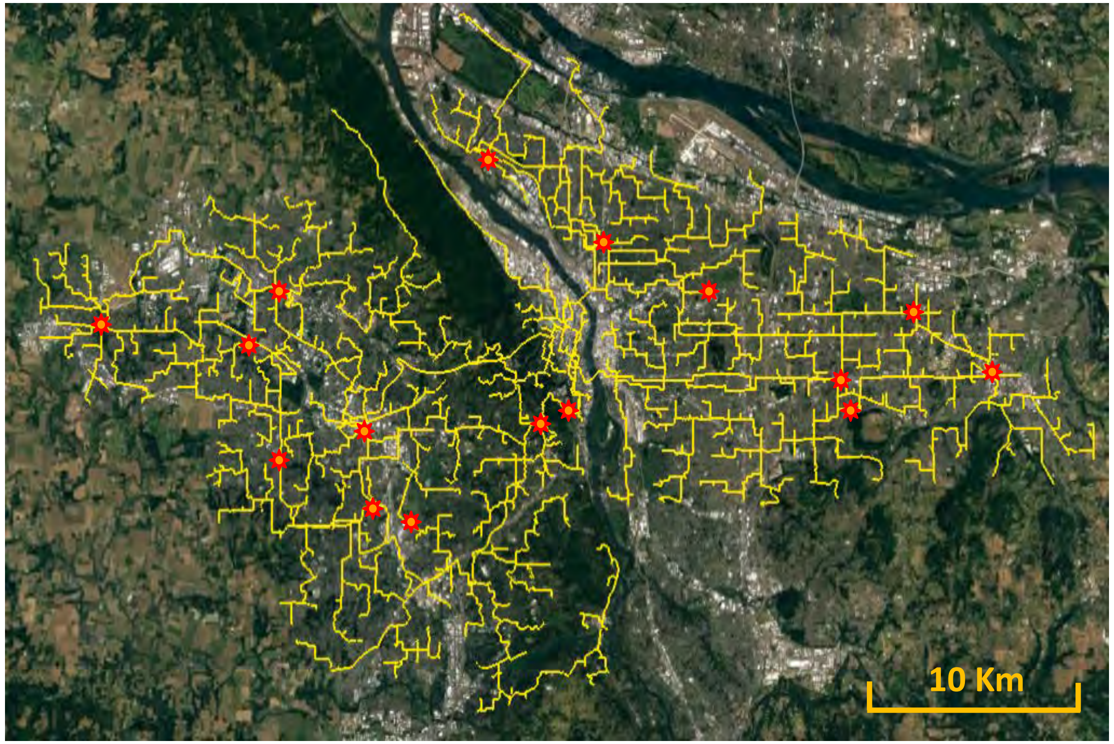



- Larger serving area
- Fewer number of COs
- Smaller fiber bundles

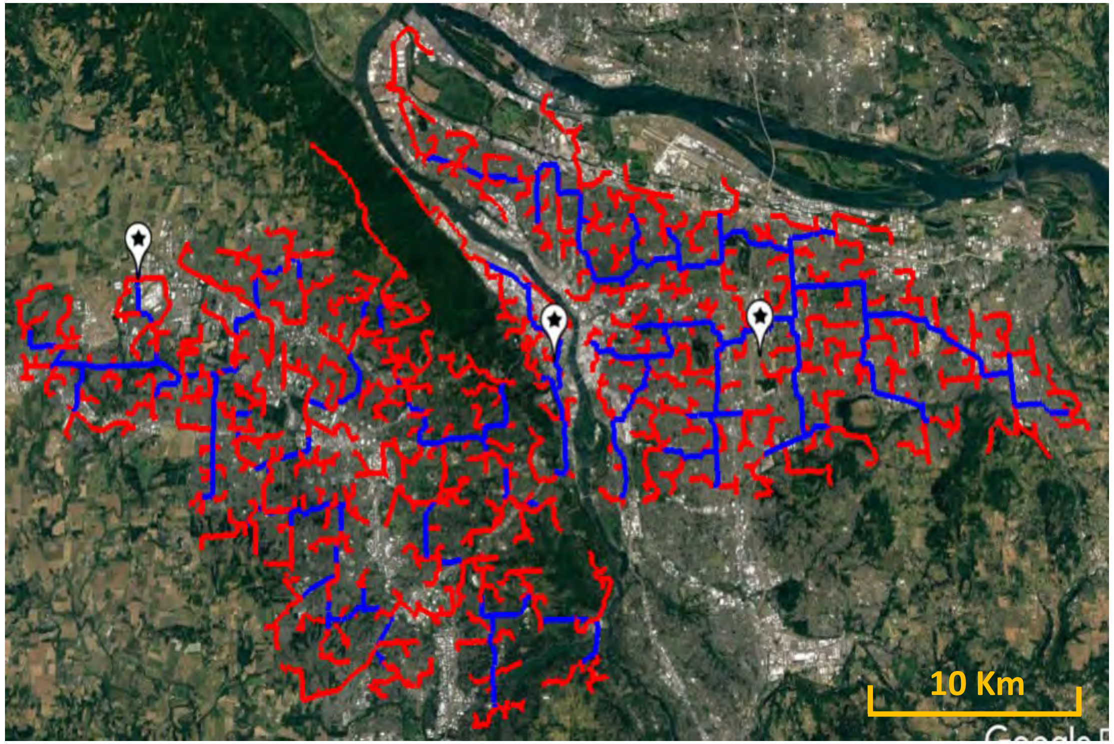
# Real Example

Conventional PON: 16 COs




Feeder fiber

Super-PON: 3 COs




CAWG feeder fiber

Splitter feeder fiber

- Significantly smaller number of COs
- Better fiber utilization
  - Much less backbone and feeder fiber
  - Lower OSP building cost

# Advantages

- Fewer fiber strands exiting a CO
  - Enables smaller/fewer cables
  - From 432-fiber cables to 12/48-fiber cables
- Lower OSP building cost
  - Smaller cables can be longer and are easier to bend/handle
  - Allows use of micro-trenching and directional boring techniques
  - Easier to repair
- CO consolidation
  - The same number of feeder fibers can serve a much greater area
  - Less COs → less OPEX

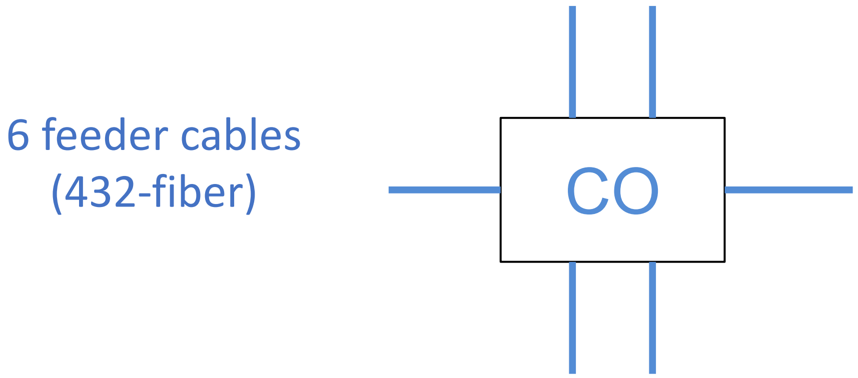
# About Trenching…

Traditional Trenching

Micro Trenching

Directional Boring

# …and Repairs





A 432-fiber cable:

- Contains 36 ribbons of 12 fibers
- ~10 min to splice a ribbon
- ~6 hours total to splice a broken cable
- Additional ~2 hours for cable manipulation
- Average time to repair a cable damage: ~8 hours

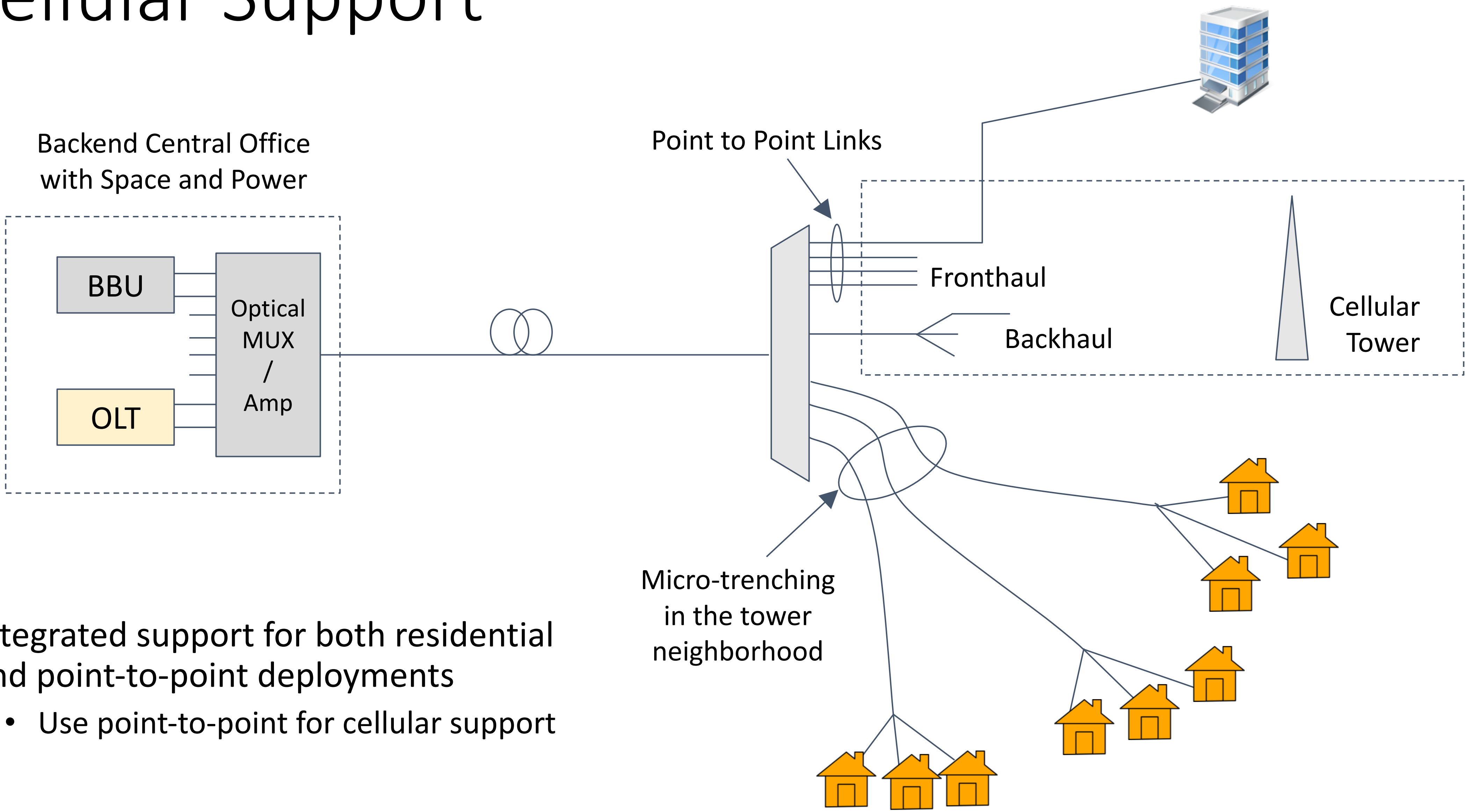
A 24-fiber cable:

- ~40 mins total to splice a broken cable
- Additional ~1 hour for cable manipulation
- Average time to repair a cable damage: ~1 hour 40’

# Super-PON Applicability

- Well suited for new optical plants (OSPs) developments
  - Significant savings in cabling and building cost
- Valuable as a retrofit to existing OSP for (5G) cellular deployments
  - Integrated support for both point-to-point and residential customers
- Can be used to consolidate COs leveraging existing fiber plants
  - A CORD (Central Office Redesigned as a Data-center) enabler
  - Increased typical utilization of OLT ports

# Cellular Support

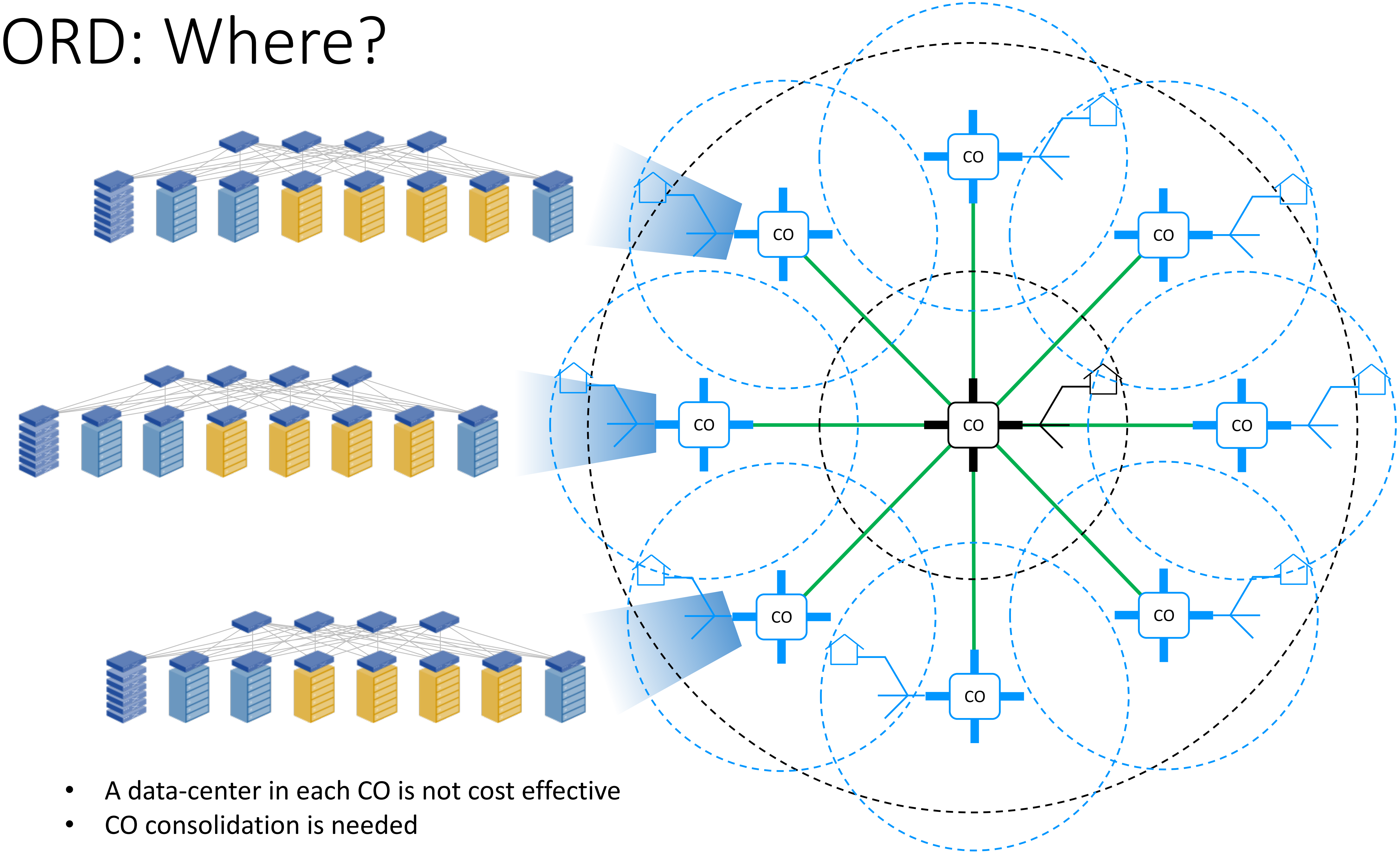



- Integrated support for both residential and point-to-point deployments
  - Use point-to-point for cellular support

# CO Consolidation

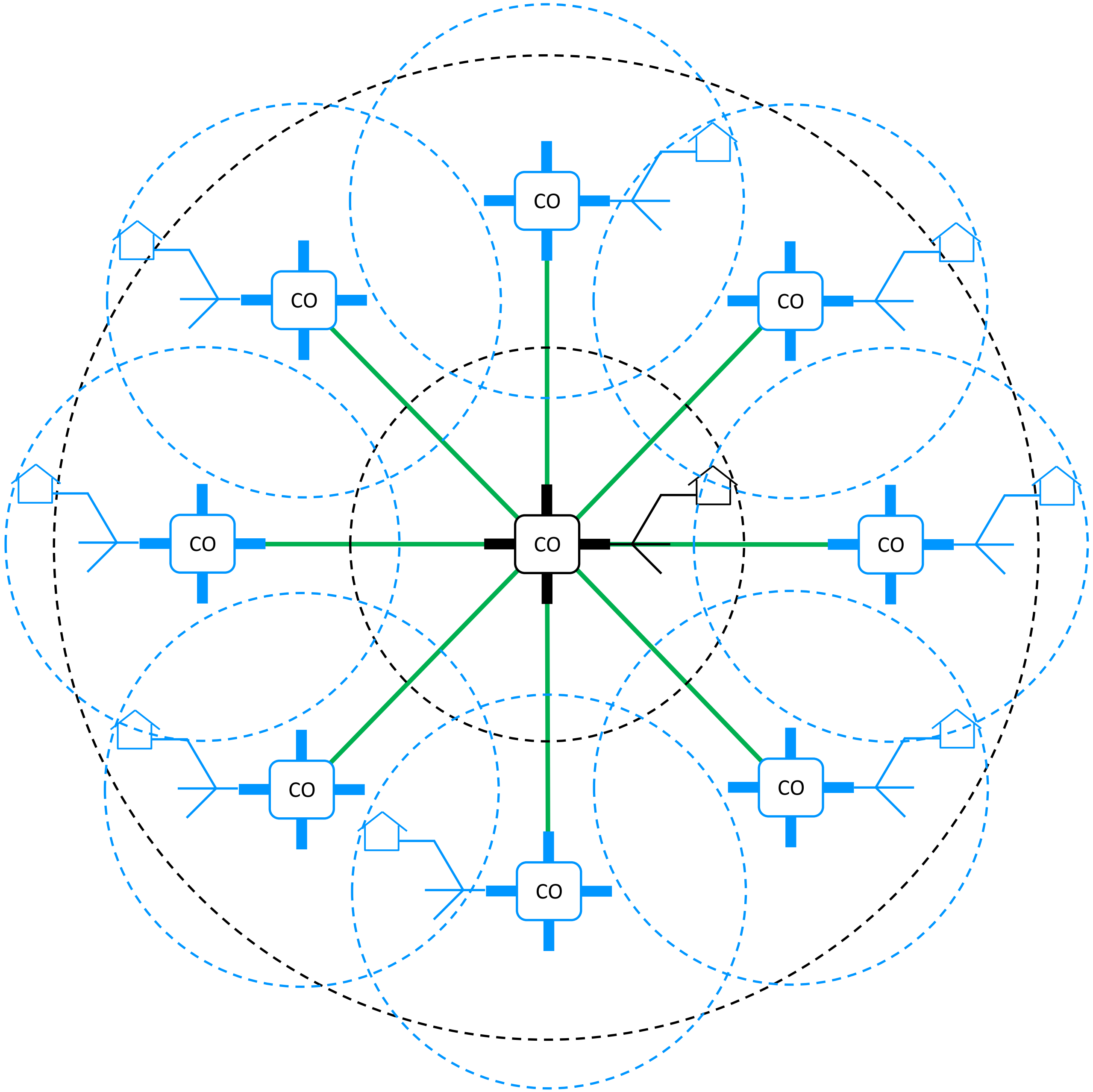
- Operators find advantageous co-locating data centers with access networks for value added services
- Current industry trend is toward Data Center consolidation
  - A small set of large data centers rather than a large set of small data centers
  - This also pushes for Central Offices consolidation
- Upcoming CORD (Central Office Re-architected as a Data center) architectures further push toward CO consolidation

# CORD: Where?

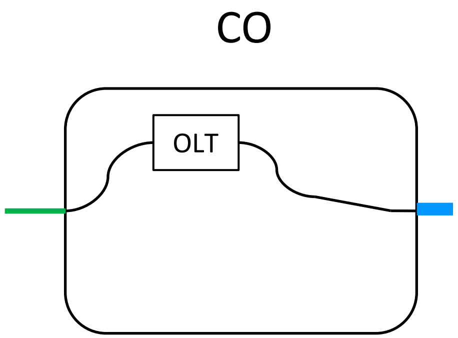


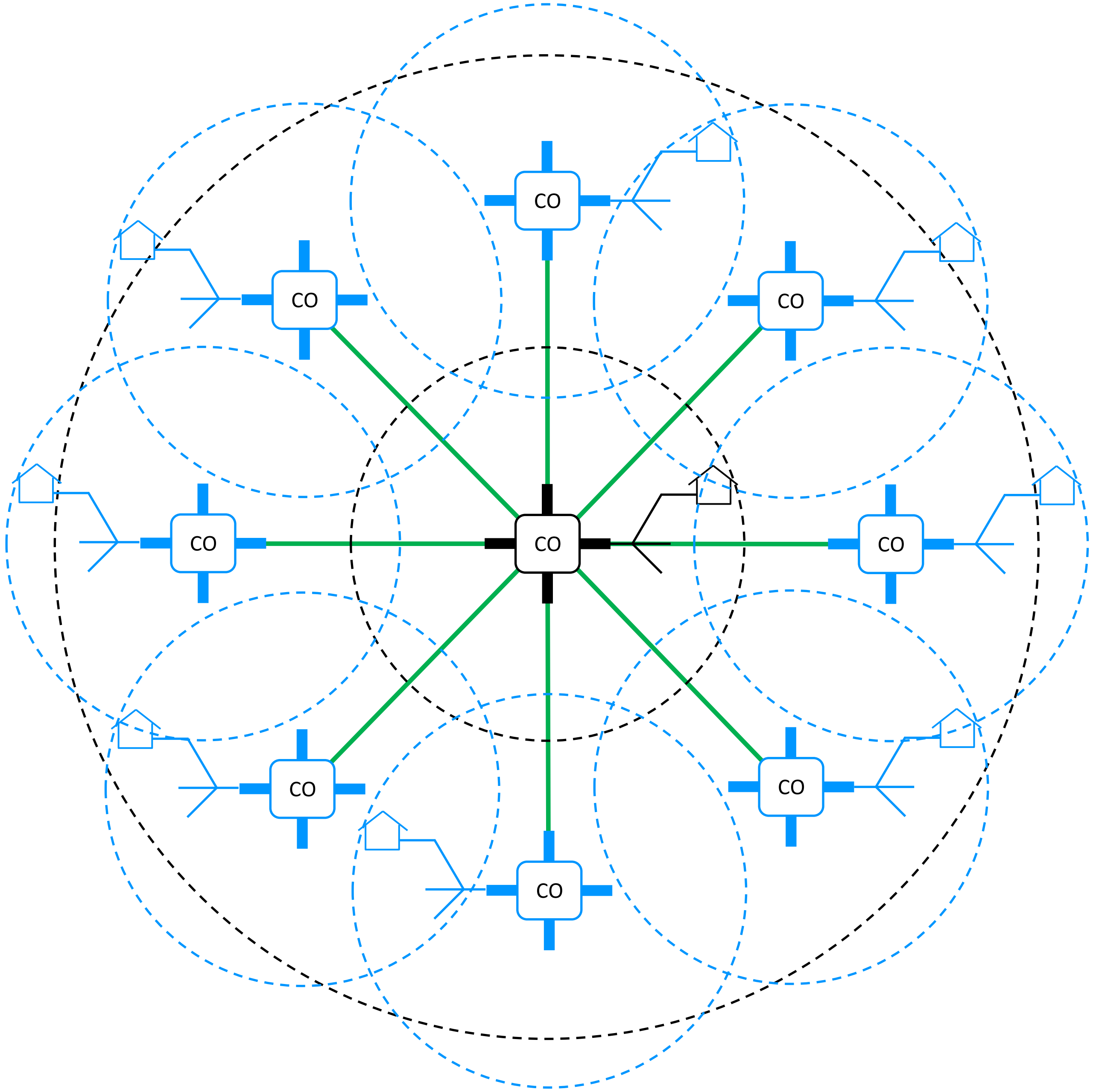

- A data-center in each CO is not cost effective
- CO consolidation is needed

# CO Consolidation

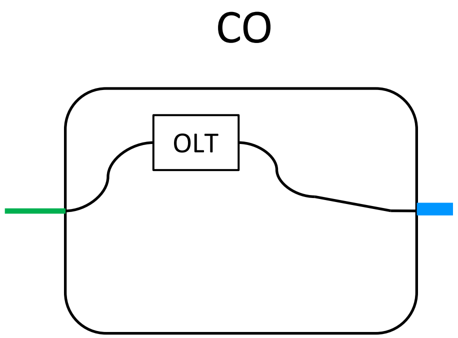


# CO Consolidation

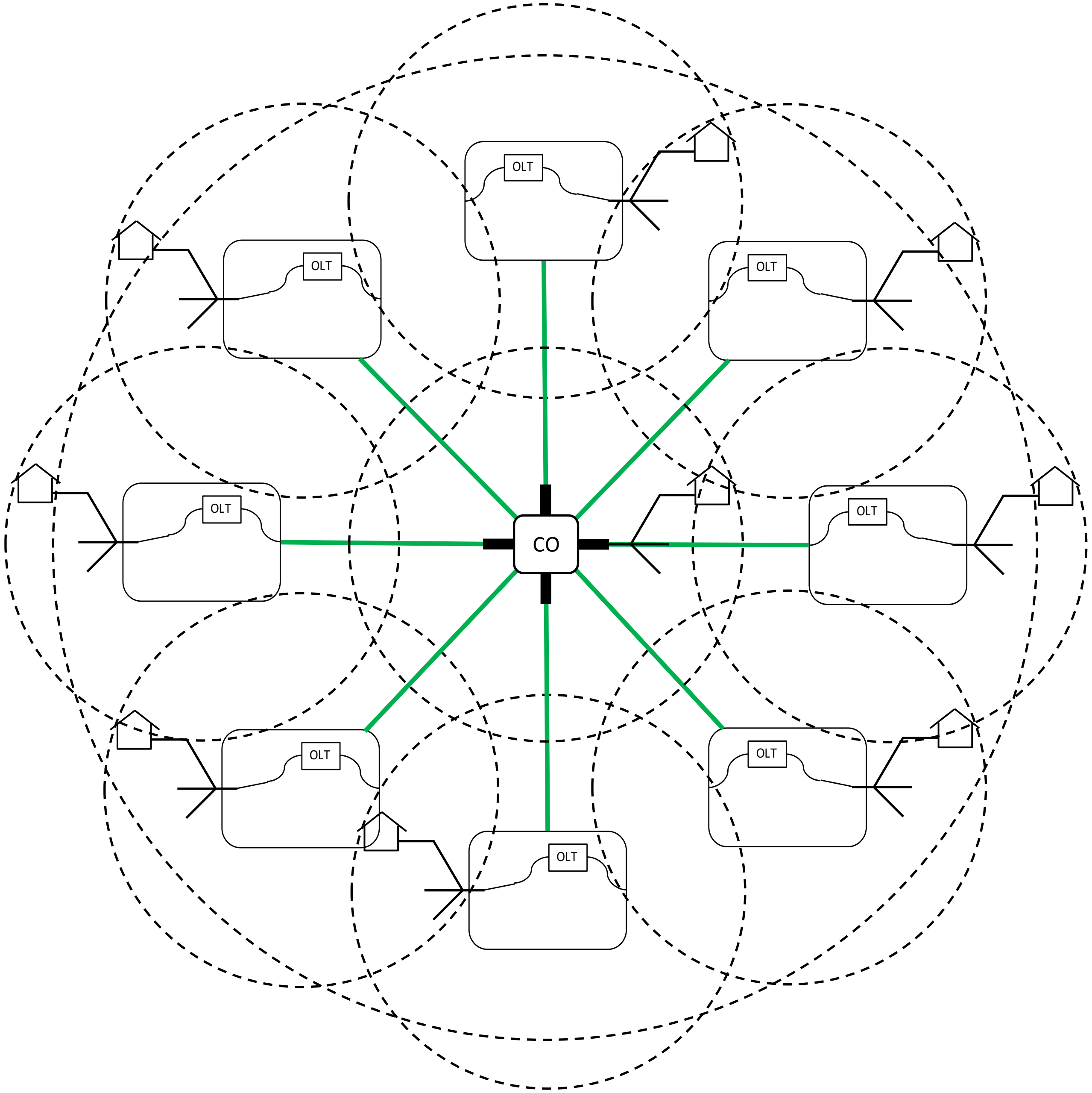


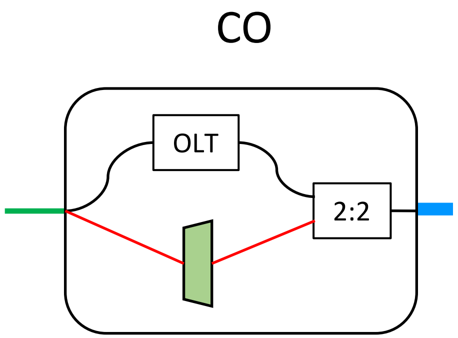
# CO Consolidation




Let’s add a CAWG
in peripheral COs



# CO Consolidation

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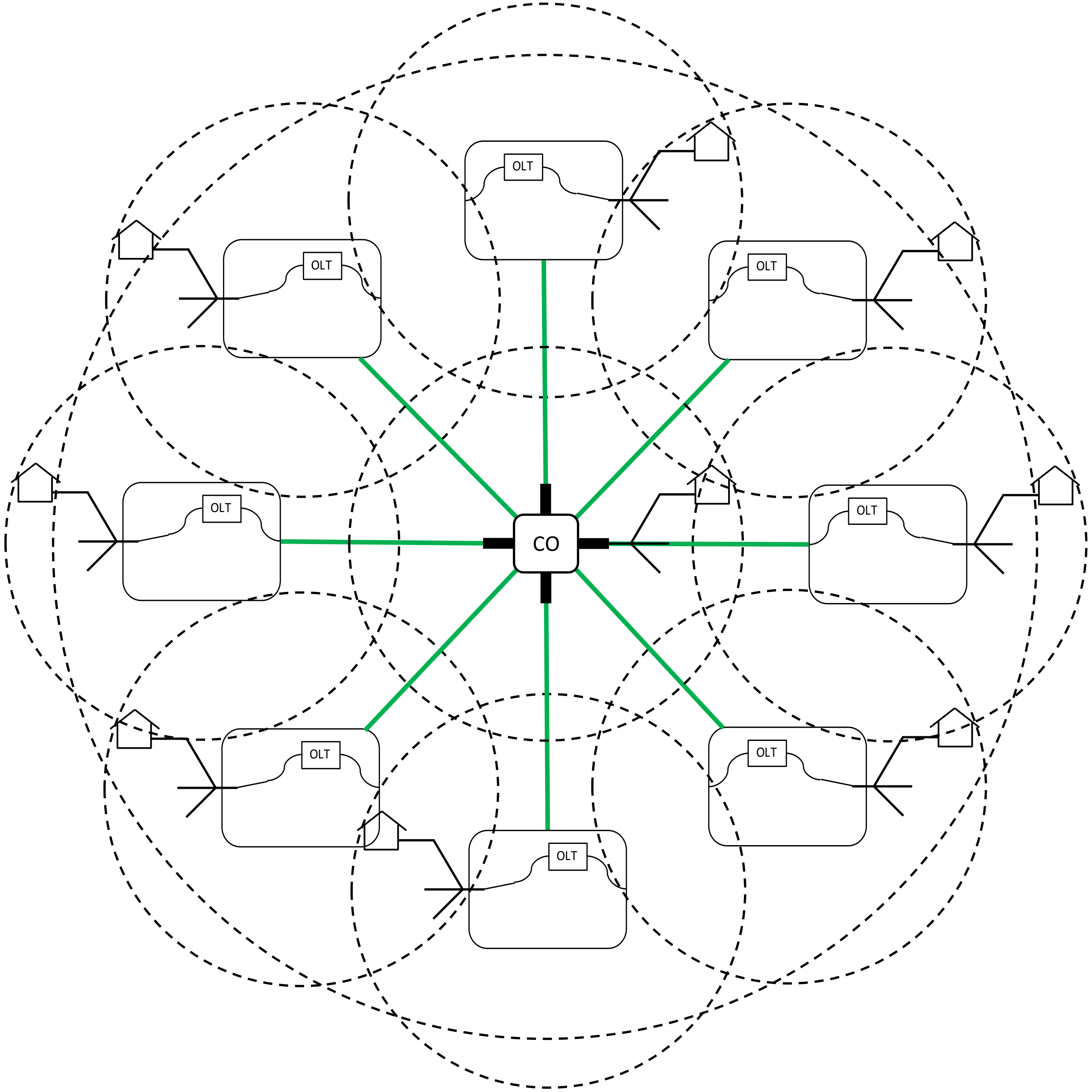

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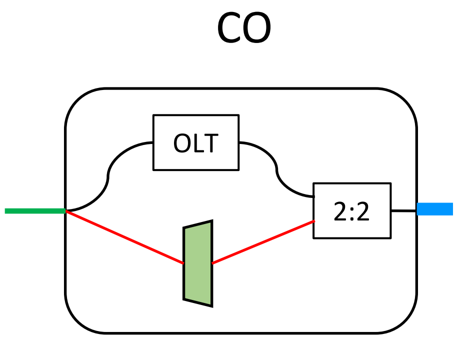


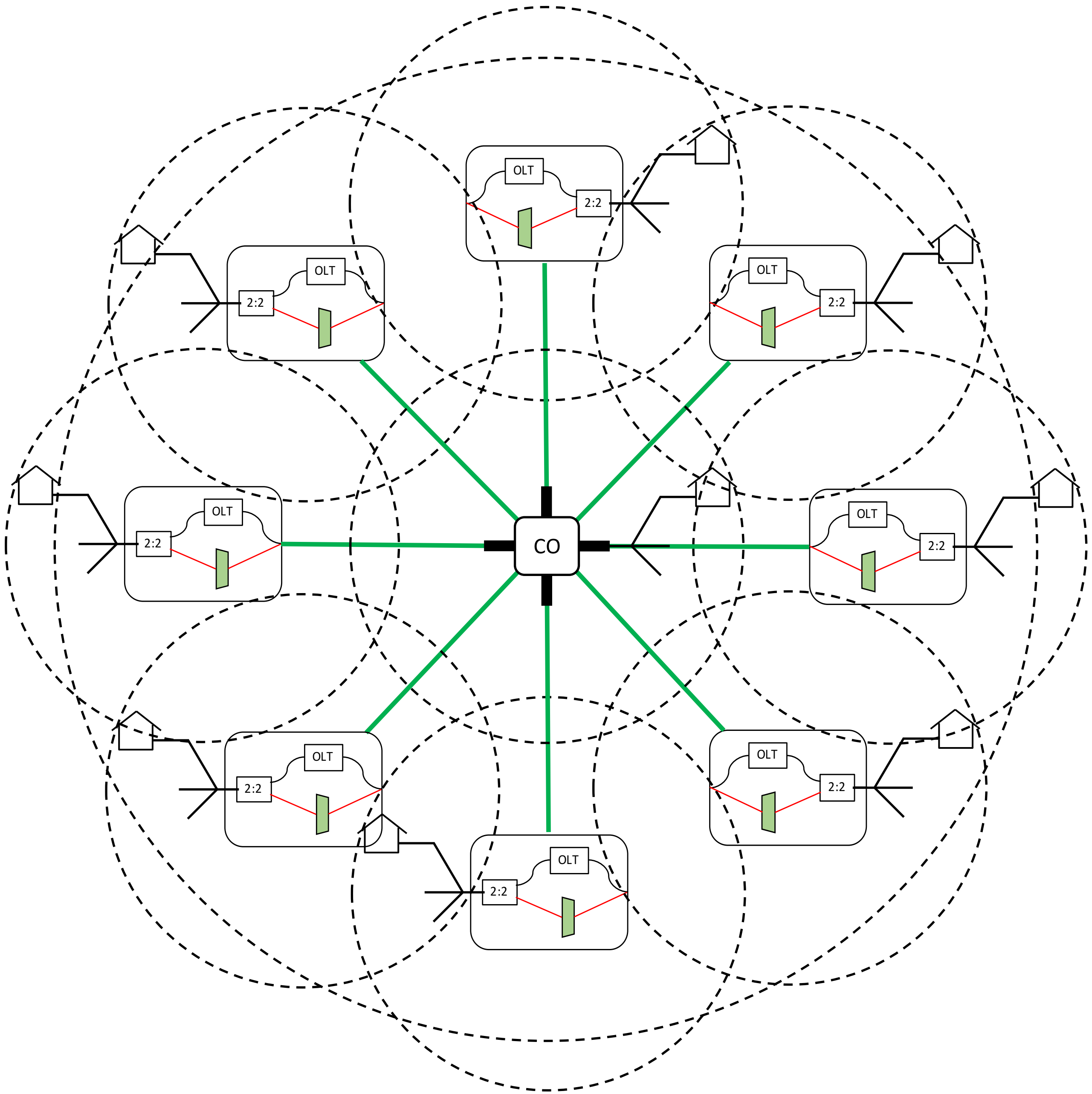

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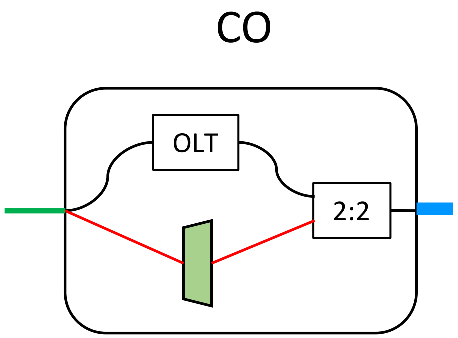
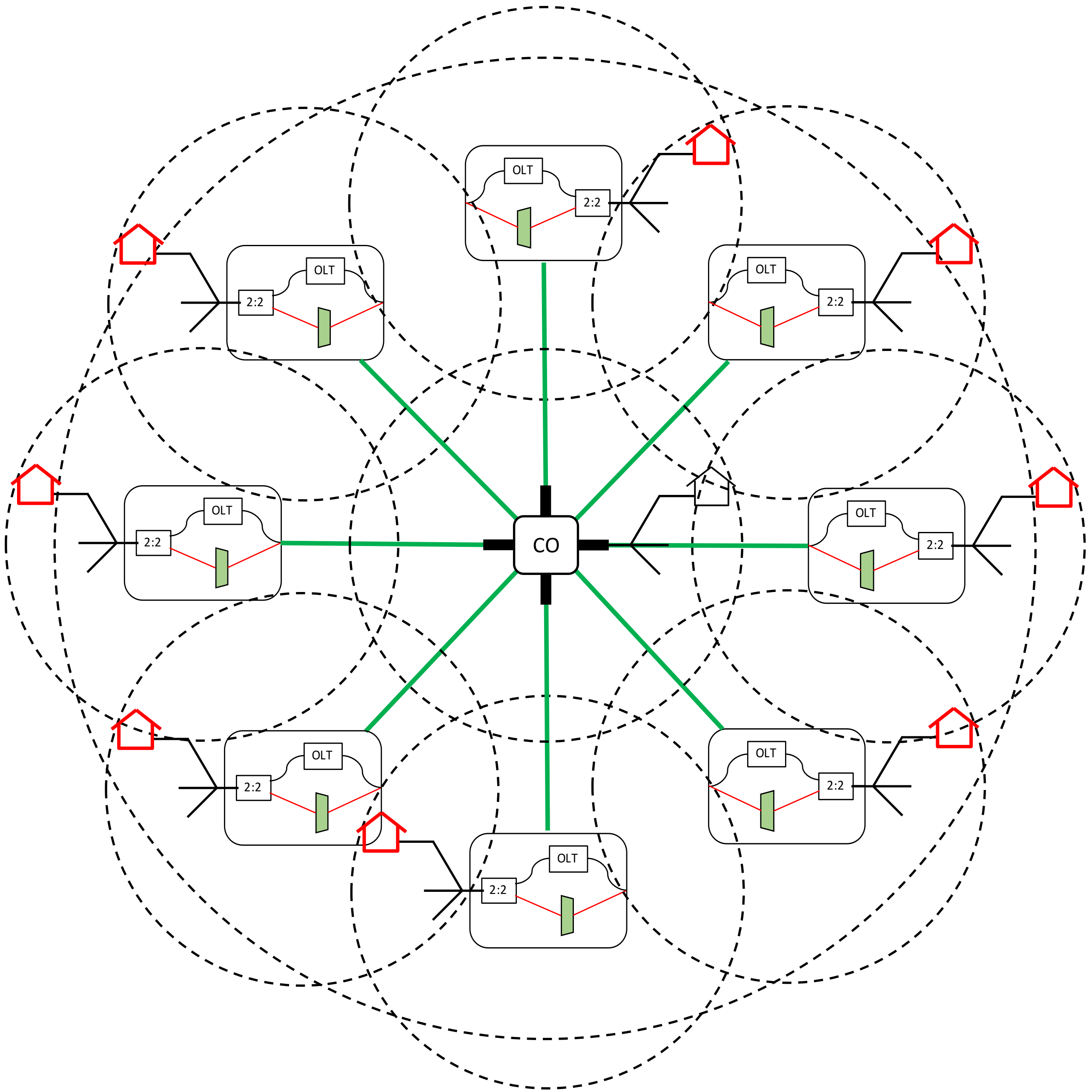



Let’s use the backbone fiber as CAWG feeder

Enable the new service



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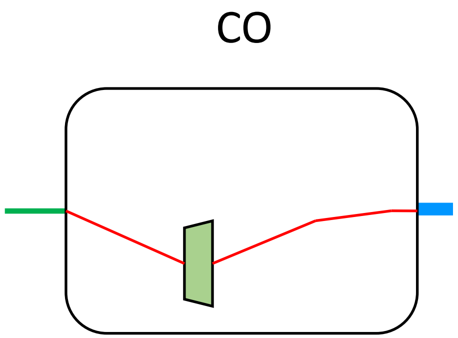
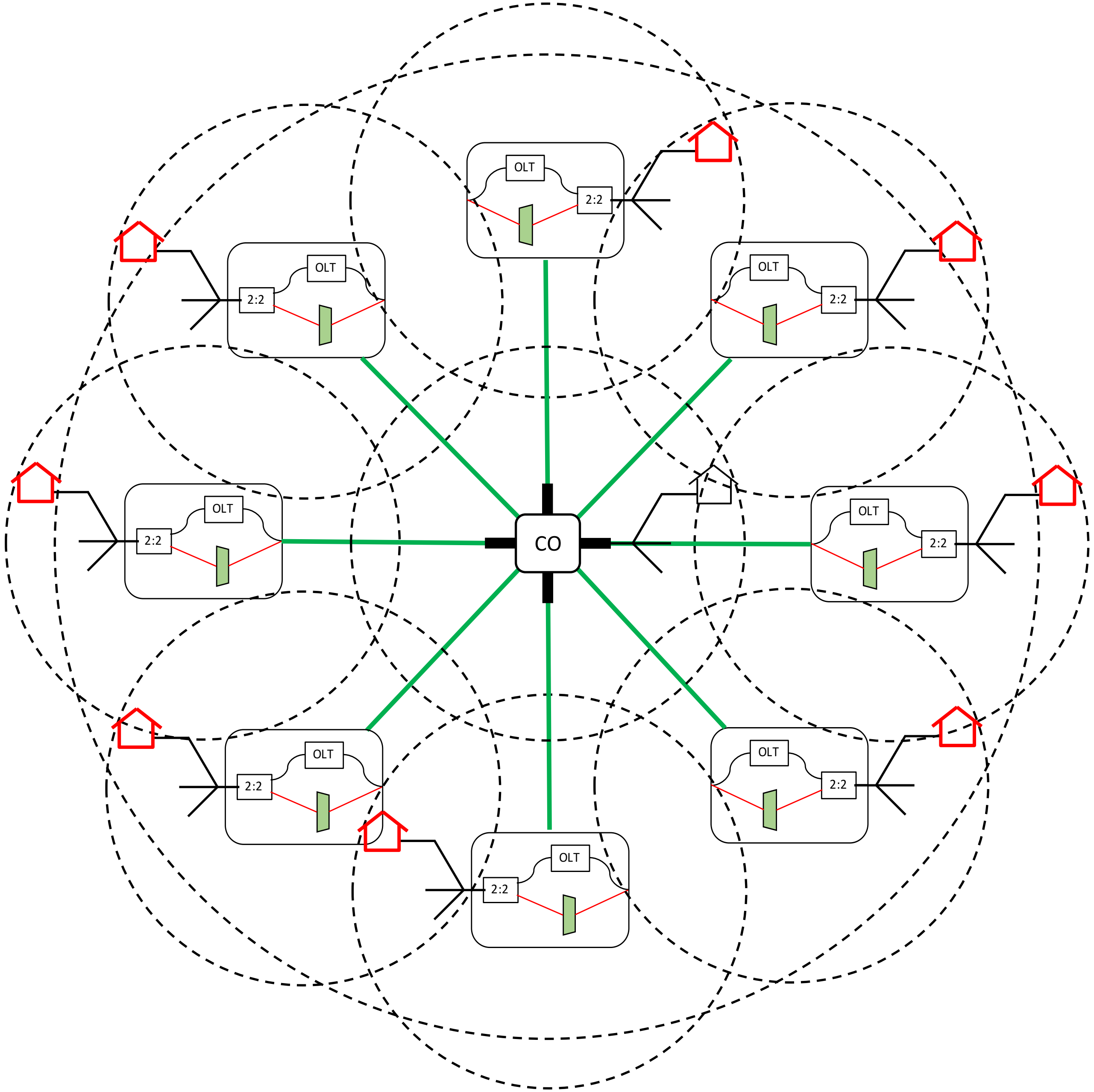



Remove the old service



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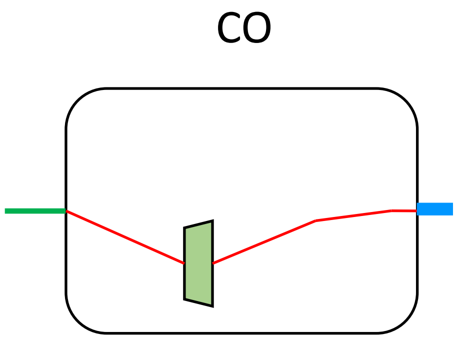
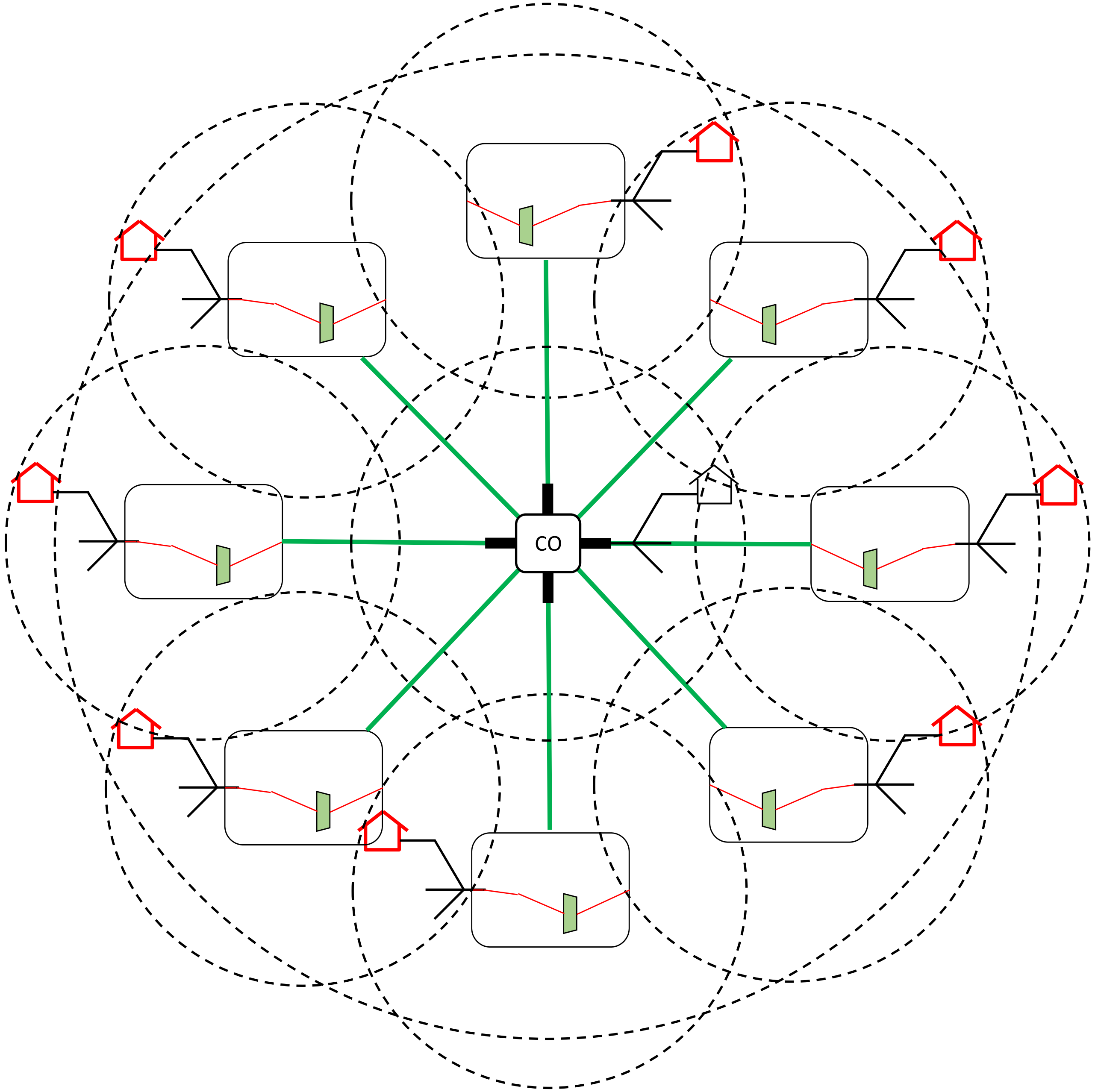
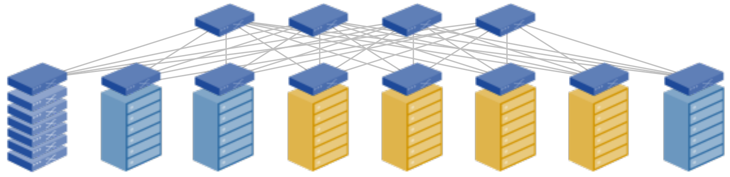



Remove the old service

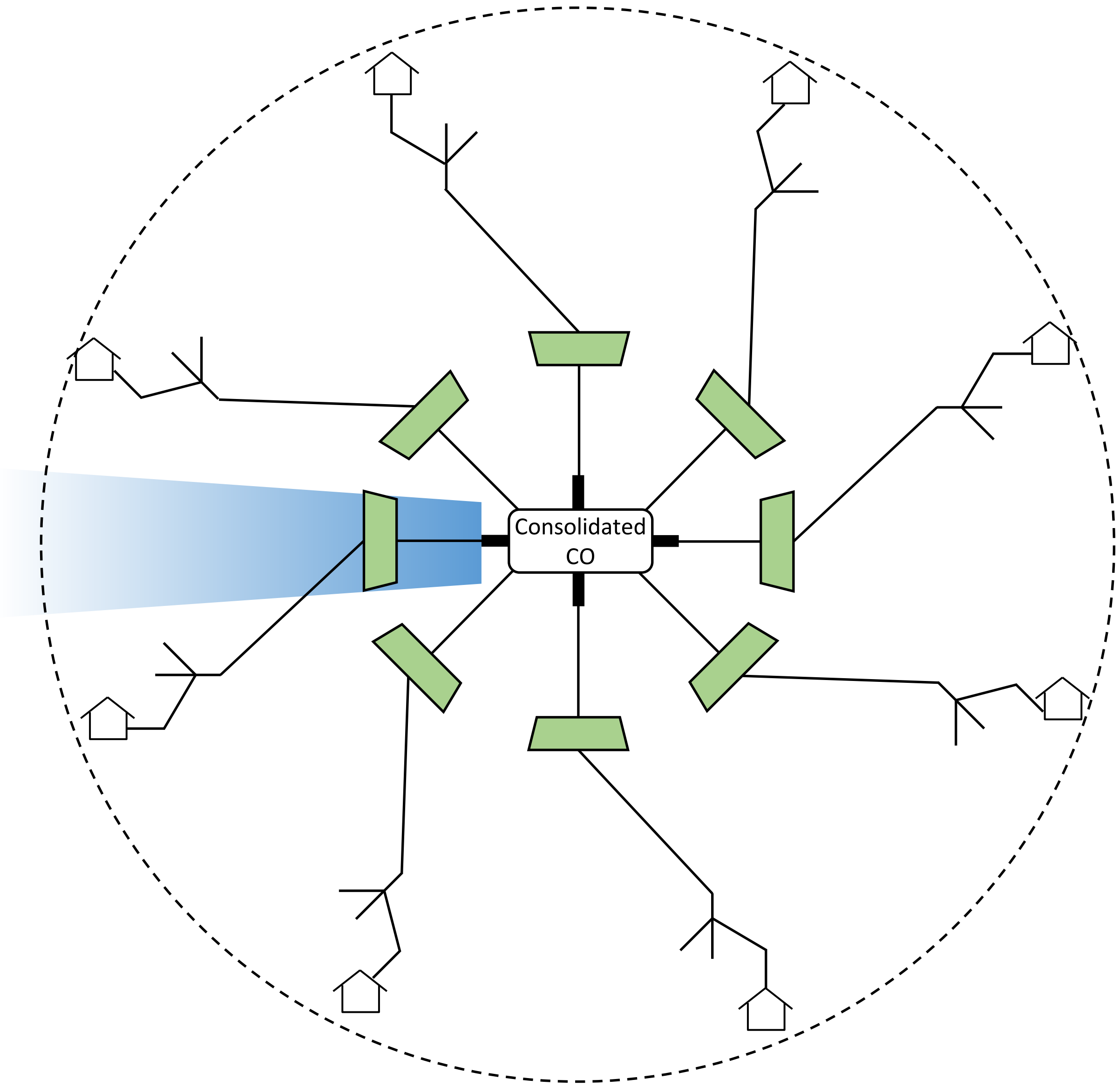



Claudio DeSanti

# Consolidated CO



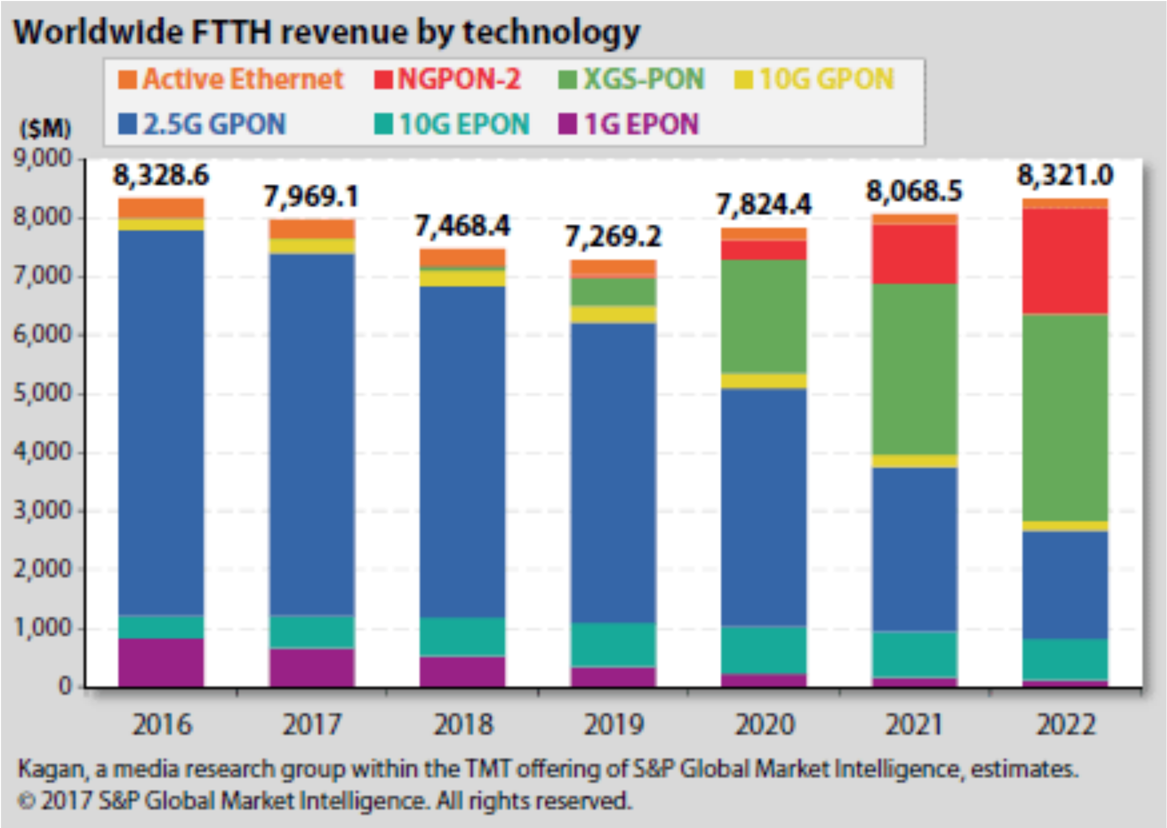
CORD is now cost effective



# Super-PON Applicability Summary

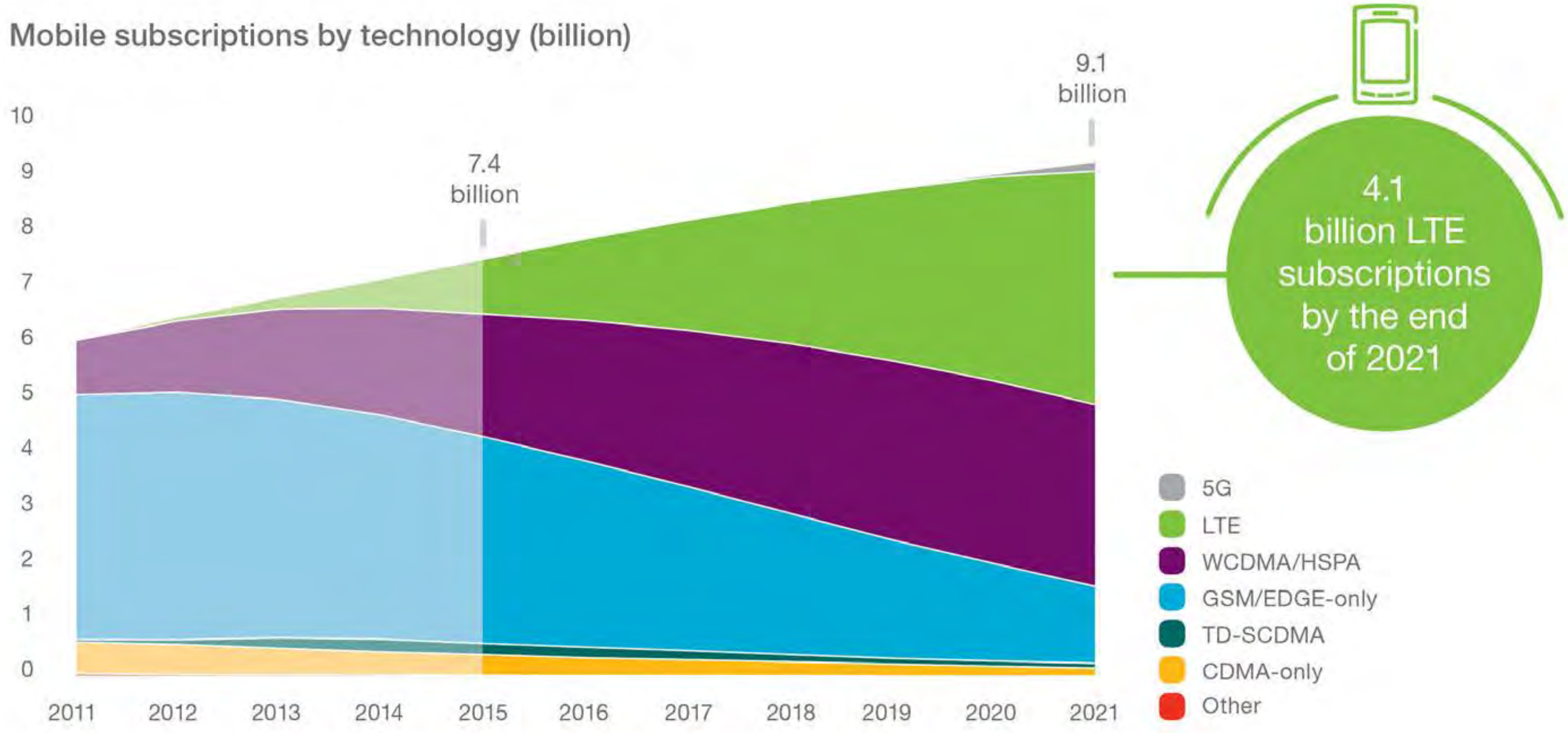
- Green field:
  - Optical fiber plant build simplification (lower CAPEX and TTM)
  - Support for both residential and point-to-point applications
- Brown field (optical fiber plant already in place):
  - CO consolidation for CORD
  - Re-use existing fiber plant and transform peripheral COs from (managed) active sites to (unmanaged) holders of passive components
  - Increased typical utilization of OLT ports
  - Point-to-Point support for (5G) cellular and specific subscribers
  - OSP expansion (i.e., additional OSP build to complement the existing OSP)

# Super-PON Residential Market Opportunity




- 2.5Gb/s GPON will continue to be mainstream technology until 2020
  - 10Gb/s PON becomes significant starting from 2020
- The transition to 10Gb/s can be a significant market opportunity for Super-PON
  - Multiple 10Gb/s channels support
- Super-PON may actually help the transition to 10Gb/s
  - Enables infrastructure optimizations

# Super-PON Point-to-Point Market Opportunity



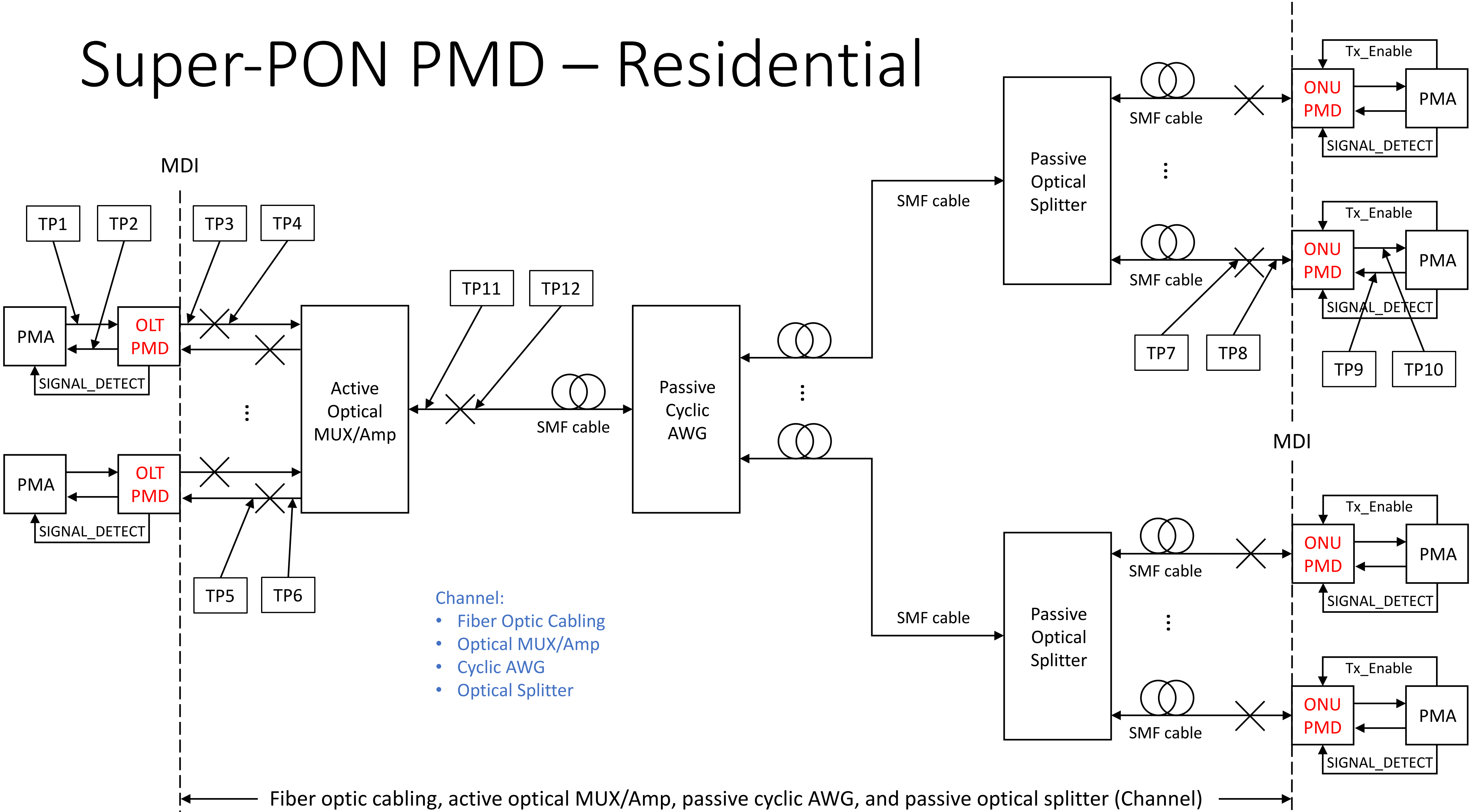

Source: Ericsson Mobility Report

The current growth of cellular networking brings significant opportunity for the point-to-point support offered by Super-PON

# Agenda

- Super-PON Idea
- Why Super-PON?
- Super-PON PMD

# Super-PON PMD – Residential

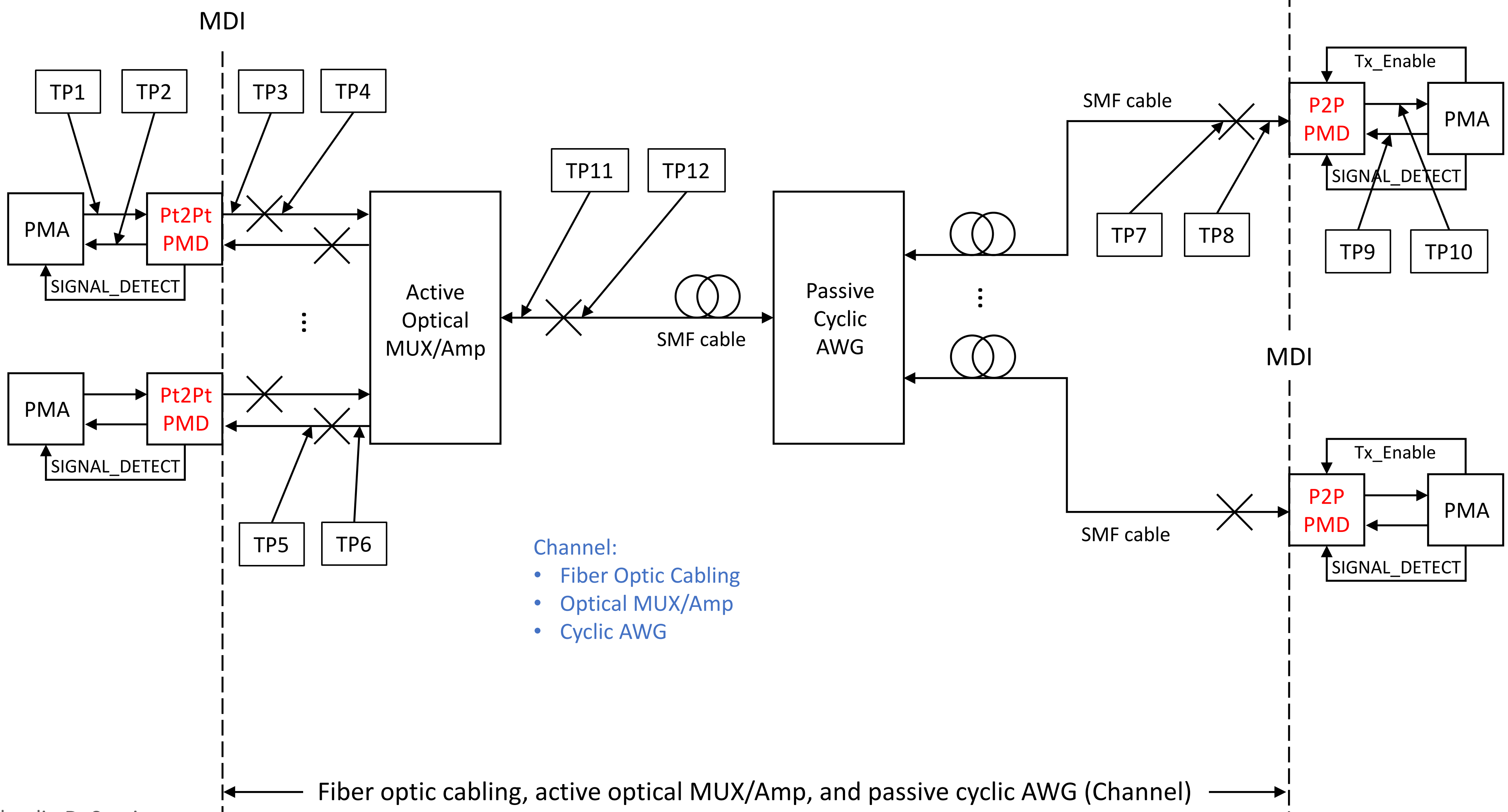



Channel:

- Fiber Optic Cabling
- Optical MUX/Amp
- Cyclic AWG
- Optical Splitter

Fiber optic cabling, active optical MUX/Amp, passive cyclic AWG, and passive optical splitter (Channel)

# Super-PON PMD – Point to Point



# Existing 802.3 PMD Definitions

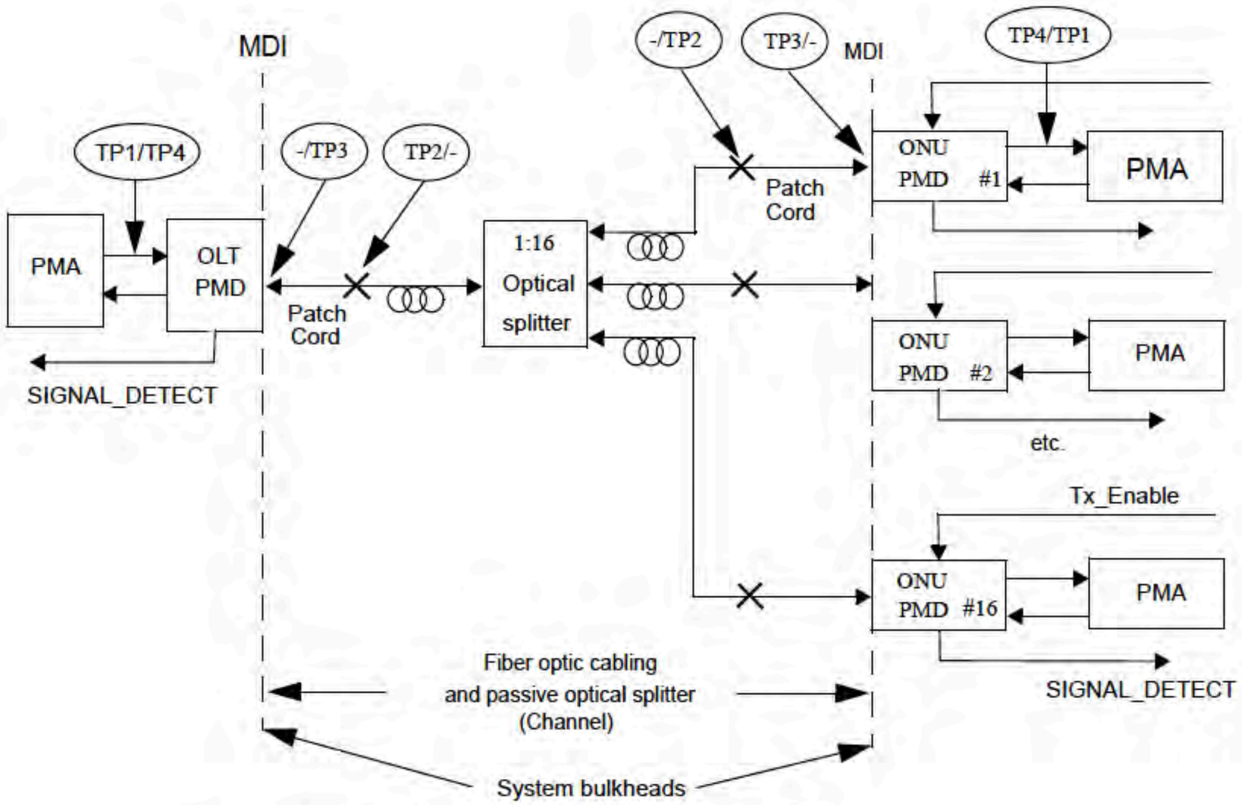



Figure 60–2—1000BASE-PX block diagram

Channel:
- Fiber Optic Cabling
- Optical Splitter

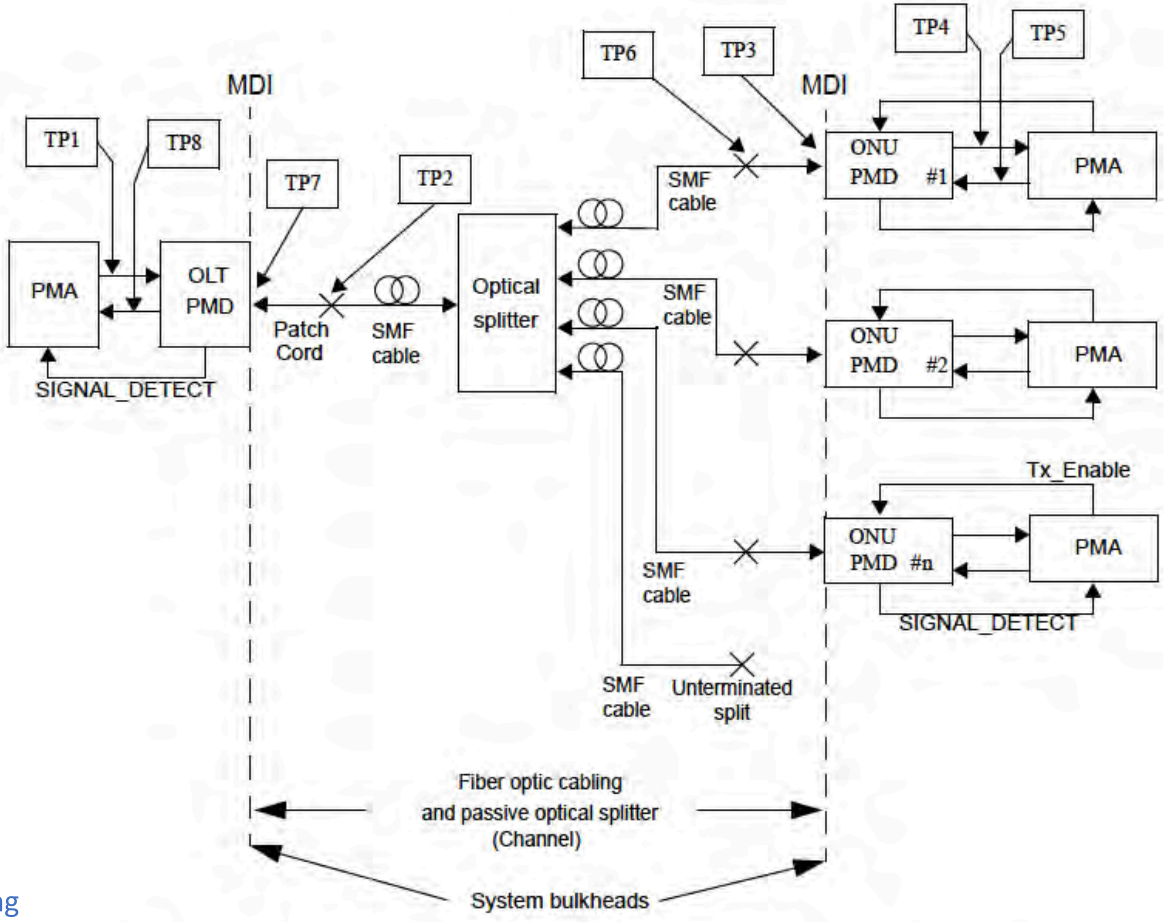
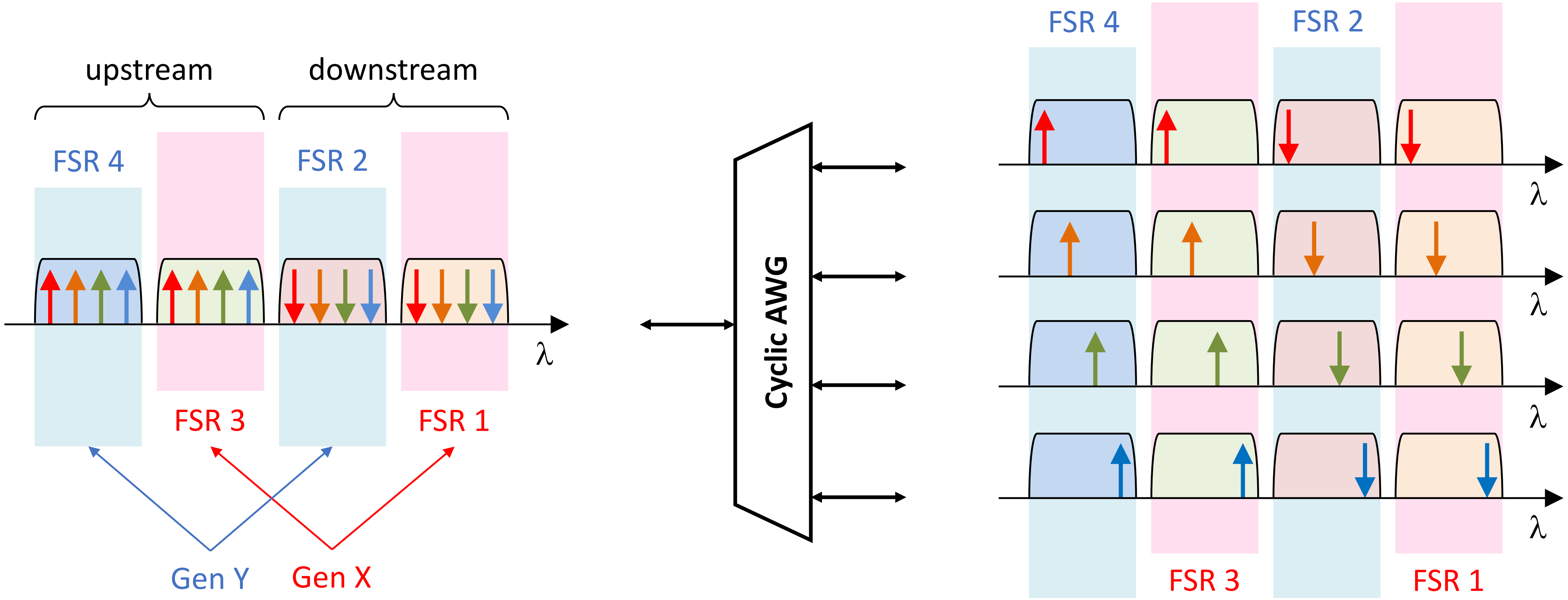


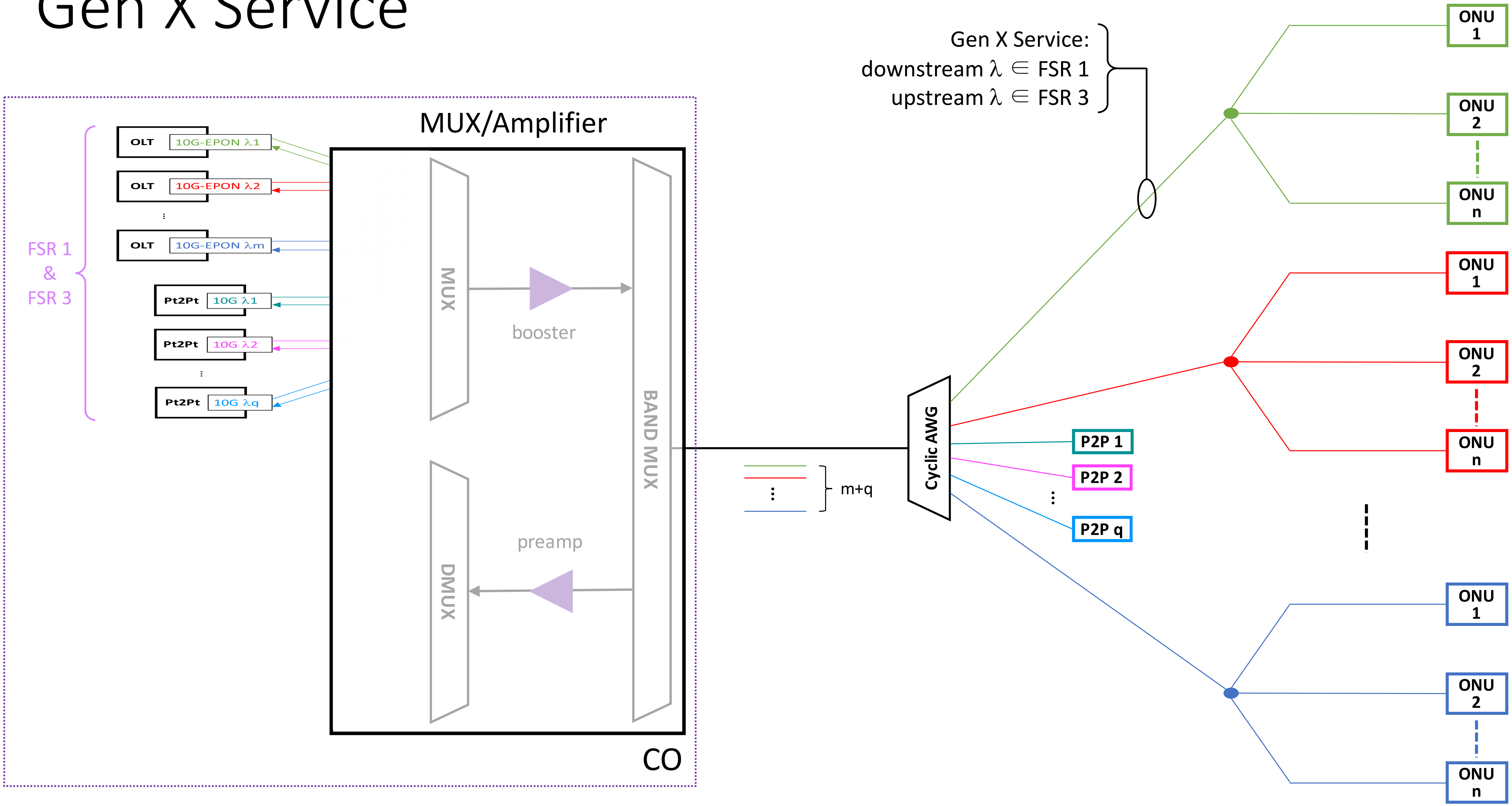

Figure 75–3—10GBASE–PR and 10/1GBASE–PRX block diagram

# Cyclic AWG

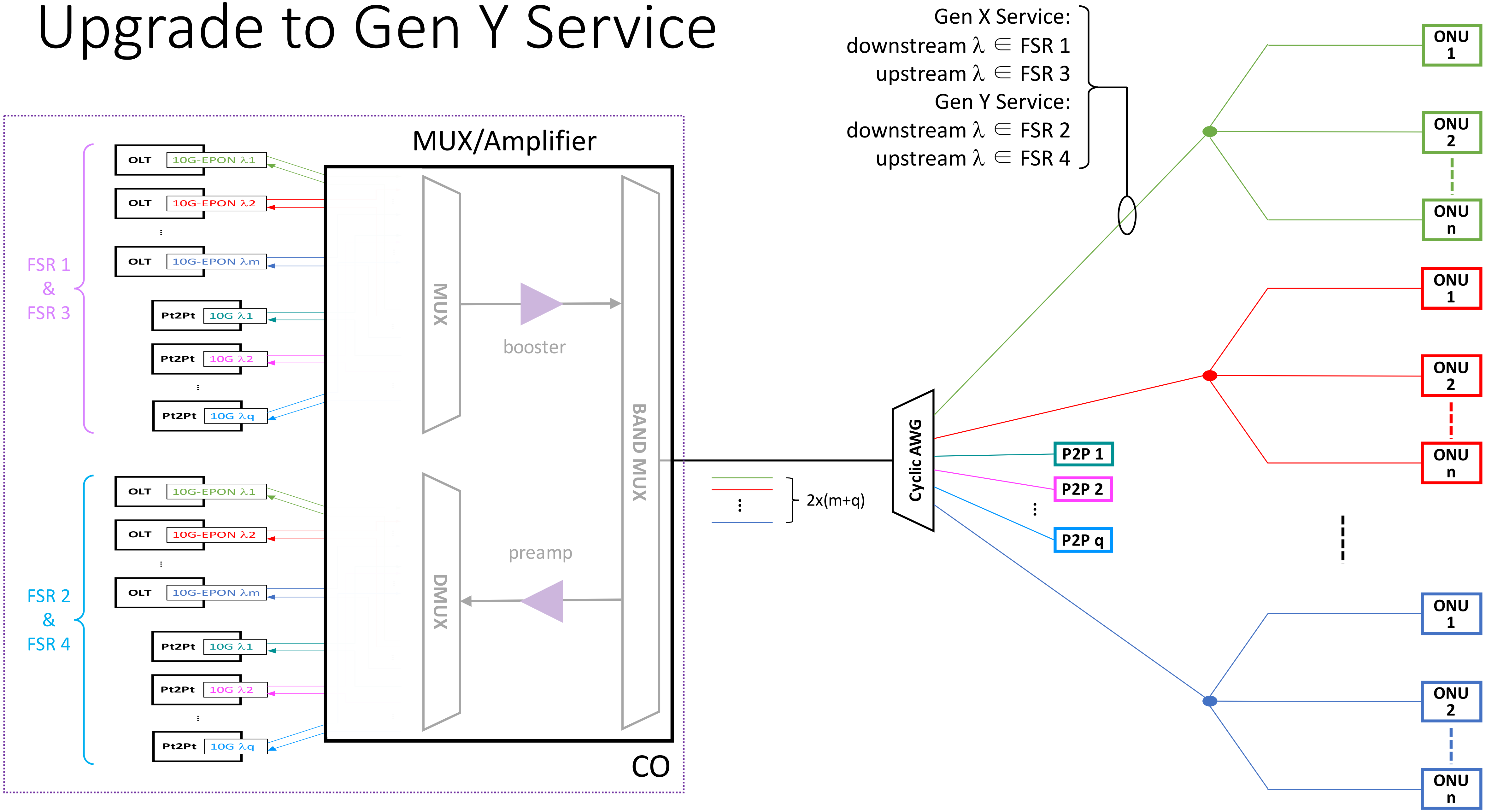
- Exhibits the same behavior across its FSRs
- This enables seamless upgrades



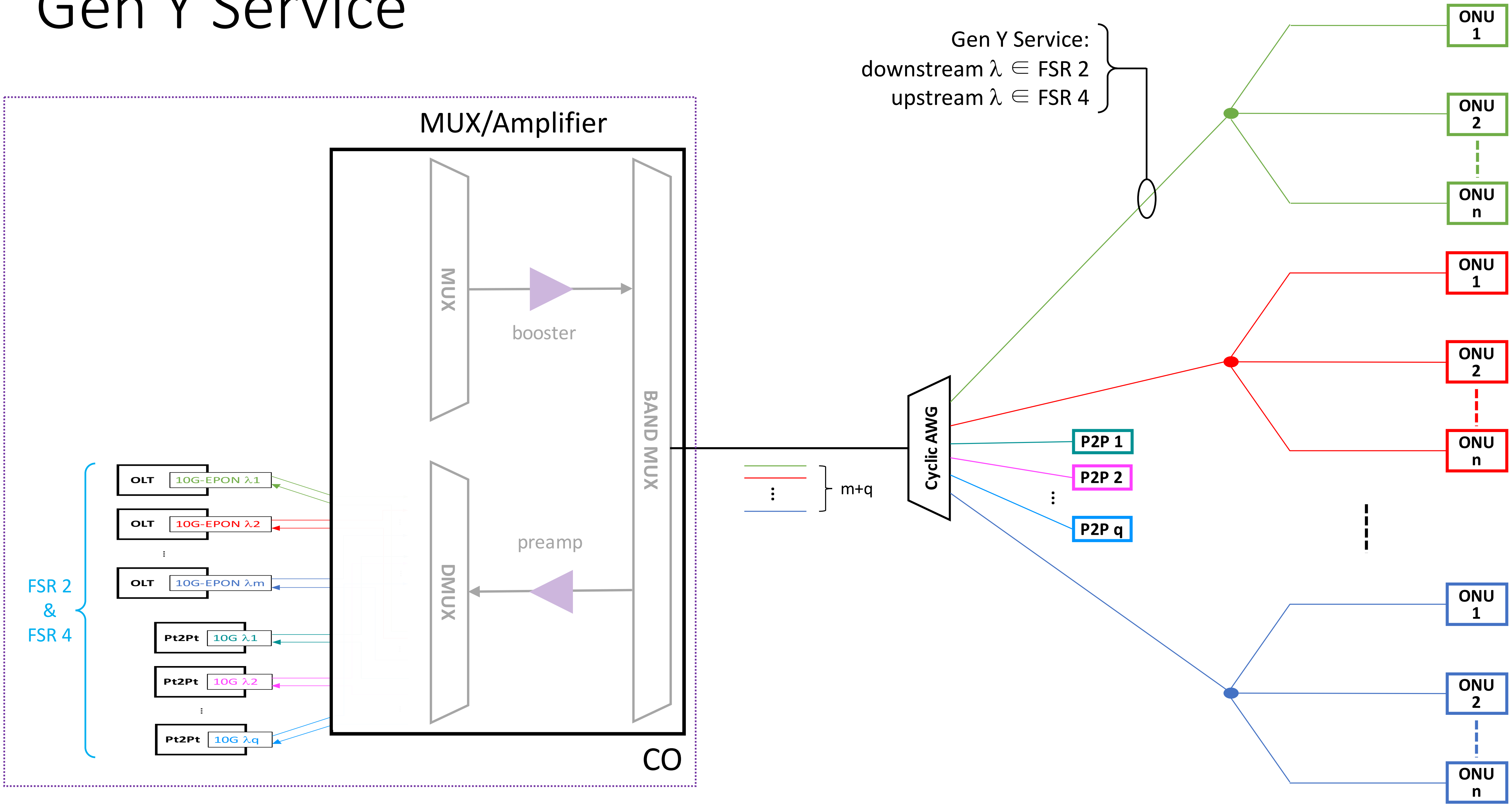
# Gen X Service



# Upgrade to Gen Y Service



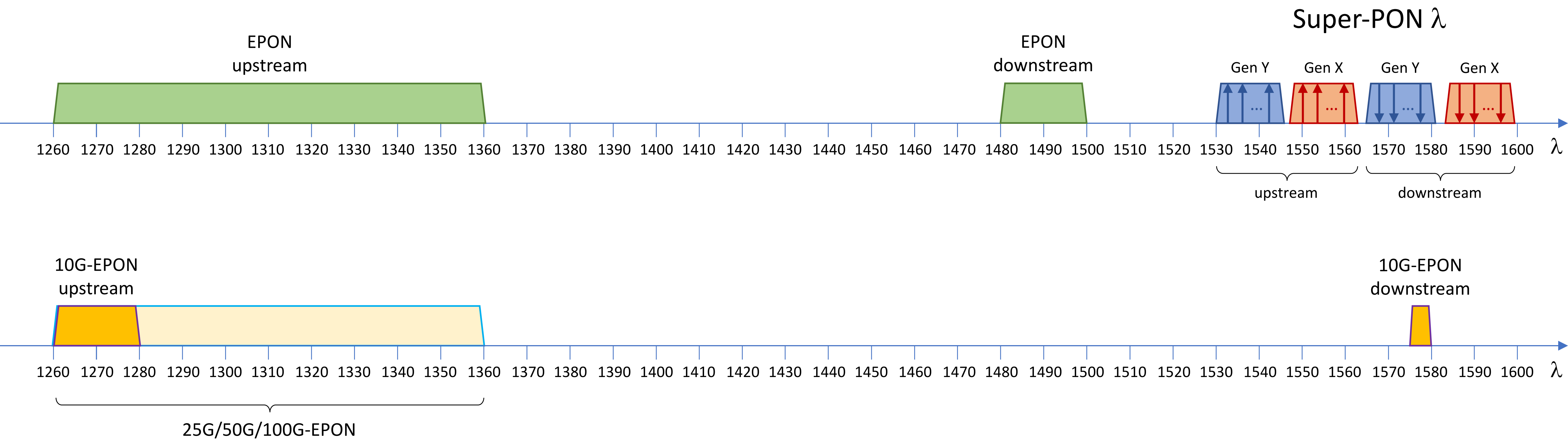
# Gen Y Service



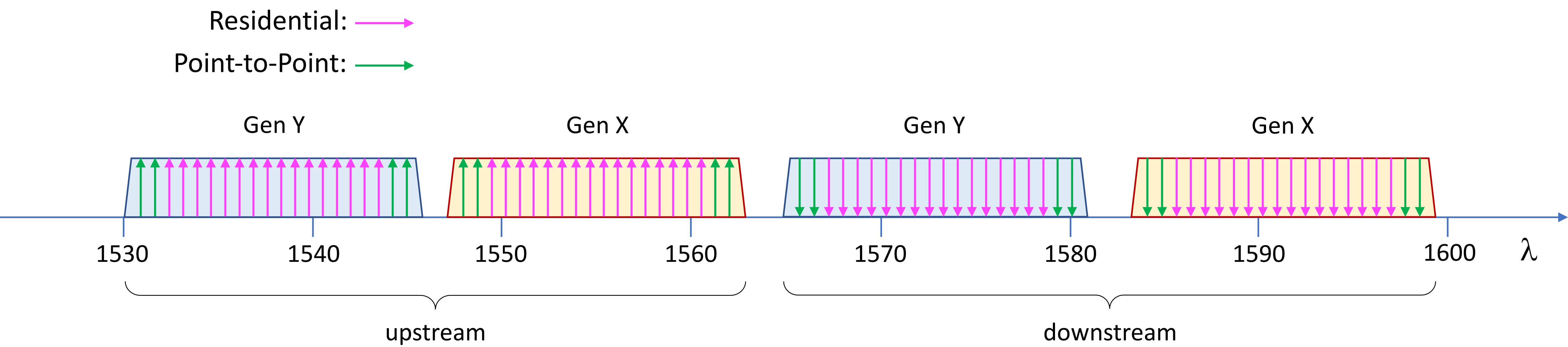
# Defining the Optical Parameters

- Using EDFAs as amplifiers implies using the C- and L-bands for wavelengths
  - C-band: 1530 .. 1565 nm, upstream
  - L-band: 1565 .. 1625 nm, downstream
- Split the bands in two ~equally sized ranges to support speed upgrades
  - Gen X upstream: ~1530 .. 1546 nm
  - Gen Y upstream: ~1547 .. 1563 nm
  - Gen X downstream: ~1565 .. 1581 nm
  - Gen Y downstream: ~1583 .. 1599 nm
- These ranges define the FSRs of the cyclic AWG
- Within each range, define a set of wavelengths to use for DWDM transmission
  - 20 channels using a nominal channel spacing of 100 GHz

# Wavelength Plan



# Example of Residential and Point-to-Point λ




- No need to specify in the standard which wavelengths are for what
  - Can be deployment/implementation specific

# Preliminary ONU PMD Requirements

- Continuous-mode wide-band receiver
- Cooled wavelength-stabilized burst-mode laser transmitter
  - 100GHz nominal channel spacing to enable operation without a wavelength locker
- Laser transmitter can be:
  - Not tunable (i.e., one $\lambda$)
  - Partially tunable (e.g., four adjacent $\lambda$)
  - Fully tunable (e.g., 16 $\lambda$, easier than full C-band)
  - $\lambda \in$ C-band {1530 .. 1565 nm}
- ONU PMD speeds can be:
  - Symmetric: 10Gb/s upstream, 10Gb/s downstream
  - Asymmetric: 1Gb/s upstream, 10Gb/s downstream or 2.5Gb/s upstream, 10Gb/s downstream
- Relaxed power budget because of amplification in the MUX/Amp

| | 1 Gb/s | 2.5 Gb/s | 10 Gb/s |
|---|---|---|---|
| Launch power | ~[-1 to 4] dBm | ~[-1 to 4] dBm | ~[4 to 9] dBm |
| Receiver sensitivity | - | - | ~-28.5 dBm (FEC) |

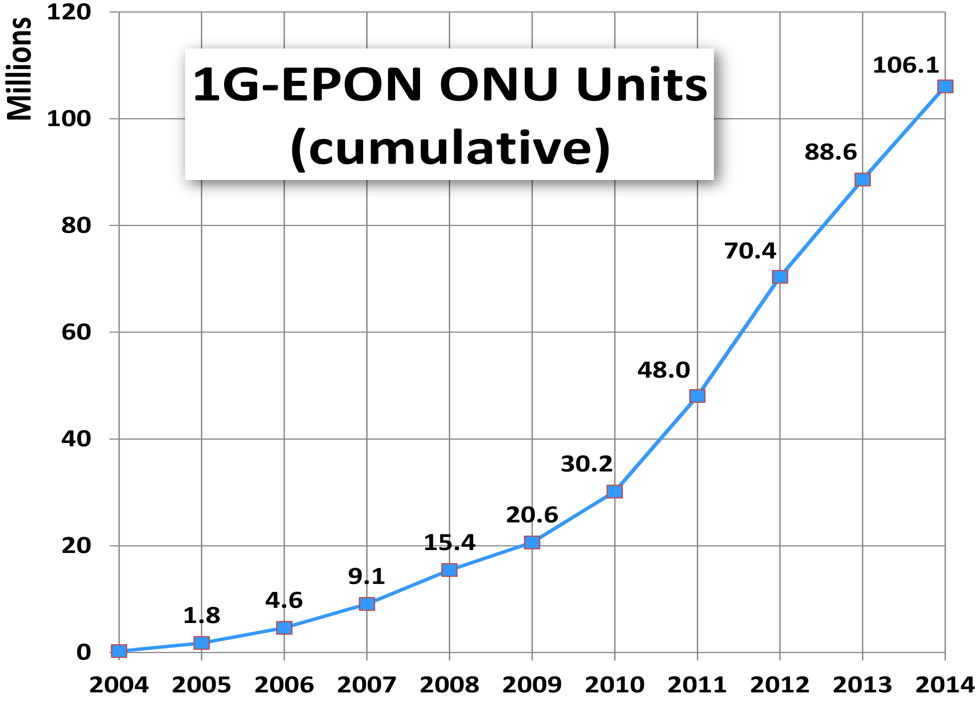
- 1Gb/s & 2.5Gb/s from PX10-U
- 10Gb/s from PR-U3
Assuming ~14.5 dB US MUX/Amp gain and ~7.5 dB effective noise figure

- From PR-U3
Assuming ~12 dB DS MUX/Amp gain

# Optics Cost Trend

- Cooled lasers are expected to have today a ~10X cost over uncooled ones
- Also 1G-EPON optics were ~10X of today’s cost when they were introduced
- Cost is strongly related to volumes

Source: Infonetics (2004-2007), Ovum (2008-2014)




See diagram on page 2 of the NG-EPON Call For Interest

# Preliminary OLT PMD Requirements

- Duplex (i.e., 2 fibers) to connect to the MUX/Amp module
- Burst-mode unfiltered receiver
  - No filter required - MUX/Amplifier performs diplexing and filtering functions
- Cooled wavelength-stabilized continuous-mode 10Gb/s laser transmitter
  - Single $\lambda$
  - $\lambda \in$ L-band {1565 .. 1600 nm}
- OLT PMD can be:
  - Symmetric: 10Gb/s upstream, 10Gb/s downstream
  - Asymmetric: 1Gb/s upstream, 10Gb/s downstream or 2.5Gb/s upstream, 10Gb/s downstream
- Relaxed power budget because of amplification in the MUX/Amp

| | 1 Gb/s | 2.5 Gb/s | 10 Gb/s |
|---|---|---|---|
| Launch power | - | - | ~[0 to 4] dBm |
| Receiver sensitivity | ~-28 dBm (No FEC) | ~-28 dBm (No FEC) | ~-28 dBm (FEC) |

- Relaxed from PR-D1
Assuming ~12 dB DS MUX/Amp gain

- From PR-D3
Assuming ~14.5 dB US MUX/Amp gain and ~7.5 dB effective noise figure

# Preliminary Point-to-Point PMD Requirements (CO side)

- Duplex (i.e., 2 fibers) to connect to the MUX/Amp module
- Continuous-mode unfiltered receiver
  - No filter required - MUX/Amplifier performs diplexing and filtering functions
- Cooled wavelength-stabilized continuous-mode 10Gb/s laser transmitter
  - Single $\lambda$
  - $\lambda \in$ L-band {1565 .. 1600 nm}
- Symmetric speed (i.e., 10Gb/s upstream, 10Gb/s downstream)
- Relaxed power budget because of amplification in the MUX/Amp
  - ~[-10 to -6] dBm launch power
  - ~-20 dBm (no FEC) receiver sensitivity

- Relaxed laser power
Assuming ~12 dB DS MUX/Amp gain

- From typical ZR SFP+ specs
Assuming ~14.5 dB US MUX/Amp gain

# Preliminary Point-to-Point PMD Requirements (Customer side)

- Bidi (i.e., 1 fiber)
- Continuous-mode wide-band receiver
- Cooled wavelength-stabilized continuous-mode 10Gb/s laser transmitter
  - Single $\lambda$
  - Partially tunable
  - Fully tunable
  - $\lambda \in$ C-band {1530 .. 1565 nm}
- Symmetric speed (i.e., 10Gb/s upstream, 10Gb/s downstream)
- Relaxed power budget because of amplification in the MUX/Amp
  - ~[-10 to -5] dBm launch power
  - ~-23 dBm (no FEC) receiver sensitivity

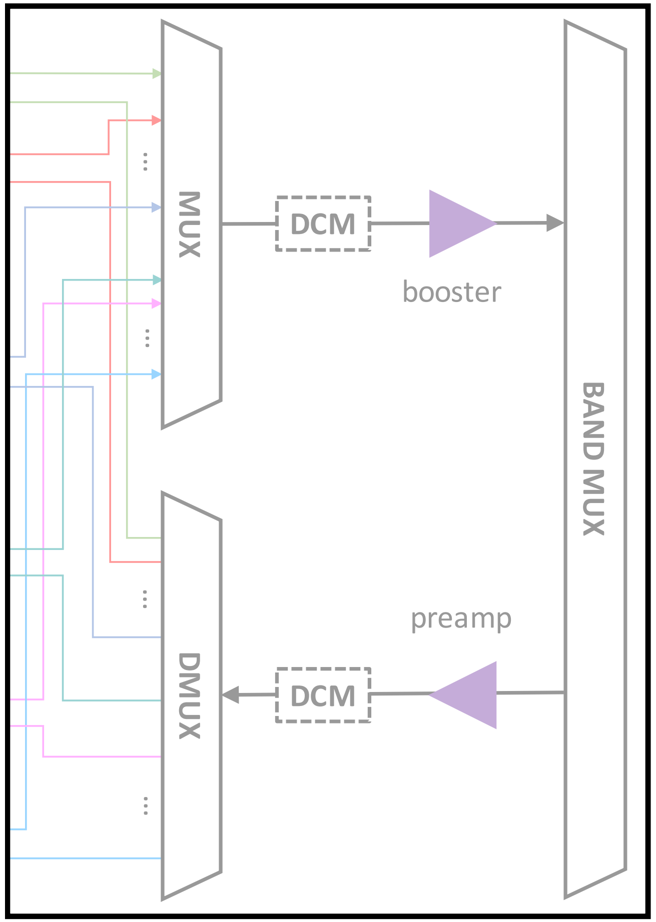
- Relaxed laser power
Assuming ~14.5 dB US MUX/Amp gain

- From typical ZR SFP+ specs
Assuming ~12 dB DS MUX/Amp gain

# Preliminary MUX/Amp Requirements

- Downstream parameters*:
  - Residential channels power: ~+12 dBm per λ
  - Point-to-point channels power: ~+2 dBm per λ
  - Port-to-Port small signal gain: >12 dB
  - Port-to-Port effective noise figure: <12 dB
- Upstream parameters*:
  - Gain clamped EDFA
  - Port-to-Port small signal gain: 14.5 to 17.5 dB
  - Port-to-Port effective noise figure: <7.5 dB
- Dispersion Compensation needed:

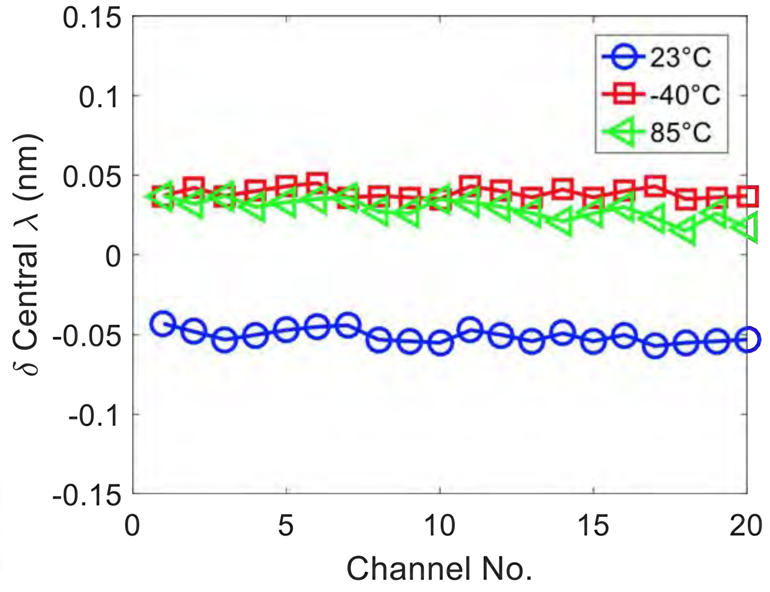
| | 1Gb/s | 2.5Gb/s | 10Gb/s | 25Gb/s |
|---|---|---|---|---|
| DML | No | No | Yes | N/A |
| EML | No | No | No | Yes |

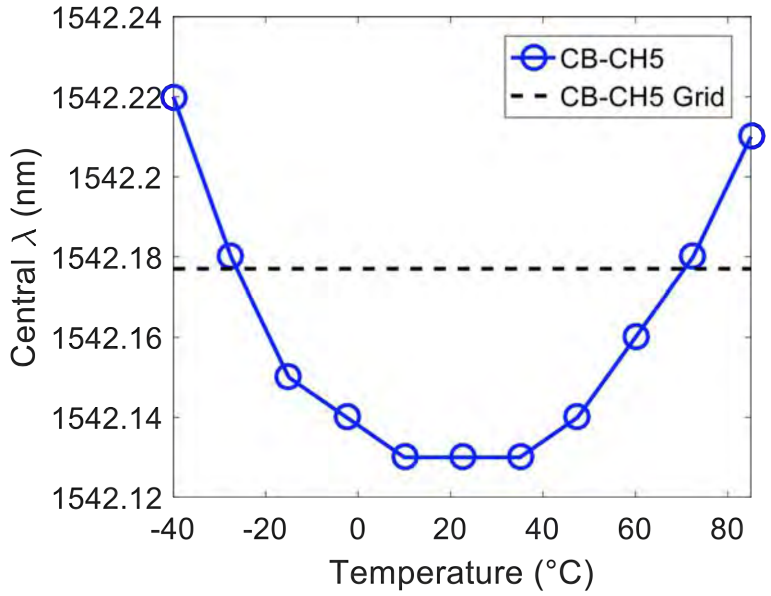



*: Gain, noise figure, and power values are computed to be consistent with the ONU/OLT PMD parameters

# Preliminary CAWG Requirements

- Bidirectional
- Athermal
  - Operational temperature range: -40°C to 65°C
  - Storage temperature range: -40°C to 85°C
- Cyclic FSRs:
  - FSR 1: ~1599 .. 1583 nm
  - FSR 2: ~1581 .. 1565 nm
  - FSR 3: ~1563 .. 1547 nm
  - FSR 4: ~1546 .. 1530 nm
- Adjacent channel attenuation: >20 dB



# Speed Considerations

- For residential support, an EML laser in the OLT and a DML laser in the ONU allow:
  - 10Gb/s downstream – 2.5Gb/s upstream
    if the MUX/Amp **does not** contain dispersion compensation
  - 25Gb/s downstream – 10Gb/s upstream
    if the MUX/Amp **does** contain dispersion compensation
- For point-to-point support, EML lasers on both ends allow:
  - 10Gb/s symmetric if the MUX/Amp **does not** contain dispersion compensation
  - 25Gb/s symmetric if the MUX/Amp **does** contain dispersion compensation
- The 2.5Gb/s Ethernet speed is already defined for UTP cabling and is being defined for backplane operations
  - IEEE 802.3bz and IEEE P802.3cb
- Defining it for optical operations seems a very doable effort
  - Down clocking the 10Gb/s specification
  - Enables to leverage for Ethernet the existing 2.5Gb/s GPON optical ecosystem

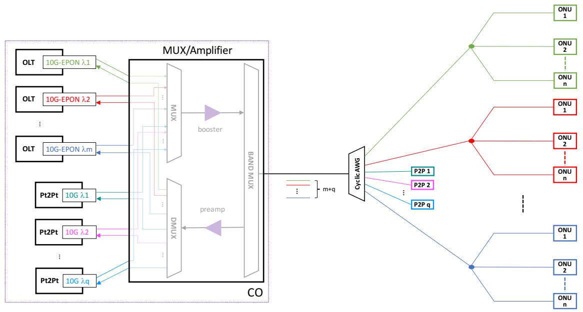
# Why Now?

- The CORD architecture is getting real
  - Implies CO consolidation
  - Super-PON complements in the access network the consolidation made possible in compute and services by CORD
- Super-PON point-to-point support helps 5G cellular deployments
- Technology advancements made cooled lasers and tunable cooled lasers more affordable than before
  - Enables narrow DWDM channel bands

# Items for Standardization

- Larger scale optical architecture
  - Including amplification and cyclic AWG
- Additional PMD specifications
  - New channels
  - Optical parameters (Wavelength plan, power budgets, etc.)
  - Wavelength-stabilized lasers (with optional tunability)
- Speeds:
  - Symmetric: 10Gb/s upstream, 10Gb/s downstream
  - Asymmetric: 1Gb/s upstream, 10Gb/s downstream
  - Asymmetric: 2.5Gb/s upstream, 10Gb/s downstream
- Protocol parameters (if any)
- …

# Summary




- Super-PON introduces new technologies in the EPON standard ecosystem
  - DWDM, amplification, mux/demux (e.g., EDFAs and CAWG)
- It operates in a different region of the spectrum in respect to existing EPON
  - DWDM C- and L-band, requiring cooled lasers
- Cooled lasers do not have to be expensive
  - Technology is fine, it is all a matter of volumes
  - Super-PON may help bringing down the cost and enable them for other EPON environments
- The 2.5Gb/s Ethernet speed could make sense for Super-PON
  - Enables leveraging the existing 2.5Gb/s GPON optical ecosystems for Ethernet
- Let’s put some effort in studying these technologies and their greater implications
  - Is there interest in performing this study and eventually prepare a CFI presentation?

# Thank you