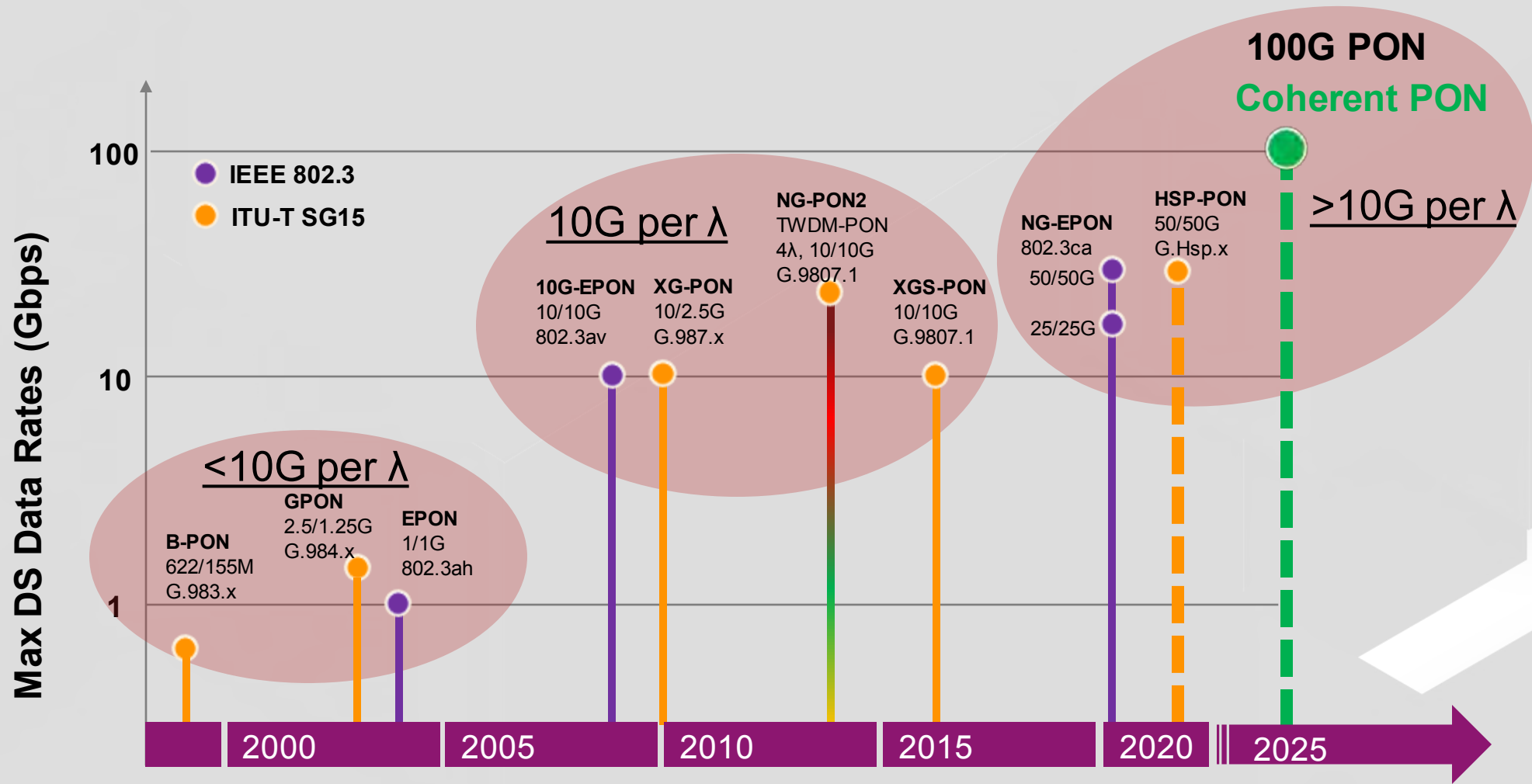# CableLabs®

100G Single-Wavelength Passive Optical Network Coherent PON (CPON)

Steve Jia, Chris Stengrim, Curtis Knittle

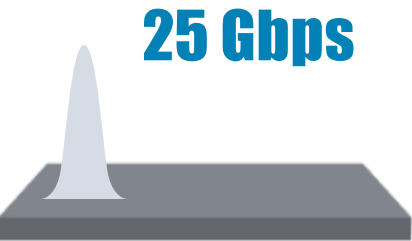s.jia@cablelabs.com, c.stengrim@cablelabs.com, c.knittle@cablelabs.com

Evolution to 100G TDM-PON

100G PON

Coherent PON

Max DS Data Rates (Gbps)

100

IEEE 802.3

ITU-T SG15

10G per λ

NG-PON2
TWDM-PON
4λ, 10/10G
G.9807.1

NG-EPON
802.3ca
50/50G

HSP-PON
50/50G
G.Hsp.x

>10G per λ

10G-EPON
10/10G
802.3av

XG-PON
10/2.5G
G.987.x

XGS-PON
10/10G
G.9807.1

25/25G

10

<10G per λ

GPON
2.5/1.25G
G.984.x

EPON
1/1G
802.3ah

B-PON
622/155M
G.983.x

1

2000   2005   2010   2015   2020   2025

IM-DD to the Limit

Coexistence with legacy PON Objective: meeting 29dB and higher (32dB) optical power budget

100 Gbps ?

50 Gbps

25 Gbps

Is IM-DD still an option?

a power penalty of minimum ~4 dB relative to 25G PON

- TWDM approach
  - Challenges in frequency drift (especially in burst mode)
  - Inter-channel crosstalk
  - Complexed control of channel bonding

- Revolutionary technology (Coherent Solution)

a power penalty of ~5 dB relative to 10G PON

- 1dB from FEC (soft-decision LDPC to replace hard-decision LDPC)

- improved receiver sensitivity (DAC/ADC/DSP, SOA + PIN, no 50G APD available)

- increase in launch power (SOA)

- Challenges of burst mode reception

- 1-2 dB from FEC (Reed–Solomon (RS) code used in XG(S)-PON at 1E-3, the low-density parity check (LDPC) code at 1E-2

- 1 dB from improved receiver sensitivity (PIN to APD)

- 2-3 dB from an increase in launch power (4-5dBm EML)

P2P to P2MP

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Point to Point

Point to Multipoint

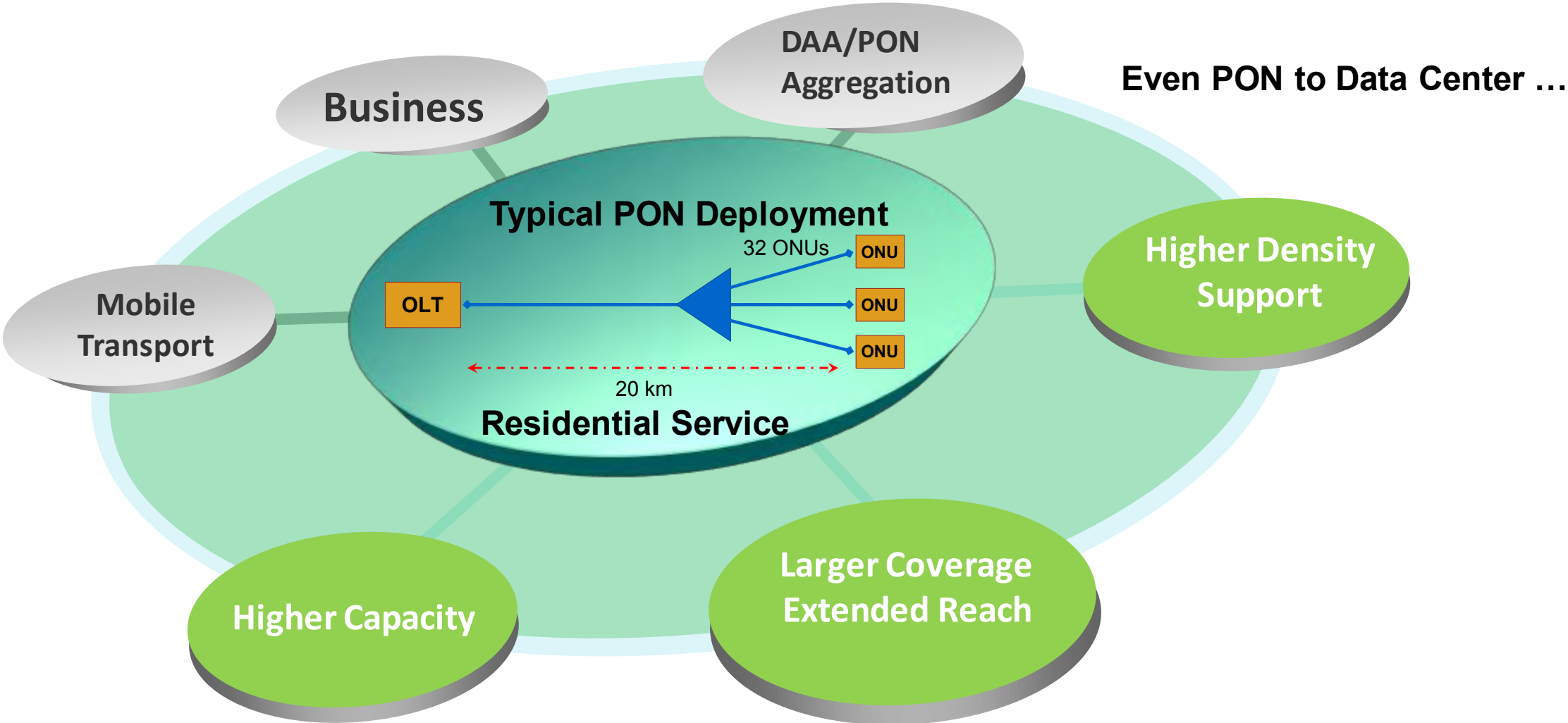| 1 Gbps	10 Gbps	25 Gbps	100G Gbps
(aka Gigabit Ethernet)	(aka 10G Ethernet)	(aka 25G Ethernet)	(P2P coherent)

1G-EPON GPON
DS: 2.5G/1G
US: 1.25G/1G

10G-EPON XGS-PON
DS: 10G
US: 10G

25G-EPON 50G-EPON
DS: 50G/25G
US: 50G/25G

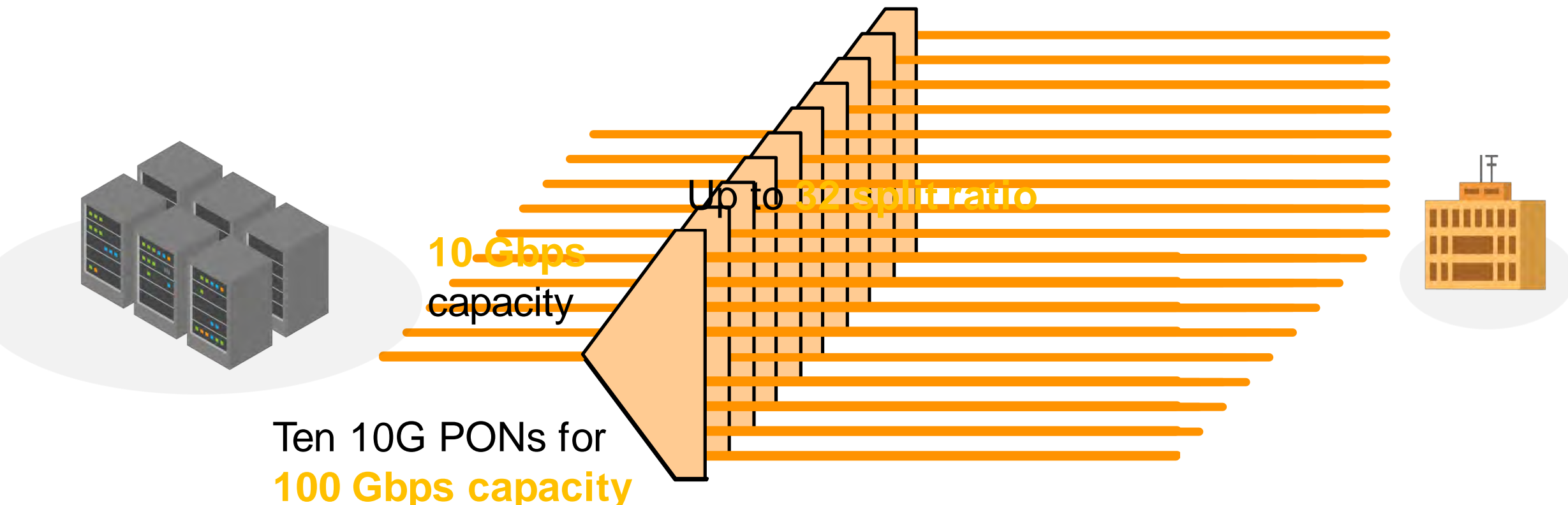**100G PON Coherent**
DS: 100G (75G/50G/25G)
US: 100G (75G/50G/25G)

Extended PON Application Scenarios

Even PON to Data Center …

Business

DAA/PON Aggregation

Mobile Transport

Higher Density Support

Higher Capacity

Larger Coverage Extended Reach

Typical PON Deployment

32 ONUs

ONU

OLT

ONU

ONU

20 km

**Residential Service**

Coherent PON and Use Cases

What is Coherent PON?

- Coherent PON is like traditional PON:
  - Passive optical distribution network
  - Point-to-multipoint topology

- Yet, Coherent PON is different:
  - Uses coherent modulation and detection instead of IM-DD
  - Optimizes optical power distribution
  - Provides longer reach & higher split ratio with improved power budget
  - Enables 100 Gbps and beyond data rate (per lambda)

Up to **32 split ratio**

10 Gbps
capacity

Ten 10G PONs for
100 Gbps capacity

IM-DD Passive Optical Network (PON)
Up to **20 km** reach

Up to **512 split ratio**

100 Gbps capacity
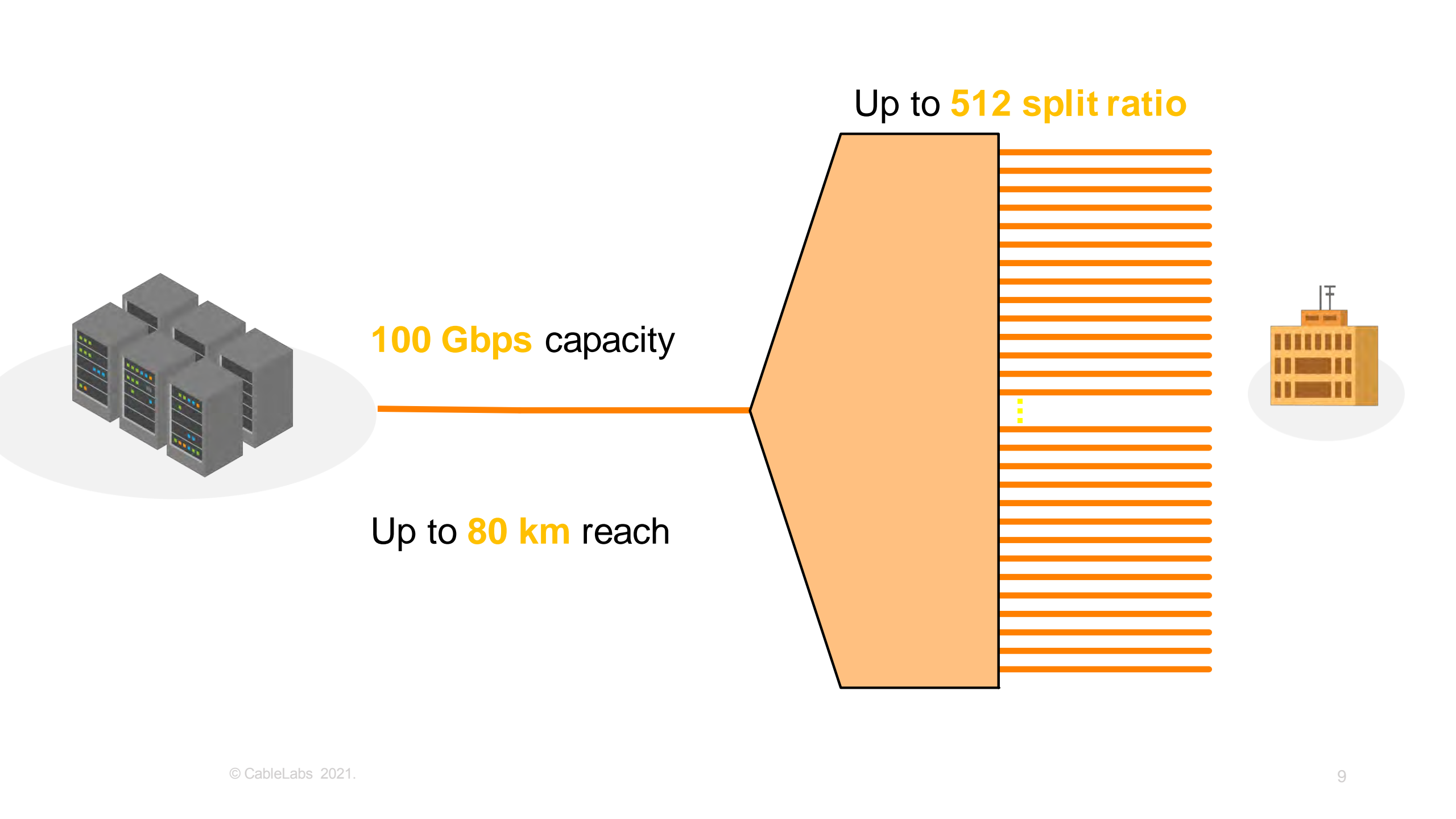
Up to **80 km** reach

What use cases will require:

100 Gbps Capacity?
80 KM Reach?
512:1 Split Ratio?

Split Ratio

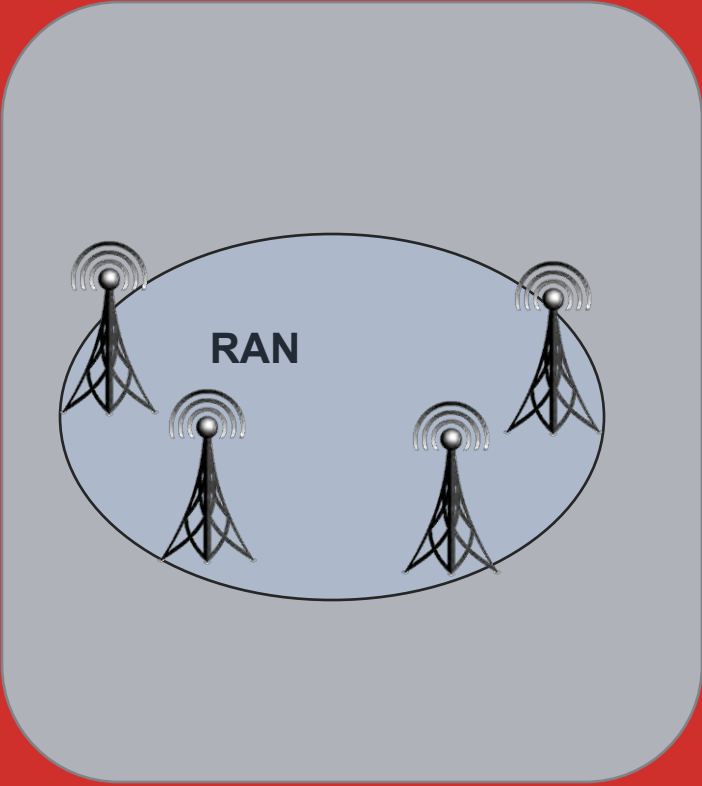Optical Reach

Capacity
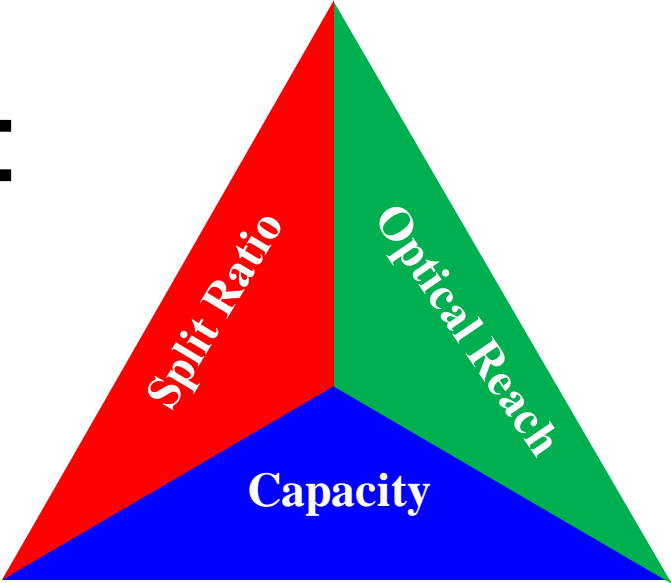
Coherent PON

Use Cases for Coherent PON

100 Gbps Network Aggregation

**Optical Access Networks:
Residential Broadband**
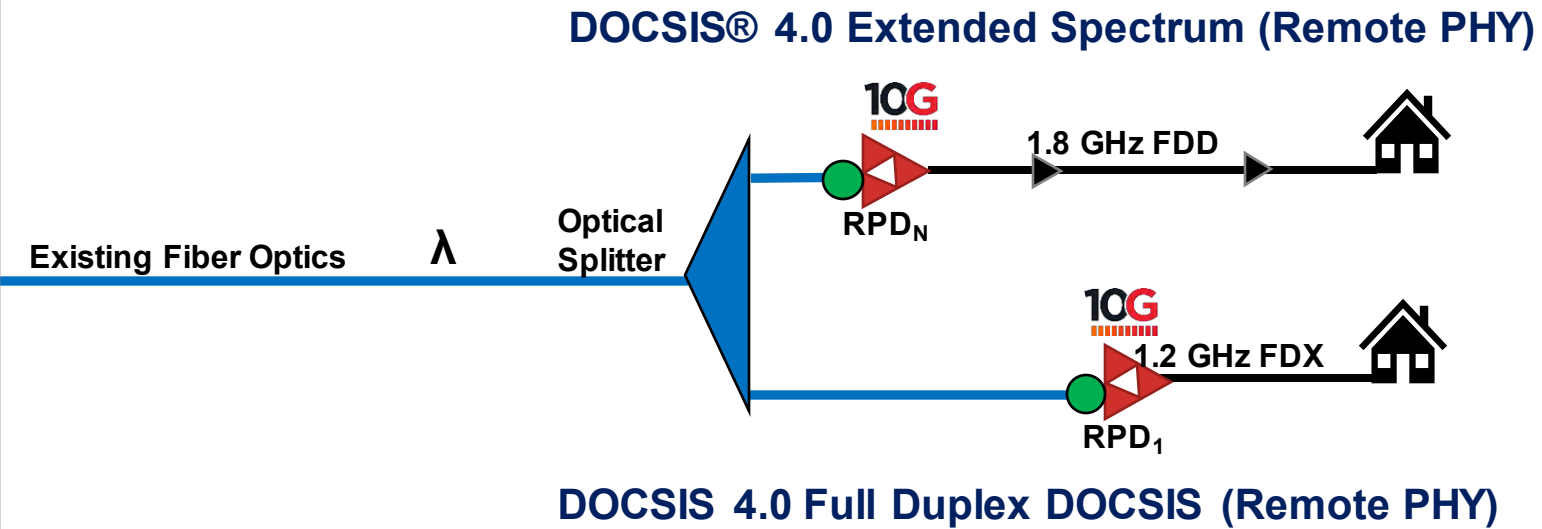

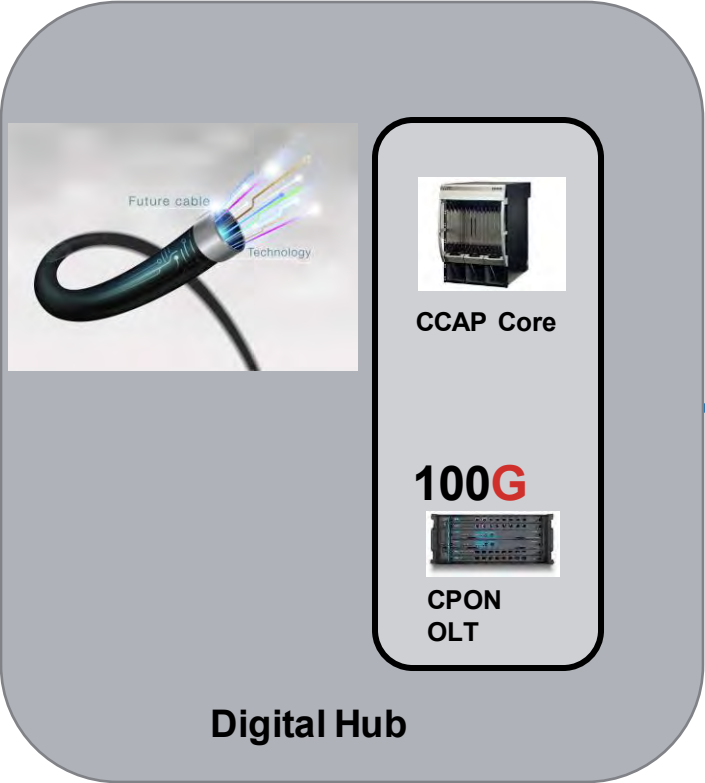**Wireless Transport:
Mid-Haul & Fronthaul**

RAN

**Fiber to Businesses and
Multi-Dwelling Units**

Use Case: Residential Broadband

Optical Access Networks: Residential Broadband

CCAP Core

100**G**

CPON OLT

Digital Hub

Existing Fiber Optics   λ

Optical Splitter

DOCSIS® 4.0 Extended Spectrum (Remote PHY)

10**G**

RPD$_N$

1.8 GHz FDD

10**G**

RPD$_1$

1.2 GHz FDX

DOCSIS 4.0 Full Duplex DOCSIS (Remote PHY)

⬤ = 100G CPON Optical Network Unit (ONU)

Use Case: Wireless Transport

Wireless Transport: Mid-Haul & Fronthaul

Mid-Haul Aggregated Bandwidth for D-RAN

| Configuration	Mid-Haul Bandwidth
C-Band 64T64R Massive MIMO Radio 3Cell (100M D16L/U8L)	10 Gbps

Fronthaul Aggregated Bandwidth for C-RAN

Configuration	Fronthaul Bandwidth
C-Band 64T64R Massive MIMO Radio 3Cell (100M D16L/U8L)	62 Gbps

Core Network

vEPC

CU

RAN

DU

DU

Optical Fronthaul Architecture will determine placement of ONUs
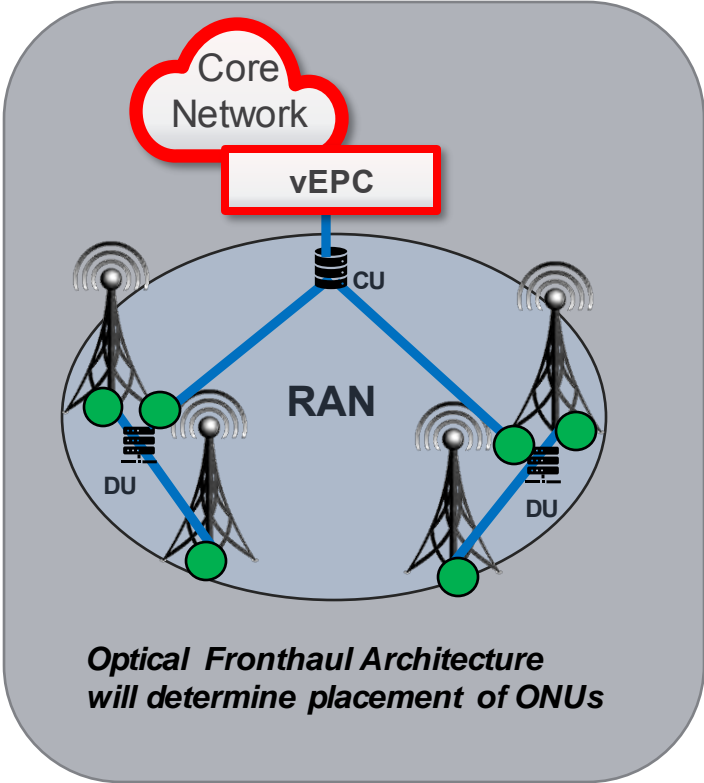
Source: VRAN Cost Modeling and Value Proposition, Samsung, 2020

● = 100G CPON Optical Network Unit (ONU)

Use Case: Fiber to the Building

Optical Access Networks: Fiber to the Building
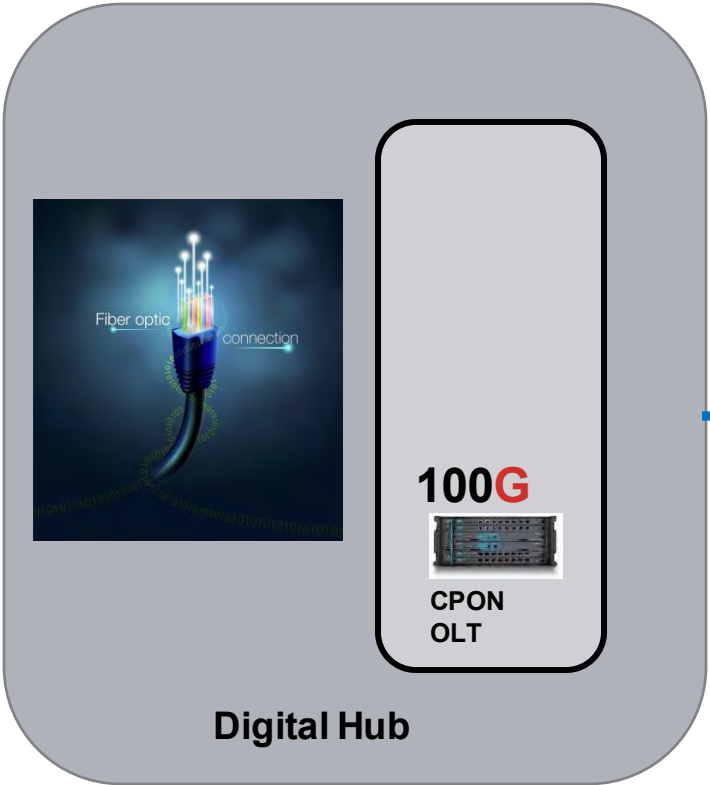
Fiber to Businesses and Multi-Dwelling Units

100G

CPON OLT

Existing Fiber Optics

λ

Optical Splitter

Digital Hub
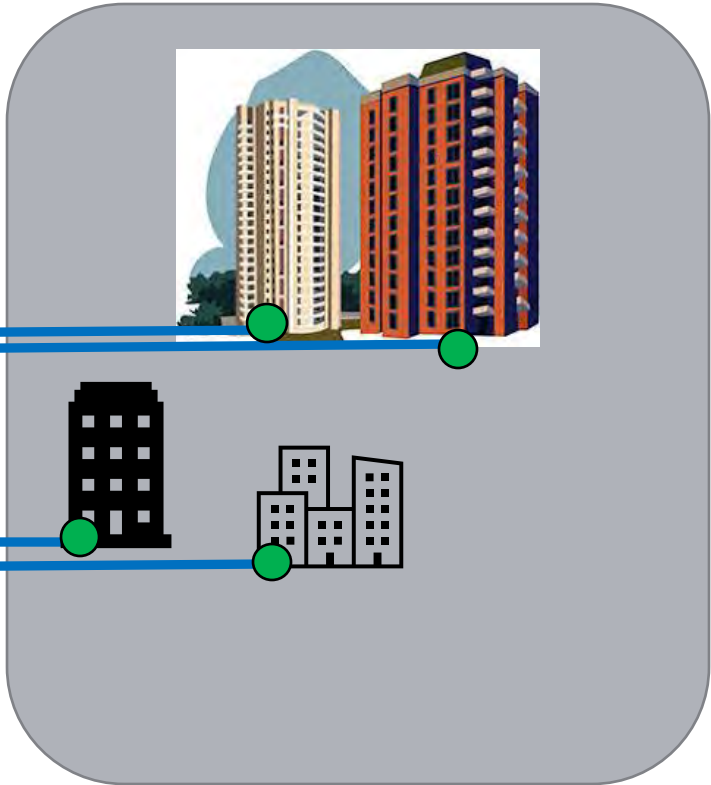
● **100G CPON Optical Network Unit (ONU)**

Edge Aggregation: 100G Coherent PON

CableLabs®

10G   **1.8 GHz FDD**

RPD$_N$

10G   **1.2 GHz FDX**

RPD$_1$

CCAP Core

100G

CPON OLT

CU

vEPC
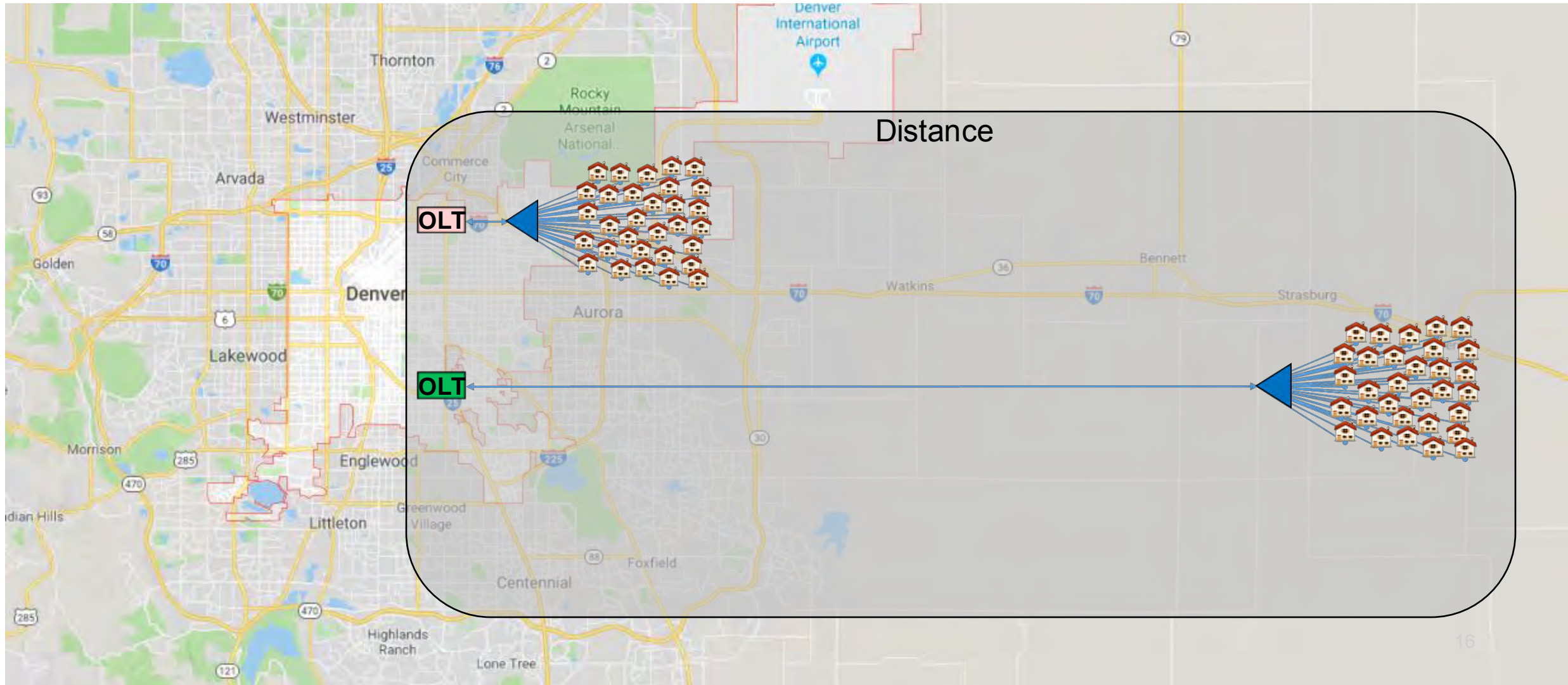
Core Network

Digital Hub

RAN

DU

DU

Optical power splitter/combiner

100G CPON Optical Network Unit (ONU)
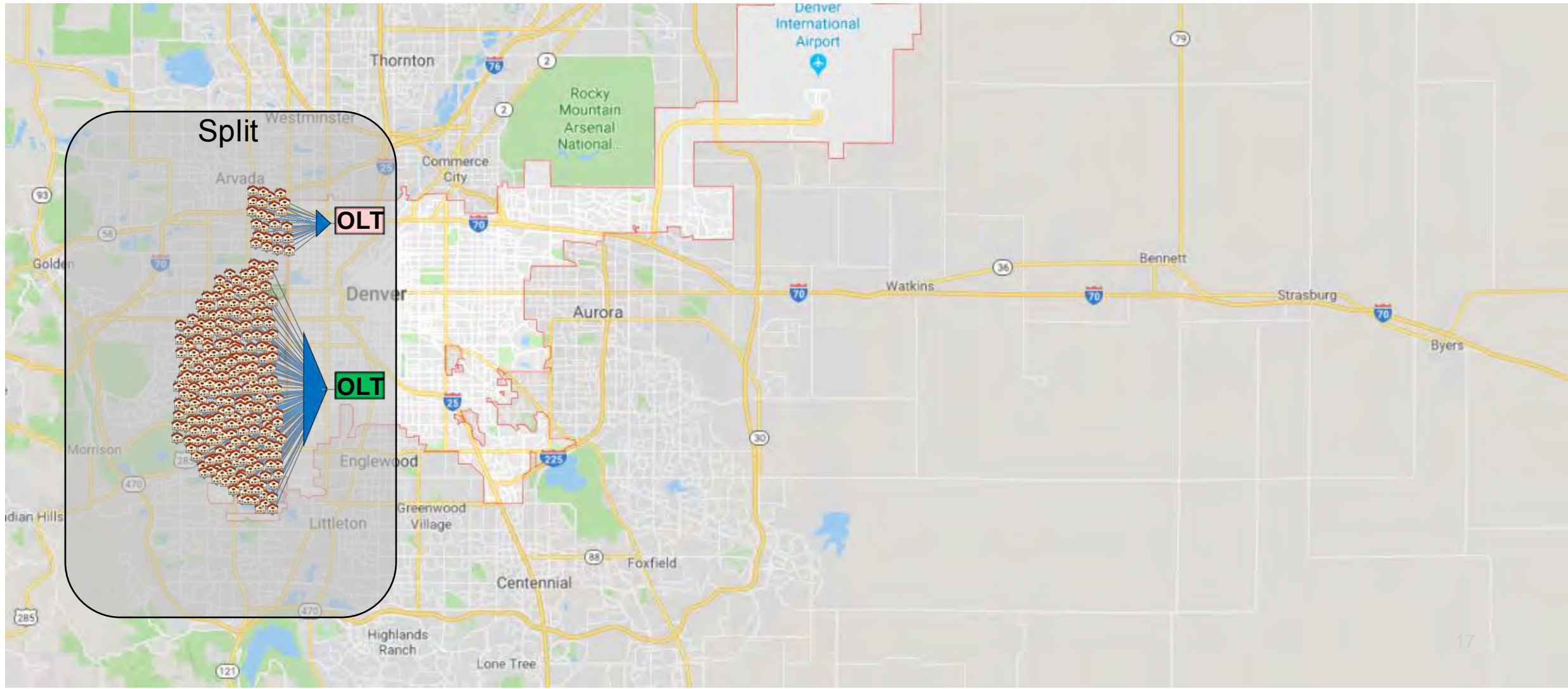
15
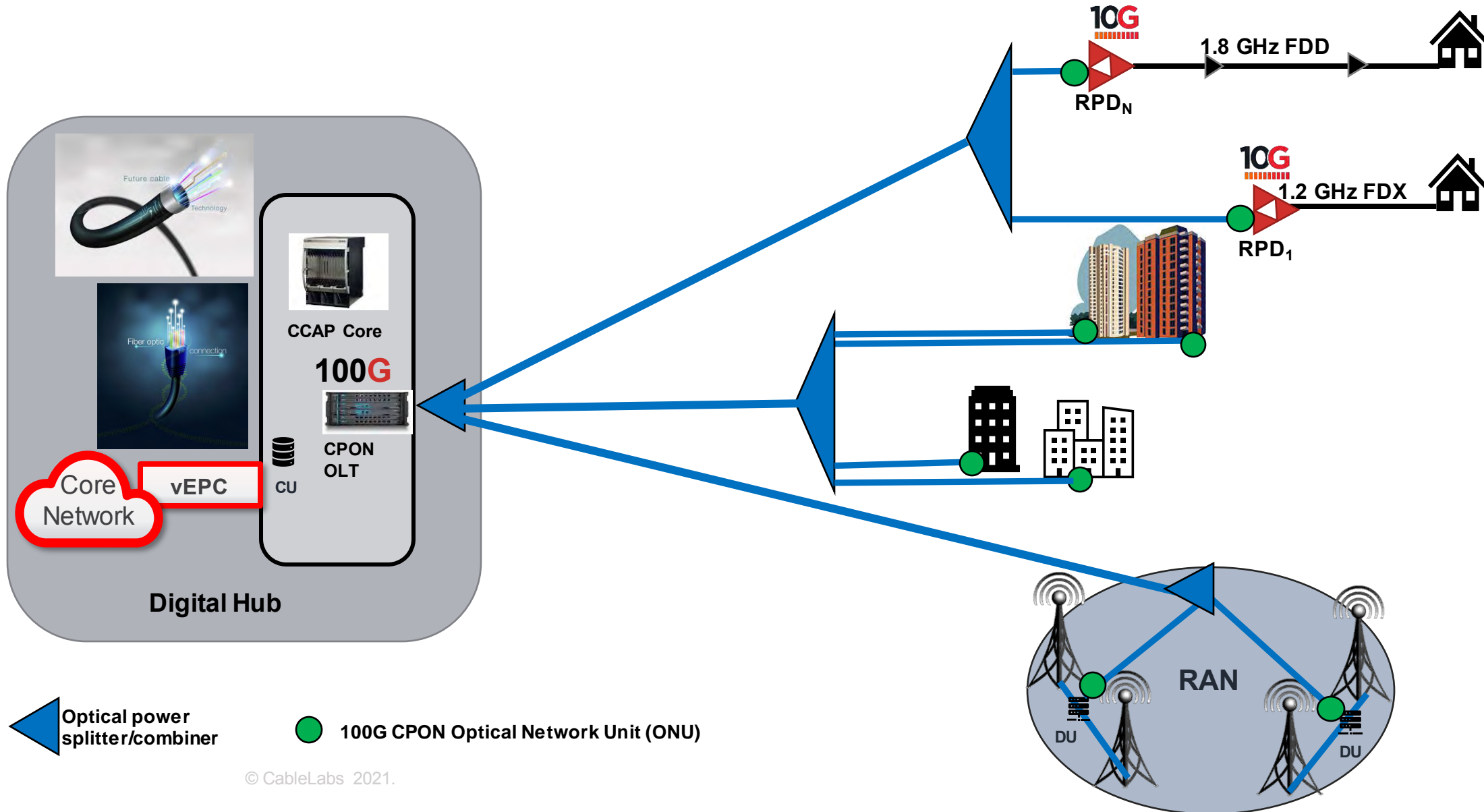
Use Case: Rural (Long Reach) FTTH

Use Case: Urban (High Density) FTTH

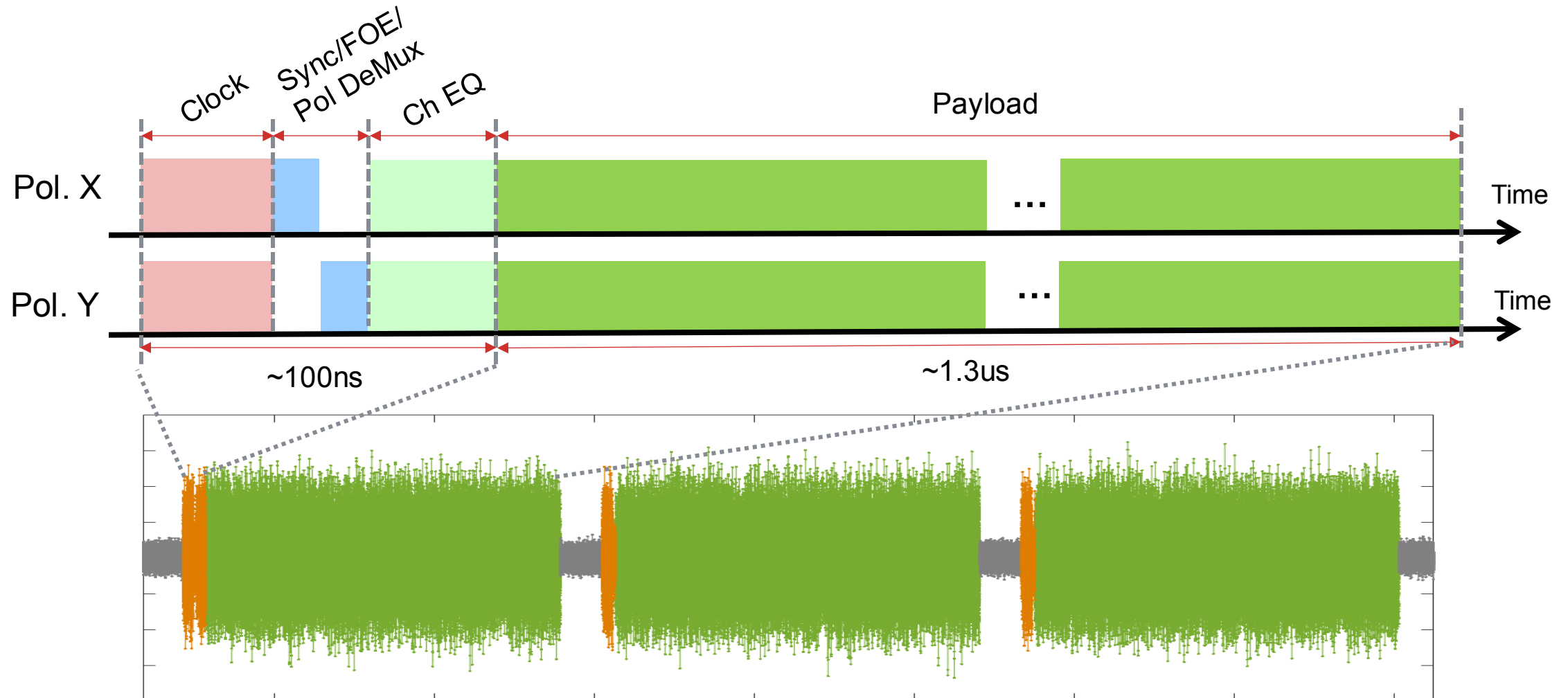# Coherent PON Advantages
vs. EPON and GPON Technologies

Features:

Higher Capacity (100 Gbps per single λ)
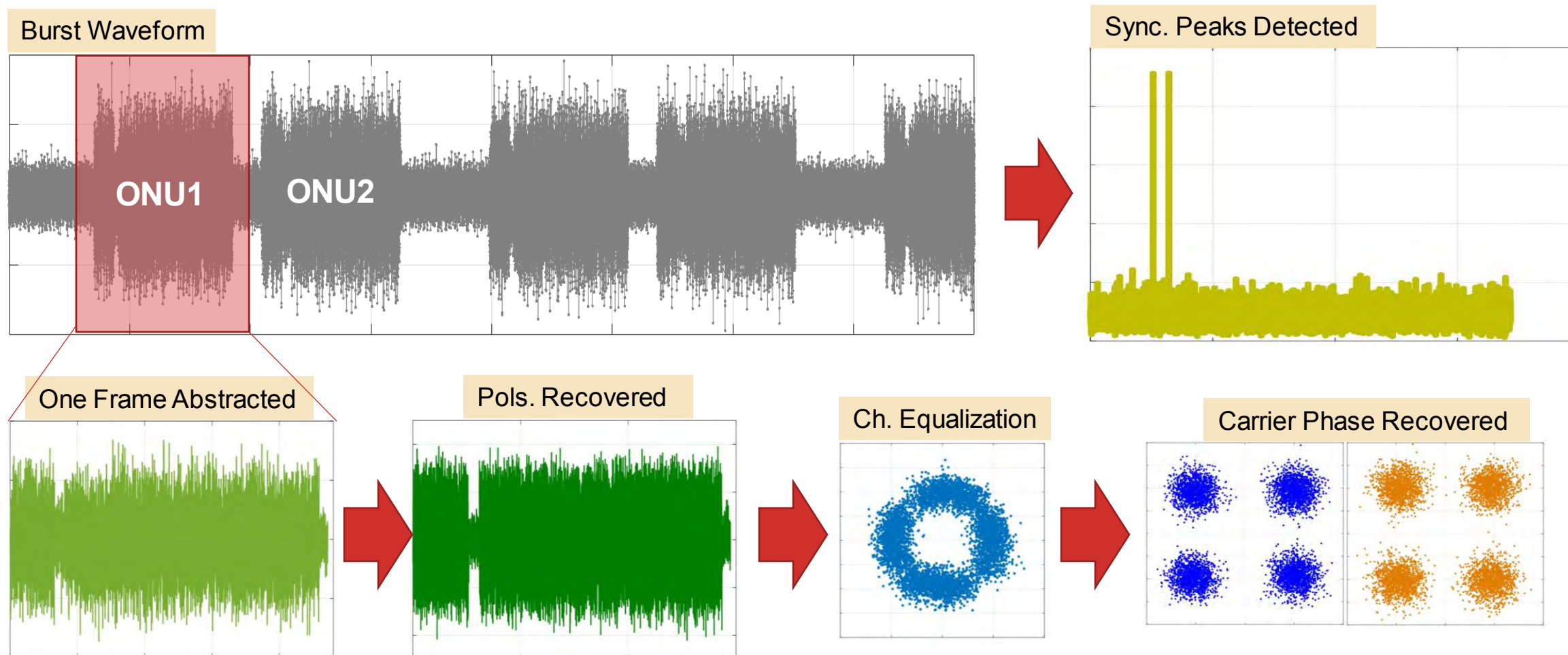Longer Reach (up to 80 KM)
Higher Density (up to 512 end points)

Benefits:

Efficient Sharing of Optical Power
Scalability to 100 Gbps and Beyond
Flexibility of High- and Low- Density Deployments
Single Platform for Network Aggregation and FTTH

Key Enabling Technologies

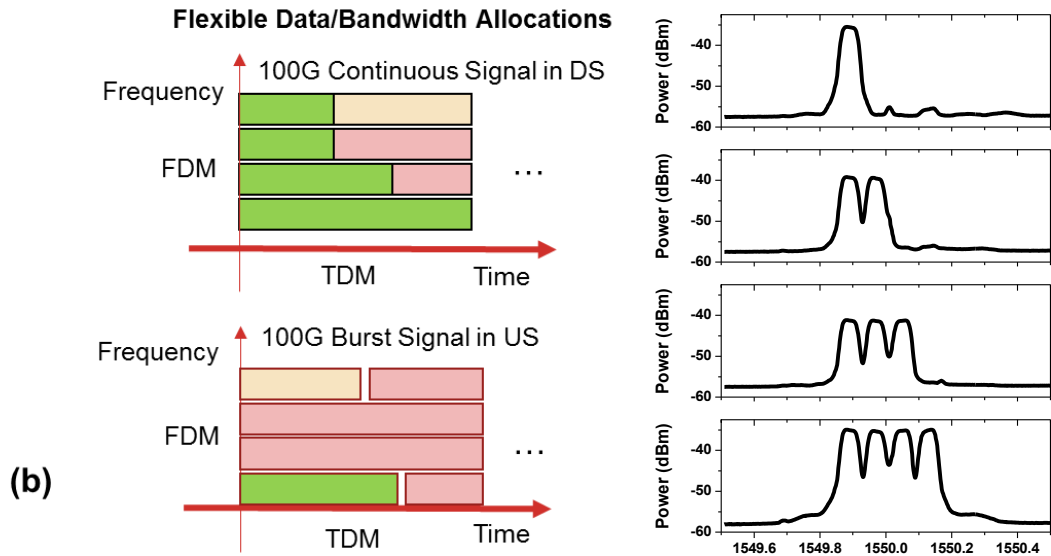# Transmitter Burst Frame Structure

Receiver Burst Processing

Burst Waveform

ONU1   ONU2

Sync. Peaks Detected

One Frame Abstracted

Pols. Recovered

Ch. Equalization

Carrier Phase Recovered

Rate-Flexible Symmetric 100G Coherent PON
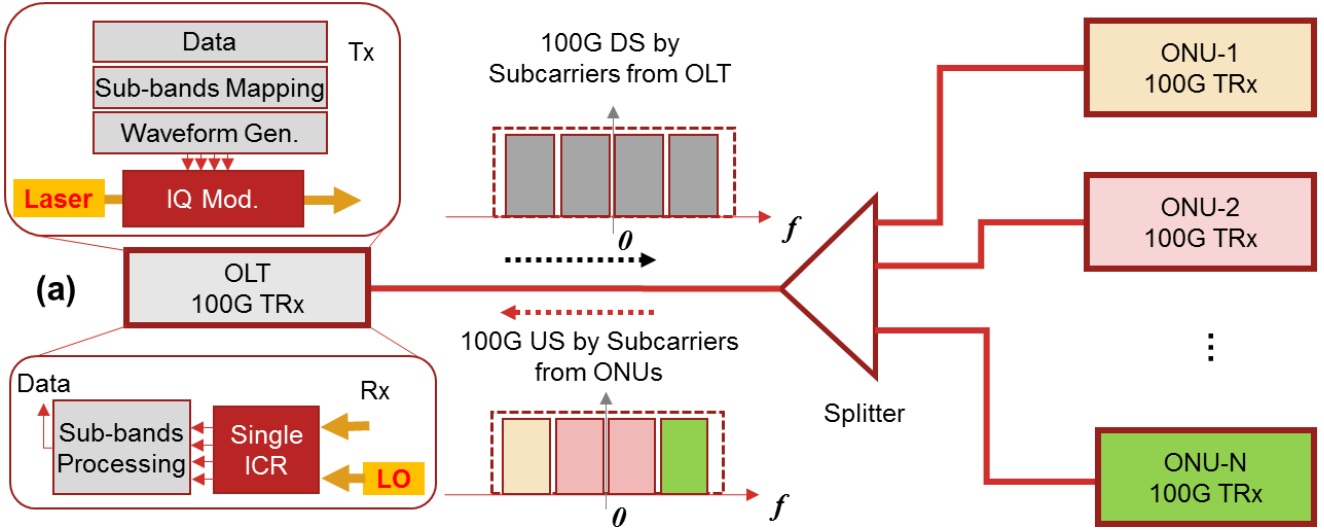
Digital subcarrier multiplexing in both time and frequency domain over a single optical wavelength, enabling 25G, 50G, 75G, and 100G flexible data rate.

Focus Area for Cost Reduction

CableLabs®

DSP

Rx

Tx
Modulator

Laser

**Traditional
Coherent Optics**

DSP

Rx

Modulator

Laser

**Access Optimized
Coherent Optics**

DSP

Rx

Modulator

Laser

P2MP CPON

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CableLabs®
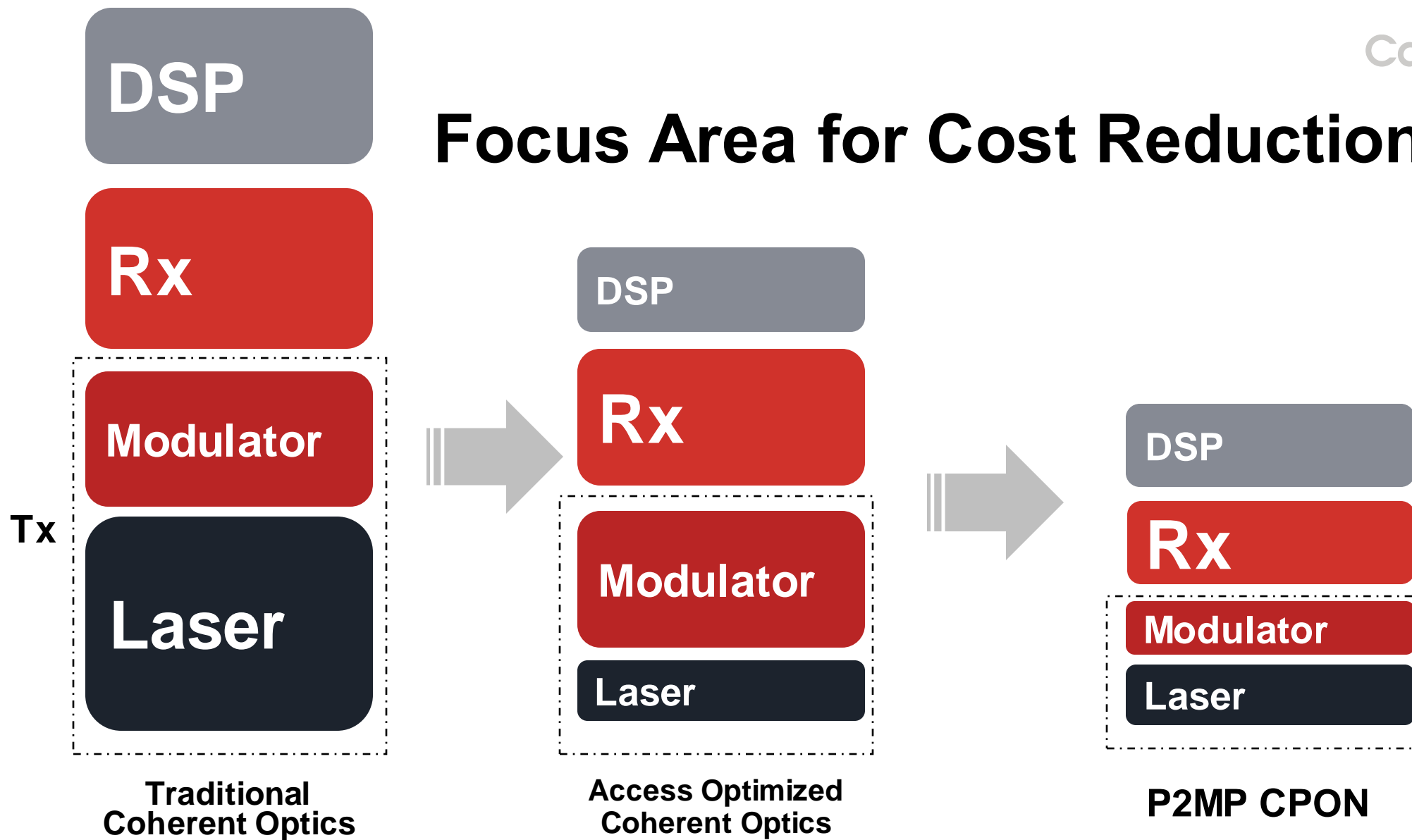
CPON Project Launch

Project Objectives

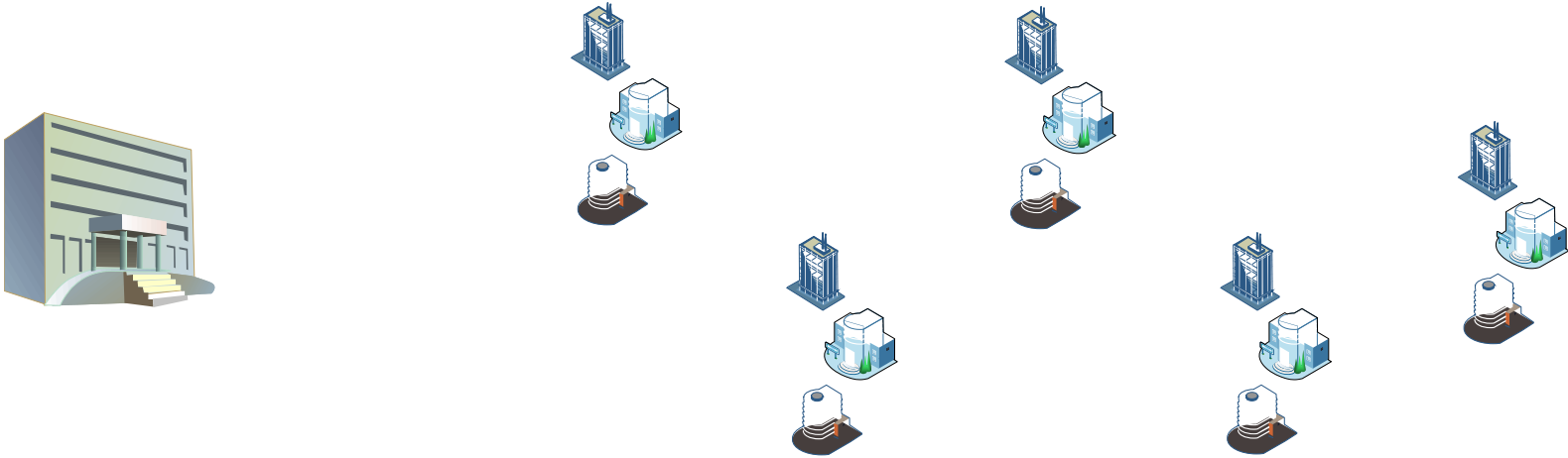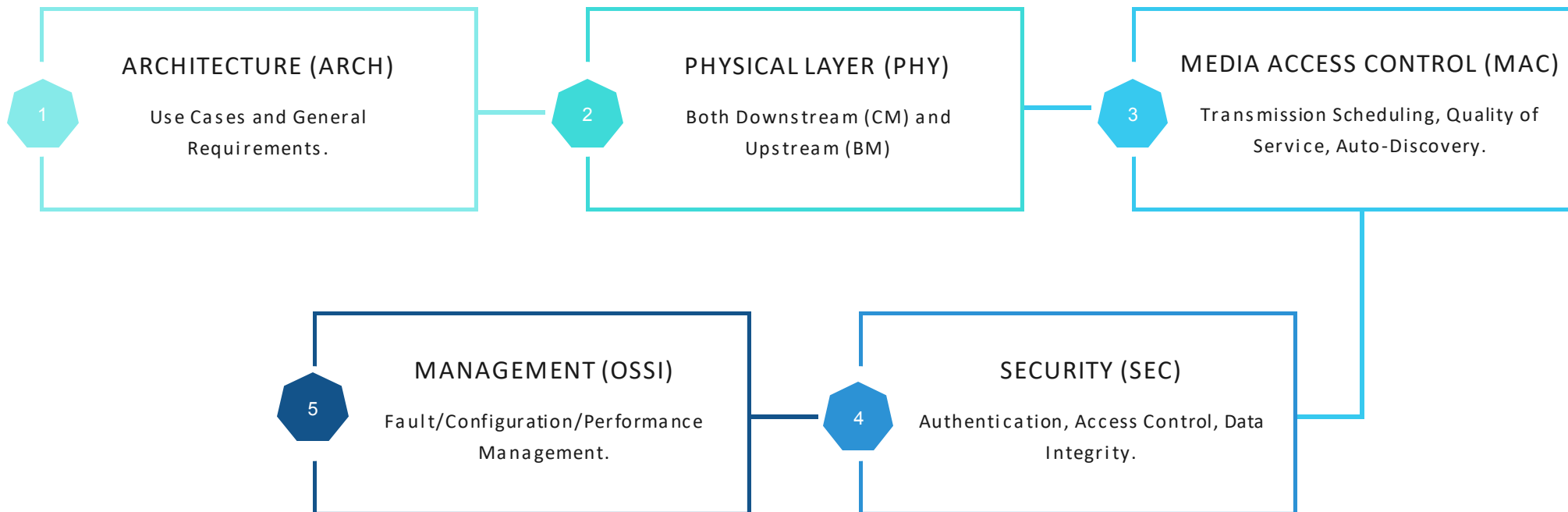- Develop specifications for Coherent Passive Optical Network solution for the Access Network
  - Specs will support cable applications, and also could be applicable to other applications (e.g., cellular, telco, data center, etc.).
  - Specs will ensure PON systems coexist on deployed infrastructure and enable interoperability, creating volumes to drive down cost.

Project Plan

ARCHITECTURE (ARCH)

1

Use Cases and General Requirements.

PHYSICAL LAYER (PHY)

2

Both Downstream (CM) and Upstream (BM)

MEDIA ACCESS CONTROL (MAC)

3

Transmission Scheduling, Quality of Service, Auto-Discovery.

MANAGEMENT (OSSI)

5

Fault/Configuration/Performance Management.

SECURITY (SEC)

4

Authentication, Access Control, Data Integrity.

Launching a Working Group (WG) to develop the specifications
Looking for companies with relevant experience to participate

Optical Project Charter

- Provides governance for CableLabs Optical Project
- Covers following topics (among others):
  - Scope
  - Conditions for Participation
  - Confidentiality
  - Intellectual Property Terms

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WG Kickoff Meeting

- Date: May 27, 2021
- Time: 9:00-11:00 am (Mountain Time)
- Location: Virtual web meeting

- Note: you **MUST** provide a signed Participation Agreement in order to receive the invitation of WG kickoff meeting and participate in any project activities

How to Participate

1. Review Project Charter

2. Sign Participation Agreement
   - One per company
   - Commits each company to Project Charter

3. Identify Contributing Engineers (CEs)
   - Up to 2 per company
   - Must have relevant experience
   - Sign CE agreement, committing ~50% of engineer's time to project

4. Attend meetings and actively participate

How to Participate

Send email to workinggroups@cablelabs.com

Coherent PON

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cablelabs.com