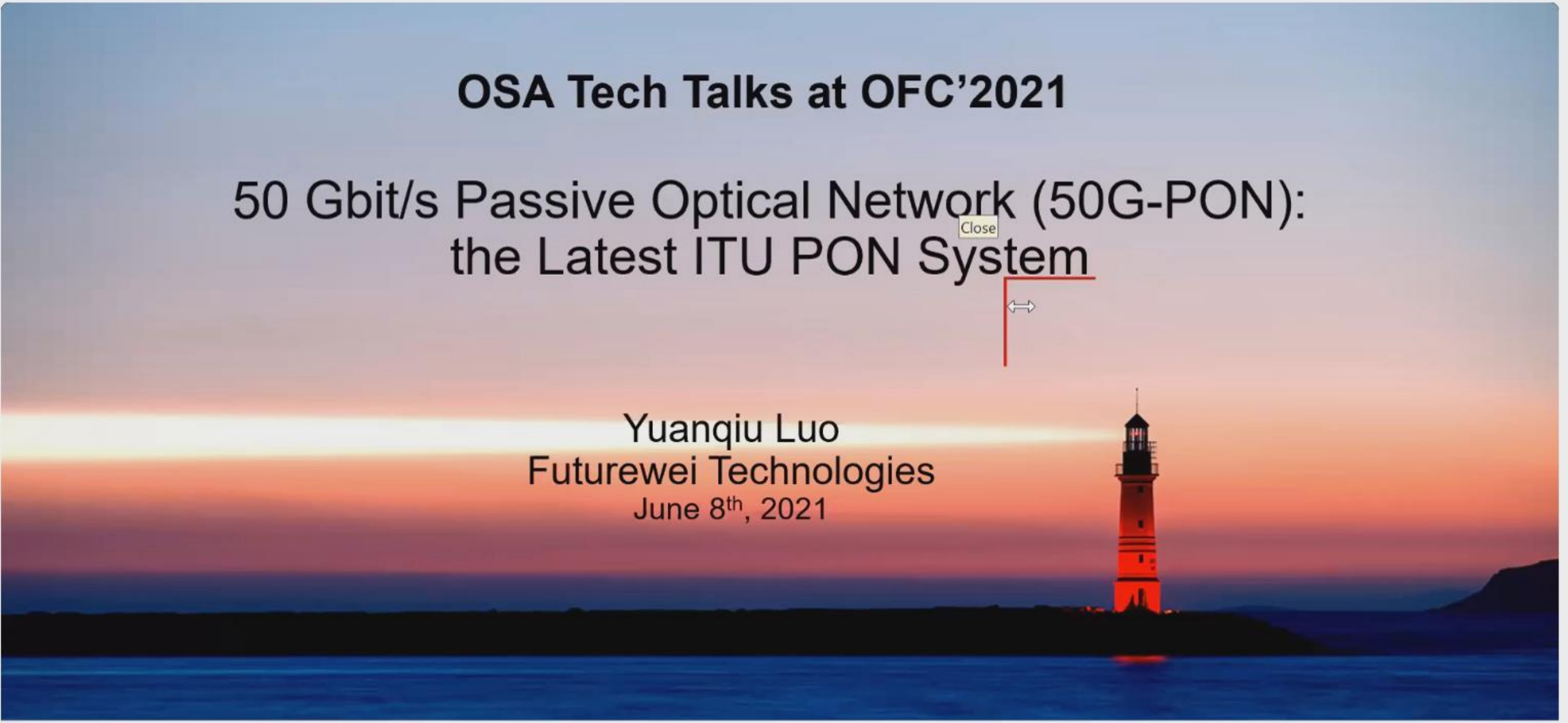

OSA Tech Talks at OFC'2021
50 Gbit/s Passive Optical Network (50G-PON):
the Latest ITU PON System
Close
Yuanqiu Luo
Futurewei Technologies
June 8th, 2021

About the Speaker

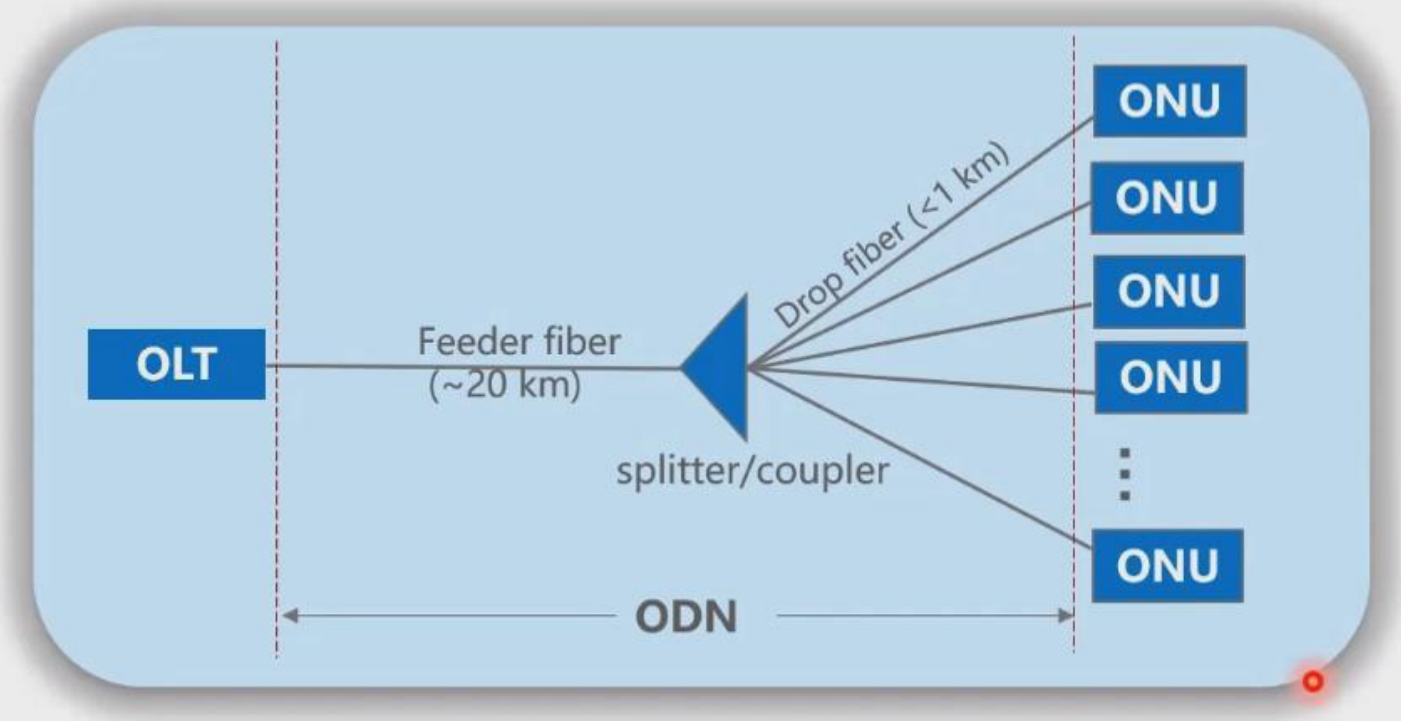
Yuanqiu Luo

- Editor of ITU-T G.9804.2 (50G-PON recommendation)
- Editor of ITU-T G.987.3 (XG-PON recommendation)
- Editor of ITU-T G.989.2 (NG-PON2 recommendation)
- Editor of ITU-T G.9807.1 (XGS-PON recommendation)
- Editor of IEEE 802.3cp (10G/25G/50G BiDi)
- Editor of ITU-T G.sup.66 (PON for 5G fronthaul)
- Director of Optical Access Standards, Futurewei Technologies

Outline

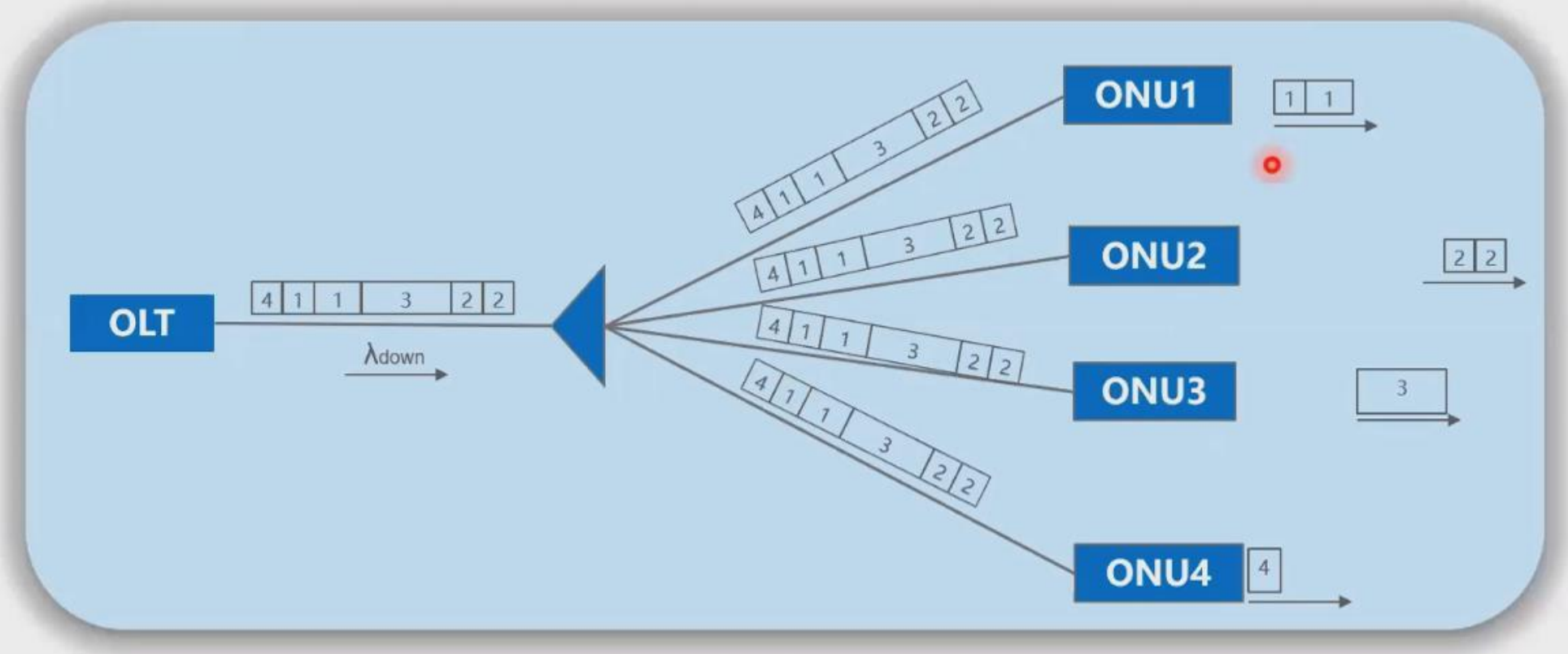
- Introduction
- 50G-PON standards
- 50G-PON applications
- Future work

Optical Access - Passive Optical Network (PON)



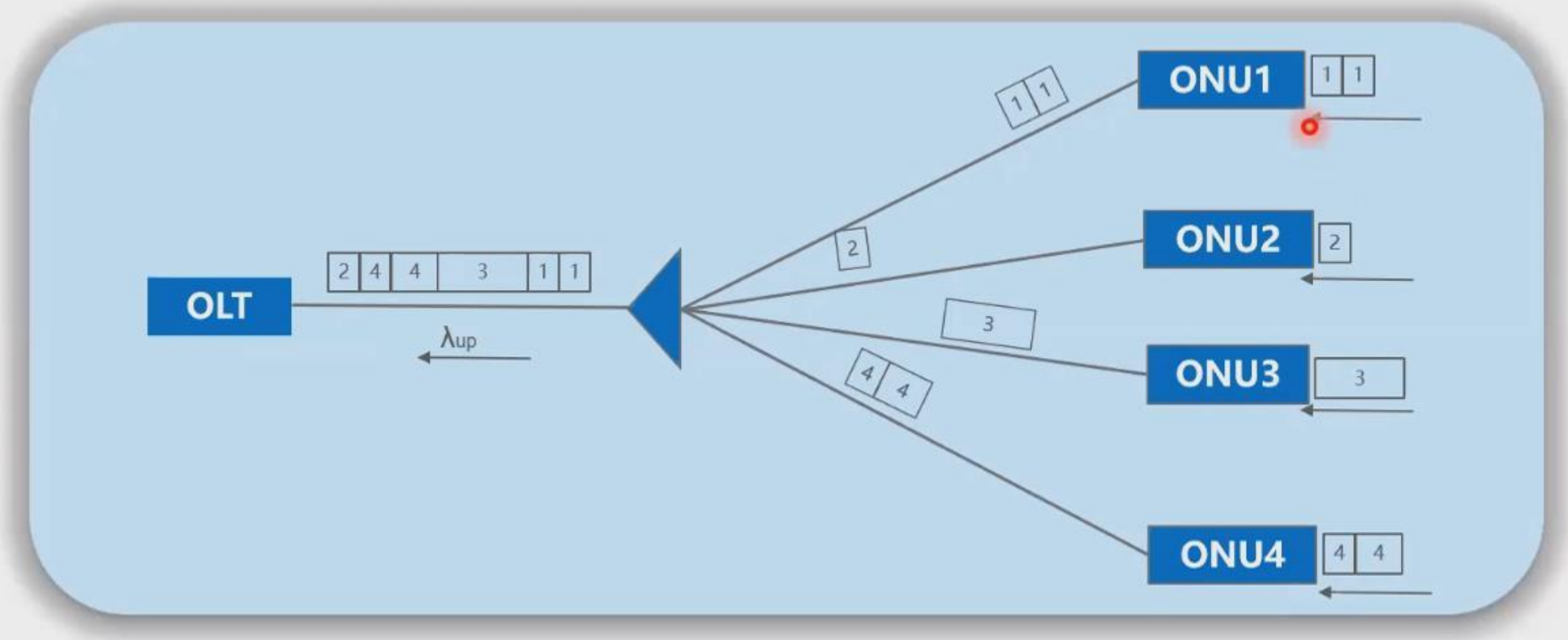
- OLT: optical line terminal, PON central office element
- ONU: optical network unit, PON user premise element
- Splitter/coupler: 1:n optical splitter in downstream and n:1 optical coupler in upstream, PON remote node element
- ODN: optical distribution network, PON contains a point-to-multipoint (PtMP) passive distribution network as the outside plant

How does PON Work: Downstream TDM



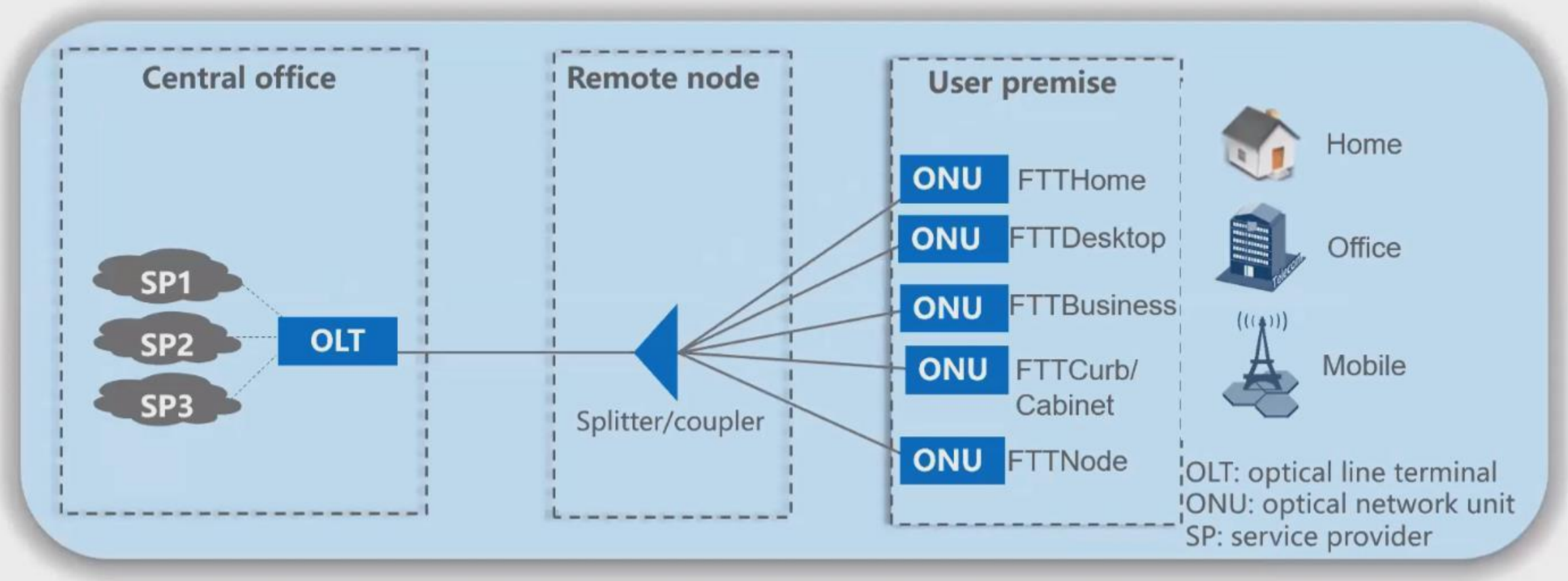
- One wavelength is employed for downstream transmission, remote note works as splitter
- OLT traffic is broadcast to all ONUs

How does PON Work: Upstream TDMA



- Another wavelength is employed for upstream transmission
- Remote node works as coupler in upstream
- The OLT schedules ONU transmission timeslots to avoid collision

Where to Employ PON



- PON is for optical access, it connects users to core networks and delivers service from the central office to user premise
- PON enables FTTx broadband access

Commercial PON Systems

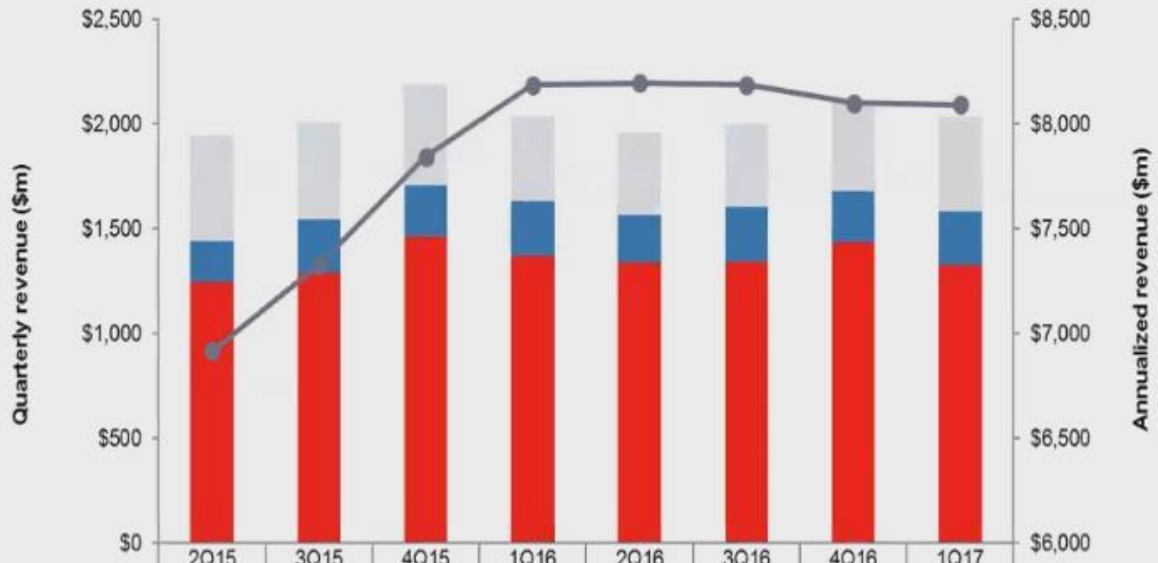
	System	Downstream rate (bps)	Upstream rate (bps)	Downstream wavelength (nm)	Upstream wavelength (nm)	Data unit	Standards	Standard approval year
<1G	B-PON	622M	155M	1490	1310	ATM cell	ITU G.983.x	1998
1G/2.5G	G-PON	2.5G	1.25G	1490	1310	GEM frame	ITU G.984.x	2003
1G/2.5G	EPON	1G	1G	1490	1310	Ethernet packet	IEEE 802.3ah	2004
10G	10G-EPON	10G	1G or 10G	1577	1270	Ethernet packet	IEEE 802.3av	2009
10G	XG-PON	10G	2.5G	1577	1270	XGEM frame	ITU G.987.x	2010
10G	XGS-PON	10G	10G	1577	1270	XGEM frame	ITU G.9807.1	2016
40G	NG-PON2	40G (4x10G)	10G (4x2.5G)	1596-1603	1524-1544	XGEM frame	ITU G.989.x	2015

B-PON: Broadband passive optical network
G-PON: Gigabit-capable passive optical network
EPON: Ethernet passive optical network
10G-EPON: 10 Gigabit EPON

XG-PON: 10-Gigabit-capable passive optical network
XGS-PON: 10-Gigabit-capable symmetric passive optical network
NG-PON2: 40-Gigabit-capable passive optical network

PON Market: Global Revenue

Global PON, DSL, and CMTS/CCAP quarterly and annualized revenues, 2Q15–1Q17



	2Q15	3Q15	4Q15	1Q16	2Q16	3Q16	4Q16	1Q17
DSL + G.fast	$508	$463	$484	$408	$390	$396	$422	$447
CMTS and CCAP	$197	$255	$243	$263	$228	$261	$249	$256
PON	$1,244	$1,289	$1,465	$1,369	$1,339	$1,342	$1,434	$1,329
Annualized	$6,919	$7,329	$7,846	$8,188	$8,196	$8,188	$8,102	$8,094

Source: Ovum

- PON dominates global wireline access network market
- PON revenue is more than $5B per year
- PON revenue is about 3 times of DSL and 5 times of CMTS

DSL: digital subscriber line
CMTS: cable modem termination system
CCAP: converged cable access platform

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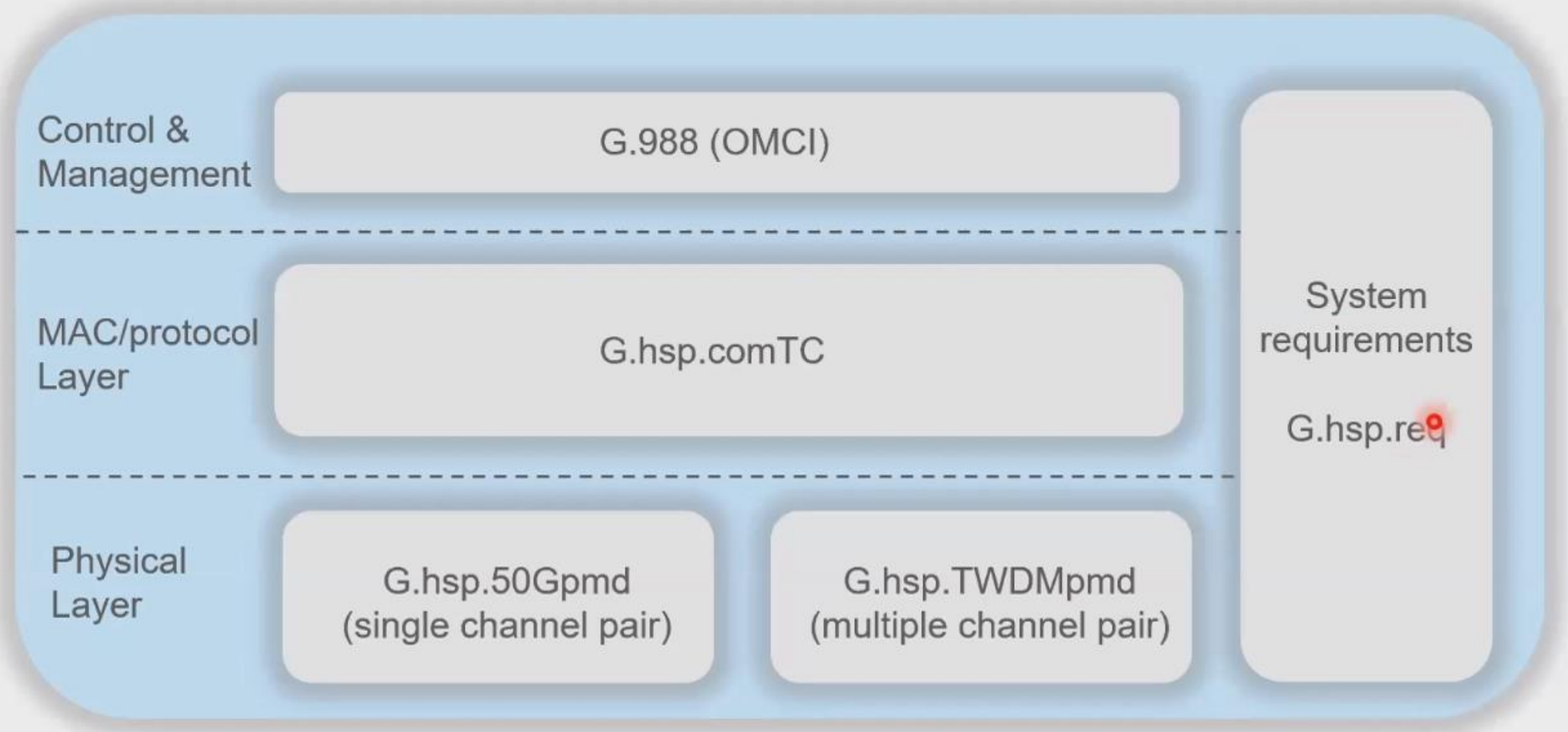
ITU 50G-PON Standards

- Preliminary study
  - From 2017 to 2018, the ITU Q2/SG15 group investigated PON transmission technologies above 10 Gb/s per wavelength
  - Results were agreed and published as ITU G.sup.64
  - https://www.itu.int/rec/T-REC-G.Sup64/en
- Project approval
  - In February 2018, the ITU SG15 plenary meeting approved to work on a new series of standards on 50G-PON (SG15-TD154-R1/WP1)
  - This project is the G.hsp.x series
- Supporters
  - Operators: AT&T, China Mobile, China Telecom, China Unicom, Vodafone
  - Vendors: Adtran, Calix, Huawei, Nokia, ZTE

50G-PON Standards: G.hsp.x

Recommendation	Scope	Editors	Progress
G.hsp.req	- Requirements for higher speed PONs - A collector of all PON requirements, application sets that define reasonable systems	AT&T, China Telecom	Consented in 2019 as G.9804.1
G.hsp.comTC	- Specifications for a converged TC layer - Cover all HSP systems (single and multiple wavelengths, fixed and tunable optics) and maximum commonality with other systems	Futurewei, Nokia, ZTE	Consent in April 2021 as G.9804.2
G.hsp.50Gpmd	- Specifications of 50G TDM PON PMD	China Mobile, Huawei	Consent in April 2021 as G.9804.3
G.hsp.TWDMpmd	- Specifications of the higher rate TWDM PMD - Consider tunable ONU optics	Adtran, Calix	Under active development

G.hsp.x


Control & Management
G.988 (OMCI)
MAC/protocol Layer
G.hsp.comTC
Physical Layer
G.hsp.50Gpmd (single channel pair)
G.hsp.TWDMpmd (multiple channel pair)
System requirements
G.hsp.req

50G-PON System Requirements

- Rate
  - 50 Gbit/s in the downstream and 25 Gbit/s in the upstream
  - Other possible DS/US rate combinations are: 50G/12.5G, 50G/50G
- Distance
  - 20 km for general applications (residential, business, office, etc.)
  - 10 km for wireless applications that are latency sensitive (e.g., 5G)
- Split ratio
  - Support 1:256 split ratio
- Optical distribution network (ODN)
  - Operate on the established splitter-based ODN
- Coexistence
  - with legacy PON systems via deployed ODN (XG(S)-PON, 10GE-PON,G-PON)

50G-PON Physical Layer Spec

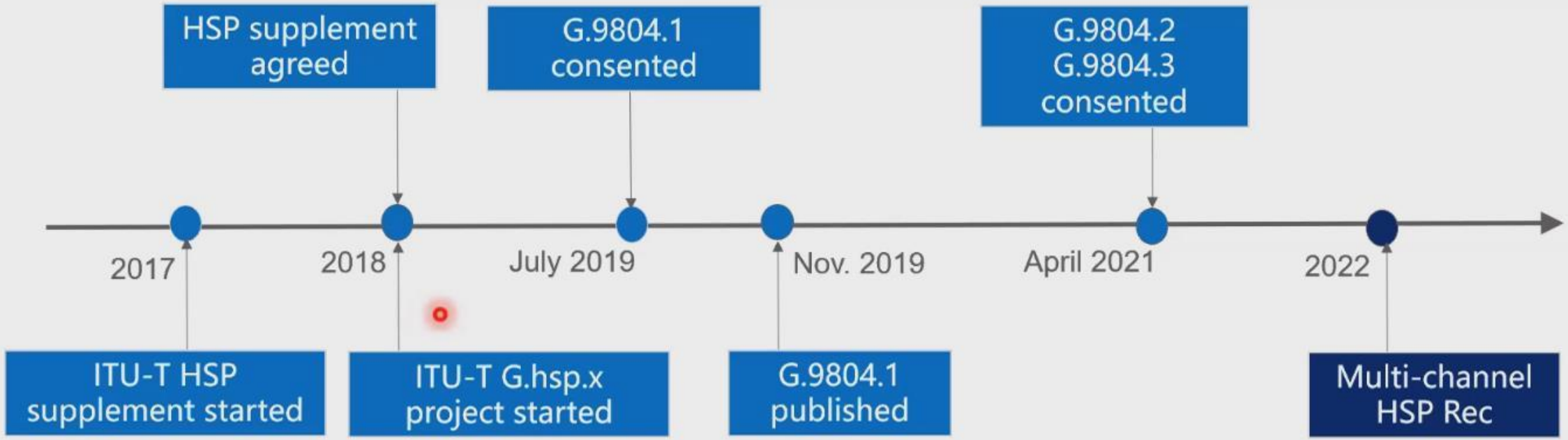
Item	Specification	Note
Typical Rates	Downstream 49.7664 Gbit/s Upstream 24.8832 Gbit/s	Other US rates: 12.4416 Gbit/s, 49.7664 Gbit/s
Wavelength plan	Downstream 1340~1344 nm Upstream 1260~1280 nm or 1290~1310 nm	1298~1302 nm (narrow band)
Line code	NRZ for both DS and US	
Bit error ratio reference level	1.0E-2	FEC is required
Optical path loss class	N1 14~29 dB; N2 16~31 dB E1 18~33 dB; E2 20~35 dB	
25G upstream	Min Rx sensitivity -24.5 dBm Min Tx launch power +5 dBm	N1 class

Source: “G.hsp.50Gpmd draft”, ITU-T Q2/15 meeting, D08, February 2021

50G-PON MAC Layer Spec

Item	Specification
Frame structure	Frame/burst header, downstream synchronization, scrambler, LDPC-FEC
User data encapsulation	XGEM frame
ONU management	Embedded OAM, PLOAM, OMCC
Upstream resource control	Bandwidth map (BWmap), dynamic bandwidth assignment model
ONU activation	Registration, authentication, timing relationship
Power saving	Watchful sleep power management mode, full power awake mode
Security	Device authentication, key derivation, data encryption, integrity protection
Performance monitoring	PM counters, defects, actions
Protection	Type B dual parenting protection

50G-PON Standards Timeline



- ITU started 50G-PON standardization work from 2017
- A supplement (G.sup.64) on candidate technologies was published in 2018
- 50G-PON system requirement recommendation (G.9804.1) was published in 2019

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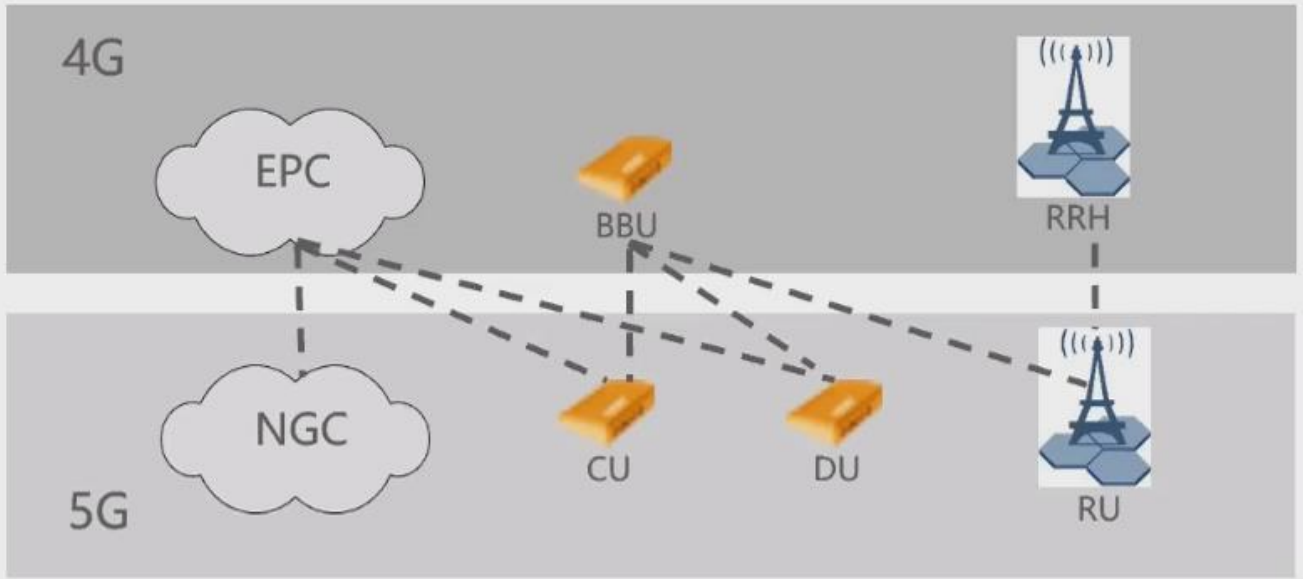
From 4G to 5G

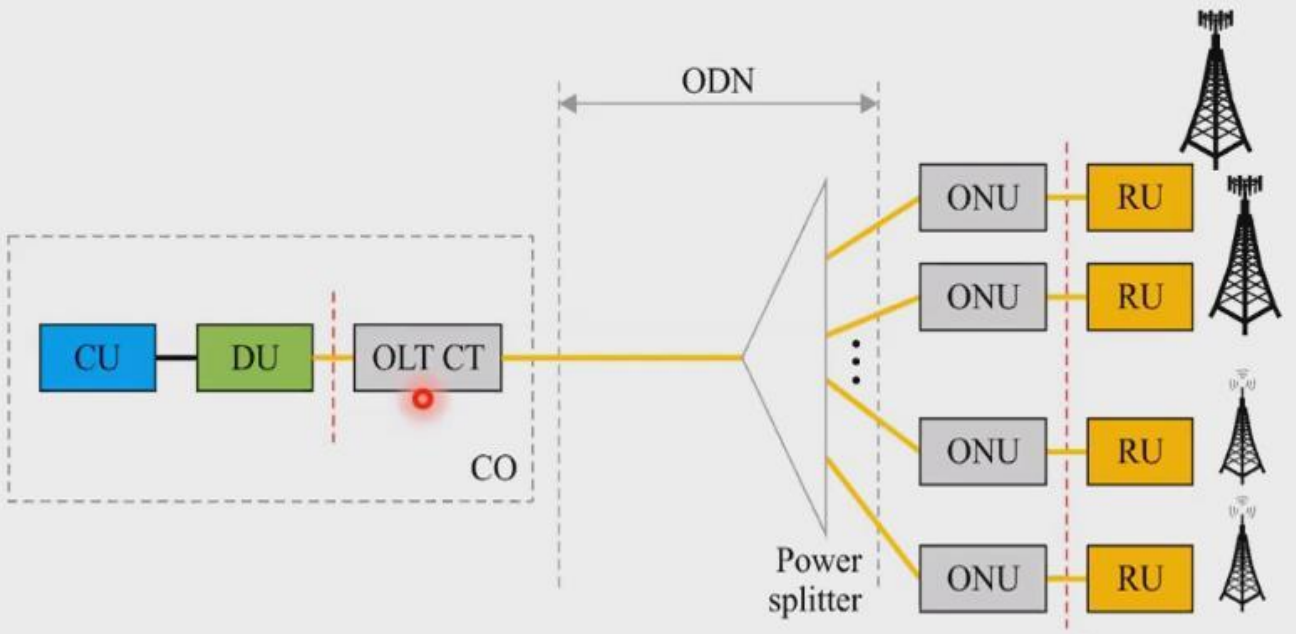


CU: central unit
DU: distributed unit
RU: remote unit
NGC: next generation core

EPC: evolved packet core
BBU: baseband unit
RRH: remote radio head

- 5G wireless network is based on user-centric (not cell-centric) design, 5G wireless network elements are reorganized into NGC, CU, DU, and RU
- 5G provides dynamic and fine-grained control of the RUs over a geographically relevant area to better serve users
- 5G network consists of huge amounts of small cells aggregating to macro cells
- 50G-PON is a good candidate to connect RU to DU and/or DU to CU

50G-PON as 5G Fronthaul



Source: ITU-T G.sup.66

- Why 50G-PON
  - 50G-PON enables low cost connection of units in the radio network layer
  - PtMP extends DU/RU coverage with less fiber, lower power, and fewer TRx
  - 50G-PON provides various speed access via TDM/TDMA to up to 50G
  - Passive ODN means no intermediate powering and minimum cost on outside plant maintenance
  - 50G-PON supports dense access from many users through traffic aggregation and multiplexing gain

Carrying CPRI Data over PON

CPRI Option	CPRI Data Rate (Gb/s)	Candidate PON Systems
1	0.6144	EPON, G-PON, XG(S)-PON, 10G-EPON, NG-PON2, 50G-PON
2	1.2288	G-PON, XG(S)-PON, 10G-EPON, NG-PON2, 50G-PON
3	2.4576	XG(S)-PON, 10G-EPON, NG-PON2, 50G-PON
4	3.0720	XGS-PON, 10G-EPON, NG-PON2, 50G-PON
5	4.9152	XGS-PON, 10G-EPON, NG-PON2, 50G-PON
6	6.1440	XGS-PON, 10G-EPON, NG-PON2, 50G-PON
7	9.8304	XGS-PON, 10G-EPON, NG-PON2, 50G-PON
8	10.1376	50G-PON
9	12.1651	50G-PON
10	24.3302	50G-PON

5G Service Traffic Characteristics

Typical service and technology	Peak rate	Average rate	e2e delay (service level)
Enhanced mobile broadband (eMBB)	5-10 / 20 Gb/s (UL/DL)	100 Mb/s per user in urban/suburban areas 1-4 Gb/s (hot spot areas)	10 ms
Ultra-reliable low latency communication (URLLC) / Critical machine type communication	much lower than in eMBB: N × Mb/s	much lower than in eMBB: n × Mb/s	1-2.5 ms
Massive machine type communication (mMTC)	much lower than in eMBB: N × Mb/s	much lower than in eMBB: n × kb/s ~ n × Mb/s	1-50 ms

Source: ITU-R M.2083

G.9804.1 (50G-PON Requirements)

Scenarios	Services categories
…	…
PON-based 5G Mobile FrontHaul (PON-MFH)	The OLT and ONUs provide transport between the CU and RU. Ultra-low latency with the use of Cooperative DBA function and quiet window reduction for the PON. An interface (named Cooperative Transport Interface or CTI) between the 5G scheduler and a PON OLT/scheduler as defined by O-RAN WG 4 group in collaboration with ITU SG15 Q2 group.

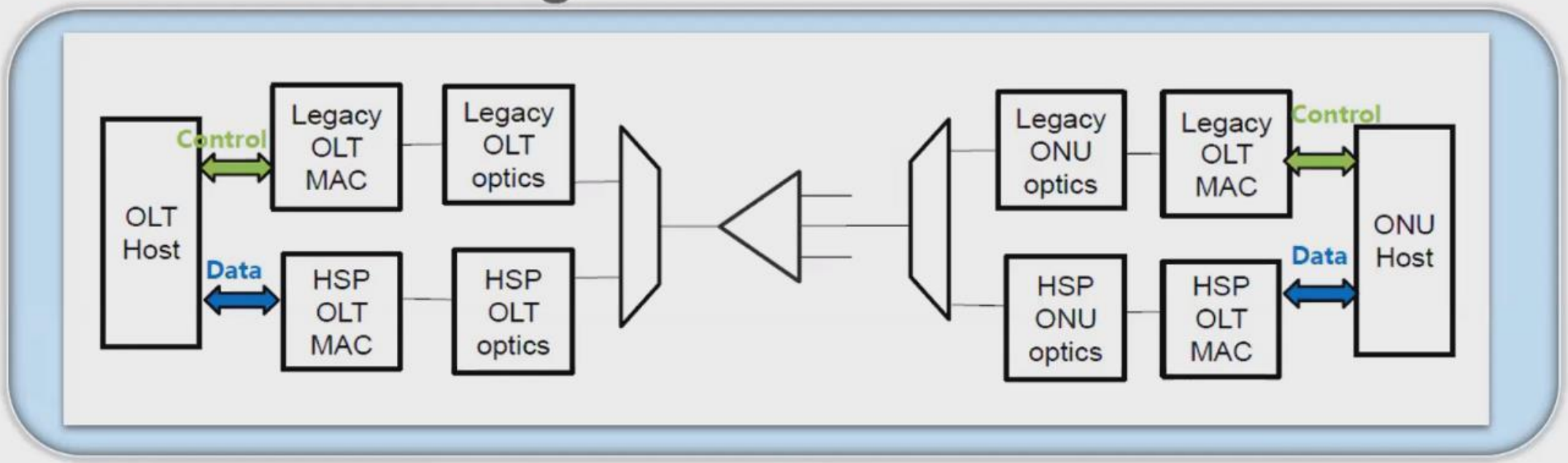
6.2.1 Common Requirements

All HSP systems that are intended to operate on the established splitter-based PON infrastructure should:

- Support the maximum fibre distance of at least:
  - 20 km for general applications
  - 10 km for wireless applications that are latency sensitive (e.g., 5G)
- Support using fibre types described in [ITU-T G.652] and [ITU-T G.657]
- Operate over ODNs comprised of fibres, connectors, splitters, and optionally wavelength selective devices

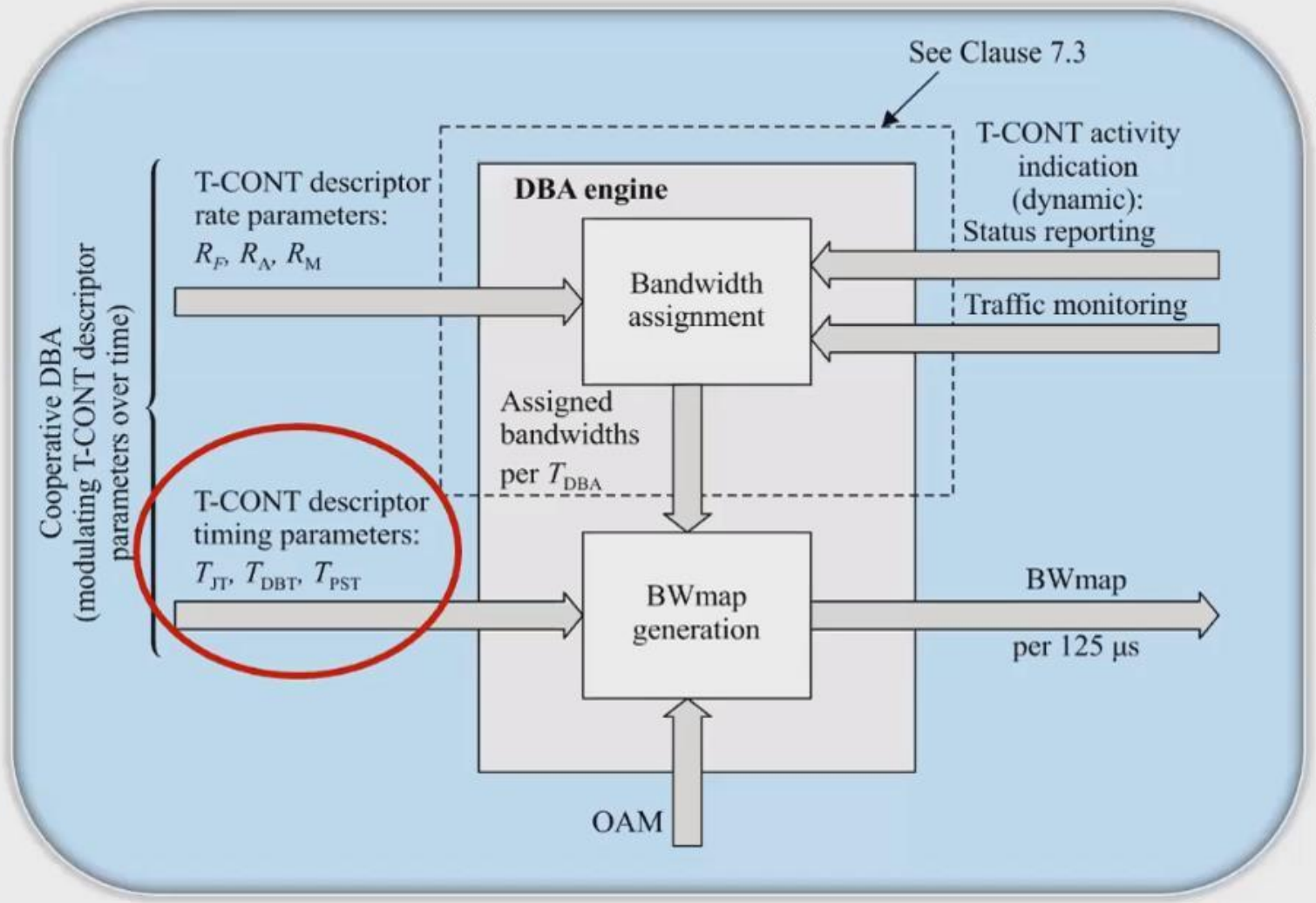
Source:
ITU-T G.9804.1, Table 6-1, Clause 6.2.1

50G-PON Fast Registration



- Legacy (low speed) PON takes care of ONU registration and management
  - Eliminate delay from conventional TDM-PON ONU registration
- 50G-PON (high speed) PON supports data transmission
  - Jitter due to PON management can also be controlled
- This improvement has been included in ITU-T G.9804.2 Appendix

Enhanced Resource Assignment



- Jitter and delay tolerance parameters are directly input to generate bandwidth assignment
- Delay from DBA cycle is eliminated for time-sensitive services

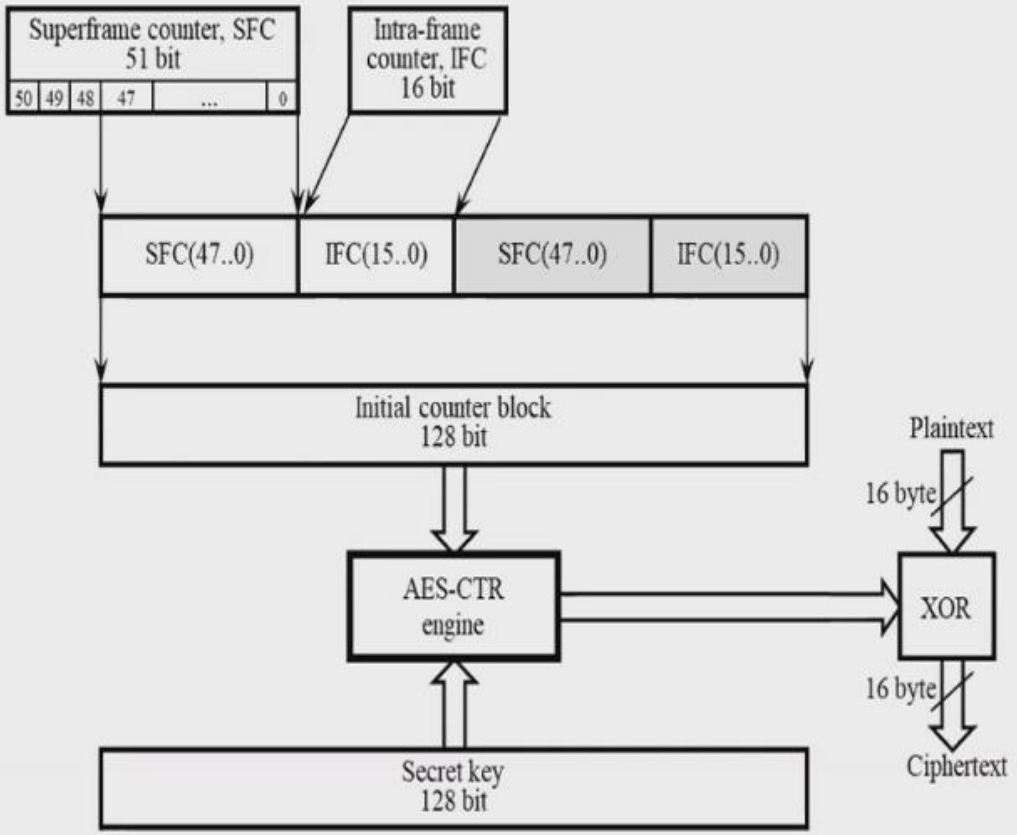
T_{JT}: jitter tolerance
T_{BDT}: bandwidth assignment delay tolerance
T_{PST}: protection switching delay tolerance

Higher Loss Budget Classes

- Current draft of G.9804.3 specifies N1 class (14~29 dB), higher loss budget classes are to be defined
  - N2 class 16~31 dB
  - E1 class 18~33 dB
  - E2 class 20~35 dB
- Enabling technologies are under active study
  - DSP
  - SOA
  - Dispersion compensation
  - Receiver equalizer
  - FEC

Security Enhancement

- Current data encryption method is AES-128
  - This may become insufficiently secure, given hardware acceleration and quantum
  - More encryption algorithms should be allowed to use in 50G-PON, such as AES-192, AES-256, Camellia, SEED, SM4, GOST, LIA
- Enhanced key security
  - The OLT manufacturer should provide a way that the operator can configure the reauthentication period
  - A new key schedule can be initiated as needed
- Key randomness



Source:

"HSP Security Checkup", ITU-T Q2/15 meeting, D15, March 2021

Slicing Provisioning

5.15.2.2 Standardised SST values

Standardized SST values provide a way for establishing global interoperability for slicing so that PLMNs can support the roaming use case more efficiently for the most commonly used Slice/Service Types.

The SSTs which are standardised are in the following Table 5.15.2.2-1.

Table 5.15.2.2-1 - Standardised SST values

Slice/Service type	SST value	Characteristics.
eMBB	1	Slice suitable for the handling of 5G enhanced Mobile Broadband.
URLLC	2	Slice suitable for the handling of ultra- reliable low latency communications.
MIoT	3	Slice suitable for the handling of massive IoT.

Source:

"System Architecture for the 5G System", 3GPP TS 23.501 version 15.3.0 Release 15

- 5G specifications include standardized slices
- When employing 50G-PON to carry cellular traffic, end-to-end packet flow management would benefit from slices being supported by 50G-PON
- This requirement is under study in G.9804.1 Amd

Summary

- ITU 50G-PON standards are a joint effort of the entire industry
- 50G-PON standards on system requirements, PHY interface, and MAC are mature
- 50G-PON is a powerful solution for 5G transport
- Advanced features need close collaboration between academia and industry