ITU-T STUDY GROUP 15

Networks, Technologies and Infrastructures for Transport, Access and Home

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NGON&5G Transport

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Cote d'Azur, France

ITU: UN Agency for ICTs

ITU's 3 Sectors

ITU-D – Development

ITU-R – Radiocommunication

ITU-T – Standardization

ITU-T Study Groups

SG2 - Operational aspects
SG3 - Economic & policy issues
SG5 - Environment, EMF & circular economy
SG9 - Broadband cable & TV
SG11 - Protocols, testing & combating counterfeiting
SG12 - Performance, QoS & QoE
SG13 - Future networks
SG15 - Transport, access & home
SG16 - Multimedia & digital technologies
SG17 - Security
SG20 - IoT, smart cities & communities

SG15 mandate

SG15 is responsible for the development of standards on:

- optical transport network
- Gigabit copper transmission
- instrumentation and measurement techniques
- optical access network
- equipment
- maintenance
- management
- test
- home network and power utility network infrastructures
- optical fibers and cables and their related installation
- control and management plane technologies

to enable the evolution toward intelligent e2e optical networks.

List of Questions

	Question Number	Question title
WP1	1/15	Coordination of Access and Home Network Transport Standards
	2/15	Optical systems for fibre access networks
	3/15	Technologies for in-premises networking and related access applications
	4/15	Broadband access over metallic conductors
WP2	5/15	Characteristics and test methods of optical fibres and cables, and installation guidance
	6/15	Characteristics of optical components, subsystems and systems for optical transport networks
	7/15	Connectivity, Operation and Maintenance of optical physical infrastructures
	8/15	Characteristics of optical fibre submarine cable systems
WP3	10/15	Interfaces, interworking, OAM, protection and equipment specifications for packet-based transport networks
	11/15	Signal structures, interfaces, equipment functions, protection and interworking for optical transport networks
	12/15	Transport network architectures
	13/15	Network synchronization and time distribution performance
	14/15	Management and control of transport systems and equipment

WP: Working Party

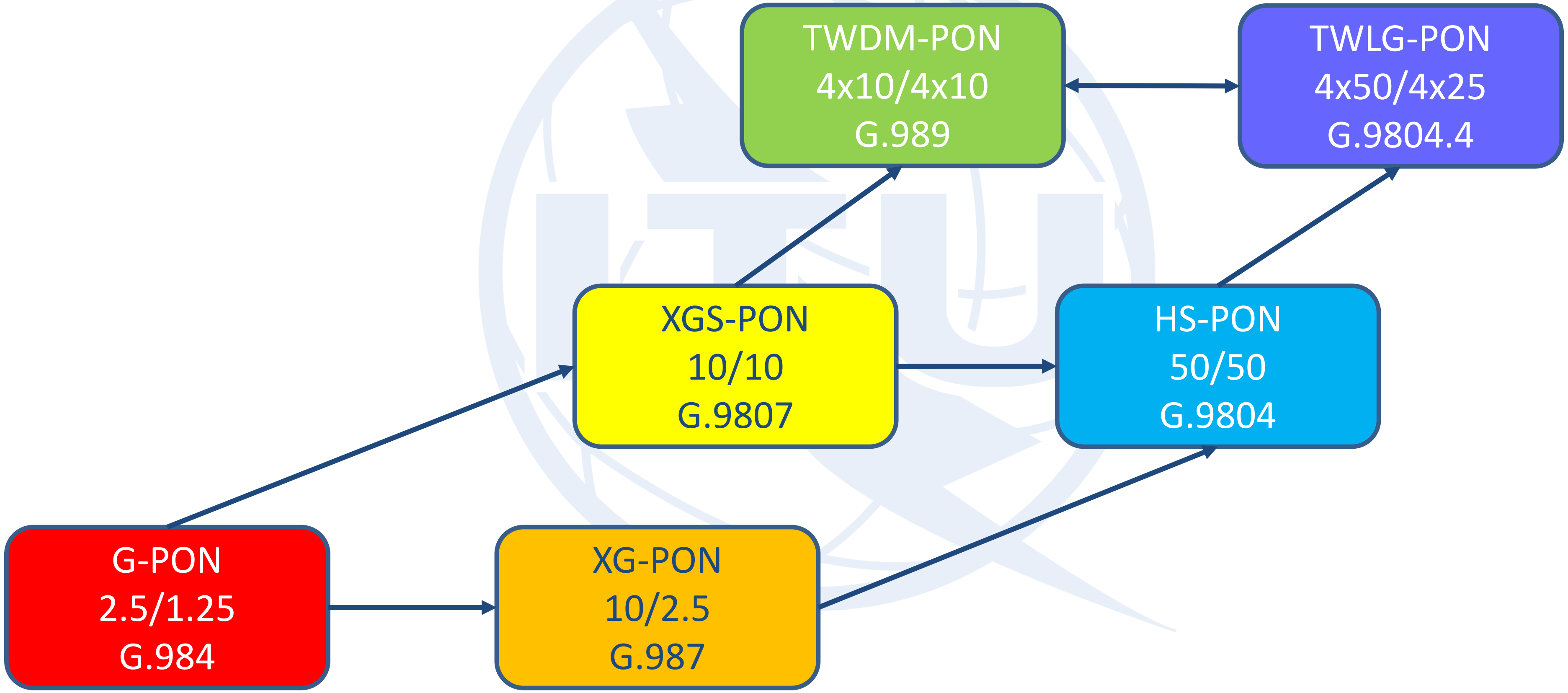
ITU-T SG15 Working Party 1:
Optical Networks for Access and Home

Work program overview

WP1 optics by application area

- The largest application of WP1 optics is to provide broadband access to home and small business users, where the emphasis is on low-cost high-volume solutions
  - There is a long history of PON system specifications, which have followed the growth of technological and service bandwidths
  - Along the way, various basic infrastructure components have been built up as well
- Starting from this core position, there are two major expansion areas
  - Wireless applications that require more than what the conventional broadband network can. New systems or improvements to existing systems can work to address these requirements
  - As access bandwidth improves, the in-home network becomes the bottleneck. Optics can be used to supercharge the home network to overcome this

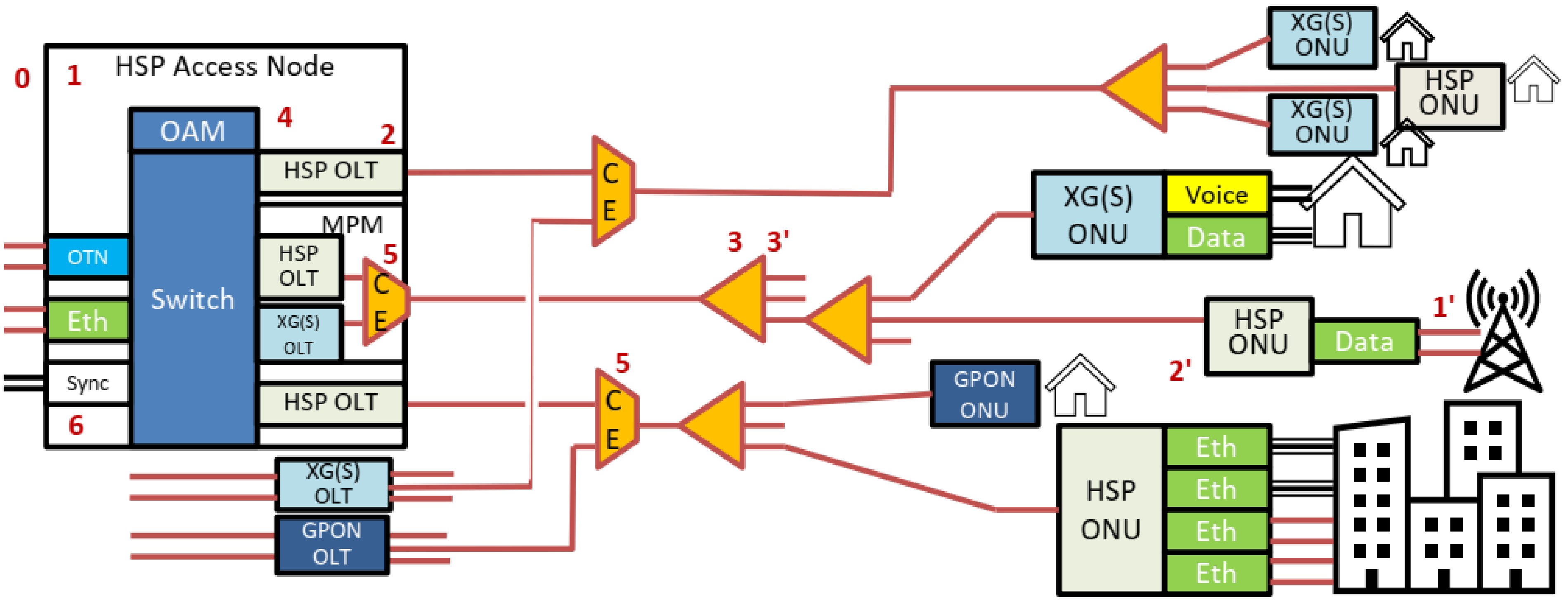
Optical broadband access



ITU-T Study Group 15

G.9804 HSP: Higher Speed Passive Optical Networks

- Full-service support – including voice, TDM, Ethernet (10/100/1000/10G/25G BASE), xDSL, wireless xhaul
- Basic physical reach is 20 km. Logical reach of up to 60 km. System is wavelength coexistent with G-PON, XG(S)-PON, 10G-EPON
- Support for bit-rate options, 50 Gbit/s downstream and 12.5 or 25 or 50 Gbit/s upstream
- Powerful OAM&P and system protection capabilities providing a feature rich and reliable service management system
- Advanced security features including authentication, rogue detection, and information privacy
- Power saving features on top of the already considerable low power nature of fibre access



Key enabling infrastructure documents

OMCI
ONU management
& Control Interface
G.988

PON Coexistence
G.9805

Optical Access
Power Conservation
G.sup.45

Rogue ONU
Considerations
G.sup.55

Network Slicing
in a PON
G.sup.74

ITU-T Study Group 15

G.9805 Coexistence of Passive Optical Network Systems

ITU-T G.9805 describes the methods and parameters for PON coexistence, where two or more PON systems share a common ODN, including

- Reference diagram of coexistence element, and sample parameters of a discrete WDM filter that enables PON evolution
- Multi-PON modules with integrated WDM to support legacy PON and NG-PON coexistence
- Methods for calculating required isolation for WDM/CE/CEM devices
- Filter considerations for XG(S)-PON/10G-EPON and HSP OLT.

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Two methods support for PON evolution: External CEx and MPM

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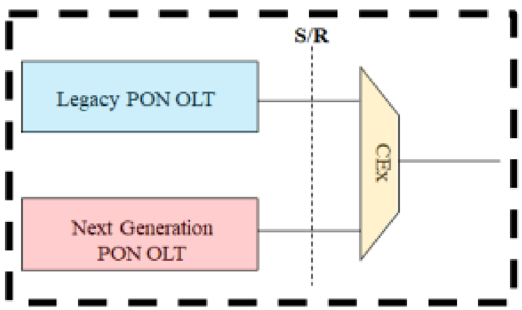
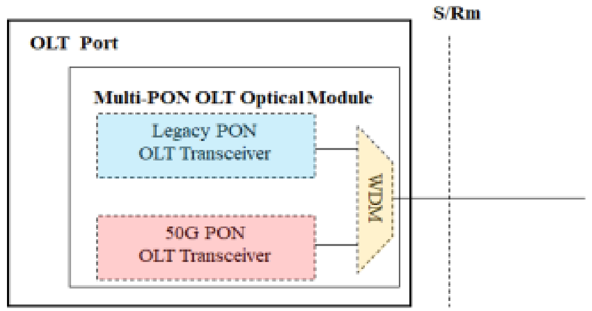


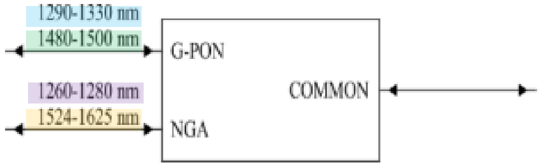
External CEx

2



MPM

GPON and XG(S)-PON Coexistence WDM filter example



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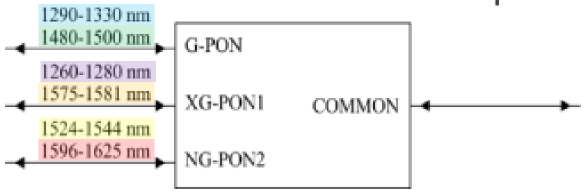
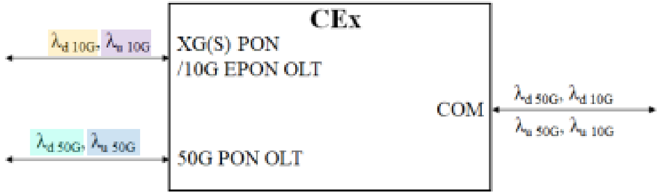
GPON , XG(S)-PON and NG-PON Coexistence WDM filter example



XG(S)-PON/10G EPON and 50G-PON Coexistence WDM filter example



The detail specification of the coexistence filter and the calculation method are defined in G.9805

Wireless applications

Point to point bidirectional optics
G.986 & G.9806

5G wireless in a PON context
G.sup.66

Cooperative Dynamic Bandwidth Assignment
G.sup.71

Radio over Fiber
G.9803

WDM-PON
G.9802

5G backhaul over TDM PON
G.sup.75

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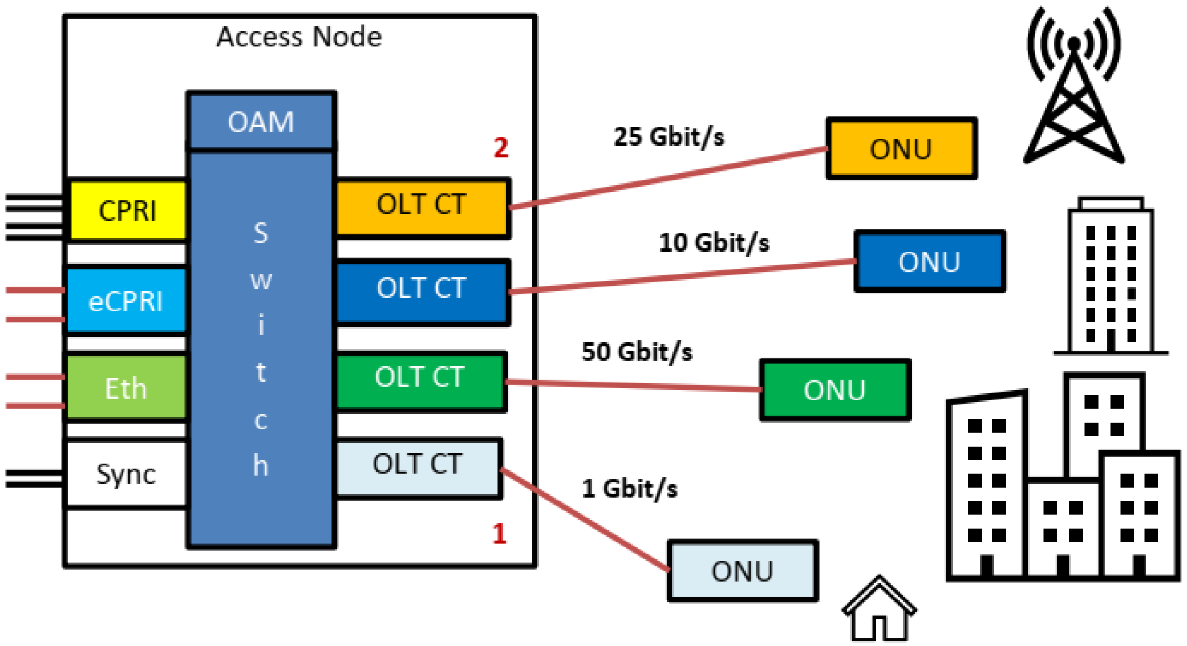
G.986 1 Gbit/s point-to-point optical access system

G.9806 Higher-speed bidirectional point-to-point

- Single fibre, point-to-point bi-directional (BiDi) transmission suite of recommendations for 1, and 10, 25 and 50 Gbit/s
- Optical budget classes cover up to 40 km with a minimal number of module types to simplify inventory and avoid gaps
- Full-service support with symmetric rates compatible with various wireless xhaul functional splits among other applications
- Powerful OAM&P capabilities providing a feature rich service management system to maximize commonality with PON operation
- A silent start feature to avoid alien ONU behaviours disturbing PONs when inserted by mistake



G.Suppl.66 5G wireless fronthaul in a PON context

- First ITU-T study that synthesizes specifications from recent 5G standards into practically realizable access network solutions
- Consider transport requirements from the 5G New Radio (NR) functional split architectures
- Review 5G wireless transport requirements for services, transport capacity, latency, and synchronization
- Discuss PON system designs to meet these requirements
- Provide practical PON implementation examples for back/midhaul (F1) and fronthaul (Fx) interfaces using TDM-PON and WDM-PON

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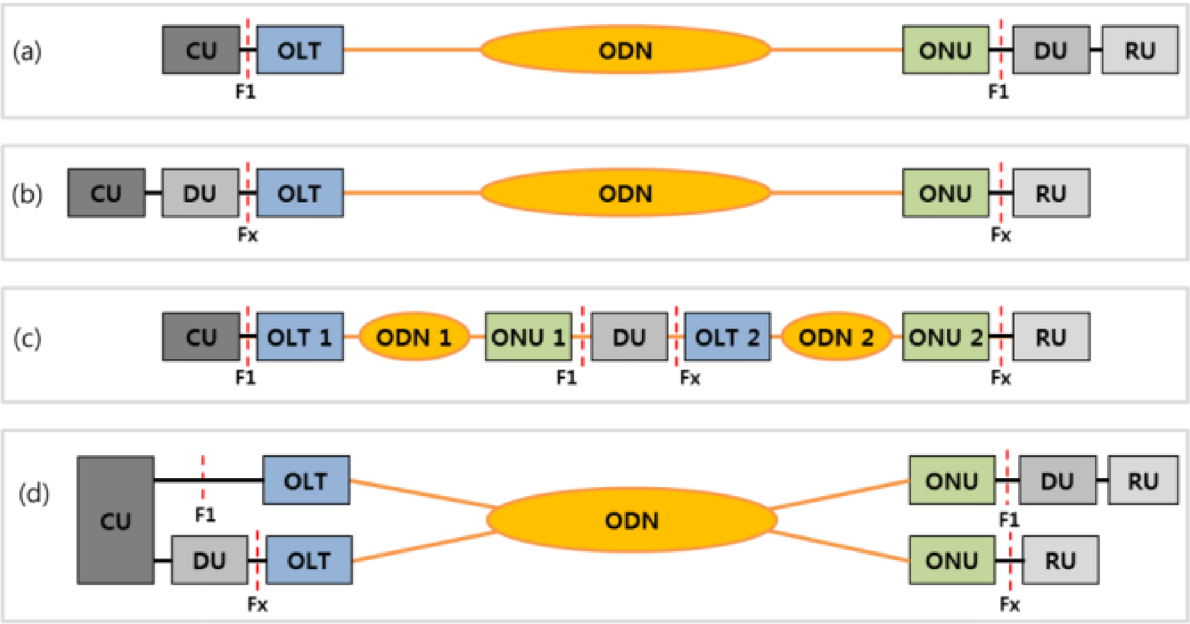

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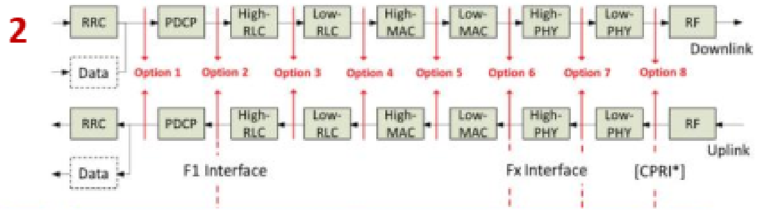

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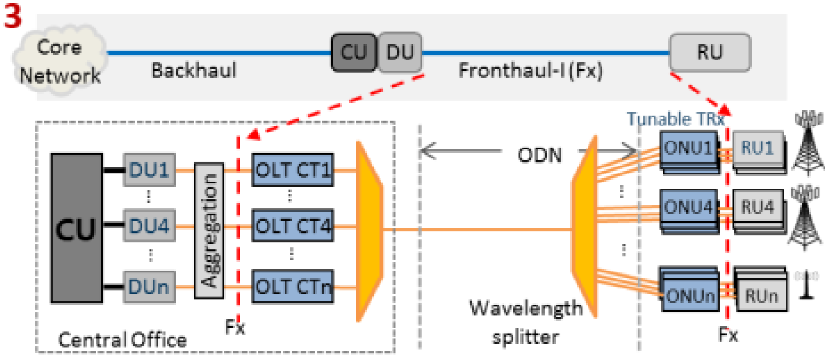
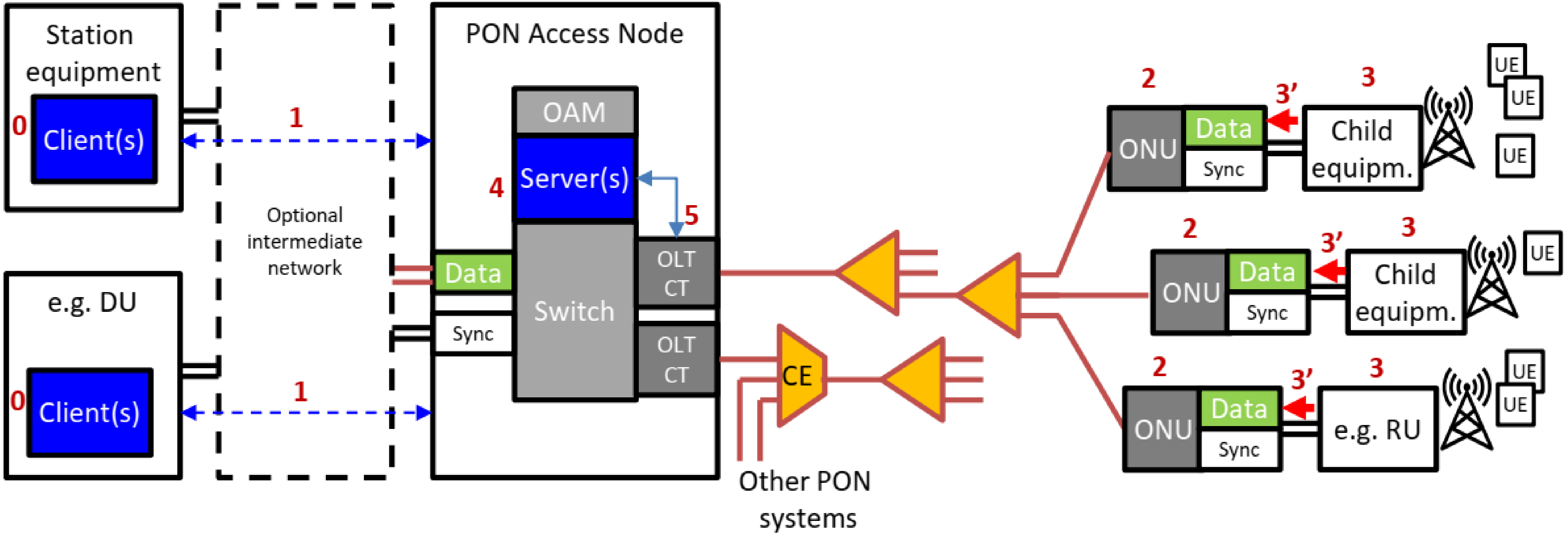


G Suppl. 71 Cooperative Dynamic Bandwidth Allocation

- Cooperative DBA (CO DBA) is a method to reduce the upstream latency in a TDM PON when applying variable bandwidth allocations to follow a variable bitrate traffic pattern, while keeping multiplexing gain.
- CO DBA is notified with information about this traffic from an external entity (station equipment) to the optical line termination (OLT). With this information the OLT applies bandwidth allocations targeted in time and size.
- External entity can be northbound of OLT (as per figure below) or connected to ONU. CO DBA as such is independent of the TDM PON technology.
- The supplement provides an interpretation of the OLT capabilities that are needed to support CO DBA; some are generic, some are specific per use case.
- The use case elaborated in the supplement is Mobile Fronthaul (MFH) using O-RAN's Cooperative Transport Interface (CTI) between OLT and Distributed Unit (DU).



Optical In-home applications

Use of visible light communications
TP.vlc

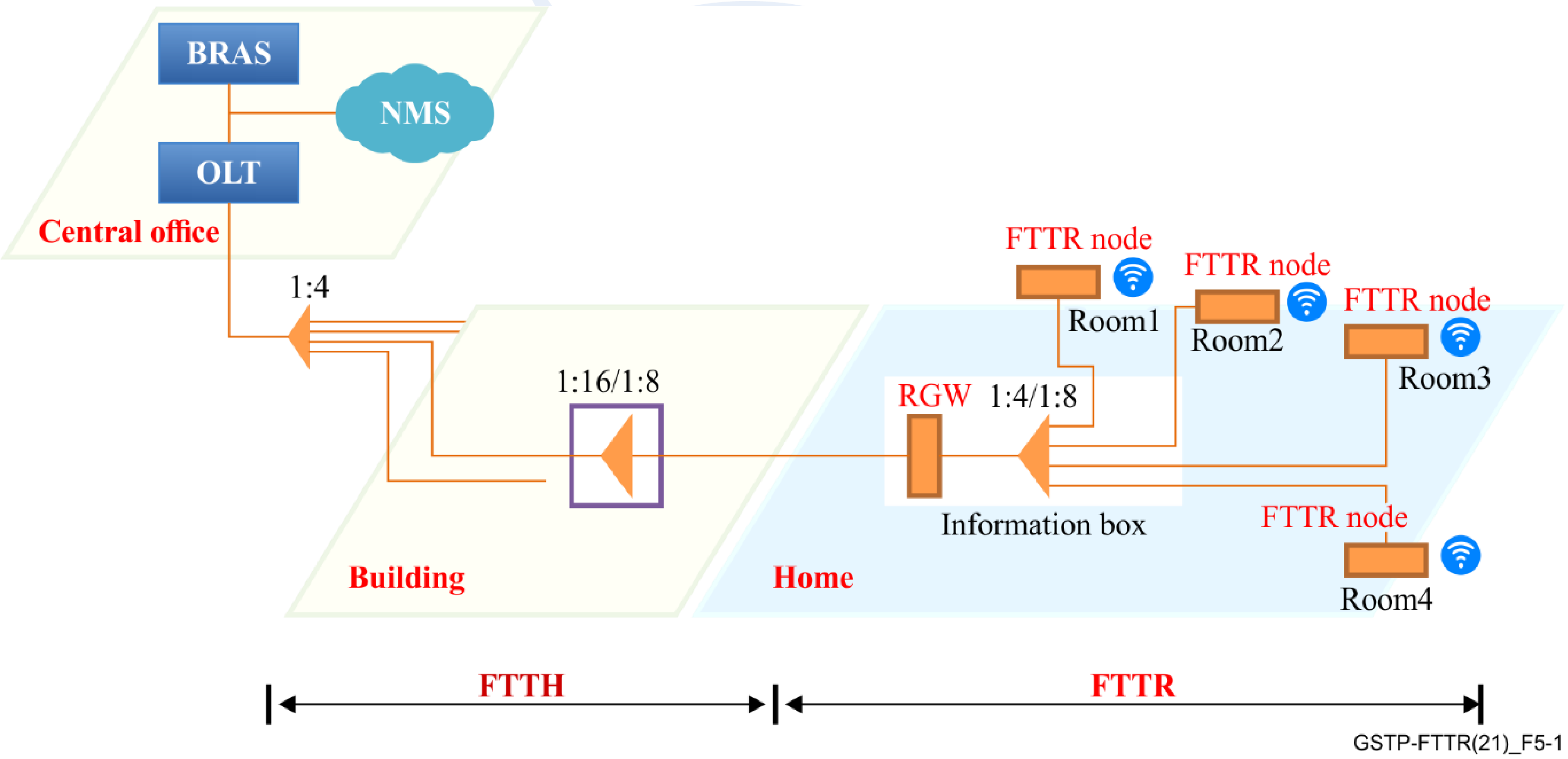
High-speed indoor visible light communication
G.9991

Indoor optical camera communication
G.9992

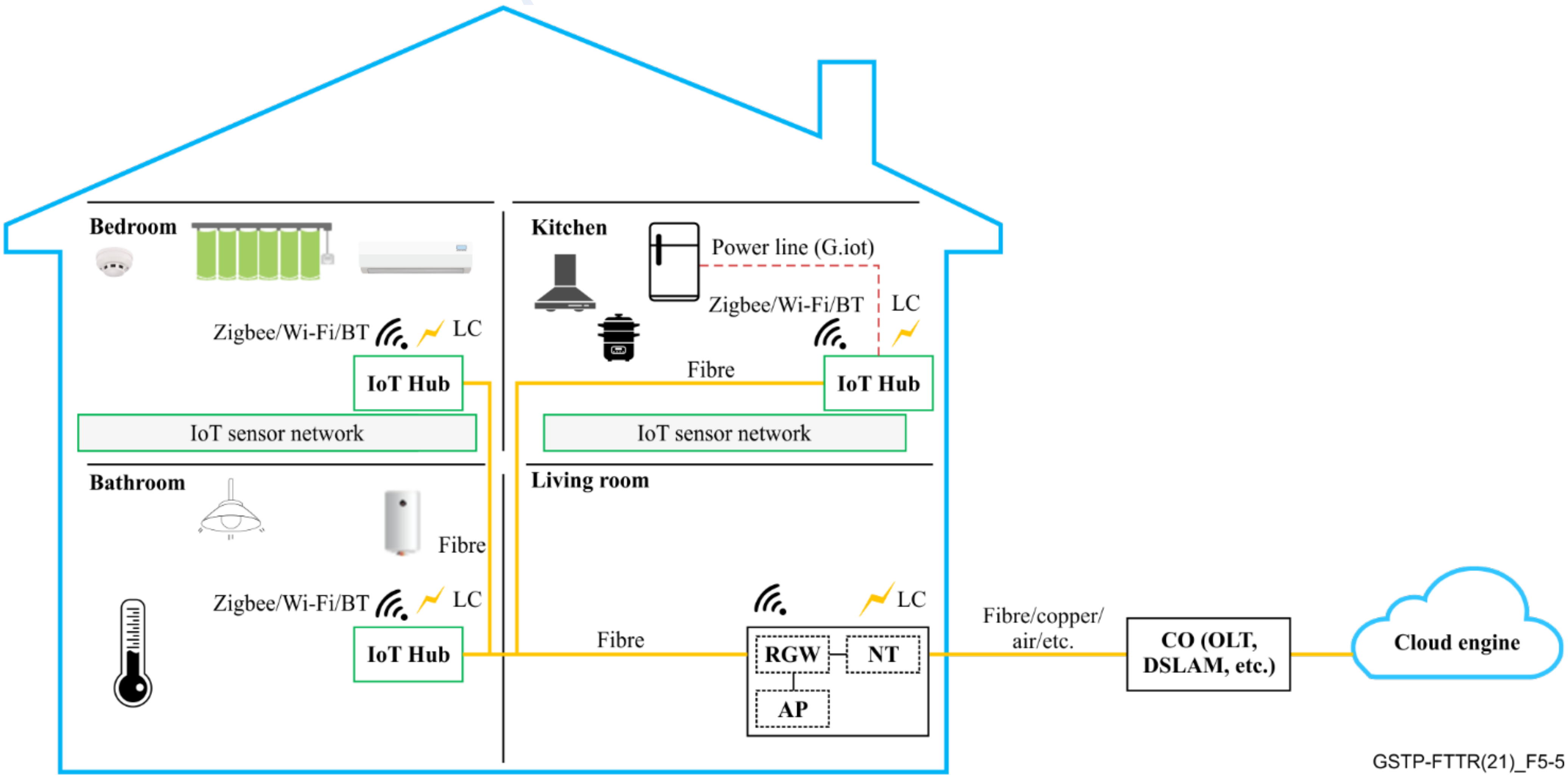
FTTR Use Cases
GSTR-FTTR

High Speed Fiber-based In-home networks
G.fin

Fibre-to-the-Room (FTTR)



Visible Light Communication



ITU-T SG15 Working Party 2:

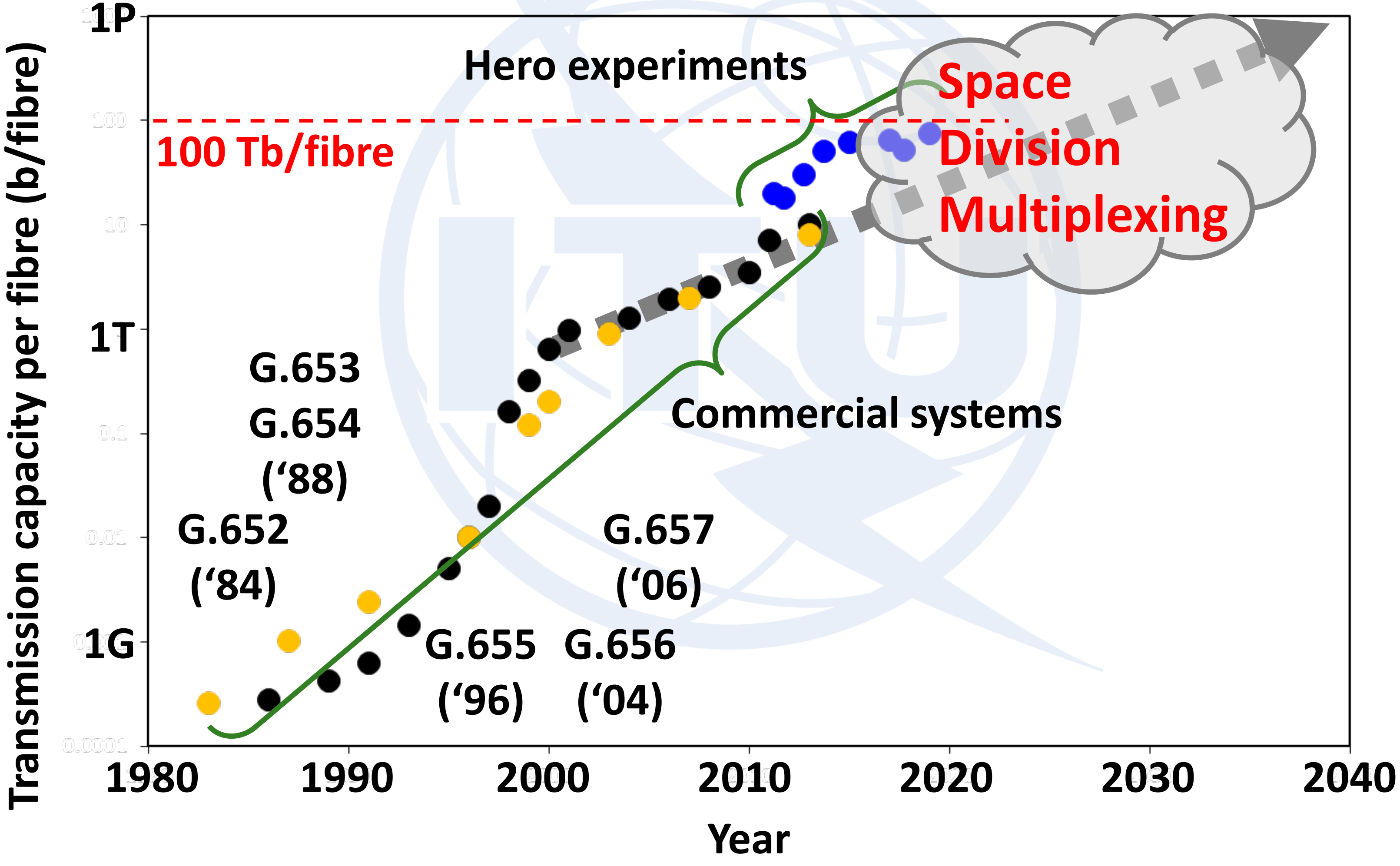
Optical technologies and physical infrastructure

Work program overview

Q5/15 - Characteristics and test methods of optical fibres and cables, and installation guidance

- Single-mode fibre Recommendations (G.652 and G.654)
- **Optical fibre, cable and components for space division multiplexing transmission (TR.sdm)**
- Characteristics of a bending-loss insensitive single-mode optical fibre and cable (G.657)
- **Optical/electrical hybrid cables for access points (L.oehc)**
- Optical fibre cables for duct and tunnel application (L.100)
- Optical fibre cables for in-home applications (L.111)
- Criteria for optical fibre cable installation with minimal existing infrastructure (L.163)

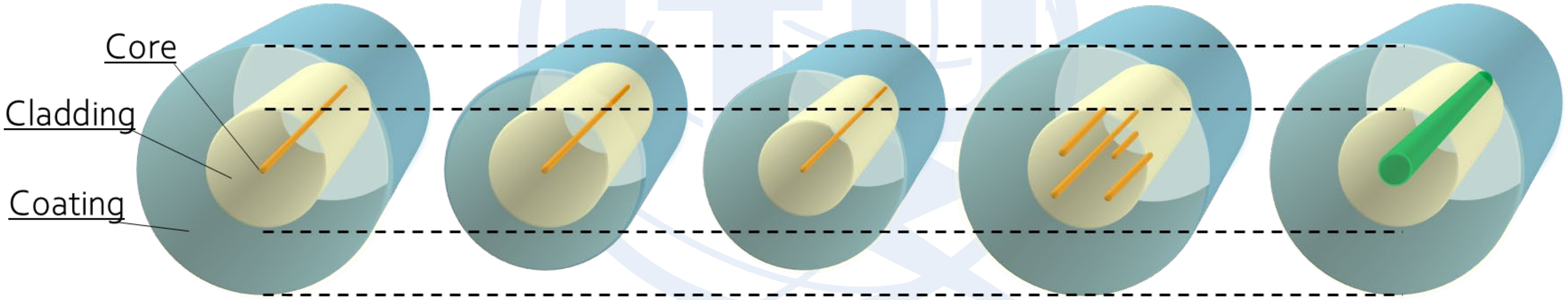
History of Optical Fibre Standards



What is SDM?

SDM Optical Fibre Cable can:

- **improve a spatial density of optical fibre in a unit cross section,**
- **increase the number of spatial transmission channels in a common cladding**

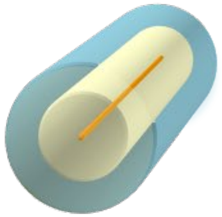
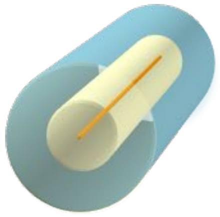
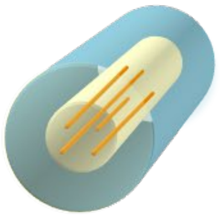
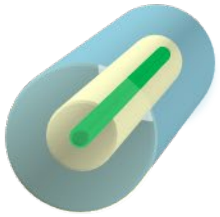


Traditional	Reduced Coating Diameter Fibre	Reduced Cladding Fibre	Multi Core Fibre	Few Mode Fibre

ITU SDM Technical Report Published

- SDM optical fibre and cable technology is expected to be a key enabler for realizing the full connected world in a sustainable manner
- ITU-T SG15 has just published a new technical report, GSTR-SDM, for SDM optical fibre and cable technology to analyse the technical status and to show the roadmap for future deployment and standardization
- First technical report on SDM published with industry concensus

SDM Advantages/disadvantages at a glance

	RCDF 	RCF 	MCF 	FMF 
Advantages	Fiber density, 125 µm cladding compatibility, No SDM components	Fiber density, compatibility, No SDM components	Increased core density in a limited cross-section, Can be designed to support compatibility with G.65x fibre	# of SDM channels in a 125 µm cladding diameter >> than MCF, Easier splicing/ connectorization than MCF
Disadvantages	May require better cable design and handling, Limited to <4X density	May require better cable design Adaptation required to 125 µm cladding, Limited to <4X density	125 µm cladding limits number of cores, Needs SDM components such as FIFO Connectorization and splicing more difficult	Needs advanced digital signal processing, Requires mode mux/demux

Q6/15 - Characteristics of optical components, subsystems and systems for optical transport networks

- Its scope encompasses all technologies needed to transmit, amplify and switch (at the physical layer) optical signals in communications networks that use optical fiber as propagation medium
- Q6/15 defines specifications for physical layer components and interfaces of single and multi-wavelength transmission systems

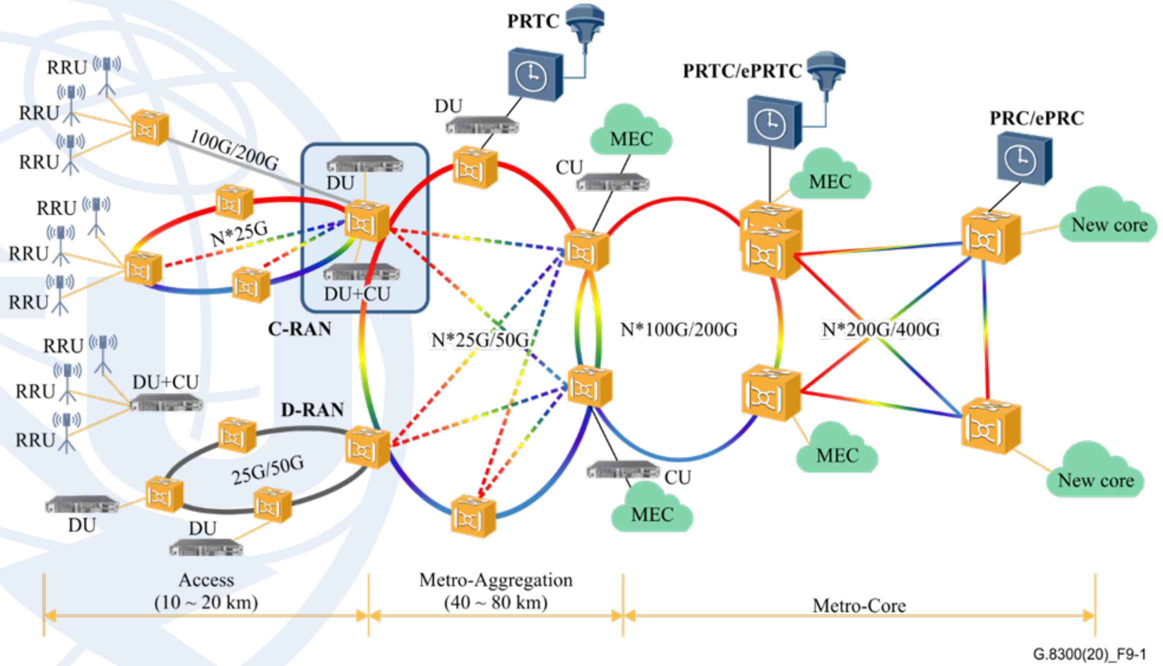
Optical components & 5G: a marriage of convenience

5G led to the introduction of a new "mobile transport network" segment, with its own peculiarities

- Short distances, as in access networks
- High capacity and multiple topologies, as in WANs
- New advanced features, such as self-configurable components and low latency transmission and switching.

What does it imply for optical components?

- Potential product volumes are high, as in datacom
- Target cost is low, as in access
- Required features are demanding, as in WAN



Example of mobile transport network topology, from ITU-T Recommendation G.8300

5G requires new optical components/interfaces, Q6/15 is standardizing interfaces targeted at 5G/NGON applications

Q6/15 5G/NGON related work

- Optical interfaces for 5G fronthaul and backhaul networks
  - 25G DWDM systems specified in G.698.1
  - Adding automation features (transmitter frequency self tuning): G.698.4
- New WDM systems in O band (Draft Recommendations G.0wdm and G.owdm2)
  - O band is around 1310 nm, C band (where traditional WDM system works) is around 1550 nm
  - O band systems offer lower cost and are mainly used for optical interconnects over short distances (100m-1 km) and fixed fiber access
  - The aim of these new system is to expand the capacity of optical fiber systems, exploiting the huge optical fiber bandwidth as efficiently as possible
- High speed optical transmission systems for WDM metro systems
  - WDM= wavelength division multiplexing, i.e., using different “colours” for different signals
  - Metro systems = distance of some hundreds of kilometers
  - 100G optical interfaces specified in G.698.2
  - Work in progress about 400G and 800G optical interfaces

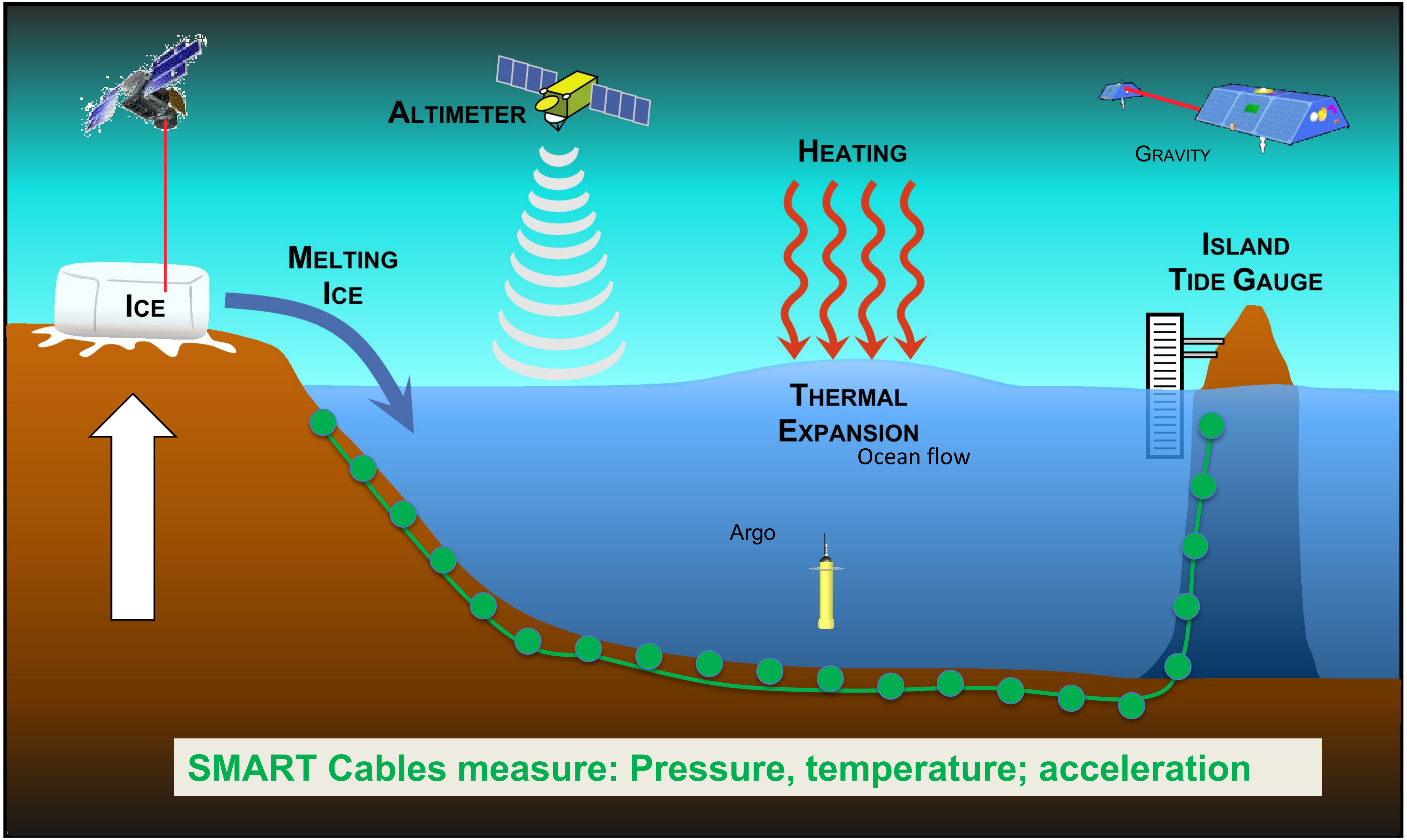
Q7/15 - Connectivity, Operation and Maintenance of optical physical infrastructures

- Telecommunication infrastructure facility management (L.330)
- Cable identification for the construction and maintenance of optical fibre cable networks with optical sensing technique(L.316)
- Maintenance of telecommunication underground facilities (L.340/L.74)
- Requirements for Passive Optical Nodes: nodes for customer indoor premises (L.ncip)
- Topologies for optical access network (L.250/L.90)

Q8/15 - Characteristics of optical fibre submarine cable systems

- Transverse compatible DWDM applications for repeatered optical fibre submarine cable systems (G.977.1)
- Dedicated Scientific Sensing Submarine cable system (G.dsssc)
- **Scientific Monitoring and Telecommunication Submarine Systems (G.smart)**

G.smart - SMART cable system



Adapted from Nerem, 2016

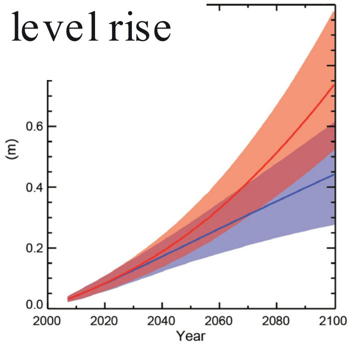
Societal Benefits

Climate change – humanity's greatest existential threat

Societal and environmental issues

UN Decade of Ocean Science

Sea level rise



Climate
SDG 13

– **Climate change** – ocean temperature, circulation direct impact on societies, short and long term

Ocean
SDG 14

– **Sea level rise** – hazard for coasts, islands, cities

Tsunami

UN
DRR

UN World Conference on Disaster Risk Reduction 2015 Sendai Japan

ISLAND VOICES GLOBAL CHOICES

– **Disaster Risk Reduction** – tsunami and earthquake monitoring throughout ocean basins and coastal margins

Infrastructure
SDG 9, 11

– **Societal Connectivity** – Enable progress with resilient and sustainable telecom infrastructure

ITU-T SG15 Working Party 3:

Transport Network Characteristics

Work program Overview

Hot topics in WP3/15

OTN beyond 400G

- 800G FlexO interfaces, including Ethernet-optimized interfaces
- 800GE client mappings

Fine-Grained OTN (fgOTN) and Fine-Grained MTN (fgMTN)

- Sub-1G
- Service-awareness

Synchronization

- PTP telecom profile evolution
- Timestamping accuracy of optical modules
- Network resilience and monitoring

Management and control

- Management of optical media and synchronization

FlexO enhancements for 800G (Q11, Q12)

- Definition of FlexO with 800G physical interfaces (FlexO-8)
  - Extends existing FlexO frame format for use with OTUC8 clients
- Definition of Ethernet-optimized 800G interfaces (FlexO-8e) for point-to-point applications
  - Reduces FlexO-8 bit rate for 800GE client (aligned with OIF 800ZR rate)
  - Supports GMP mapping of 100G, 200G, 400G, and 800G Ethernet directly to the FlexO-8e frame
- FEC frames for both FlexO-8 and FlexO-8e will be defined later (December 2023)
  - FlexO Recommendations will be reorganized to separate common aspects from FEC frame-specific aspects
- Additional enhancements to support regeneration applications are under study

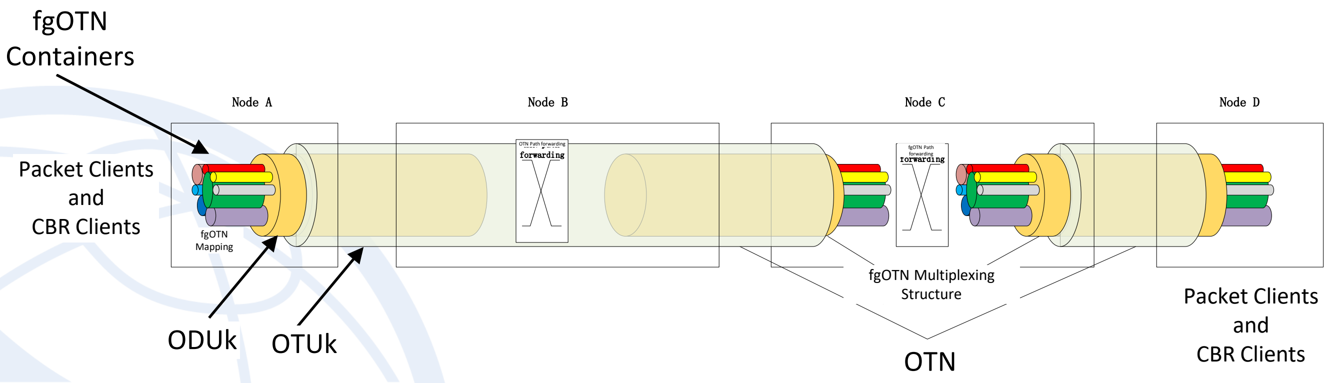
Aligns FlexO Recommendations with 800G extensions that have been done in other organizations

800GE client mappings to OTN (Q11)

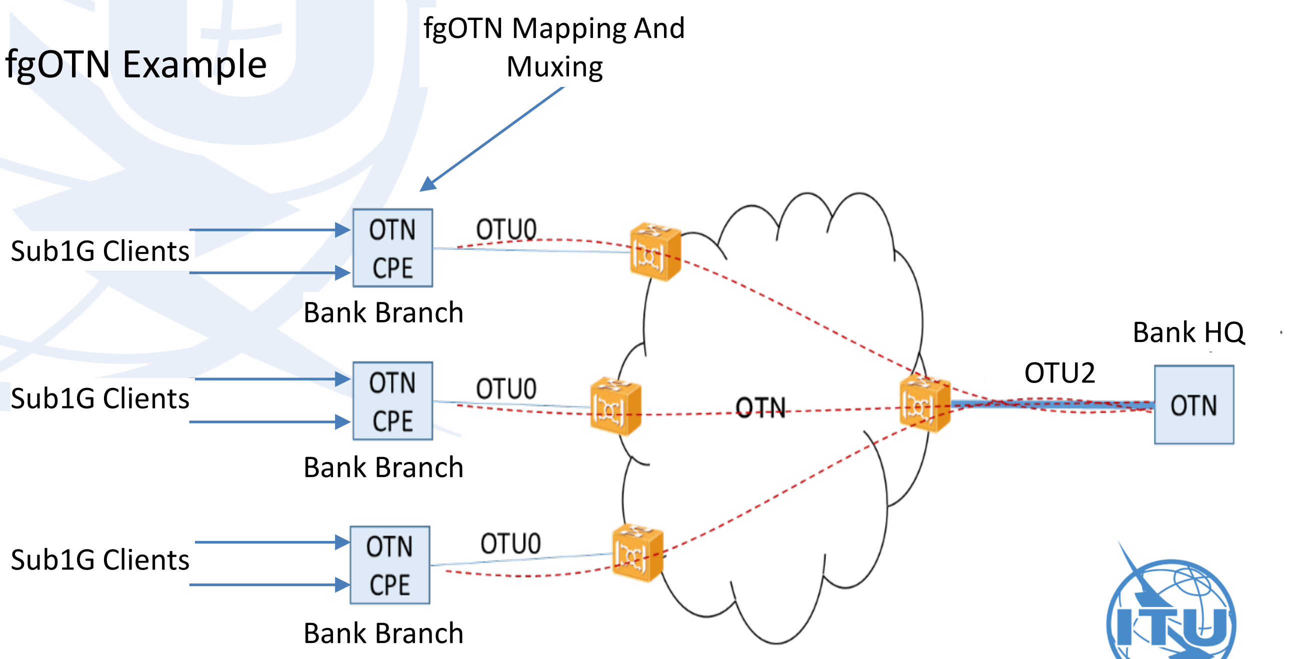
- IEEE P802.3df has defined a reference point for mapping 800GBASE-R to OTN
- Q11 will define two mappings:
  - Mapping to ODUflex, supporting full OTN networking applications
  - Mapping to FlexO-8e, supporting point-to-point applications
- Similar new mappings will be needed for 1.6T Ethernet being developed in IEEE P802.3dj

Fine Grain OTN (fgOTN)

- Target Consent November 2023
- Reuses ODU like Frame structure (4 by 3824 bytes)
- Reuses ODU OAM
  - Additional OH to satisfy the OAM repetition rate
    - Extra 16 columns OH
  - Two layers of Tandem connection (TCM)
- Support Sub 1G CBR and Packet mapping
  - CBR is timing transparent
  - no need for low pass filters in intermediate nodes -> simplifying cross connection
  - Current CBR clients are SDH and PDH
  - Current packet clients are Ethernet packets
- Support Single Step Hitless resizing



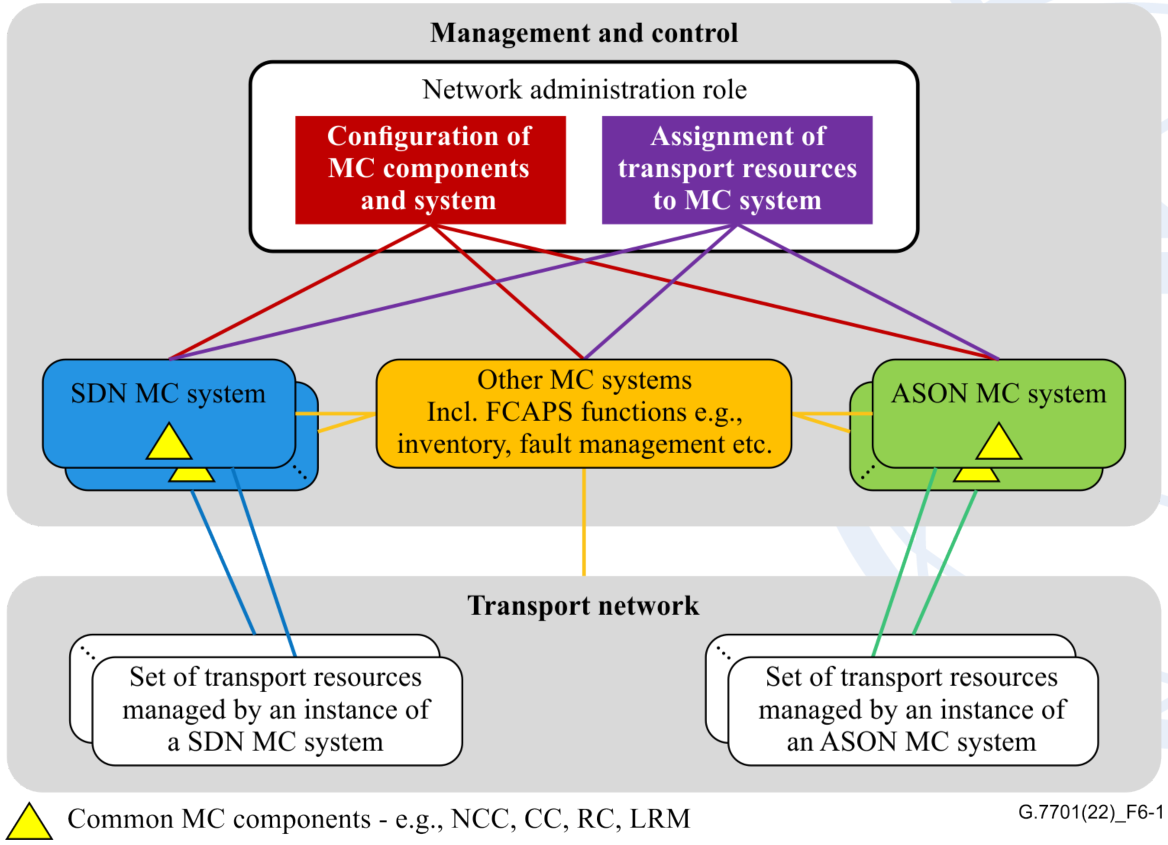
fgOTN Example



Synchronization (Q13)

- Evolution of the Precision Time Protocol (PTP) Telecom profiles (e.g., management, security, robustness)
- Synchronization network performance monitoring
- Synchronization network resiliency (e.g., against loss of GNSS)
  - ePRTC holdover enhancements (1 month)
  - “cnPRTC” (network of PRTCs)
- Timestamping accuracy of optical modules
  - Addresses fronthaul network needs

Management and control (Q12, Q14)



- Development of generic management/control architecture
- Specification of management requirements and information models for the optical media layer
  - Includes management of amplifiers, ROADMs, etc.
  - The management information models are specified through pruning/refactoring the common core information model and extended with technology-specific properties
- Specification of management requirements and information models for synchronization

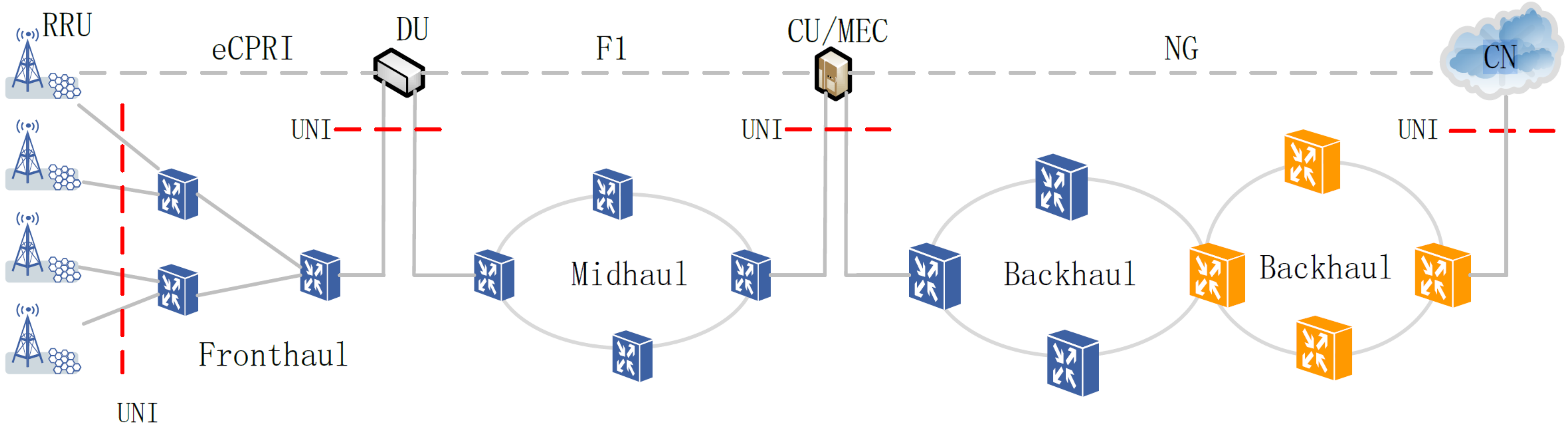
WP3/15 Recommendations related to optical transport networks

Topic	Common	OTN	Media	Transport Ethernet	Sync
Transport Architecture	G.800, G.805	G.872	G.807	G.8010	G.826x G.827x
Interfaces	-	G.709 G.709.x	G.698.x	G.8012 G.8013	G.703 G.8271
Protection	G.808.x	G.873.x	-	G.803x	-
Equipment	G.806	G.798	-	G.8021 G.8023	G.781 G.781.1
DCN	G.7712	G.7712	-	G.7712	-
Management and Control Architecture	G.770x	-	-	-	-
Management Requirements	G.7710 G.7716 G.7718	G.874	G.876	G.8051	G.7721
Management Info Model	G.7711 G.7719	G.875	G.876	G.8052 G.8052.x	G.7721 G.7721.1

ITU-T SG15 Relationship to 5G

5G Transport: High-level 5G architecture

Example:Transport network architecture for Independent CU and DU deployment



GSTR-TN5G: Transport network support of IMT-2020/5G, February 2018

5G Transport: Requirements

Interface	Capacity Requirement	Latency
Fronthaul	See below	< 100 µsec
F1	DL 4016 Mb/s; UL 3024 Mb/s	1.5 ~10 msec
NG	100+Gb/s for Core Network	Service dependent

Fronthaul Capacity

Number of Antenna Ports	Radio Channel Bandwidth			
	10 MHz	**20 MHz**	**200 MHz**	**1GHz**
2	1 Gbps	2 Gbps	20 Gbps	100 Gbps
8	4 Gbps	8 Gbps	80 Gbps	400 Gbps
64	32 Gbps	64 Gbps	640 Gbps	3,200 Gbps
256	128 Gbps	256 Gbps	2,560 Gbps	12,800 Gbps

Reach

Fronthaul	1~20km
Midhaul	20~40km
Backhaul	1~10km Aggregation: 5-80km Core: 20~300km

GSTR-TN5G: Transport network support of IMT-2020/5G, February 2018

5G Transport support for 5G features

- Support for 5G Slicing
- Managment and Control System coordination
- Multi-Service Support
- Flexibility for various 5G deployment options

Summary of 5G Transport

Cooperative PON DBA
and 5G mobile in a PON context

**5G small cell backhaul/
midhaul over TDM-PON**

Network slicing in a PON context

Application of OTN to
5G transport

Metro transport network (MTN)
for 5G optimized transport

WDM for
5G transport

Time Synchronization
(Packet and OTN)

Transport and synchronization
for 5G mobile xHaul

Core Information model
enhancement for management of
synchronization and optical media

For more information see: LS/r ITU-T SG15 reply to JCA IMT2020, "Information from ITU-T SG15 on its IMT-2020 and beyond related activities"

ITU-T SG15 Collaborations and Conclusions

Collaboration with other organizations

SDO	Related SG15 Questions	Topics
BBF	Q2, Q3, Q4, Q14	G.fast, MGfast, xDSL and PON, YANG
CENELEC TC86A & TC86BXA	Q5, Q7	Optical fibers and cables, optical connectors & passive components
ETSI ISG F5G	Q2, Q3, Q11	PON, Fiber to the Room (FTTR), Transport Architectures
IEC TC86 - SC86A	Q5	Optical Fibers and cables
IEC TC86 - SC86B	Q7, Q5	Optical connectors & passive components
IEEE 802.1	Q10, Q12, Q13, Q14	VLAN Bridging, OAM/CFM, Synchronization, Time Sensitive Network (TSN), Information modeling Issues, YANG
IEEE 802.3	Q2, Q6, Q11, Q12, Q14	OTN mappings for Ethernet, Optical characteristics of Ethernet modules used for OTN, PON, Information modeling Issues, YANG
IEEE 1588	Q13, Q14	Time Synchronization, Synchronization Management
FSAN	Q2	PON
MEF	Q10, Q11, Q14	Ethernet Services, OTN & Wavelength services, LSO
OIF Networking, IETF (CCAMP, TEAS, PCE), ONF	Q12, Q14	Optical Control Plane, SDN, Information modeling Issues, YANG
OIF PLL	Q6, Q11	Flex Ethernet, 400ZR, 800ZR

Conclusions

✓ Leading development of

Optical Transport Networks

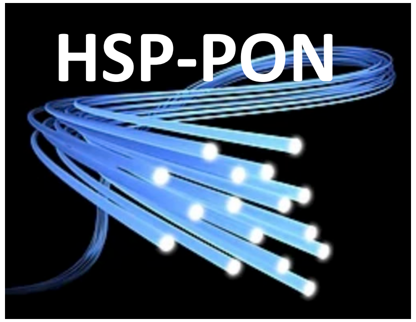
ACCESS NETWORK

Home Networking

✓ The LARGEST and MOST PRODUCTIVE group in ITU-T with broad, global industry participation

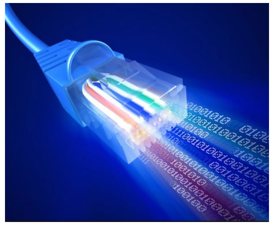
✓ Highlights include:

Home Networking



Broadband access

High Speed Access



Transport Technologies

The Optical Transport Network

Thanks

Questions?