

---

# Standardization of Broadband Optical Access Network

June 20, 2007

NTT Access Network Service Systems Laboratories

Kenji Nakanishi

nakanisi@ansl.ntt.co.jp

---

# **1. International standardization bodies**

## **2. Standardized PON systems**

### **3. B-PON: ITU-T G.983 series**

### **4. G-PON: ITU-T G.984 series**

### **5. E-PON: IEEE802.3EFM**

## **6. Other optical access systems**

# Aim of international standardization

**Unified international standardization,  
such as ITU-T Recommendations**

Multi-vendor  
inter-operability

For operators

Operators can purchase  
devices from any vendors  
> Reducing investment

Multi-operator  
common spec.

For vendors

Vendors can sell devices to  
any operators  
> Reducing development risk

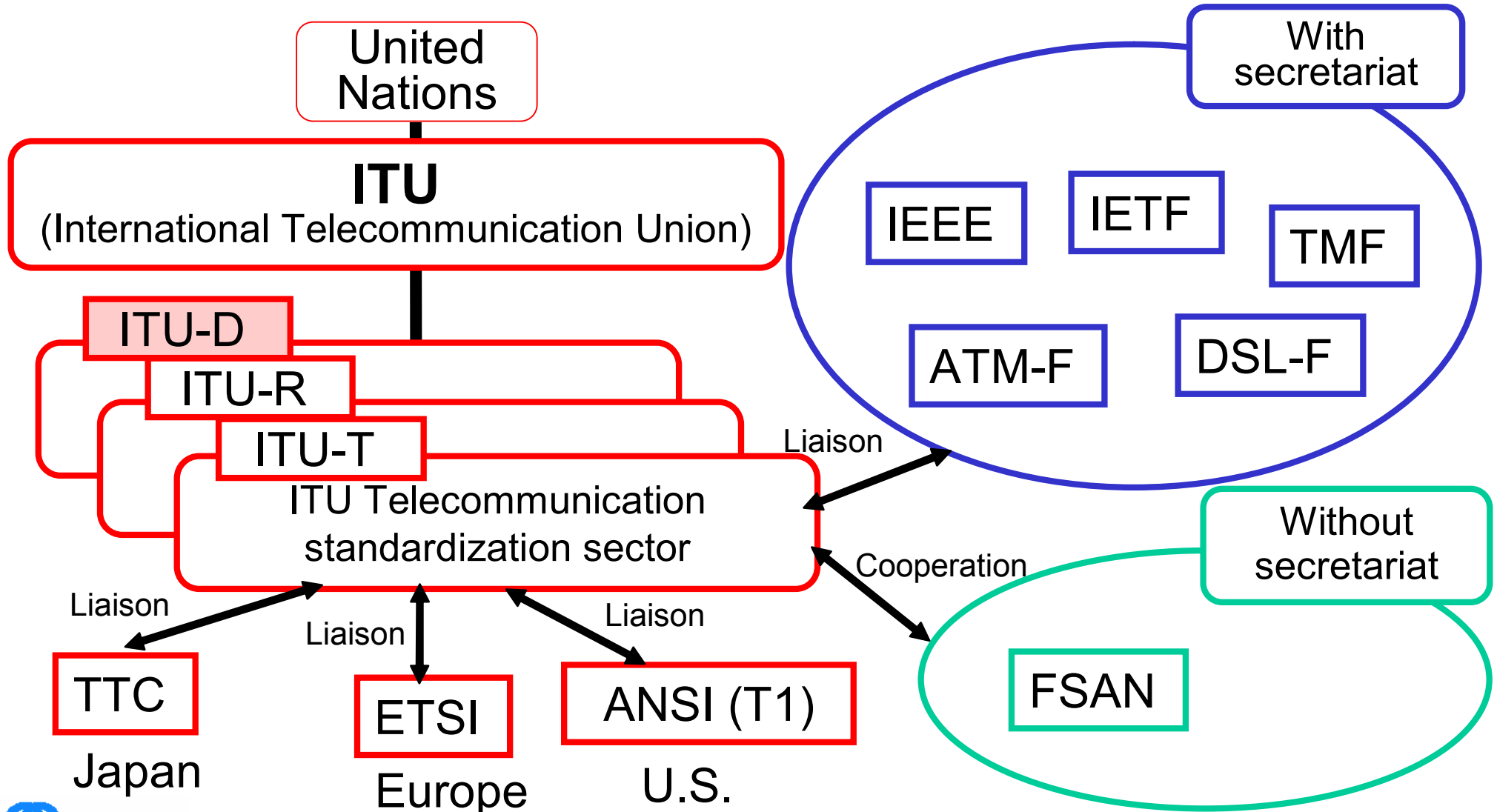
**Cost reduction in worldwide scale**

- Sharing development resources (Launched with small capital)
- Globalizing the market (Low-cost and matured technology)

# International standardization bodies

## Public organizations

## Private organizations



# Activity of ITU-D

- ITU-D aims at achieving the sector member's objectives through access to infrastructure and information and communication services.
- The detail is shown at <http://www.itu.int/net/ITU-D/index.aspx>

## Focusing issues on ITU-D

### -Partnership Portal

Help connect the unconnected

### -Emergency Telecommunications

Telecommunications provide the necessary medium and link to mitigate disasters irrespective of their nature.

### -The ICT-eye website

A one stop shop for ICT information

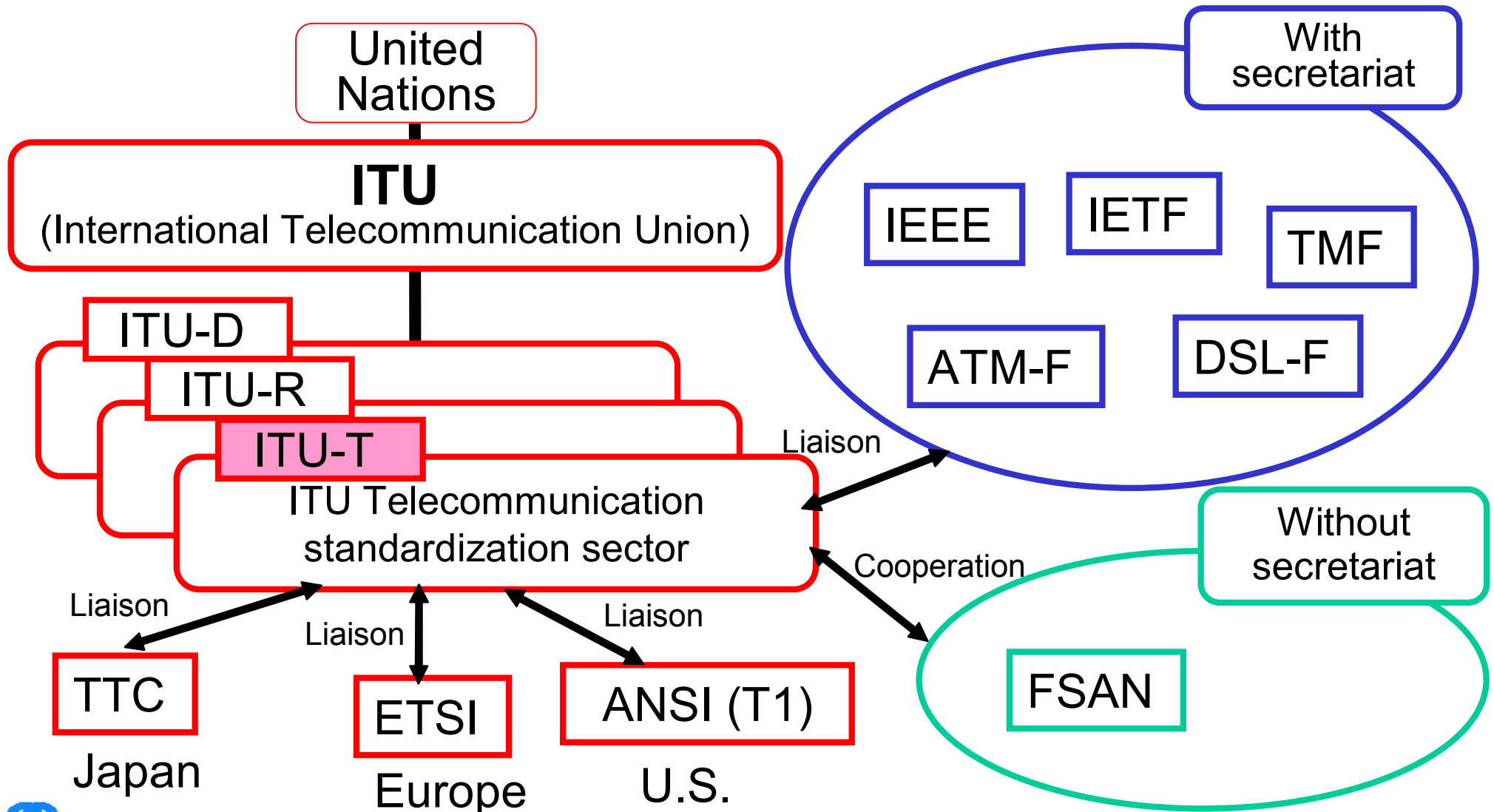
### -Cyber-security

Building confidence and security in the use of ICTs

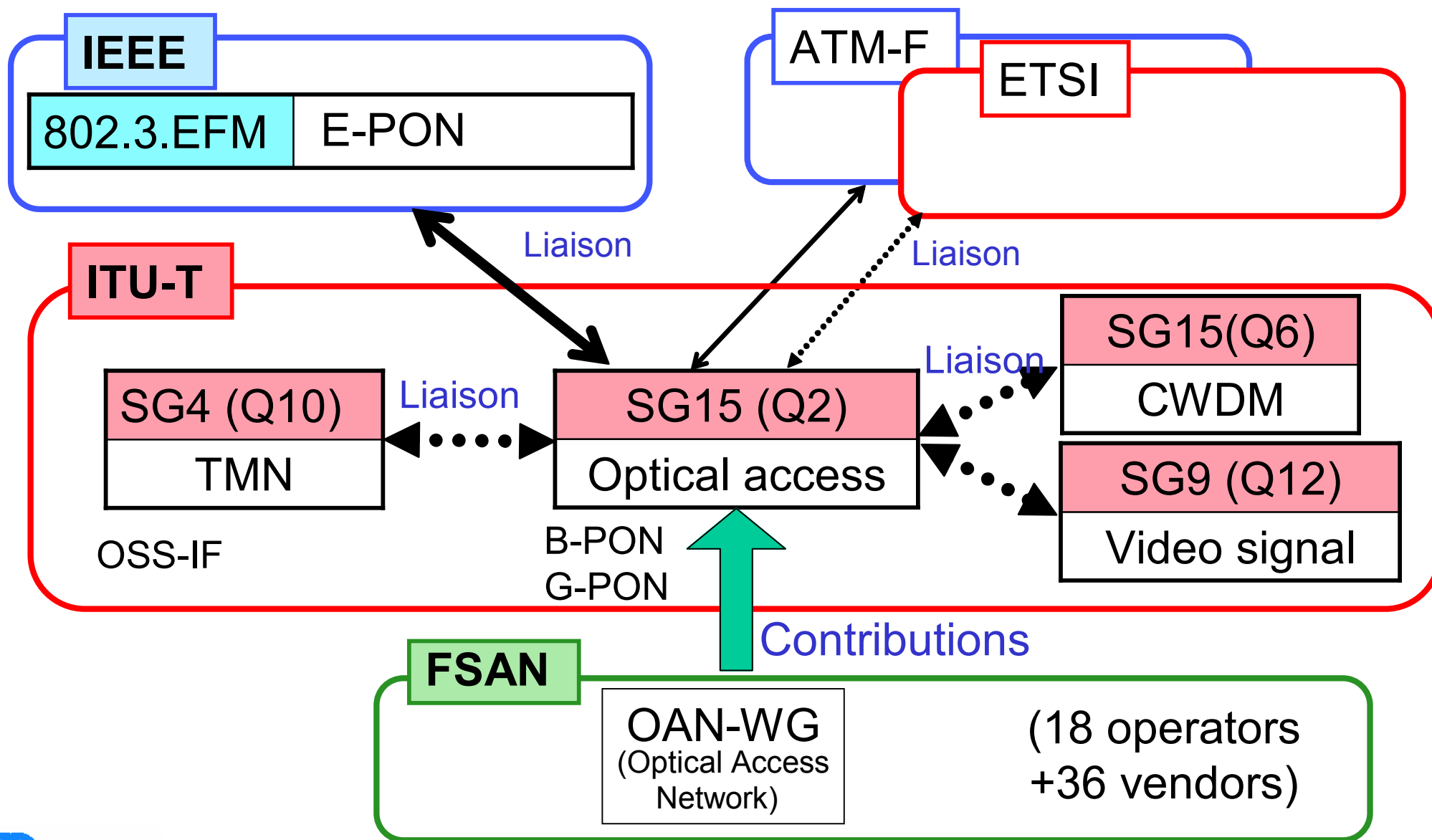
# International standardization bodies

Public organizations

Private organizations

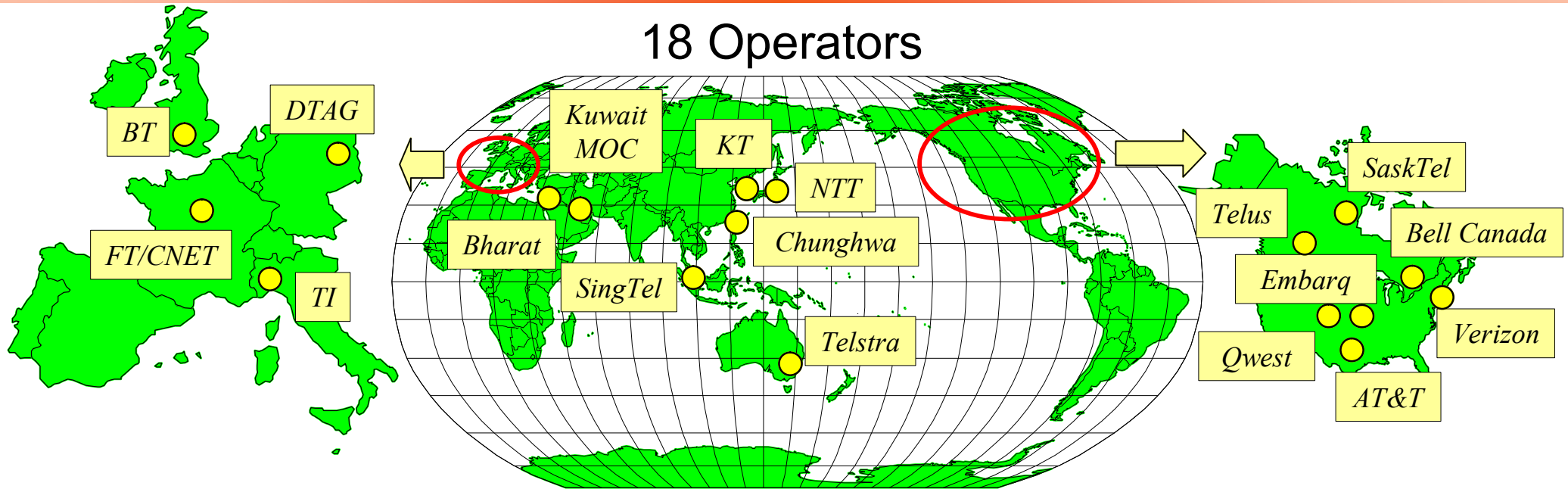


# Organization related to PON standardization



# FSAN Members

## 18 Operators



## 36 Vendors

Adtran	Alcatel-Lucent	Alphion	AMCC	BroadLight	Calix	Cambridge	
Conexant	ECI Telecom	Ericsson	FlexLight	Freescall	Fujitsu	Hitachi	
Huawei	Iamba	Infineon	iPhotonics/TXP	LG Electronics	Maxim/Dallas	Mitsubishi	
LS Cable	Motorola	NEC	Nortel	Novera Optics	OKI	Optical Zonu	
PMC Sierra	Samsung	Siemens	Tellabs	Terawave	Vitesse	Zarlink	ZTE

## 6 Observers

ETRI	ICL/ITRI	KTL	NTS	NTT-AT	Telcordia
------	----------	-----	-----	--------	-----------



---

**1. International standardization bodies**

**2. Standardized PON systems**

**3. B-PON: ITU-T G.983 series**

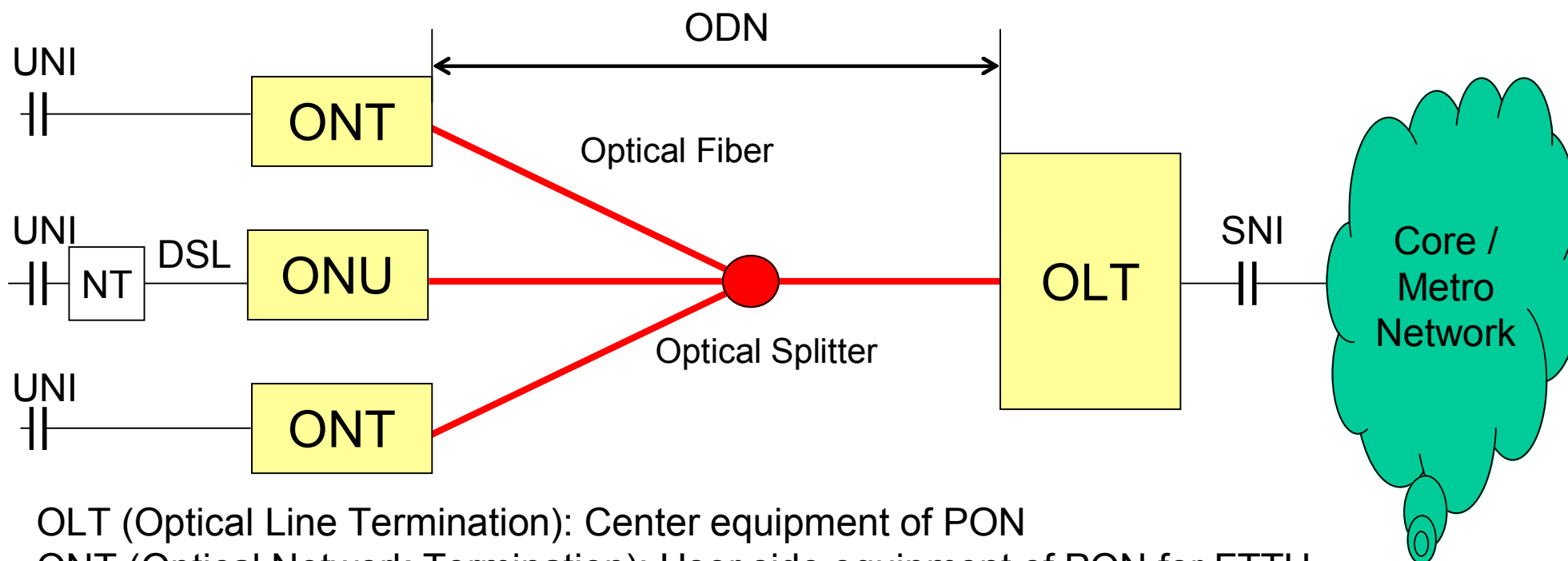
**4. G-PON: ITU-T G.984 series**

**5. E-PON: IEEE802.3EFM**

**6. Other optical access systems**

# PON configuration outline

- PON (Passive Optical Network) is the most popular solution for optical broadband access systems.



OLT (Optical Line Termination): Center equipment of PON

ONT (Optical Network Termination): User side equipment of PON for FTTH

ONU (Optical Network Unit): User side equipment of PON for FTTC

ODN (Optical Distribution Network): Transmission network between OLT and ONTs/ONUs

UNI: User Network Interface

SNI: Service Node Interface

# Standardization bodies for PONs

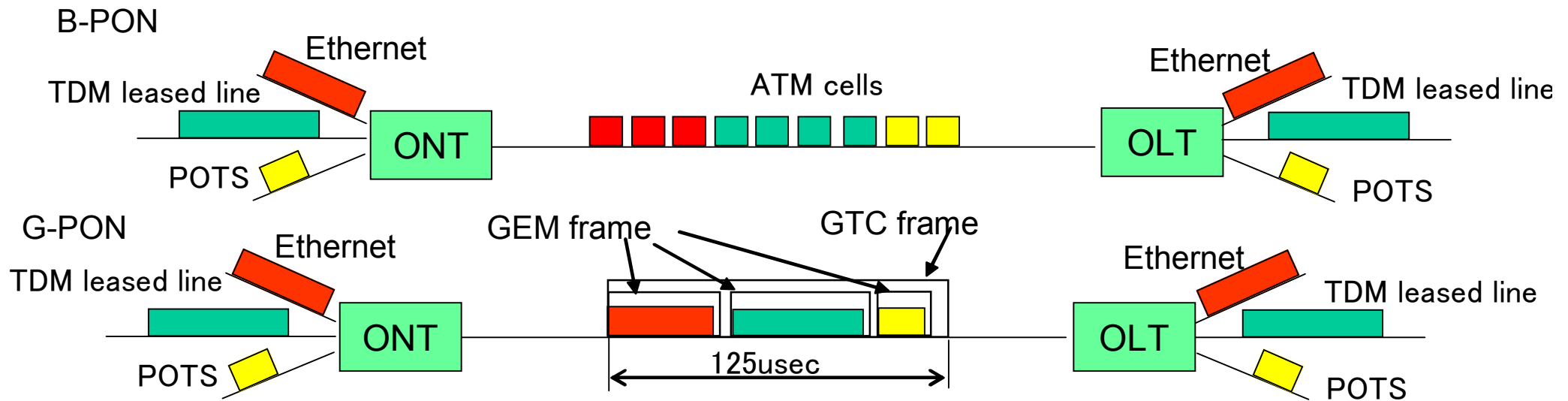
- Three PONs are standardized internationally by ITU-T and IEEE

PON	Outline	Standardization bodies
B-PON Broadband PON	155~622Mb/s <b>ATM</b> cells Asymmetric for up/down	ITU-T FSAN
G-PON Gigabit-capable PON	<b>GEM</b> frame for 155~2488Mb/s Asymmetric for up/down	ITU-T FSAN
IEEE E-PON Ethernet PON	1250Mb/s <b>Ethernet</b> frame Same bandwidth for up/down	IEEE802.3EFM
E-PON	100~600Mb/s <b>Ethernet</b> frame	N.A.

Note: IEEE E-PON is called GE-PON in Japan.

# Schematics of PON frames

- B-PON divides any signals into ATM cells.
- G-PON packs each signal to a GEM frame whose length is variable. GTC frames includes GEM frames and is synchronized to 8kHz clock.
- E-PON transmits Ethernet information by Ethernet frames.



GEM: G-PON Encapsulation Method    GTC: G-PON Transmission Convergence

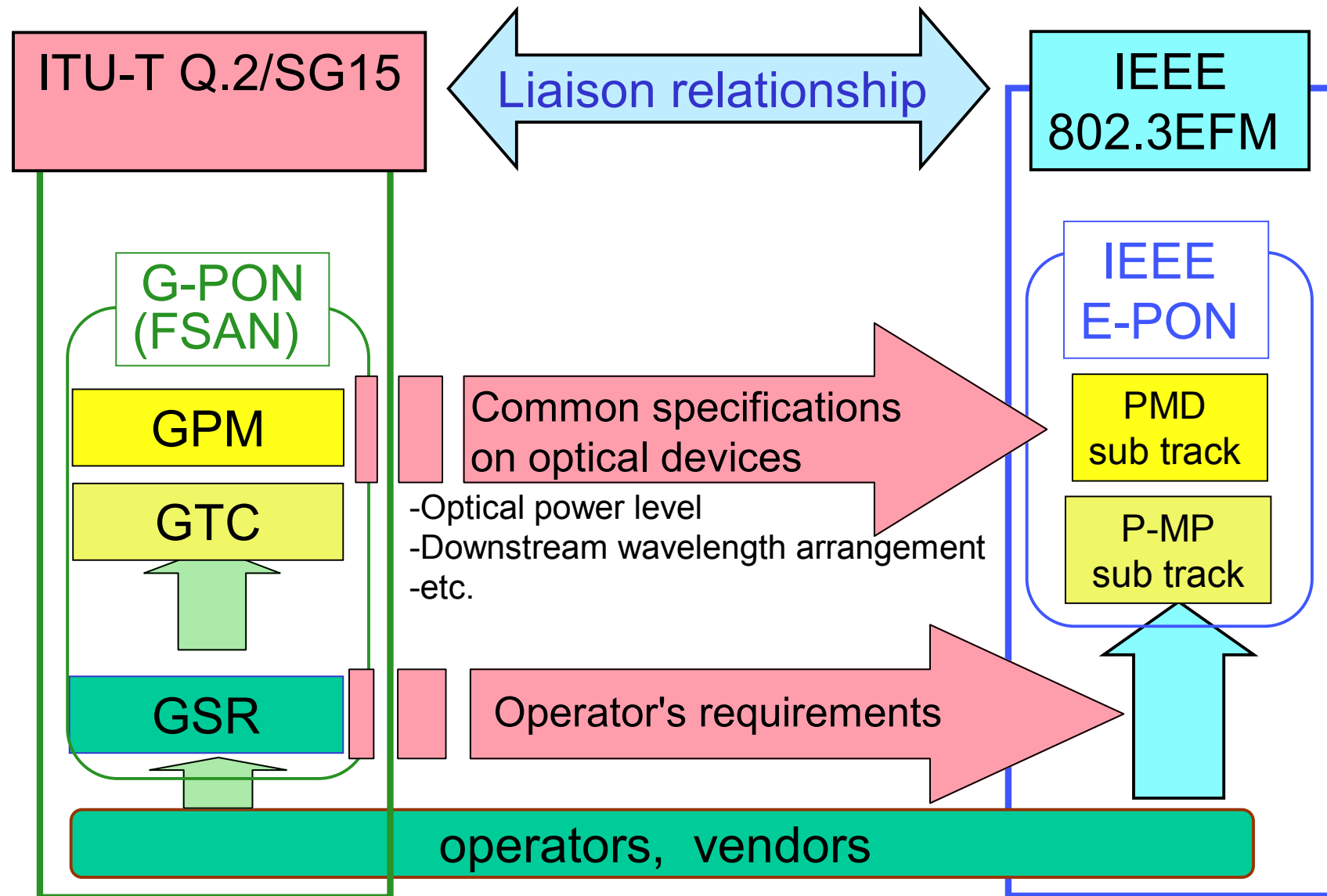
E-PON (IEEE)  
Ethernet



# Comparison between B/G/E-PON

Items	B-PON	G-PON	IEEE E-PON
Bit rate	Up & Down : 155, 622 Mbit/s, Down only: 1.24 Gbit/s	Up & Down : 1.24, 2.48 Gb/s Up only: 155, 622 Mbit/s	Up and Down : 1.25Gb/s (1Gb/s after decoding)
Distance	Max. 20 km	Max. 60km	Max. 20km
Loss budget	10-25 / 10-28 / 15-30 dB	5-20 / 10-25 / 13-28/ 15-30 dB	5-21 / 10-26 dB
Branches	Max. 64	Max. 254	Max. over 16
PON header for upstream	Guard : 4 bits Preamble : 12 bits Delimiter : 8 bits Independent on bit rate	Guard : 25.7ns Preamble : 35.4ns Delimiter : 16.1ns Example for 1.24 Gb/s	Laser on / off : 512ns AGC, CDR setting : 400ns
Cipher	Churn or AES (Down)	AES (Down)	Option
Protocol	ATM Cell	GEM frame	Ethernet frame
DBA	Based on G.983.4	Based on G.984.3	Option
Services	Full services (Ethernet, TDM, POTS)	Full services (Ethernet, TDM, POTS)	Ethernet services
Error Correction	N.A.	FEC (Optional)	FEC (Optional)

# Relation between ITU-T and IEEE in PON



---

1. International standardization bodies

2. Standardized PON systems

**3. B-PON: ITU-T G.983 series**

4. G-PON: ITU-T G.984 series

5. E-PON: IEEE802.3EFM

6. Other optical access systems

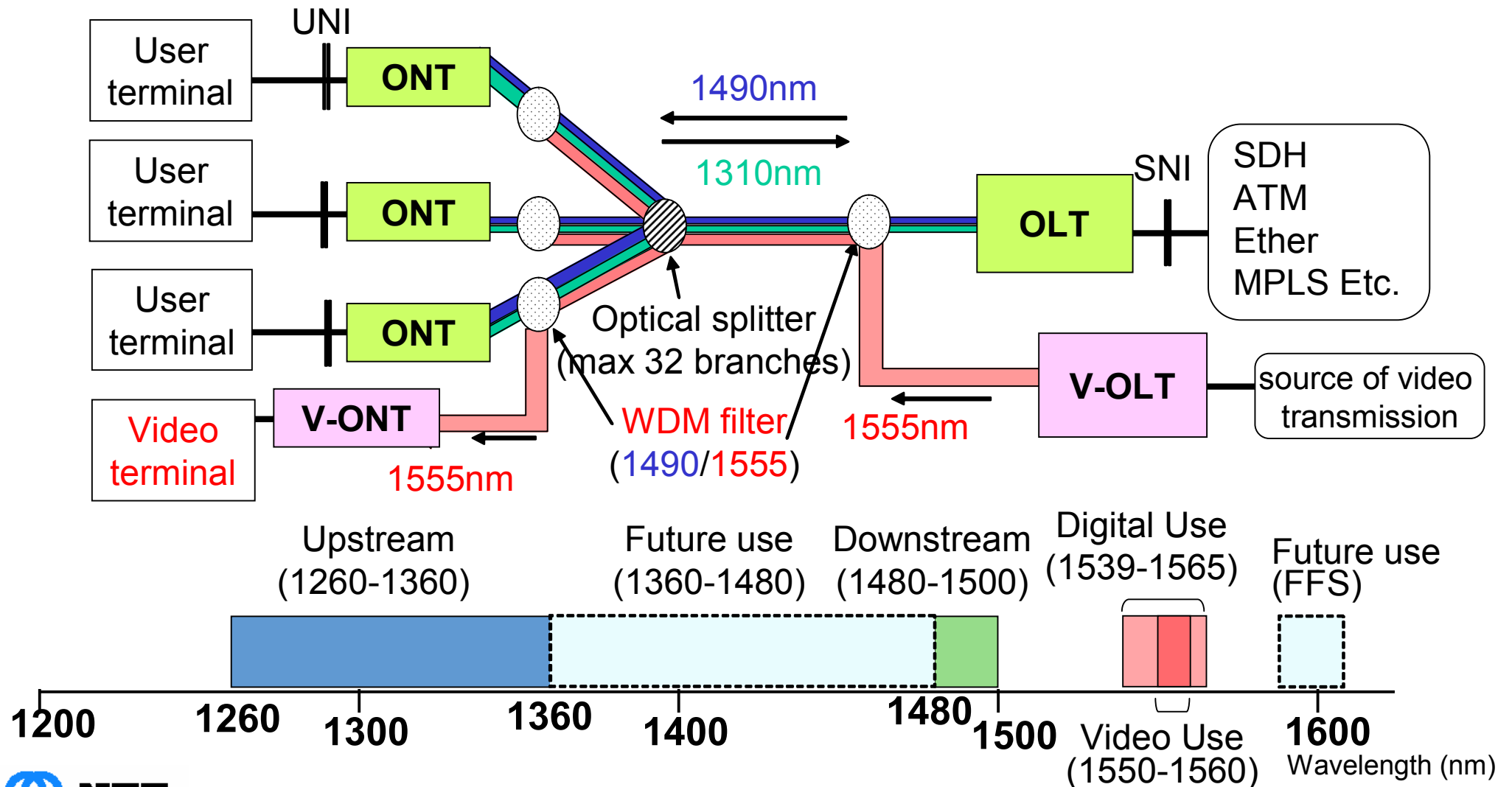
# B-PON Recommendations (G. 983 series)

No.	Outline	Approval date
G.983.1	Physical interface regulation between OLT-ONT A new ODN class B+ is defined.	Oct. 1998 Jan.2005 Revision May 2005 Amd1
G.983.2	Regulation on OLT-ONT management control interface (OMCI) Revision upon and clerical errors supplement.	Apr. 2000 May 2005 Revision
G.983.3	Regulation of wavelength arrangement on multiplex B-PON and video signals	Apr. 2001 Jul. 2002 Amd1
G.983.4	Regulation of Dynamic Bandwidth Assignment (DBA) on upstream signals	Dec. 2001
G.983.5	Regulation on survivability (SUR) between OLT-ONT	Jan. 2002



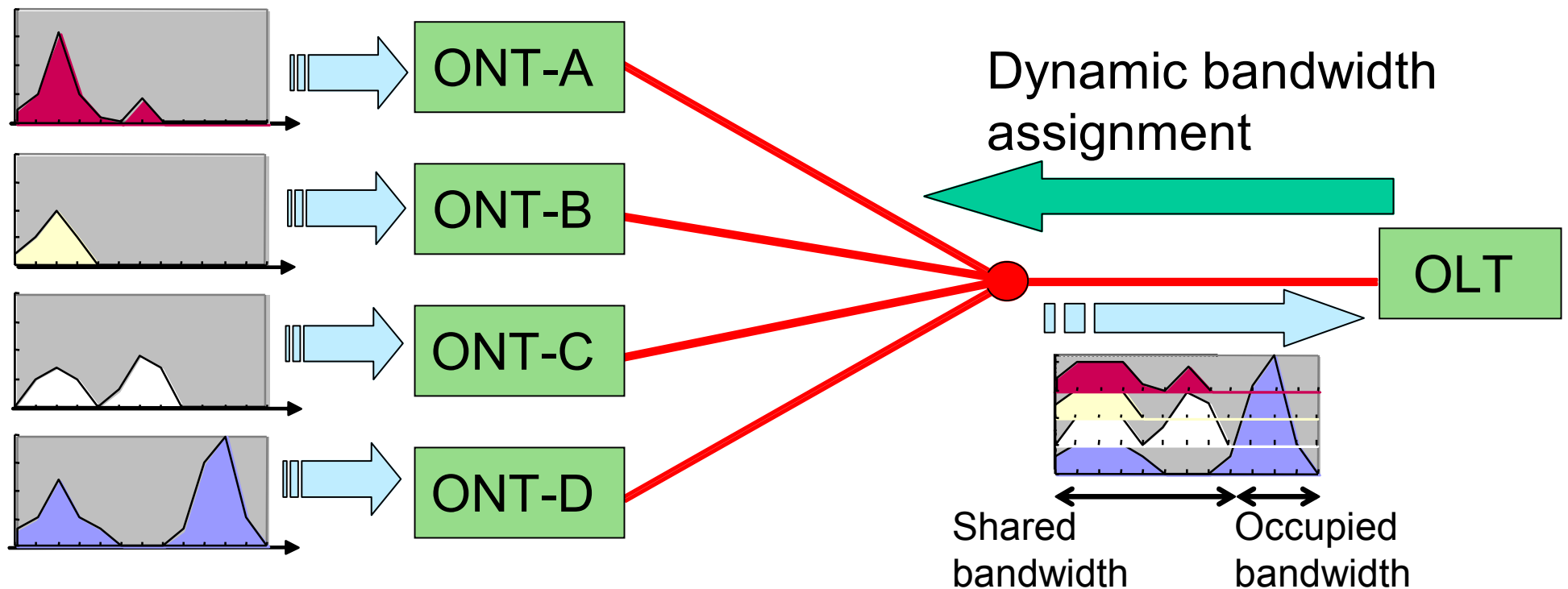
# Example of 3 wave multiplex on B-PON

The WDM filter for video signal multiplexing is added between OLT-ONT.



# DBA function (G. 983.4)

- It is an important issue to keep fairness among the users.
- OLT can allocate downstream bandwidth directly, and manage upstream bandwidth using DBA.



---

**1. International standardization bodies**

**2. Standardized PON systems**

**3. B-PON: ITU-T G.983 series**

**4. G-PON: ITU-T G.984 series**

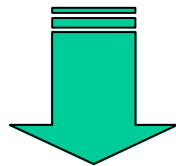
**5. E-PON: IEEE802.3EFM**

**6. Other optical access systems**

# From B-PON to the gigabit class PONs

## Issues on B-PON

- Bandwidth shortage on accommodating GbE or IP-TV in UNI.
- AAL5 accommodate Ethernet packets inefficiently.
- High cost of interface card because of un-spread of the full specification ATM
- Reduction on role of ATM in core system



## Expectation for gigabit class PON which has a new frame

FSAN&ITU-T: Aim to accommodate full service by using a generic frame.

→ G-PON

IEEE802.3EFM: Aim to cost reduction by using Ether frame.

→ E-PON

# B-PON and G-PON Recommendations

G-PON completes its specifications as useful as B-PON

## B-PON Recommendations

G.983.1 (Basic)

G.983.2 (OMCI)

G.983.3 (Wavelength allocation)

G.983.4 (DBA)

G.983.5 (SUR)

## G-PON Recommendations

G.984.1 (requirements)

G.984.2 (Physical layer)

G.984.3 (TC layer)

G.984.4 (OMCI)

G.984.5 (Enhancement band)

Solid lines show approved Recommendations in G-PON

Broken lines show planned Recommendations in G-PON

# G-PON Recommendations

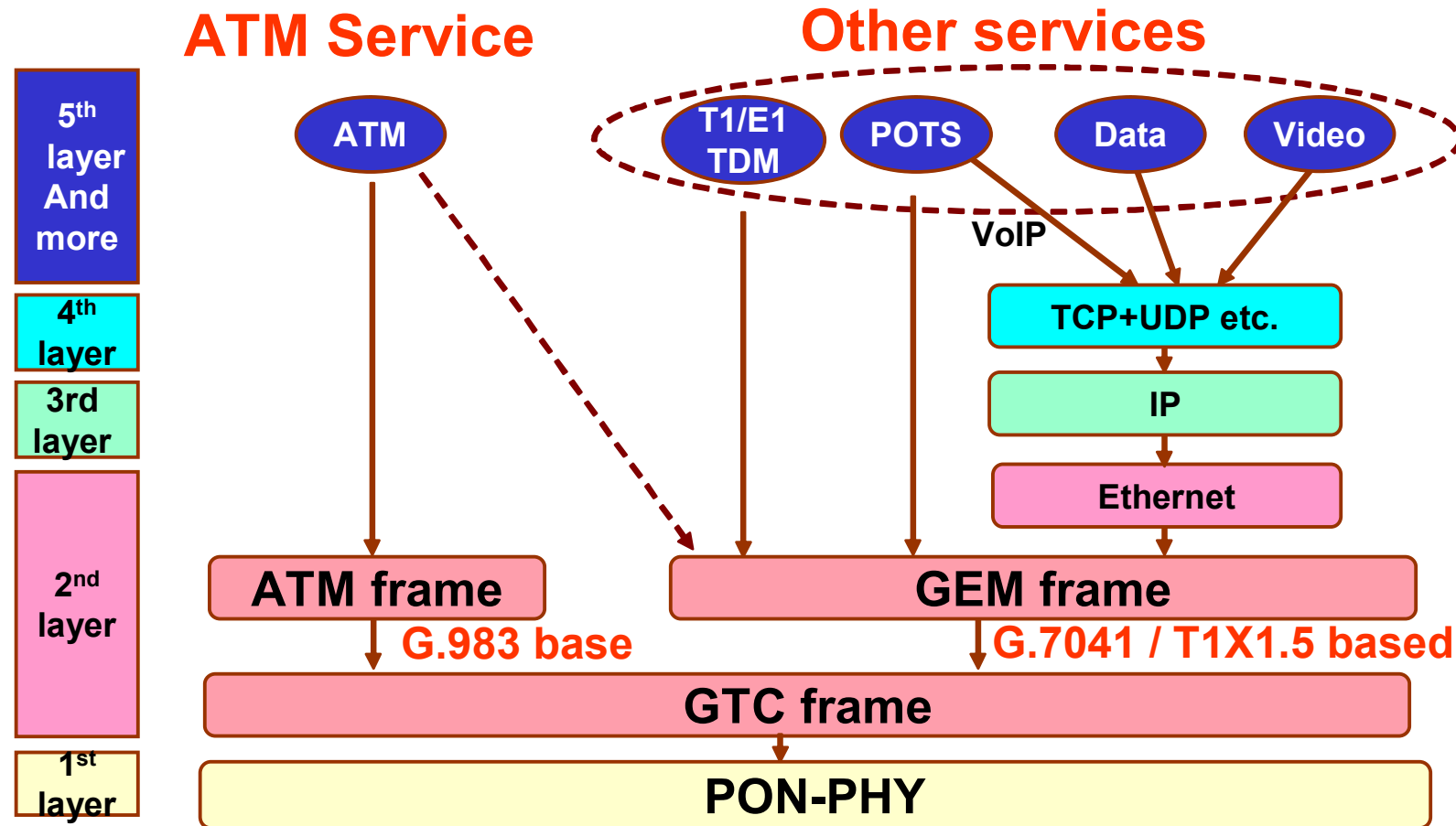
- Making G.984 series recommendations has been completed.
- ITU-T and FSAN discuss the modifications of G.984 series for the better interoperability and the easier implementation.

No.	Outline	Approved
G.984.1	G-PON Service requirements	Mar. 2003
G.984.2	G-PON Interface between OLT-ONT physical layer specifications	Mar. 2003 Feb. 2006 Amd1
G.984.3	G-PON Interface between OLT-ONT TC layer specifications	Dec. 2003 Mar. 2006 Amd2
G.984.4	G-PON ONT management control interface regulation	Jun. 2004 Mar. 2006 Amd2
G.984.5	Enhancement band of G-PON	Jun. 2007 <sub>(consent)</sub>

# Physical layer specifications (G.984.2)

Items	Specifications
Bit rate	1.244 Gbit/s and 2.488 Gbit/s up/down 155.52 Mbit/s and 622.04 Mbit/s only for upstream. Error rate: better than 1E-10
Correction of errors by fiber dispersion	Under 10km : FP-LD is used without error correction by FEC. ----- Under 20km : after adding the error correction by FEC, DFB-LD or FP-LD is used.
optical device	LD+PIN (APD is also available)
overhead of upstream signal	4Bytes (155.52Mbit/s), 8Bytes (622.08Mbit/s) 12Bytes (1.244Gbit/s), 24Bytes (2.488Gbit/s)
ODN Classes (Optical Loss between OLT and ONT)	Class A: 5 – 20dB Class B: 10 – 25dB Class C: 15 – 30dB <b>Class B+: 13 – 28dB</b>

# Service accommodation method (G. 984.3)



GEM : Gigabit Encapsulation Method.

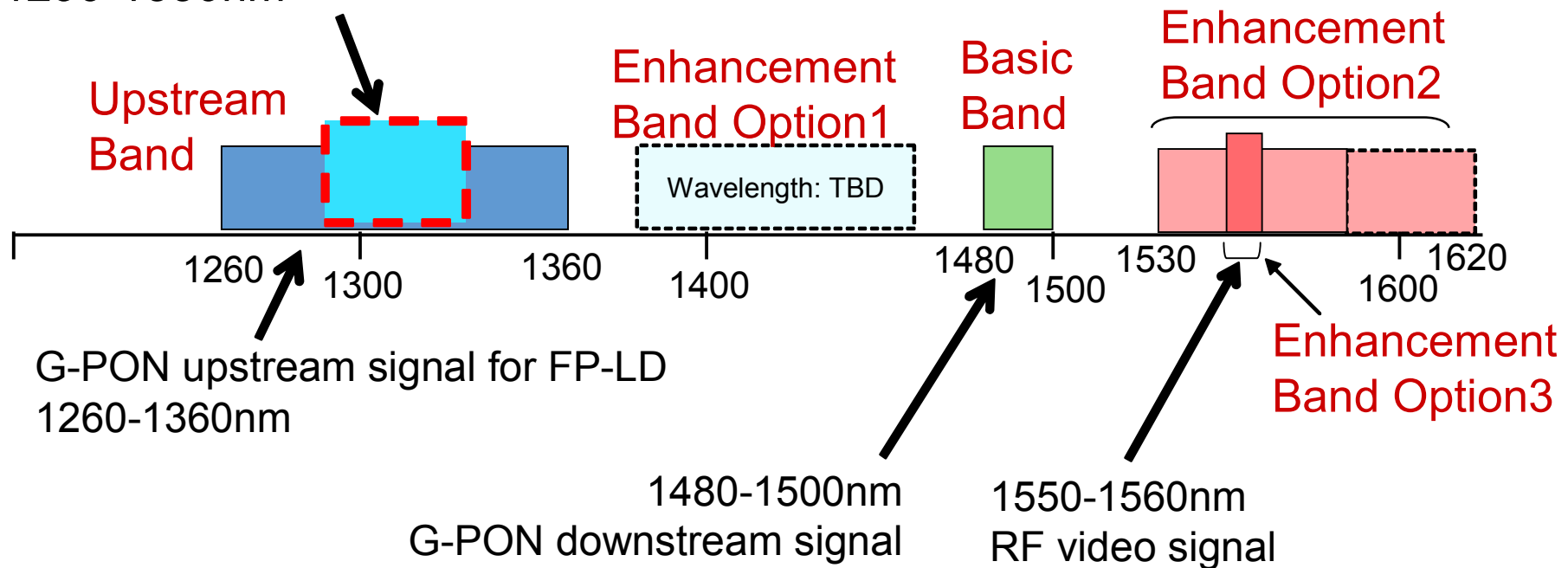
Based on Generic frame defined in G. 7041.



# Enhancement band (G. 984.5)

- 3 enhancement bands are proposed for a next optical access systems. But Option1 is TBD, and Option3 has been used for RF video distribution services.
- Upstream band could be narrower using DFB-LD.

G-PON upstream signal for DFB-LD  
1290-1330nm



---

**1. International standardization bodies**

**2. Standardized PON systems**

**3. B-PON: ITU-T G.983 series**

**4. G-PON: ITU-T G.984 series**

**5. E-PON: IEEE802.3EFM**

**6. Other optical access systems**

# Scope of IEEE E-PON standard

E-PON is one of Ethernet interface series.

E-PON System consists of both std. and out of scope specifications.

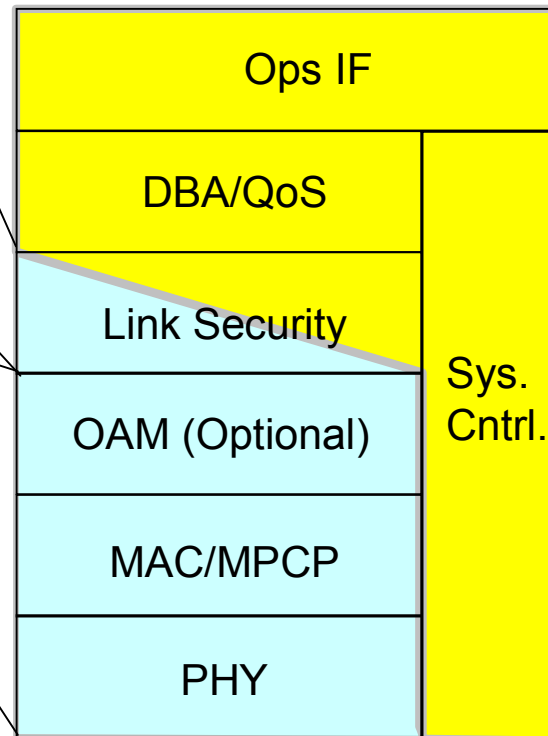
## Standardized specifications

Basic functionalities for transmission

IEEE802.1AE  
Need more time for specifying technical issues

IEEE802.3ah(EFM)  
Technical specifications are matured.  
Standard will complete June 2004.

## E-PON System



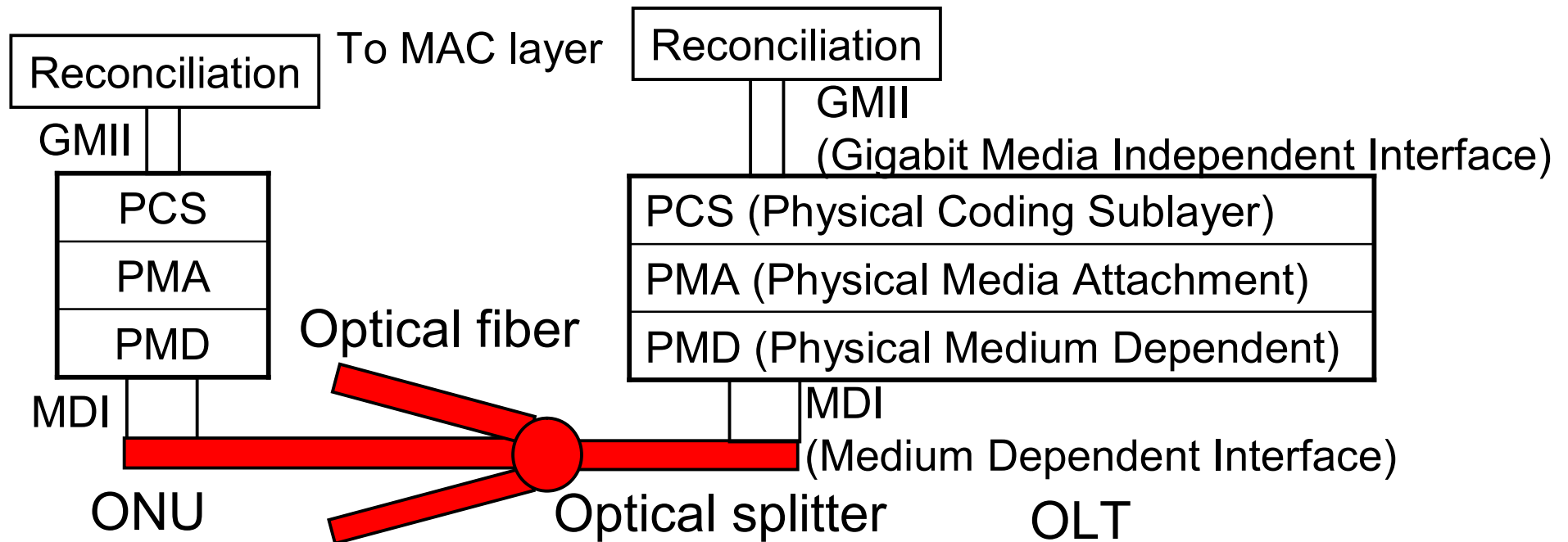
## Out of scope specifications

System functionalities for carrier service provisioning

- Operation system interface  
OAM&P, Test, DB-IF....
  - DBA (Dynamic Bandwidth Allocation)  
Bandwidth control
  - Authentication  
User/ONU registration/Deregistration
  - System OS  
Private MIB, Alarm process.....
  - System configurations  
Fault recovery, powering, cooling....
- And more ....

# PHY layer specifications in E-PON

- PHY layer consists of three sub-layers, PMD, PMA and PCS
- PMD is newly defined for GE-PON, but PMA and PCS are expanded from the other Giga-bit Ethernet specifications



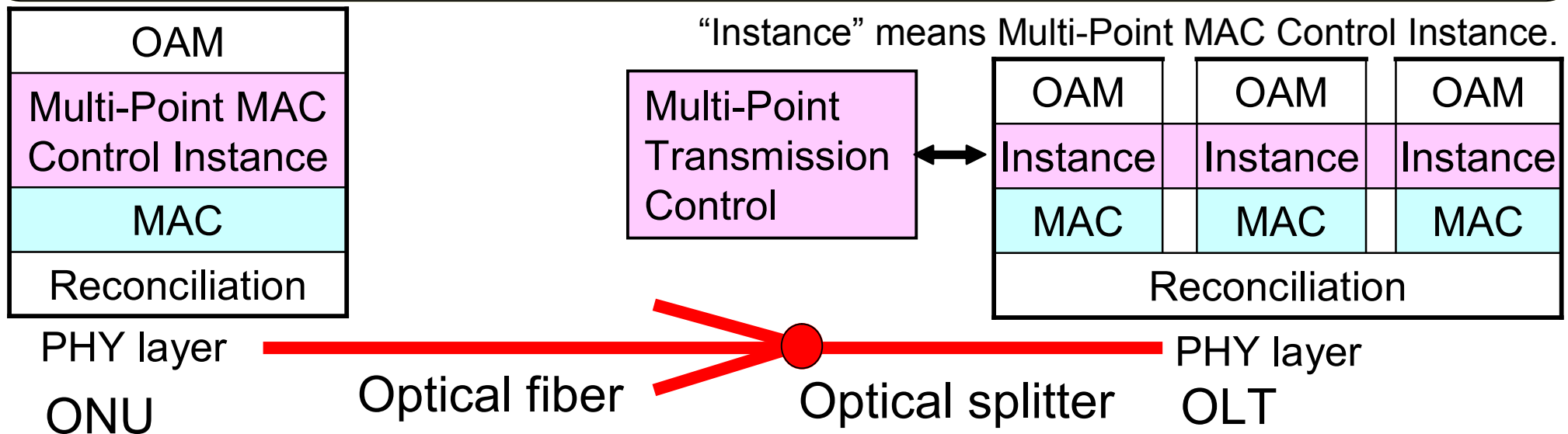
PCS: 8B10B codec (Mandatory), **Forward Error Correction (FEC; Optional)**

PMA: **Bit synchronization of burst signals**, Group synchronization with 10bit

PMD: **Power, wavelength and eye pattern of optical signals, ON/OFF time of LD**

# MAC layer specifications in E-PON

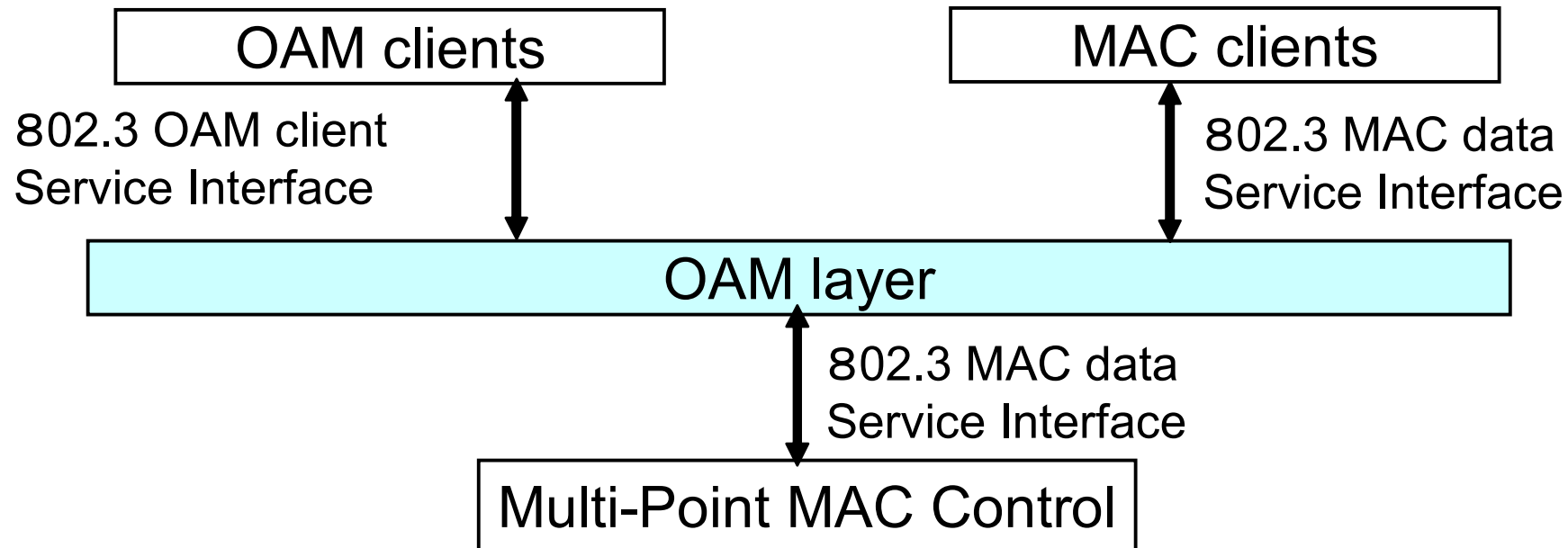
MAC layer includes MAC sub-layer which is common in all Ethernet interface, and Multi-Point MAC Control sub-layer which is specified for GE-PON.



- Multi-point MAC control sub-layer consists of Multi-Point Transmission Control and Multi-Point MAC Control Instance.
- The instance and MAC manage the GE-PON system as a point-to-point system.
- The control selects an active instance for each Ethernet frame.

# OAM specifications in E-PON

- OAM premises a logical point-to-point configuration which is common in all Ethernet specifications.
- OAM does not provide any functions that are specified only for GE-PON.
- OAM is optional in Ethernet specifications.

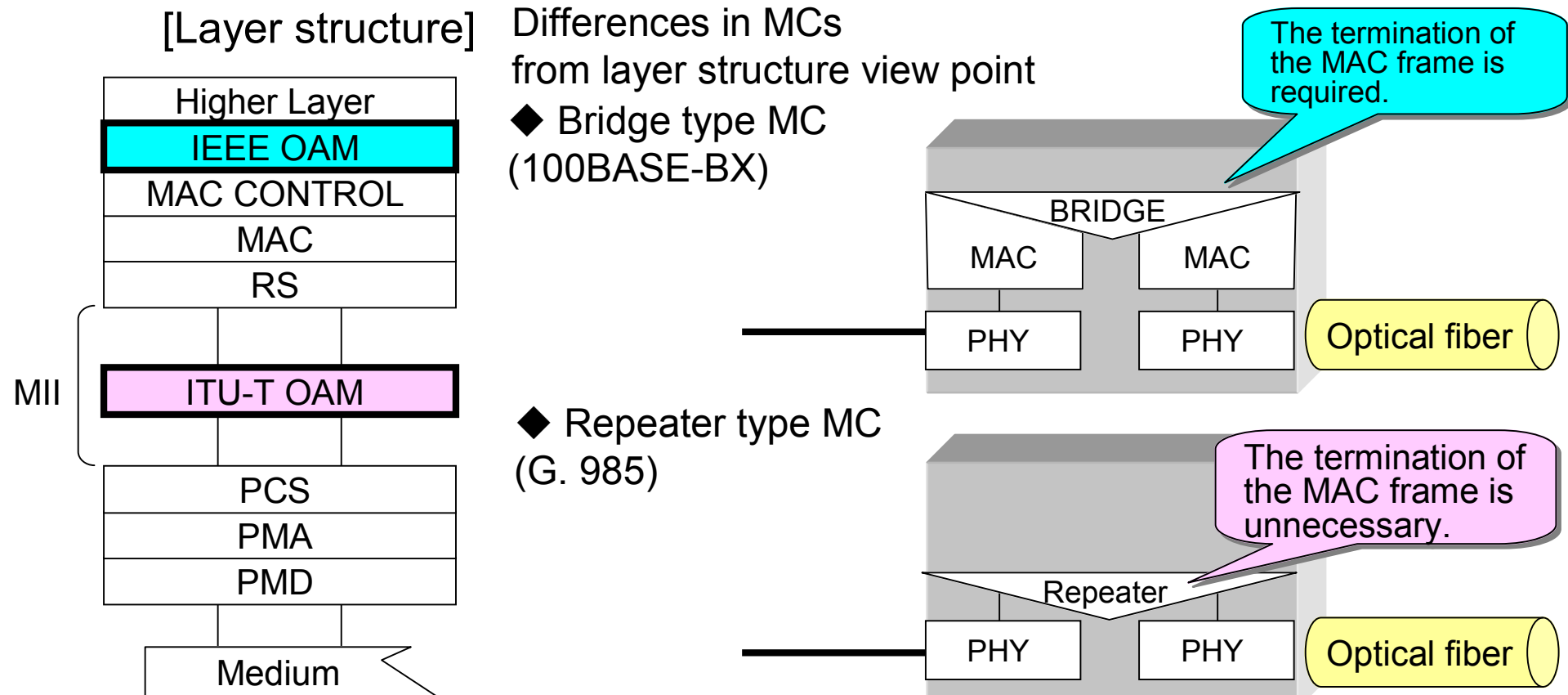


- 
1. International standardization bodies
  2. Standardized PON systems
  3. B-PON: ITU-T G.983 series
  4. G-PON: ITU-T G.984 series
  5. E-PON: IEEE802.3EFM
  6. **Other optical access systems**

# Differences in MC specifications

Media Converter (MC) is another cost effective solution when the user density is low enough.

ITU-T and IEEE make different standards for MC.





# Standardization trend of WDM systems

## 1 Economization of CWDM system (G.695)

For supplying various services in metro / access system, economical CWDM system is examined.

- 20nm interval (1271-1611nm) wavelength grid- approved G.694.2.
- For application services SDH and GbE are planned.
- Subdivision of interface specified points, and multiplex numbers 4-16 are under discussion.

## 2 DWDM system application to the metro / access system (G.698.1)

DWDM system is mainly used in core system, and applying it to metro / access system is examined by specializing for short distance with low cost

- Wavelength grid is 100GHz, 50 GHz, 25 GHz, 12.5 GHz-G.694.
- Focus functions by abbreviating 3R and such (clarify services applied)
- Subdivide interface specified point aiming at multi vendors

# Conclusions

---

- ✓ PON is the cost effective solution for broadband optical access network.
- ✓ International standards of PON have been established in ITU-T (B-PON and G-PON) and IEEE (E-PON).
- ✓ The 3 PONs have different PON frames, but their physical layer specifications are nearly same.
- ✓ Inter-operability and common specifications are the next issue for deploying broadband optical access systems
- ✓ WDM access systems are discussed in ITU-T and FSAN towards the future standards.

---

***Thank you***



***The beckoning cat, Maneki Neko,  
brings Luck.***