IEEE Com Soc NA Region Distinguished Lecturer Tour
Concordia University, Montreal, Canada 2/18/2015

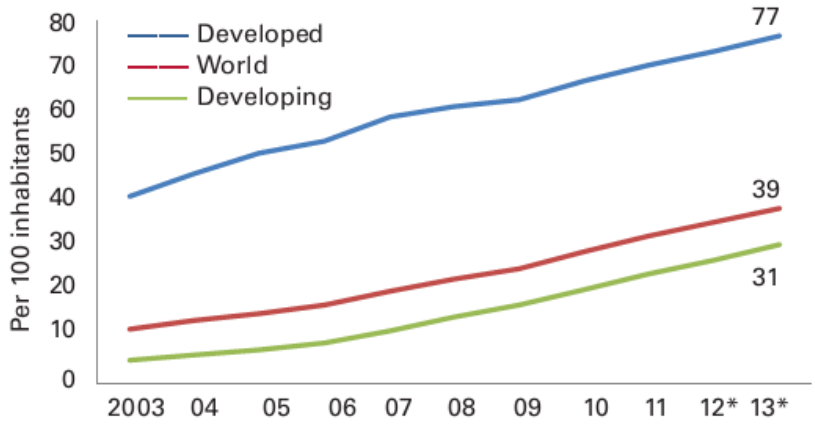
Trends and Issues of FTTH and G-PON

Koichi Asatani, PhD
Chair Professor, Nankai University
IEEE Distinguished Lecturer

- What is going on?
- Where are we going to?
- What will be the Next?

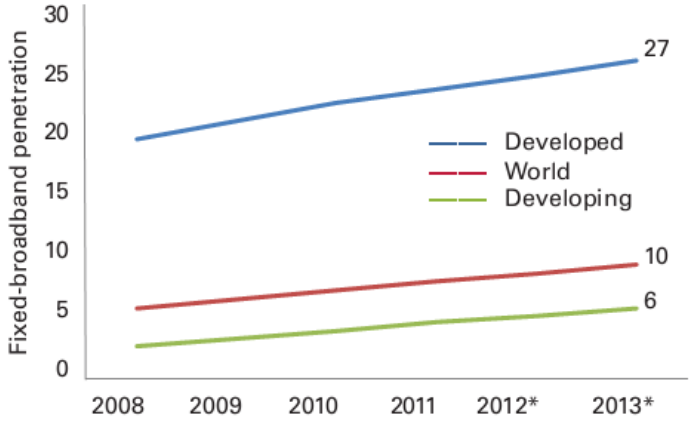
What is happening.

Global Internet Penetration



Source: ITU World Telecommunication/ICT Indicators
Note: * Estimate

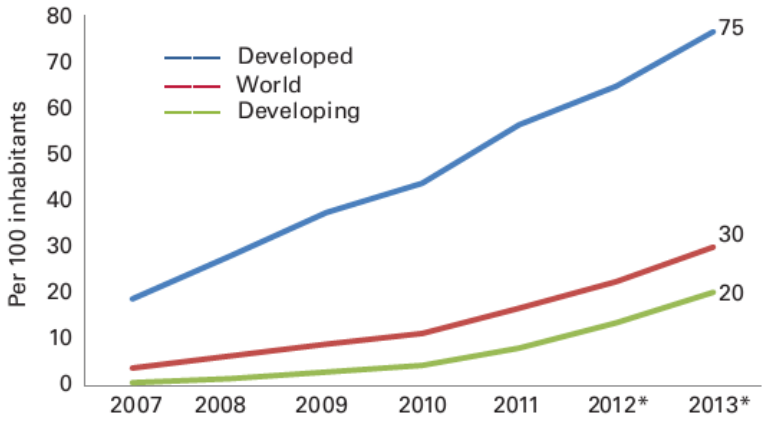
Global Wired Broadband Penetration



Source: ITU World Telecommunication/ICT Indicators
Note: * Estimate

Koichi Asatani 2015

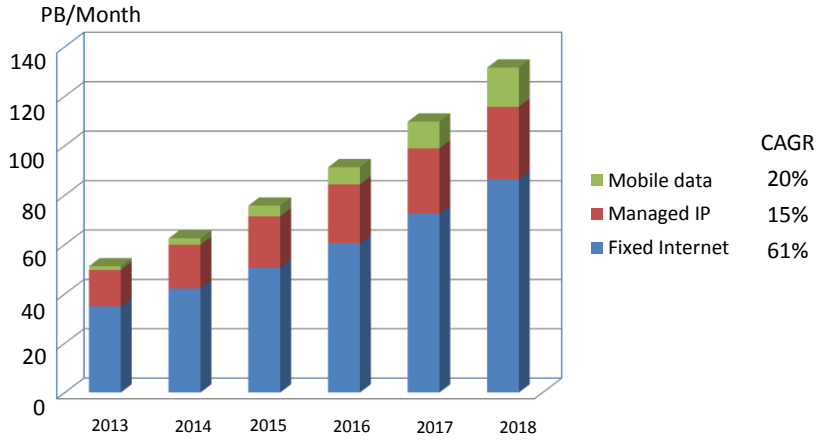
Global Mobile Broadband Penetration



Source: ITU World Telecommunication/ICT Indicators
Note: * Estimate

Koichi Asatani 2015

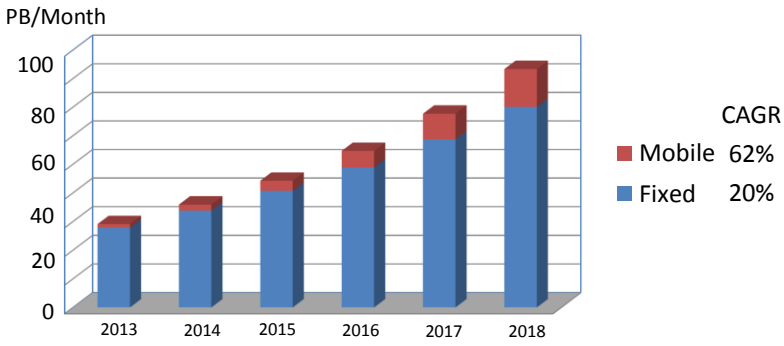
Global IP Traffic 2013-2018



Source: CISCO VNI 2014

Koichi Asatani 2015

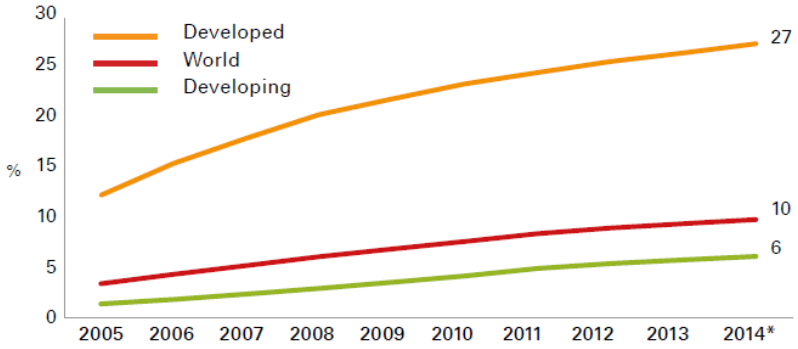
Wired and Wireless Global IP Traffic 2013-2018



Source: CISCO VNI 2014

Koichi Asatani 2015

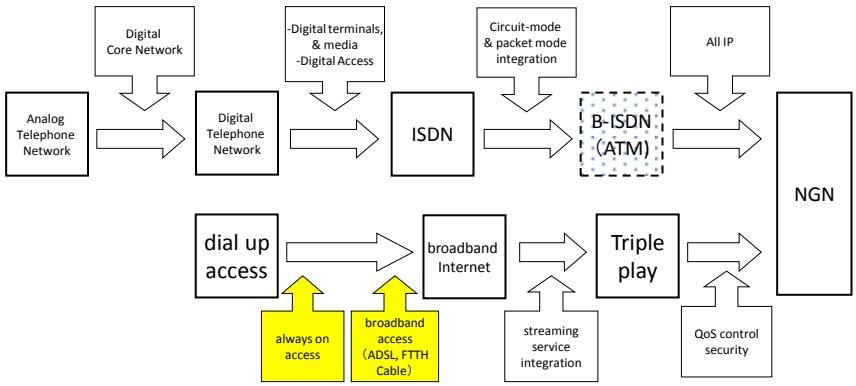
Fixed (wired)-broadband subscriptions per 100 inhabitants, 2005-2014*



Note: * Estimate
Source: ITU World Telecommunication/ICT Indicators database

Introduction to Access Networks

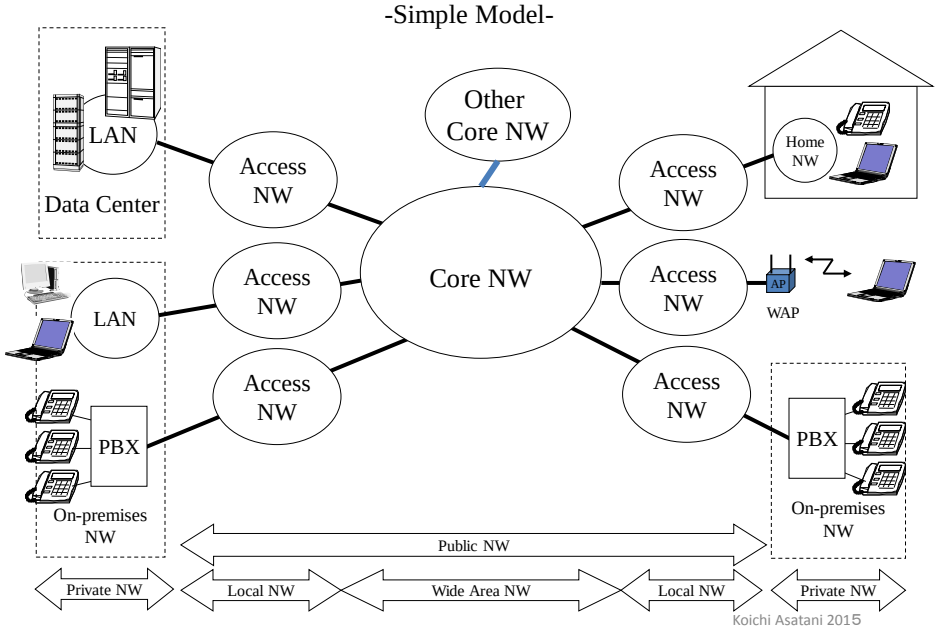
Network Evolution toward NGN



Koichi Asatani 2015

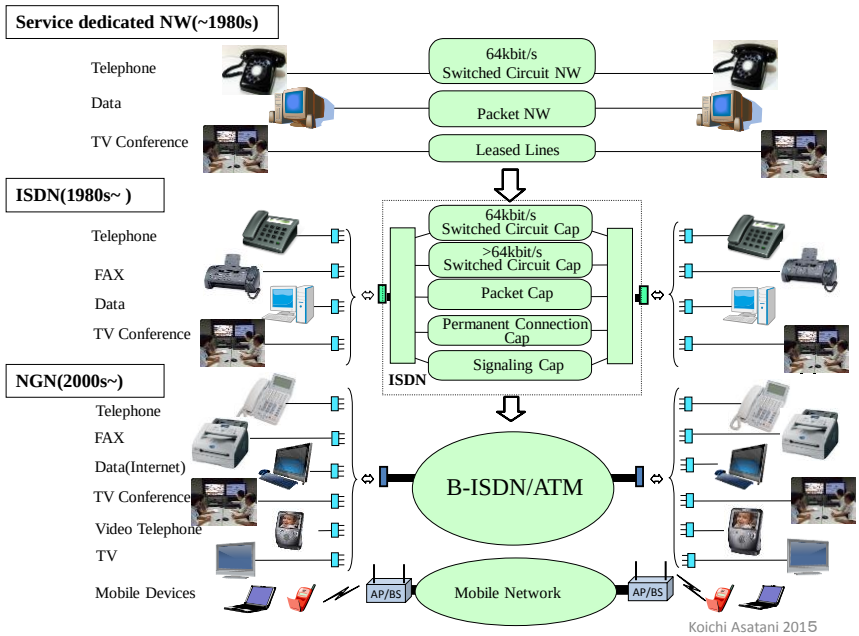
Basic Network Configuration

-Simple Model-

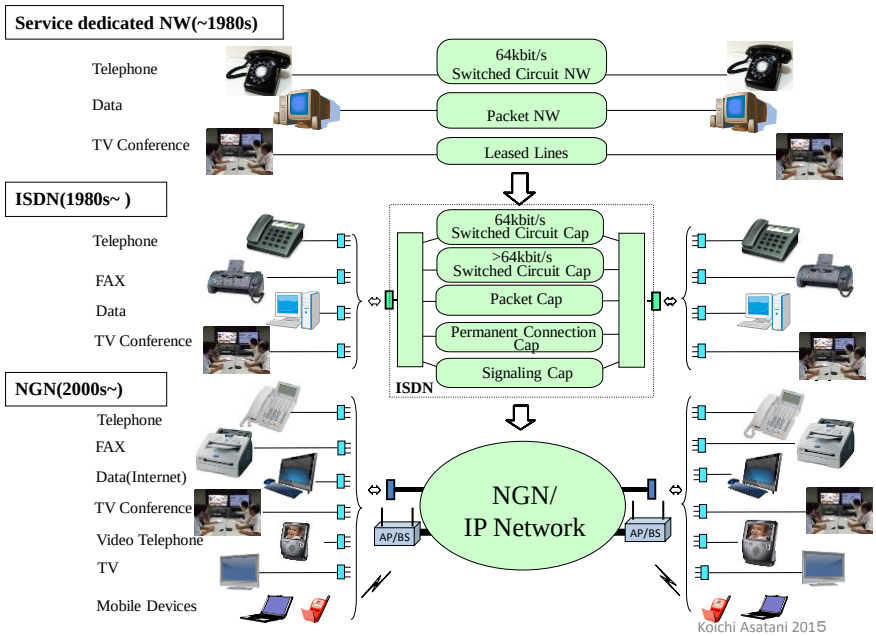


Koichi Asatani 2015

Access Evolution Scenario Toward B-ISDN



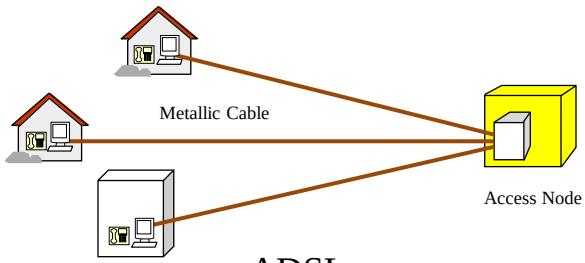
Access Evolution Scenario -Real Story-



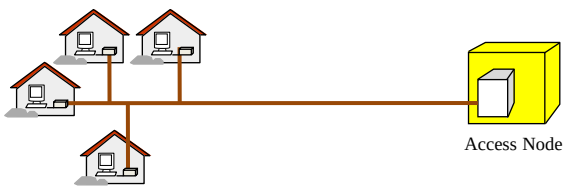
Broadband Access Technologies

FTTx Access	Network access by using Fiber to the Home, Building, Curb, and Cabinet (FTTH, FTTB, FTTC, FTTCab)
DSL Access	Network access by using twisted pair cables for telephone(ADSL)
CATV Access	Network access by using cables for CATV including HFC(Hybrid Fiber-Coaxial)
Fixed Wireless Access (FWA)	Wireless network access for fixed user devices
Broadband Wireless Access (BWA)	Broadband network access by using WiMAX at 2.5GHz band
4G Access	Network access by using 4G Cellular phone (LTE)

Access Configurations -ADSL & Cables



ADSL

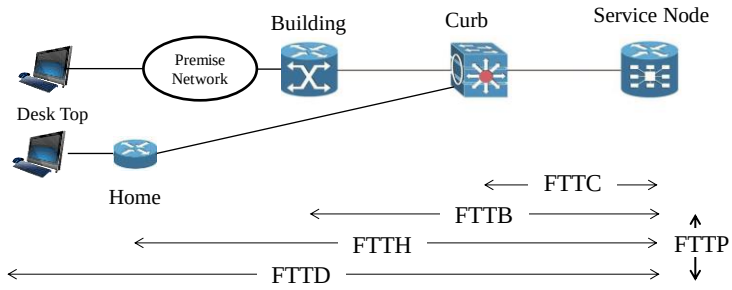


Cables

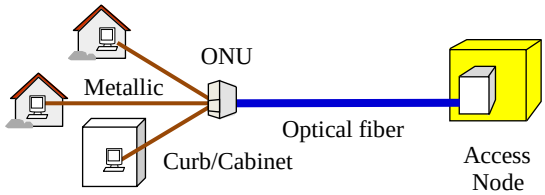
(ADSL: Asymmetric Digital Subscriber Line)

FTTx in Telecom

- FTTP: Fiber-To-The-Premises
- FTTH: Fiber-To-The-Home
- FTTB: Fiber-To-The-Building (Basement)
- FTTC: Fiber-To-The-Curb
- FTTD: Fiber-To-The-Desktop



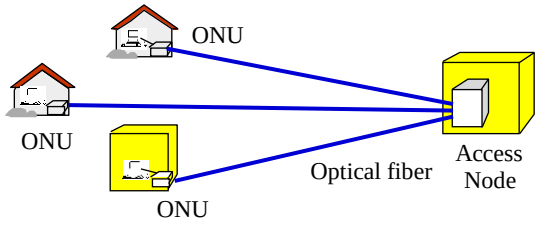
Access Configurations – FTTC(FTTCab)



FTTC(FTTCab)/VDSL

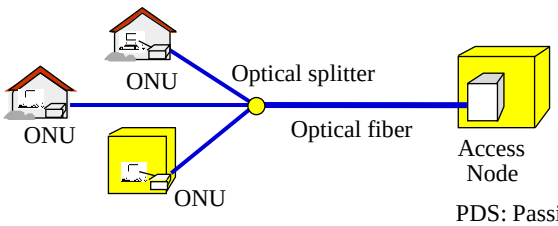
FTTC: Fiber To The Curb
VDSL: Very High-speed Digital Subscriber Line)

Access Configurations - FTTH & PON



FTTH（SS, PtP)

SS: Single Star
PtP: Point to Point



FTTH(PDS, PON)

PDS: Passive Double Star
PON : Passive Optical Network

Koichi Asatani 2015

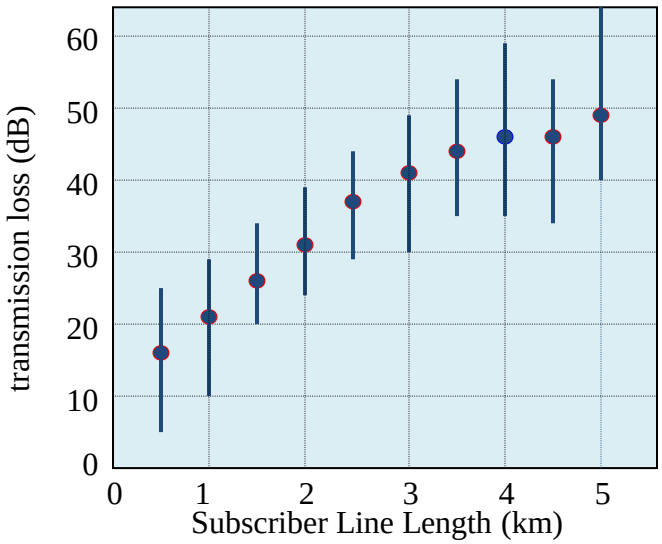
Why Fiber (FTTH/PON)?

Koichi Asatani 2015

Because FTTH/PON features

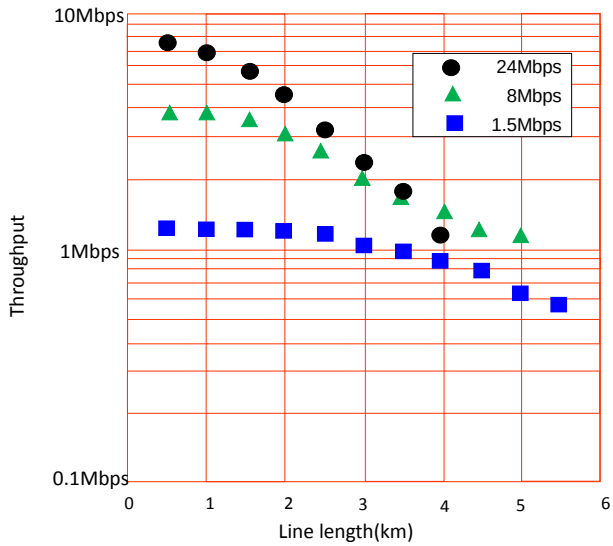
- High-speed and Stable Throughput: Better than ADSL and Cables
- Technical Maturity: Optical access deployments happening worldwide, with regional customized flavors built on generic transmission
- Cost Effective: Most cost effective solution found to be PON
  - Sharing opto-electronic devices in the central office
  - Sharing part of the fiber infrastructure through passive splitters
  - Energy efficient
- Better Opex

Transmission loss vs. subscriber line length



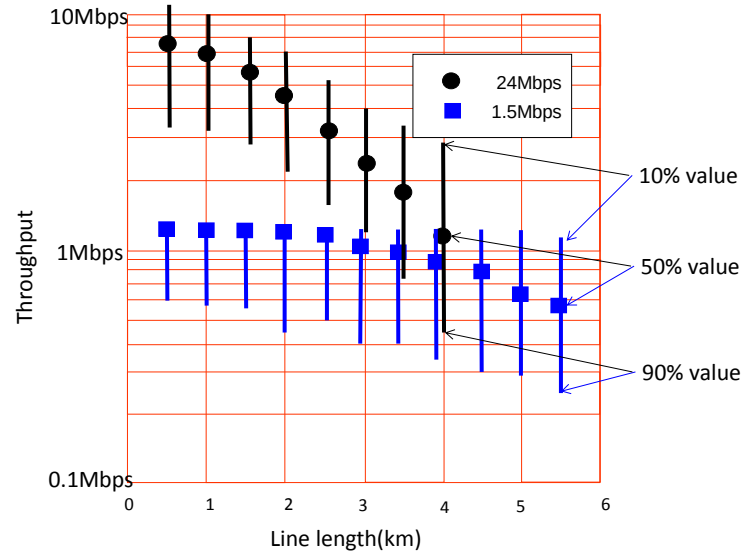
Source : http://www.bspeedtest.jp/stat1_1.html

ADSL Throughput vs subscriber line length



Source：http://www.bspeedtest.jp/stat1_1.html

ADSL Throughput Variation vs subscriber line length



Source：http://www.bspeedtest.jp/stat1_1.html

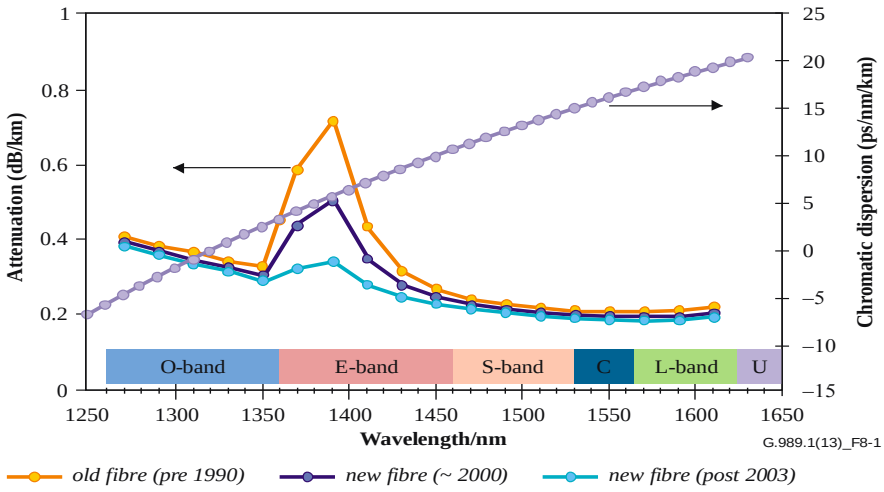
FTTH/PON Advantages

- Very high speed data up to 10Gbps to home and businesses
- Maintenance cost reduction due to no electronics between CO and customers
- Low cost due to fiber and CO interface shared by multiple customers (32-256)
- Constant data rate regardless of reach/EMC immunity
- Multiple applications supports including data (IP), video and voice (triple play)

Benefits of WDM PON

- Capacity increases of existing networks (sparse WDM)
  - introducing new 10G systems into existing networks on new wavelengths, coexisting with legacy systems on the same ODN
  - 4 x G-PON on parallel wavelengths having 4 times reduced split factor
- Optimized utilization of fiber infrastructure (massive WDM)
  - parallel operation of many TDM-PONs
  - add services
  - high speed connections in overlay for select customers (business, FTTB)
  - point-to-point links for many users
  - flexible reconfiguration of optical links
  - suitable wavelength ranges: 1260 – 1360 nm, 1460 -1625 nm

Optical Fiber Loss Attenuations



Koichi Asatani 2015

Why GPON

- Standardized by telecom operators and telecom vendors in ITU-T
- Various operation and management capability inherited from conventional proved telecom technologies
- Future-proof bandwidth
  - 2.4 G / 64 users = 35 M per user
  - 35 M = 6 M (HDTV-MPEG4) x 4 ch + 10 M (Internet)
- Suitable for business users because of various
- QoS and bandwidth management

Koichi Asatani 2015

Requirements to GPON

- Key requirements
  - 1 Gb/s capacity minimum
  - Full service (including legacy) support
  - Oriented towards IP services
  - Cost effective and FCAPS manageable
- Key “non-requirements”
  - Compatibility with B-PON not required

FCAPS:Fault Management, Configuration Management, Accounting Management, Performance Management , Security Management

Key Elements for Innovation

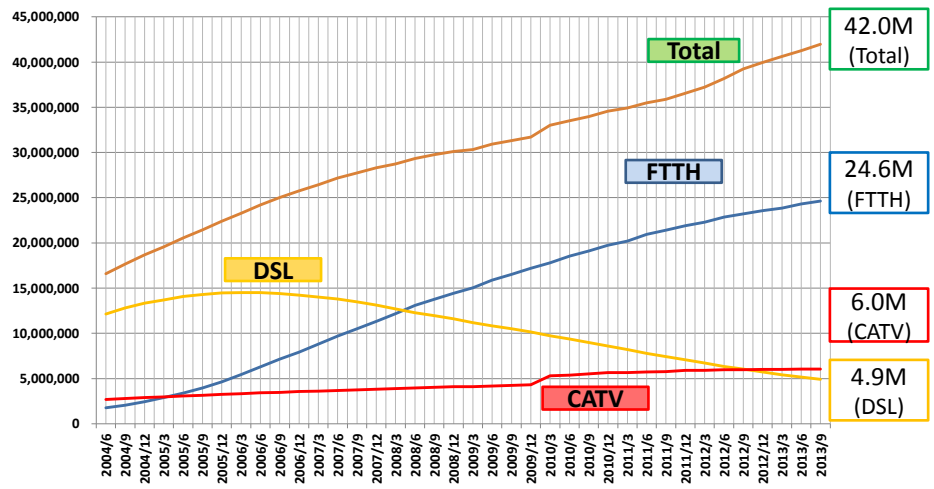
- meet new requirements
- CAPEX, OPEX
- technical maturity
- forward compatibility
- backward compatibility
- ecology

G.980 series Recs

- G.981: PDH optical line systems for the local network
- G.982: Optical access networks to support services up to the ISDN primary rate or equivalent bit rates
- G.983.1: Broadband optical access systems based on Passive Optical Networks (PON)
- G.983.2: ONT management and control interface specification for B-PON
- G.983.3: A broadband optical access system with increased service capability by wavelength allocation
- G.983.4: A broadband optical access system with increased service capability using dynamic bandwidth assignment
- G.983.5: A broadband optical access system with enhanced survivability
- G.984.1: Gigabit-capable passive optical networks (GPON): General characteristics
- G.984.2: Gigabit-capable Passive Optical Networks (G-PON): Physical Media Dependent (PMD) layer specification
- G.984.3: Gigabit-capable Passive Optical Networks (G-PON): Transmission convergence layer specification
- G.984.4: Gigabit-capable passive optical networks (G-PON): ONT management and control interface specification
- G.984.5: Gigabit-capable Passive Optical Networks (G-PON): Enhancement band
- G.984.6: Gigabit-capable passive optical networks (GPON): Reach extension
- G.984.7: Gigabit-capable passive optical networks (GPON): Long reach
- G.985: 100 Mbit/s point-to-point Ethernet based optical access system
- G.986: 1 Gbit/s point-to-point Ethernet-based optical access system
- G.987: 10-Gigabit-capable passive optical network (XG-PON) systems: Definitions, abbreviations and acronyms
- G.987.1: 10-Gigabit-capable passive optical networks (XG-PON): General requirements
- G.987.2: 10-Gigabit-capable passive optical networks (XG-PON): Physical media dependent (PMD) layer specification
- G.987.3: 10-Gigabit-capable passive optical networks (XG-PON): Transmission convergence (TC) layer specification
- G.987.4: 10-Gigabit-capable passive optical networks (XG-PON): Reach extension
- G.988: Optical network unit management and control interface specification
- G.989.1: 40-Gigabit-capable passive optical networks (NG-PON2): General requirements

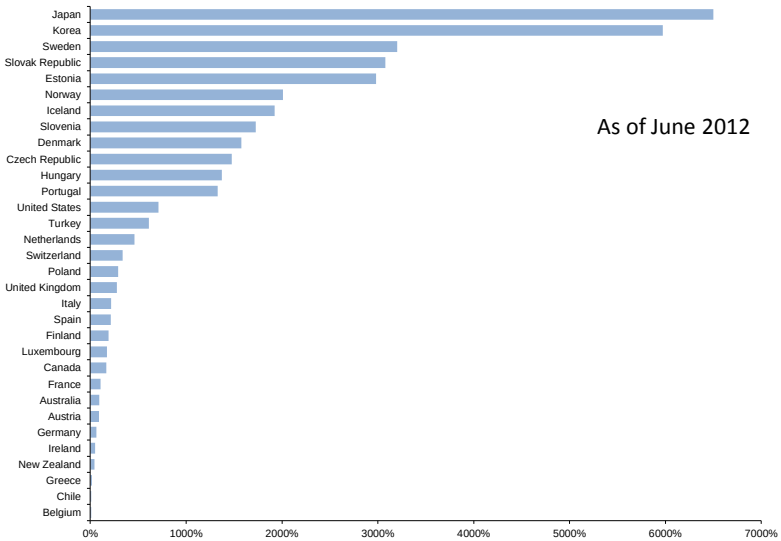
PON Market

Broadband Access in Japan



Source: Ministry of Internal Affairs and Communications, Japan

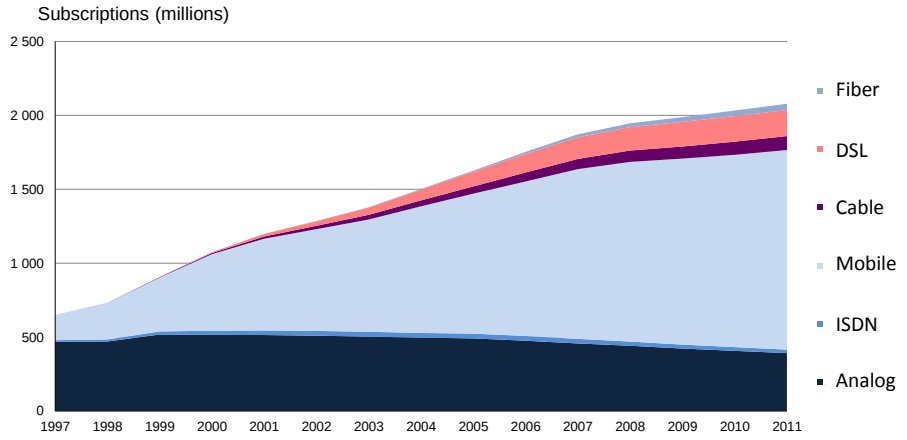
FTTH/FTTB Penetration Ranking



As of June 2012

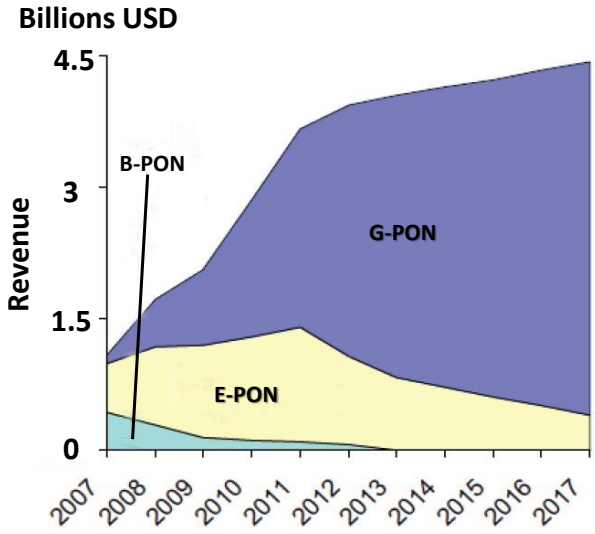
http://dx.doi.org/10.1787/888932798506

Fixed, Mobile and Broadband Access in OECD



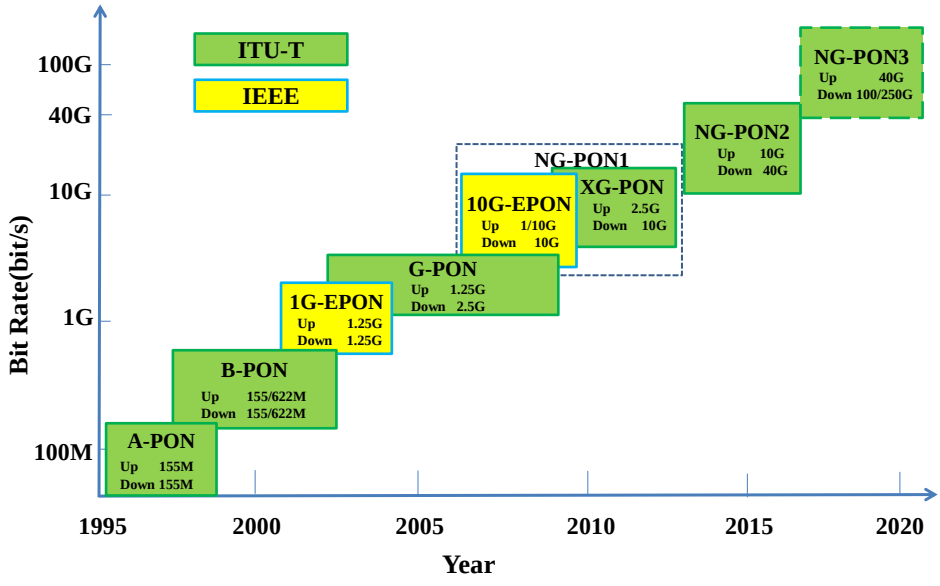
http://dx.doi.org/10.1787/888932798829

Market Growth of PON



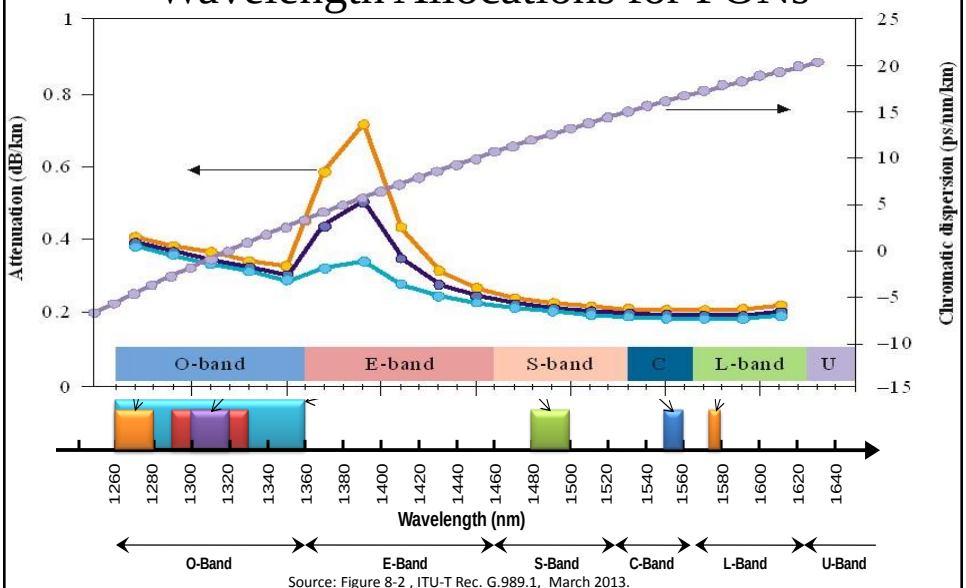
Source: Dell'Oro Group

PON Standardization



Koichi Asatani 2015

Wavelength Allocations for PONs



Source: Figure 8-2 , ITU-T Rec. G.989.1, March 2013.
Table 9-1, Draft new Recommendation ITU-T G.989.2, 40-Gigabit-capable passive optical networks 2 (NG-PON2): Physical media dependent (PMD) layer specification, TD 170 Rev.2 (PLEN/15) , April 2014.

Koichi Asatani 2015

IEEE PON vs ITU-T PON

Organization	IEEE	ITU-T
Group	IEEE 802.3ah IEEE 802.3av IEEE 802.3bk	ITU-T SG15 Q2
PON Specs	1G-EPON 10G-EPON Extended EPON	B-PON G-PON XG-PON NG-PON2
Management System	SIEPON	OMCI
Frame	Gbps based Ethernet Frame	GEM
Services	Ethernet Service	Full Service (Ethernet, TDM, POTS)

SIEPON: Service Interoperability in Ethernt Passive Optical Networks
OMCI: ONU Managmeent and Control Interface
GEM: G-PON Encapsulation Method
GTC: G-PON Transmission Convergence

Koichi Asatani 2015

PON Specifications

System			B-PON (Broadband PON)	G-PON (Gigabit-capable PON)	GE-PON (Gigabit Ethernet PON)	10G-EPON (10Gigabit Ethernet PON)	XG-PON1 (10Gigabit-capable PON)
Standard			ITU-T G.983 (1983/2005)	ITU-T G.984 (2003/2008)	IEEE802.3 ah EFM (2004/2005))	IEEE802.3 av EFM (2009)	ITU-T G.987 (2010)
MAC	Service		Ether, TDM, POTS	Ether, TDM, POTS	Ethernet Data	Ethernet Data	Ether, TDM, POTS
	Frame		ATM Frame	GEM Frame	Ethernet Frame	Ethernet Frame	XGEM Frame
Physical Layer	Distance		10/20km	10/20km (logical 60km)	10/20km	10/20km	10/20km
	Maximum Splitting		64	64	16 or over	16/32	64
	Speed	Up	156M, 622Mbps	156M, 622M, 1.25G	1.25Gbps	1.25G, 10.3Gbps	2.5Gbps
		Down	156M, 622Mbps	1.25G, 2.5Gbps	1.25Gbps	10.3Gbps	10.3Gbps
	Code		Scrambled NRZ	Scrambled NRZ	8B10B	64B66B	Scrambled NRZ
	Optical Link Budget		25/30dB	15/20/25dB	20/24dB	20/24/29dB	29/31dB
	Wavelength Allocation	Up	1260-1360nm	1260-1360nm	1260-1360nm	1260-1280nm(10Gbps) 1260-1360nm(1Gbps)	1260-1280nm(XG-PON1) 1290-1330nm(G-PON)
		Down	1480-1500nm	1480-1500nm	1480-1500nm	1575-1580nm(10Gbps) 1480-1500nm(1Gbps)	1575-1580nm(XG-PON1) 1480-1500nm(G-PON)
		RF-TV	1550-1560nm	1550-1560nm	1550-1560nm	1550-1560nm	1550-1560nm
Remarks					EFM: Ethernet in the First Mile		also called NG-PON1

Koichi Asatani 2015

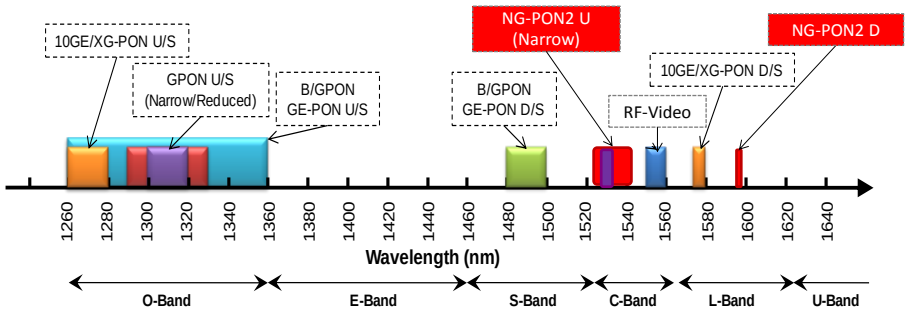
Requirements for NG-PON2 (1/2)

- Wide Applications:
  - Residential, business, mobile backhaul and others
- Base system: 40Gbps downstream, 10Gbps upstream
  - 4 channels in each direction
  - Compatible with G-PON, XG-PON, and RF video overlay
  - 20km @ 1:64 split ratio fully passive plant capable
- Optional extra capabilities
  - 8 channels in each direction
  - 10Gbps upstream
  - DWDM overlay

Requirements for NG-PON2 (2/2)

- Power saving; Sleep modes and eco devices
- Long reach and high splitting ratio
- Synchronization in frequency and time
  - Application to support mobile backhaul
- Highly reliability
  - Cost effective redundant configuration
- Upgradability and Unbundling; WDM
  - Regulators impose an obligation to provide access to third parties in the European Union
  - G-PON/XG-PON coexistence
- Conformance and multi-vendor Interoperability

Wavelength Allocations for PONs



Source: Figure 8-2 , ITU-T Rec. G.989.1, March 2013.
Table 9-1, Draft new Recommendation ITU-T G.989.2, 40-Gigabit-capable passive optical networks 2 (NG-PON2): Physical media dependent (PMD) layer specification, TD 170 Rev.2 (PLEN/15) , April 2014.

Koichi Asatani 2015

NG-PON2(draft)

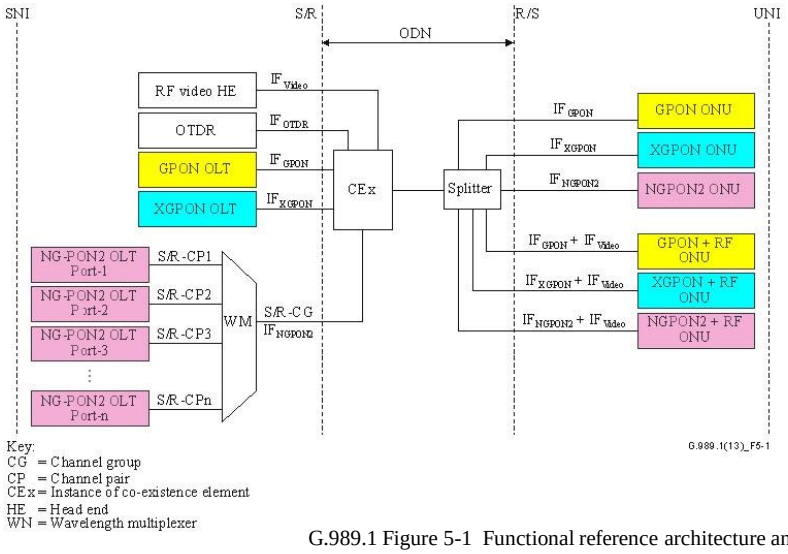
System			NG-PON2 (Next Generation PON2)			
Standard			ITU-T G.989 (2015)			
Application			BASIC	EXTENDED	BUSINESS	Mobile Backhaul
MAC	Service		Ether, TDM, POTS			
	Frame		XGEM Frame/TWDM			
Physical Layer	Distance		40km(60km)			
	Maximum Splitting		256			-
	Speed	Up	10Gbps(2.5Gx4WDM)	20Gbps(2.5Gx8WDM)	40Gps(10Gx4WDM)	1.25G, 2.5G, 10Gbps
		Down	40Gbps(10Gx4WDM)	80Gbps(10Gx8WDM)	40Gps(10Gx4WDM)	1.25G, 2.5G, 10Gbps
	Code		Scrambled NRZ			
	Optical Link Budget		25/30dB			
	Wavelength Allocation	Up	1524-1544nm(Wide) 1528-1540nm(Reduced) 1532-1540 (Narrow)			1603-1625nm (shared) 1524-1625nm(expanded)
		Down	1596-1603nm			1603-1625nm (shared)
		RF-TV	1550-1560nm			1550-1560nm
Remarks			XGEM: XG-PON encapsulation method			

Koichi Asatani 2015

NG-PON2 standards arrangement

- G.989.1 : Requirements
  - Consented at Sep 2012 meeting
- G.989.2 : Physical medium dependent layer
  - Draft in progress
- G.989.3 : TC layer
  - NG-PON2 specific TC features
- G.987.3 : Transmission convergence layer
  - 10Gbps upstream to be added to this base standard
- G.multi : Multiple Wavelength Passive Optical Networks (MW-PON), wavelength control layer
- G.988 : ONU management and control interface

NG-PON2 Coexistence with Legacy PON



Key:
CG = Channel group
CP = Channel pair
CEx = Instance of co-existence element
HE = Head end
WN = Wavelength multiplexer

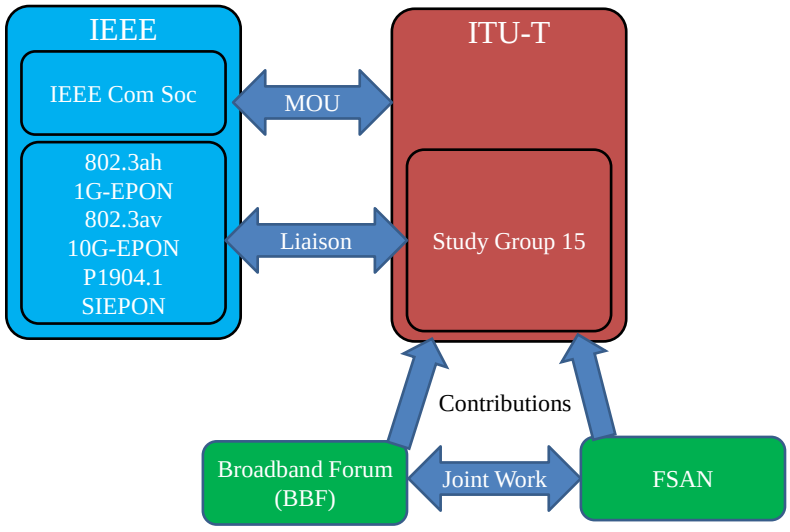
G.989.1 Figure 5-1 Functional reference architecture and points for NG-PON2 system coexistence with legacy systems

TWDM standards arrangement

- G.ngpon2.1 = Requirements
  - Consented at Sep 2012 meeting
- G.ngpon2.2 = Physical medium dependent layer
  - Draft in progress
- G.ngpon2.3 = TC layer
  - NG-PON2 specific TC features
- G.987.3 = Transmission convergence layer
  - 10G upstream to be added to this base standard
- G.multi = Wavelength control layer
  - Draft already started in Q2/15
- G.988 = ONU management and control interface
  - Standard in force, can be easily reused for TWDM

Koichi Asatani 2015

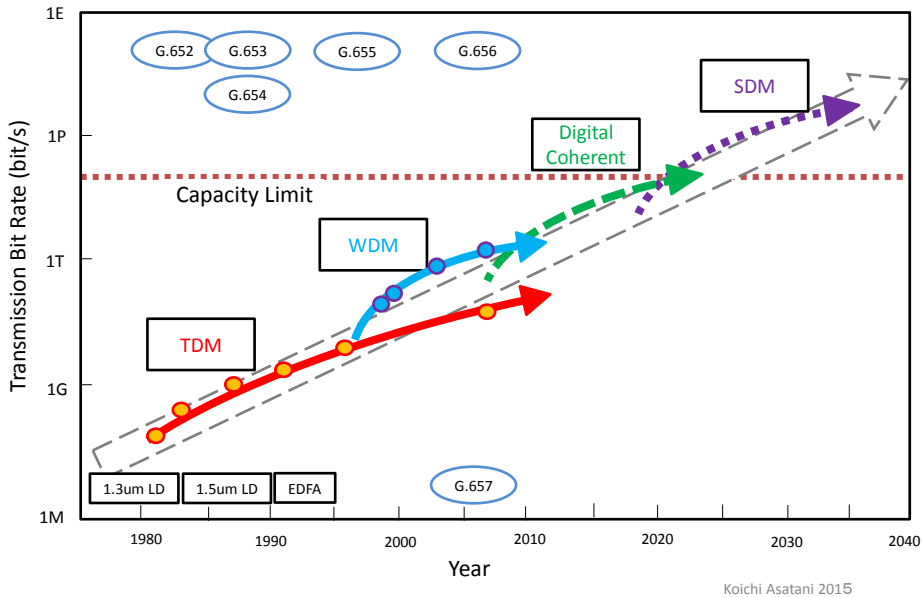
PON Standards related Organizations



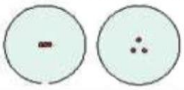
Koichi Asatani 2015

Future Issues

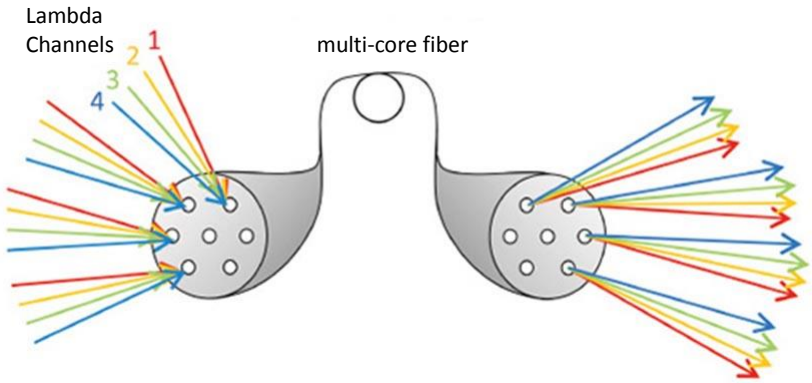
Core Transmission Systems



Multi-Core Fibers

Number of modes	Single-core	Multi-core	
		Uncoupled-type	Coupled-type
Single	SMF 	Homogeneous/Heterogeneous 	LMA fiber 
Few	FMF 	Few-mode MCF  Hybrid structure 	Strongly/Weakly coupling 
Multi	MMF 	Multi-mode MCF 	LMA fiber 

Multi-Core Fiber with WDM



Summary

- PON is one of the most successful technologies from view point of economy and ecology based on global standards developed by ITU-T and IEEE.
- Further development for higher bandwidth and lower cost is essential to meet rapidly growing traffics.
- Regulations?

Merci!
Thank you!