FTTx Network rEvolution

Challenges and Solutions

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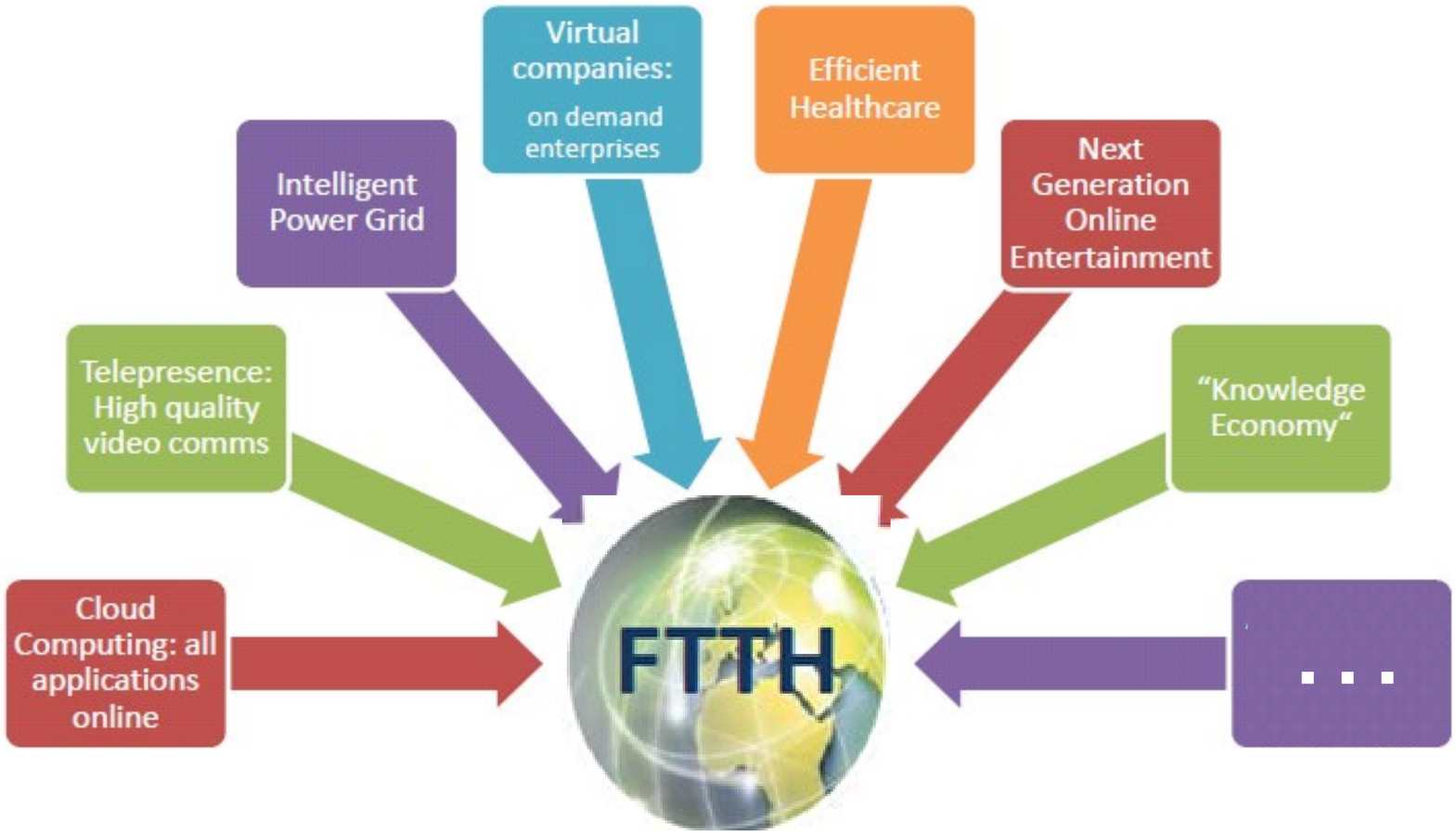
Demand for Broadband and Infrastructure

Technology Infrastructure for

- The Government
- Buildings
- Transportation
- Utility Domains
- e-Health
- e-Learning
- …

Secure communication systems, to ensures a faster economic development & growth !

New applications addressed



The demand for bandwidth and services

…require High-Quality-Networks

B2C services

- Internet of things
- Smart home
- 4k/8k TV
- TV on demand
- Online Gaming

B2B services

- Video conferencing
- Decentralization
- Joint CAD-development
- VPN – work from home

Challenges for High Quality Networks

Permanent availability

- Constant transmission throughout the entire service life
- Maintenance with minimal effect on links in operation
- Secure Fiber Management prevents performance loss

Highest Flexibility

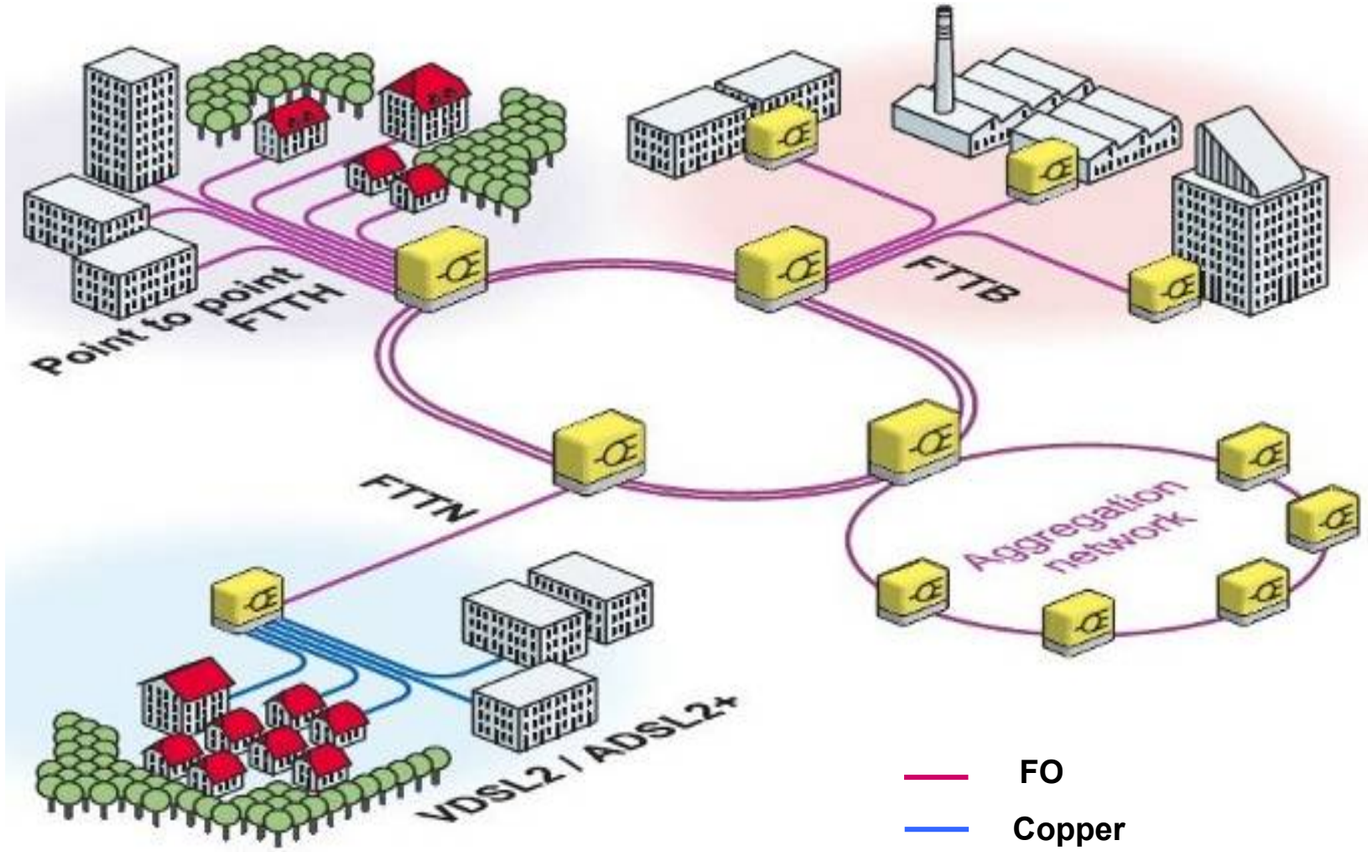
- Modularity ensures extension of systems
- Modular systems assure adaptation and extension
- Scalability “grow as your investment”

OPEX

- Reduction of network downtime
- Reduction of network maintenance
- Product design which supports easy Installation
- Trained persons

Network

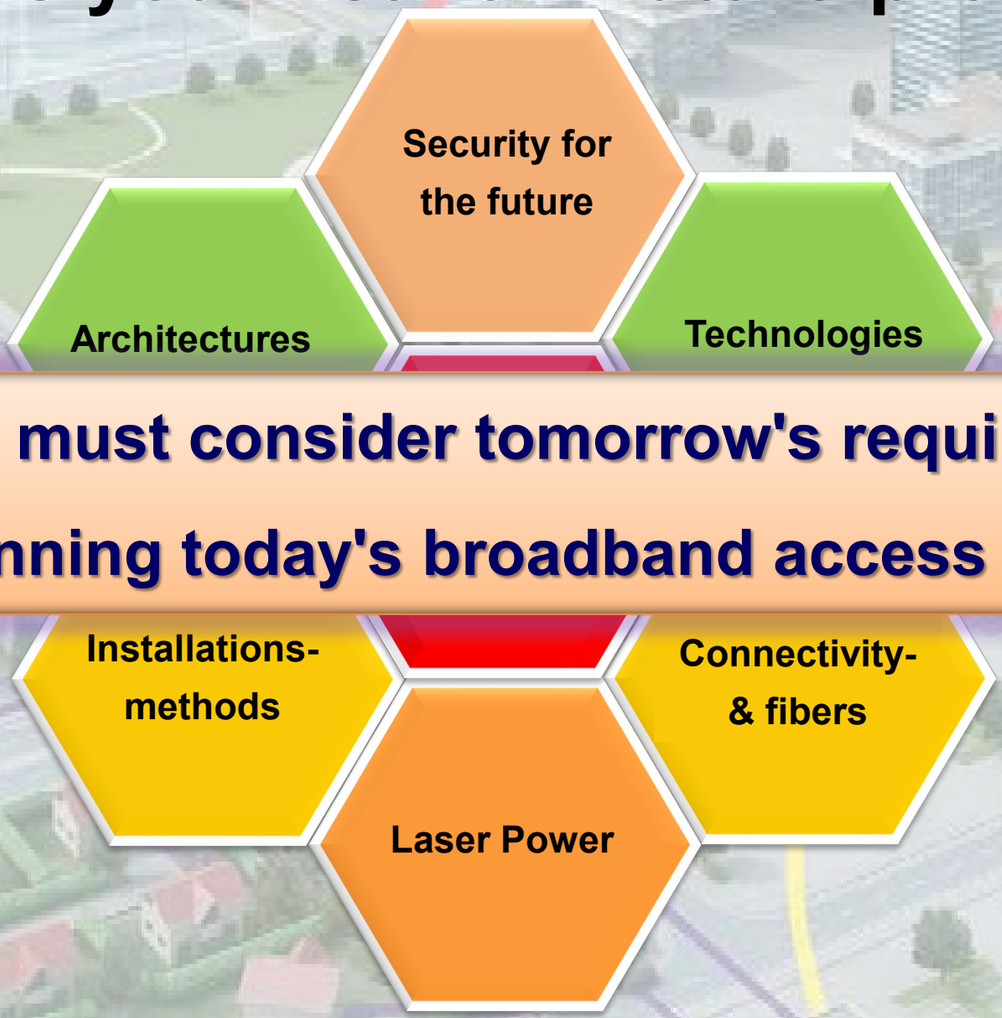
High-performance fiber optic and copper networks have to meet ever increasing demands concerning transmission performance and operational reliability



In particular, the quality of passive components plays an important role!

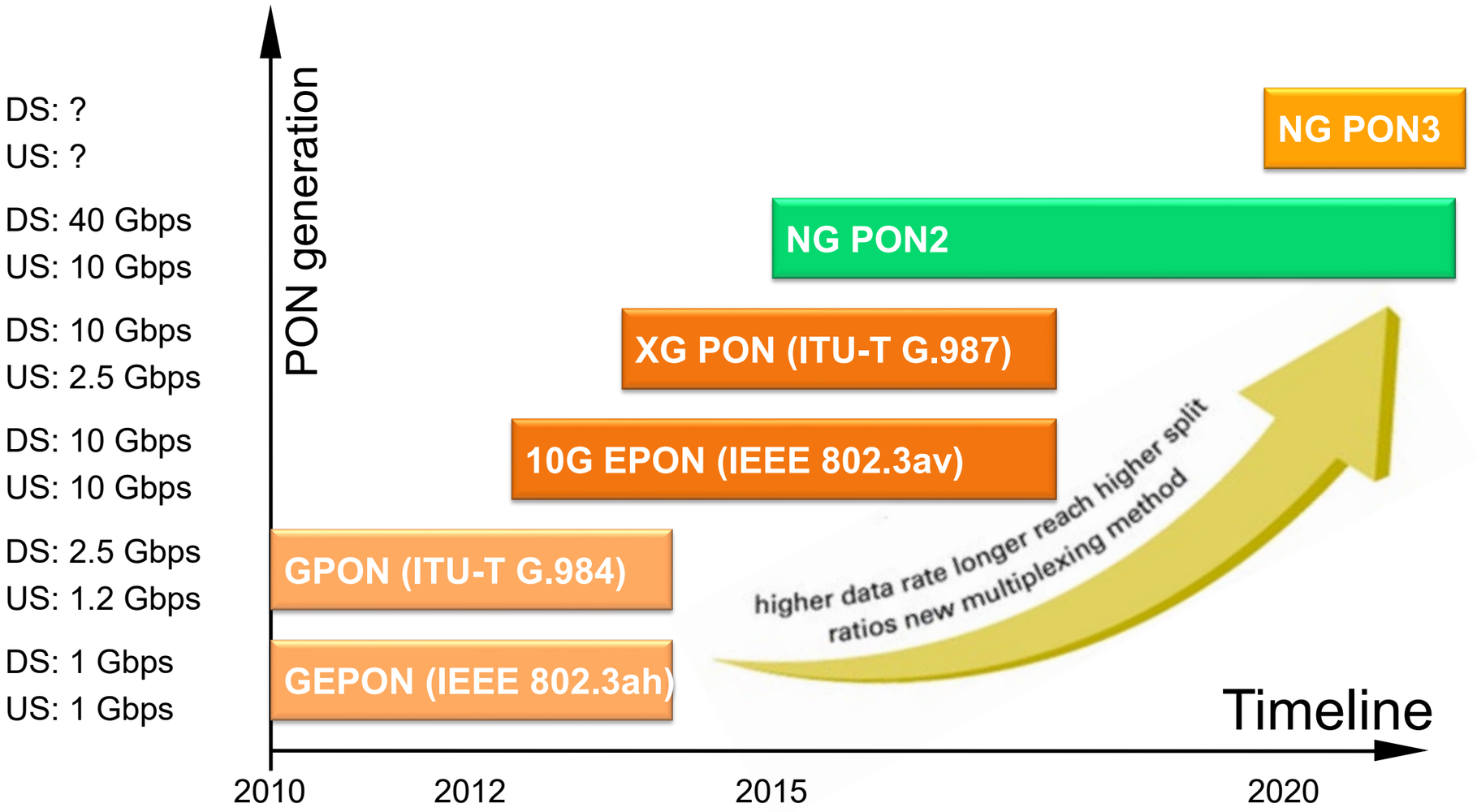
Influences on Layer 1

… is your network future-proof?



Carriers must consider tomorrow's requirements when planning today's broadband access networks

The Evolution of PON Technology

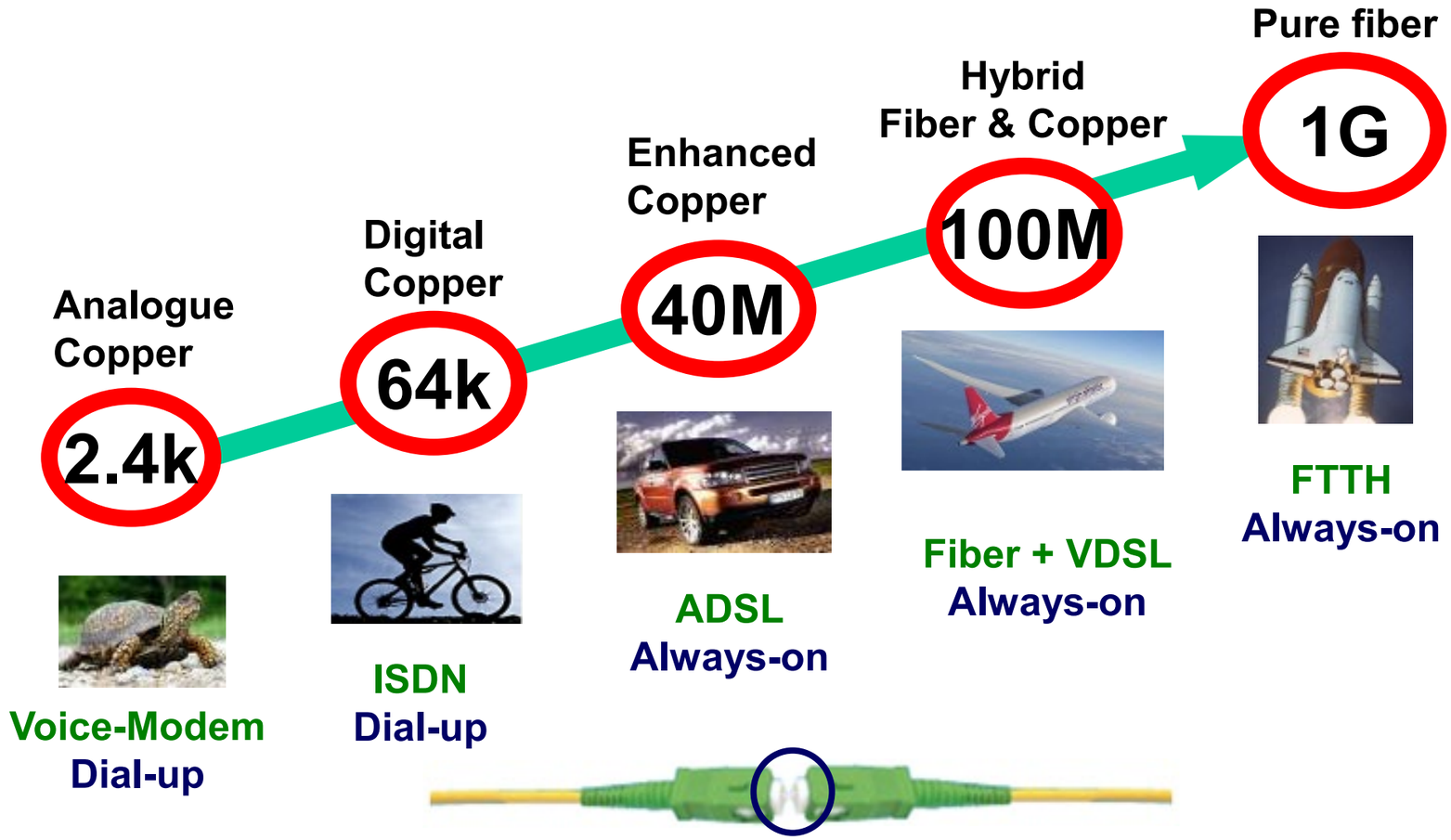


Where is the influence for layer 1

	GEPON	GPON	10G EPON	XG PON	NG PON2
Data Rate DS / US [Gbps]	1 / 1	2.5 / 1.2	10 / 10	10 / 2.5	40 / 10*
Power Budget [dB]	26	30	30.5	35	~ 40 dB**
Laser Power US (ONU) / DS (OLT) [mW]	0.8 / 1.6	1.6 / 2.0	2.5 / 3.2	1.6 / 28.2	~1.6 / ~10**
Physical Reach (typ.) [km]	20	20	20	40	40 / 60*
Split Ratio	≥ 1:16 Max: 1:32	≥ 1:32 Max: 1: 64	≥ 1:32 Max: n.a.	≥ 1:64 Max: 1:256	Must support at least: 1:256*
Multiplexing Method	TDM	TDM	TDM	TDM	TWDM* (4 wavelength pairs $\{\lambda_{US},\lambda_{DS}\}$)
Standard	IEEE 802.ah	IEEE 802.ah	IEEE 802.3av	ITU-T G.987	ITU-T G.989*

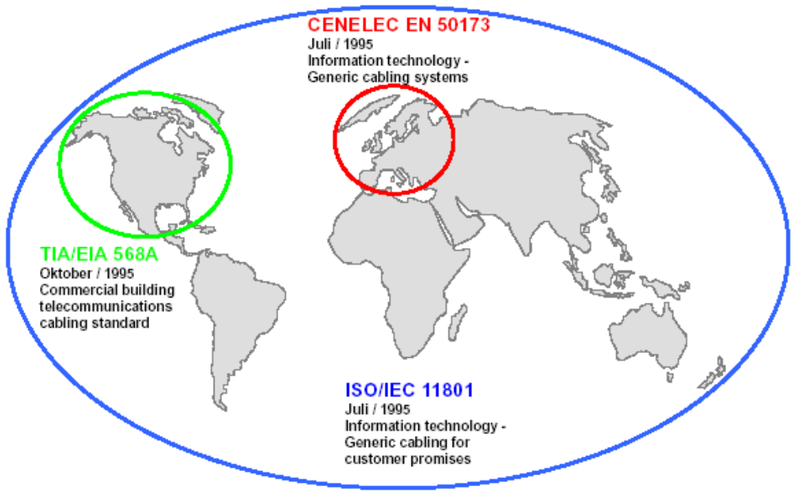
Reason for new Connector Standards

…growth of Bandwidth



IL 0.2 dB corresponds to 4.5 % loss of Light

New Standards IEC 61755 & IEC 61753



IEC 61755

- **Grade A = Singlemode (high**
- **Grade B = Singlemode (adv**
- **Grade C = Singlemode (star**
- **Grade D = Singlemode (economic performance)**
- **Grade M = Multimode**
- **Grade 1 - 4 = RL Values**

IEC 61753

Environmental conditions

New Standard IEC 61755-1

Optical Interfaces

Table 2 – Single mode attenuation grades at 1 310 nm and 1 550 nm (dB)

Attenuation grade	Attenuation (≥ 97%)[a]	Mean	Notes
A	≤ 0.15	≤ 0.07	Reserved for future application
B	≤ 0,25	≤ 0,12	
C	≤ 0,50	≤ 0,25	
D	≤ 1,0	≤ 0,50	

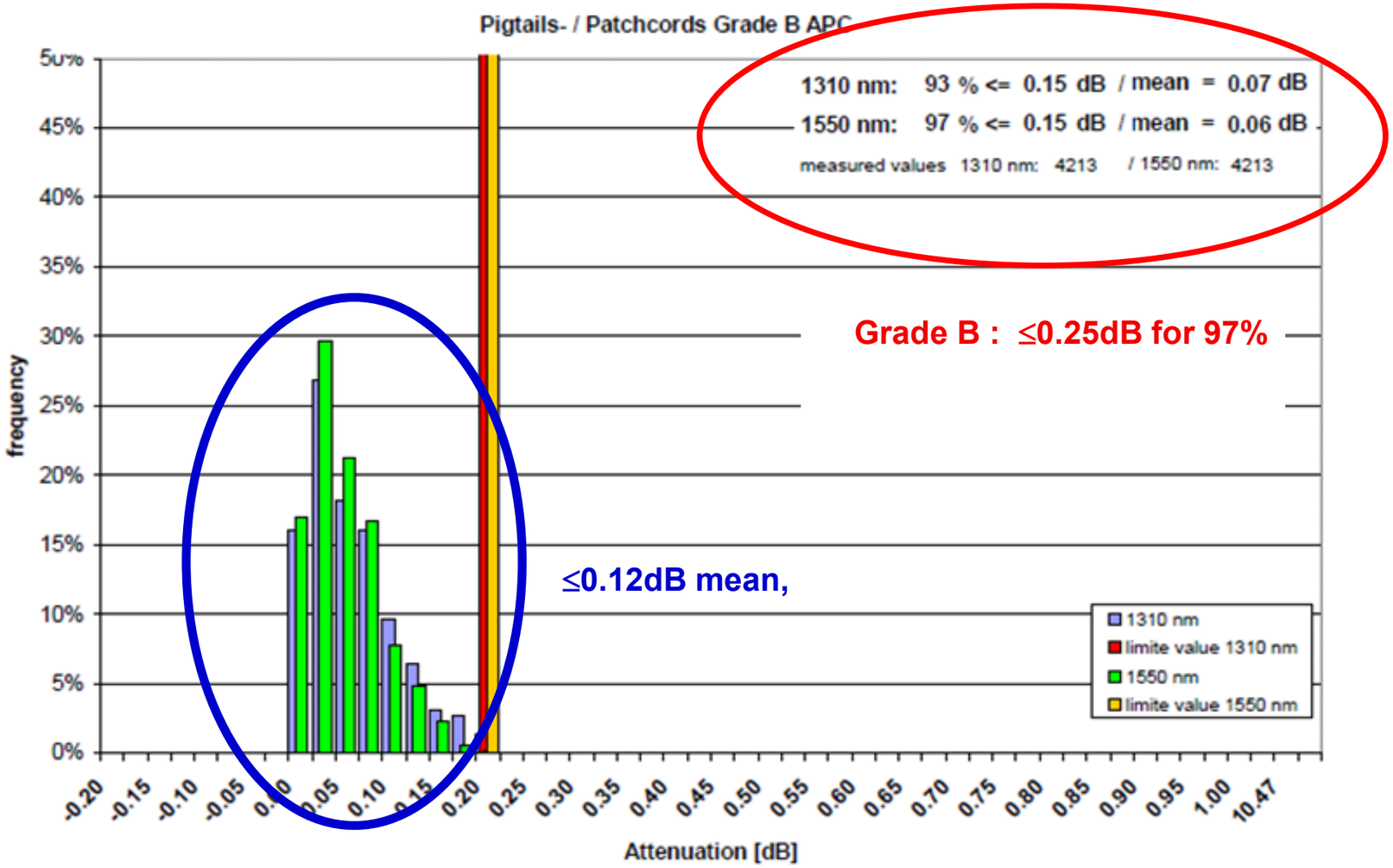
[a] The probability of a random mated connector set of meeting or exceeding the specified level of attenuation will be ≥ 97 %. This performance is reached considering a statistical distribution of connector's parameters (MFD, eccentricity and tilt angle) and using a nominal value for wavelength.

Table 3 – Single mode return loss grades at 1 310 nm and 1 550 nm (dB)

Return loss grade	Return loss (mated)	Notes
1	≥ 60	≥55 dB in unmated condition (APC only)
2	≥ 45	
3	≥ 35	
4	≥ 26	

original chart out of IEC standardization

IL Values

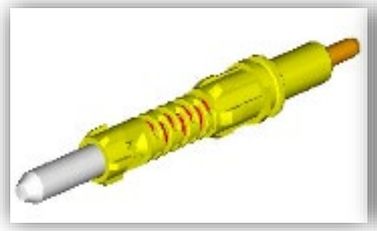

Pigtails- / Patchcords Grade B APC
1310 nm: 93 % <= 0.15 dB / mean = 0.07 dB
1550 nm: 97 % <= 0.15 dB / mean = 0.06 dB
measured values 1310 nm: 4213 / 1550 nm: 4213
Grade B : ≤0.25dB for 97%
≤0.12dB mean,
frequency
Attenuation [dB]
1310 nm
limite value 1310 nm
1550 nm
limite value 1550 nm

The key factors of low loss connectors

The right combination of fiber and ferrule

The polishing process and the material

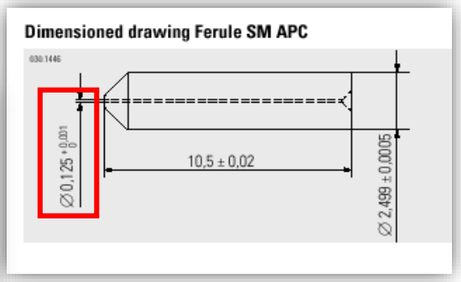
Tuning

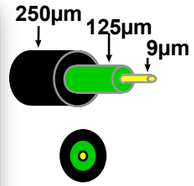


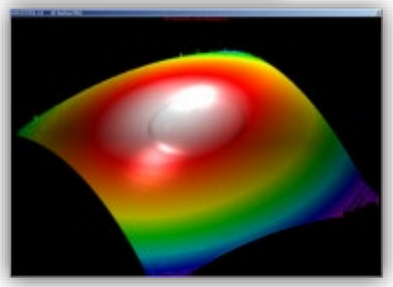
Interferometer & visual control

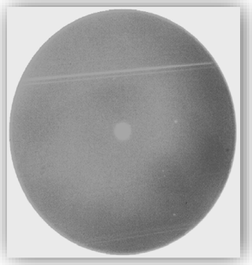
Cleaning & measurement

125um / + 0.001









Your advantage:

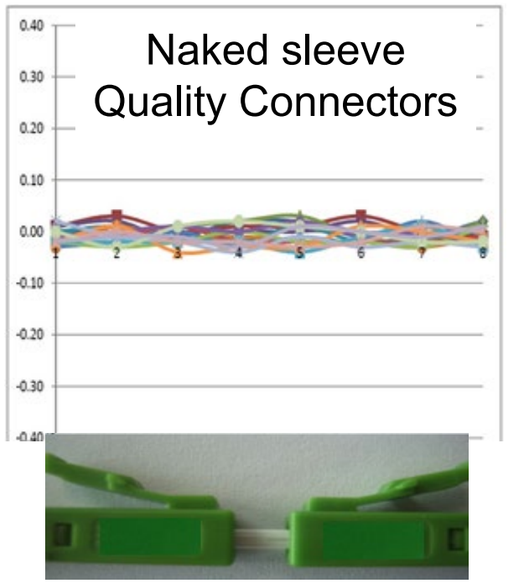
- 100% quality ensurance
- Longterm reliable connectivity

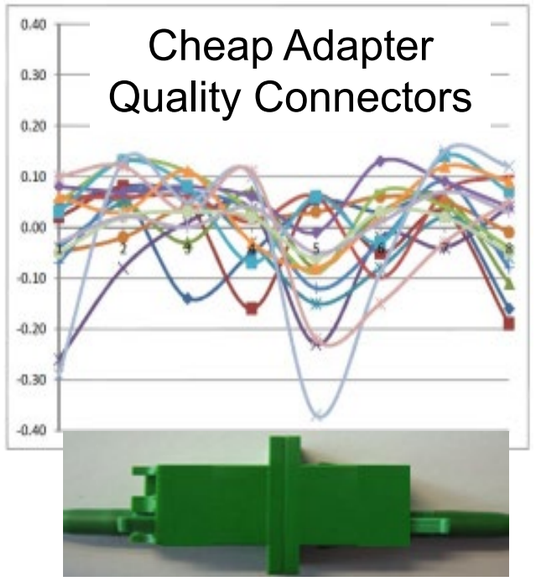
…but important is the connection system

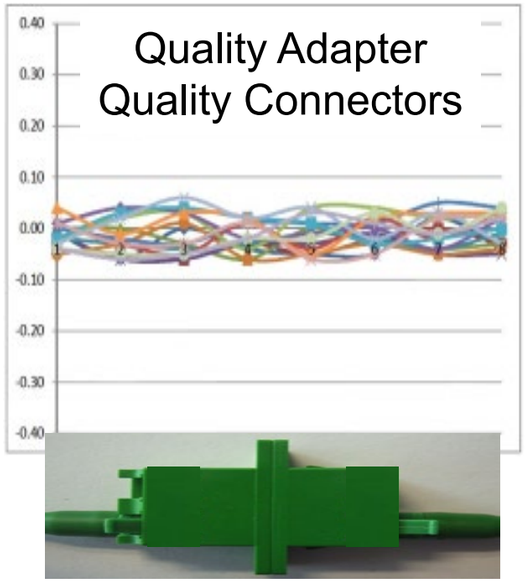
connector + adapter

Performance influence of the adapters

- ➔ geometry of the adapter, standard compliance is not enough!
- ➔ sleeve-quality and cleanness!
- ➔ Measurement, device, method, cable and cleanness

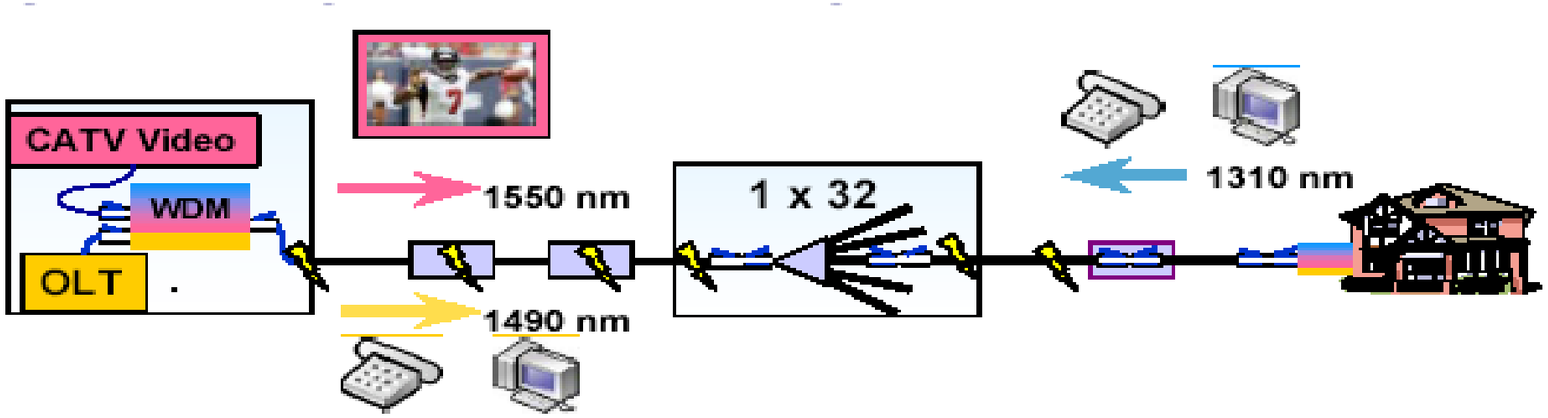






Why new Connector Standards?

Low Loss System extends Reach !



BPON ONU to OLT (1310nm), 25dB optical power budget – ITU Class B Optics – 155Mbps	
Standard FTTP Cabling System	
4 typical SC connections	2.40dB
6 fusion splices	0.44dB
1x32 typical splitter	18.3dB
Maintenance margin	1.0dB
Remaining optical budget	2.86dB
Typical fiber cable attenuation	0.40dB/km
Maximum expected effective reach	7.15km

PON Equipment

Central Office Equipment

- Optical Line Terminal (OLT)
- Basically an Ethernet or ATM Edge Switch w/ a PON interface found at the CO, Headend or POP
- Broadcasts downstream traffic through one or more ports
- Manages “Ranging” or synchronization of same-PON ONTs

Outside Plant Equipment

- Splitters/Combiners/Couplers (Splits or combines signals into multiple branches)
- Found in controlled environments like manholes, under curbs, or in ruggedized outdoor cabinets

PON Equipment

Customer Premise Equipment

- Optical Networking Terminal (ONT) or Unit (ONU)
- Terminates PON network and converts Optical to Electrical
- Filters out frames not addressed to itself
- Converts incoming signal to specific type of CPE traffic such as T1, Ethernet, ATM
- Pass traffic on to Enterprise equipment such as Switches,Routers, PBXs, etc.
- In FTTC, the ONT is located outside of the CP and allows subscribers of other services, like DSL, to access to the PON

Summary PON

PON is the **ideal** solution for delivering Broadband services into FTTH

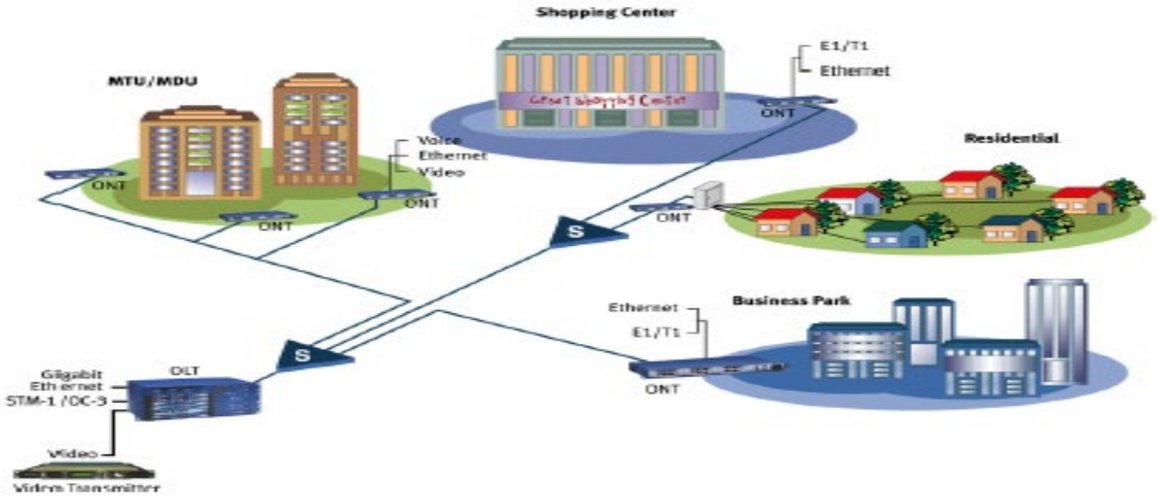
GPON is the **ideal** PON solution for **FTTH**

GPON over **CWDM** guarantees even **more BW** for the future

Established standards

Broad industry support

WDM-PON is the “new kid on the block”



Technology & Deployment

The main factors affecting the infrastructure deployment are:

- Which technology addresses better the requirement (...maybe a combination) ?
- Bandwidth availability & capacity,
- Maintenance & fault isolation
- The use of existing infrastructure?

- Type of FTTH as a green or brown field
- Network architecture P2P or P2MP.
- Local labor costs, local Regulatory , …
- Termination Point (FTTH, FTTB, …)
- Upgradable for new Technologies

PON Standard Fundamentals

	BPON	EPON	GPON
Standard	ITU G.983	IEEE803.2ah	ITU-T G.984
Data Packet Cell Size	53 bytes (48 payload and 5 overload)	1,518 bytes	Variable size, from 53 bytes up to 1,518
Maximum Bandwidth	1.2 Gbit/s downstream; 622 Mbit/s upstream	Up to symmetric 1.25 Gbit/s	Downstream configurable from 1.2 Gbit/s to 2.5 Gbit/s; upstream configurable in 155 Mbit/s, 622 Mbit/s, 1.25 Gbit/s, or 2.5 Gbit/s
Downstream Wavelength	1480nm to 1500nm	1550nm	1480nm to 1500nm
Upstream Wavelength	1260nm to 1360nm	1310nm	1260nm to 1360nm
Traffic Modes	ATM	Ethernet	ATM, Ethernet, TDM
Voice	TDM	VOIP or TDM	Native TDM
Video	1550nm overlay	1550nm overlay	Either as RF or over IP
ODN Classes Supported	A, B, and C	A and B	A, B, and C
Max PON Splits	32	16	64

Total Loss Budget Standards

Defined by the standards.

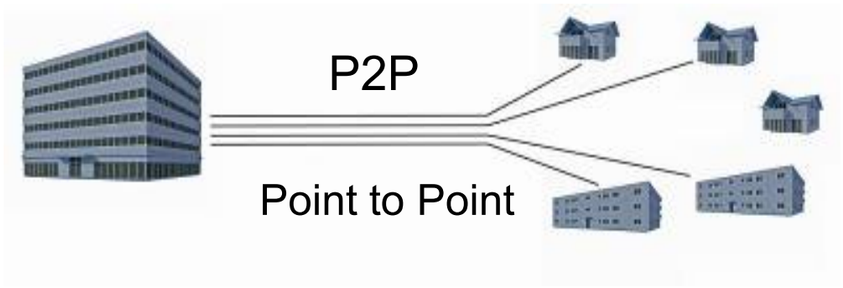
The **ITU** organization will specify the maximum loss in order to get an “error free”transmission:

Table G.984.2 – Classes for optical path loss

	Class A	Class B	Class B +	Class C
Minimum loss	5 dB	10 dB	13 dB	15 dB
Maximum loss	20 dB	25 dB	28 dB	30 dB
NOTE – The requirements of a particular class may be more stringent for one system type than for another, e.g. the class C attenuation range is inherently more stringent for TCM systems due to the use of a 1:2 splitter/combiner at each side of the ODN, each having a loss of about 3 dB.				

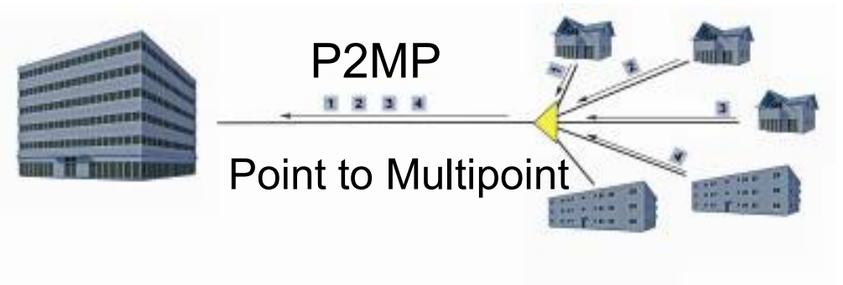
FTTH – Network Topologies

B2B services



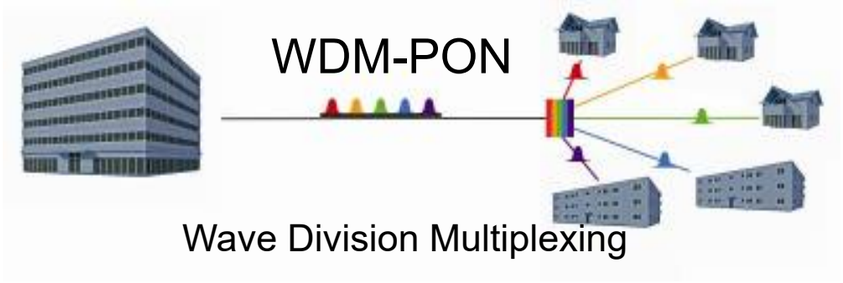
Home Run
- P2P connections via Ethernet Switch
- Typical distance 10km (max 40km)
- Very common for MDU

B2C services



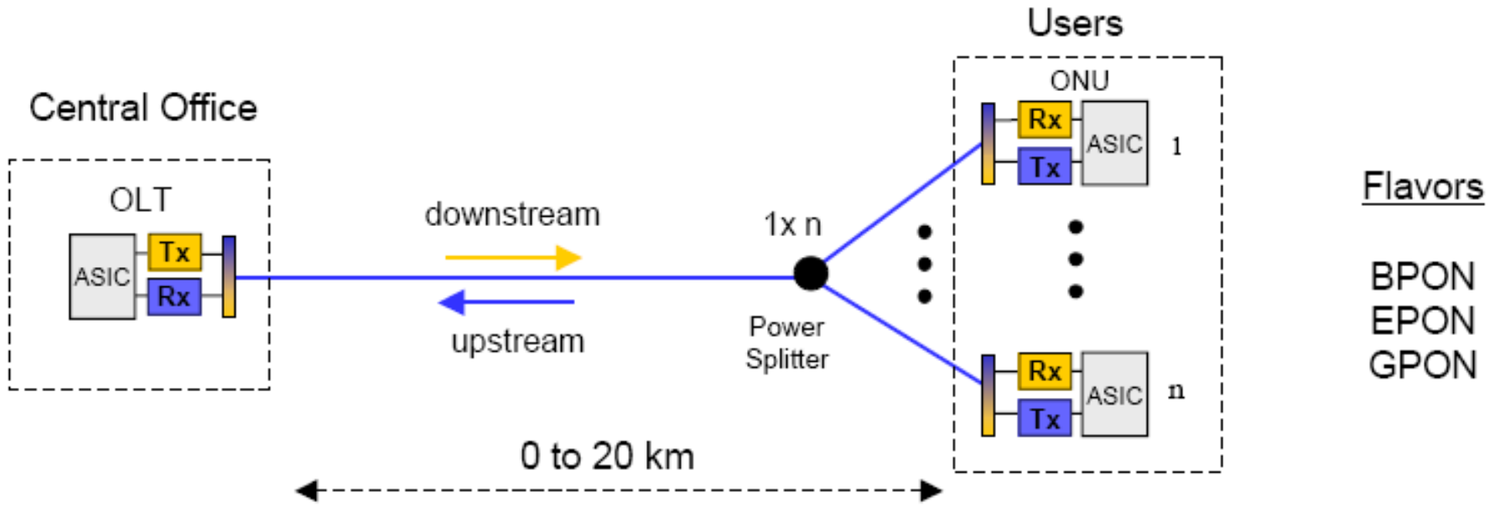
Power Split
- Split Upstream (TDMA); 20km (60)
- 32 – 128 subscribers per PON
- Variants BPON, EPON, GPON (common for mass markets)

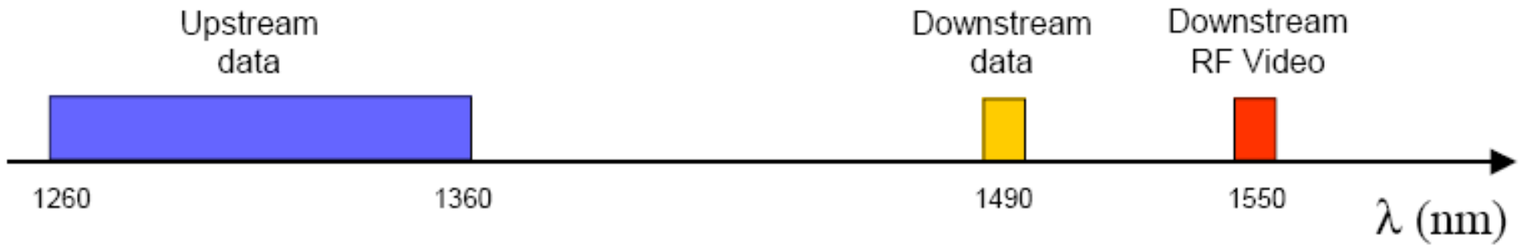
B2C / B2B



WDM PON
- Wavelength (color) per customer
- Under standardization
- High bandwidth per customer
- Combines advantages of P2P and P2MP

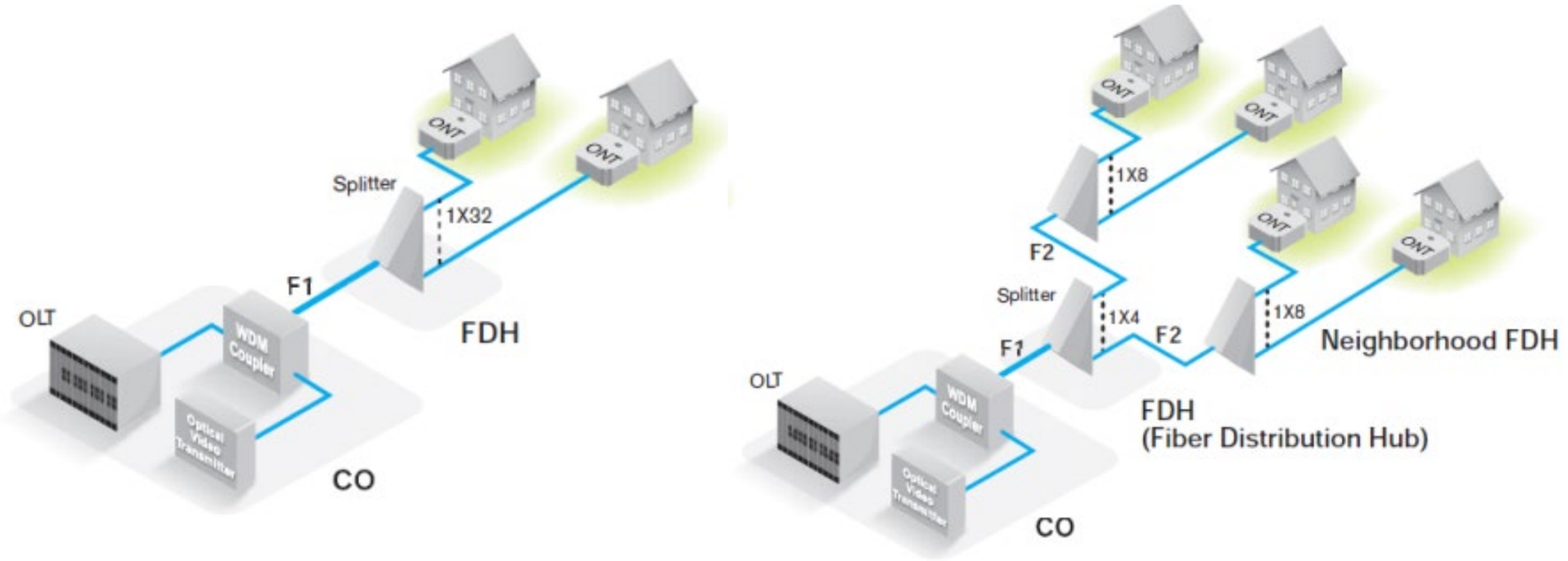
P2MP Connectivity





Deployment Topology GPON

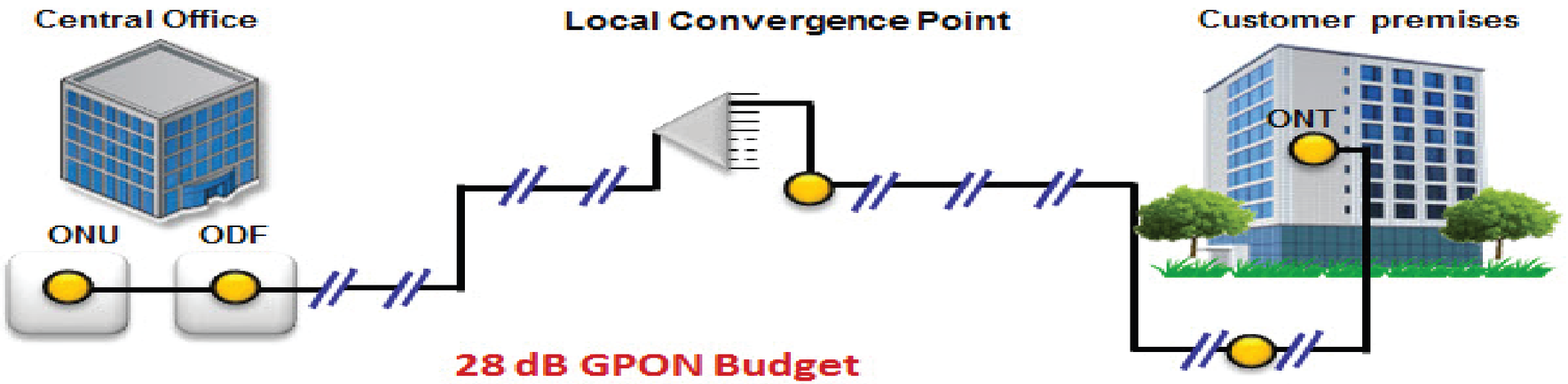
Power budget vs Splitters

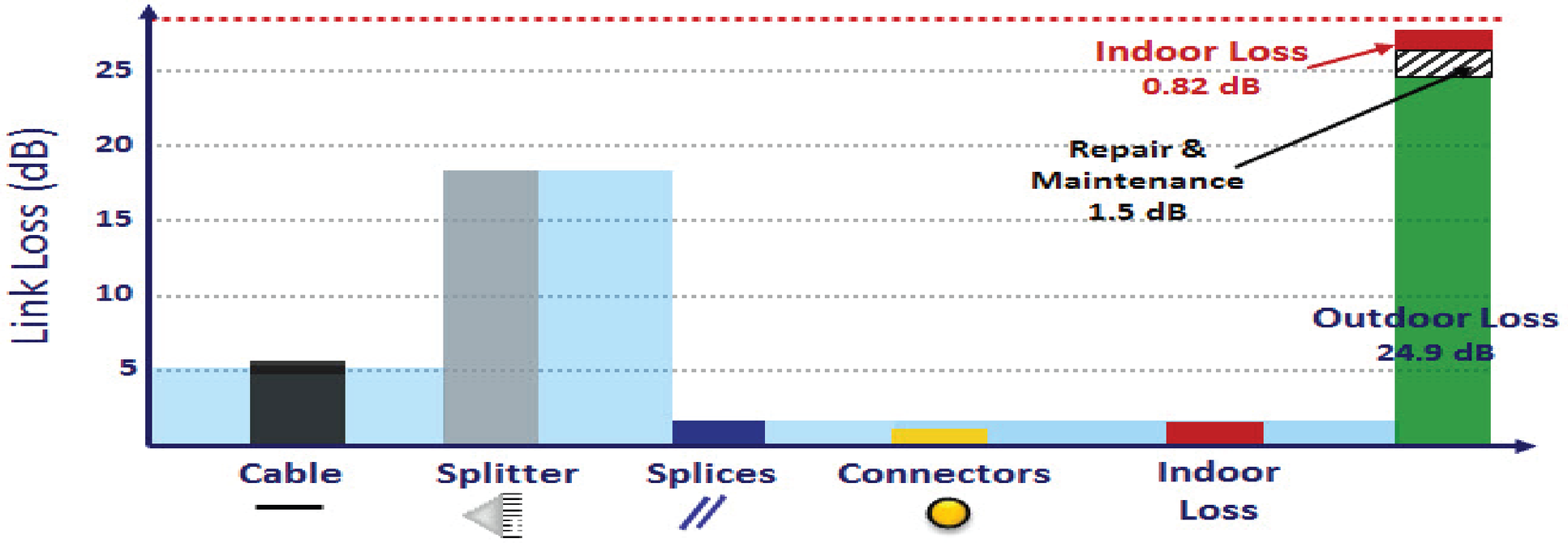


In a power budget for a GPON scenario with e.g 28 dB, cannot be implemented any number of splitters. (Today: 1:32 or 1: 4 and 1: 8 recommended). All connections, cable attenuations, connectors and components have to be included in the Budged-Calculation.

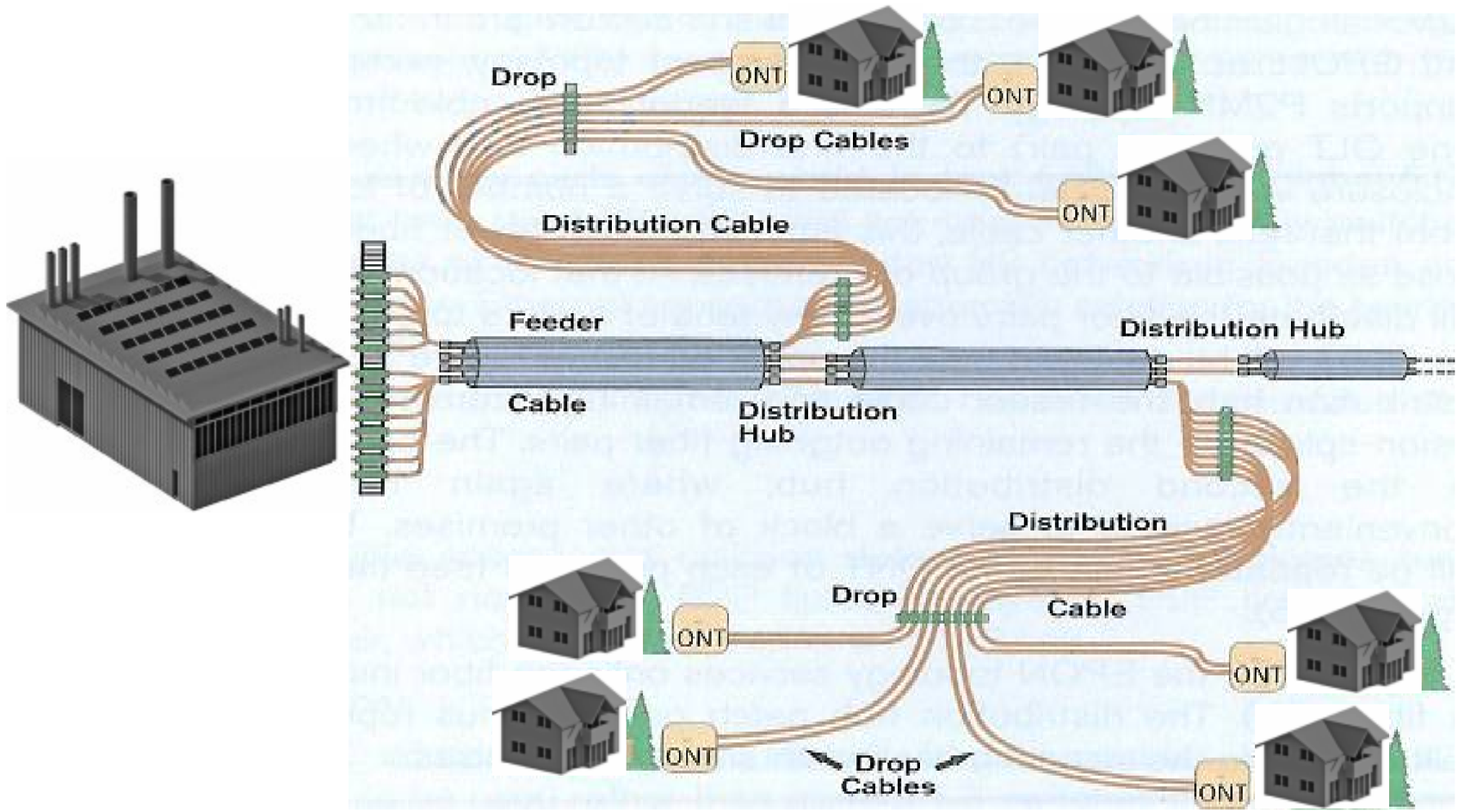
Deployment Topology GPON

Power budget vs Splitters

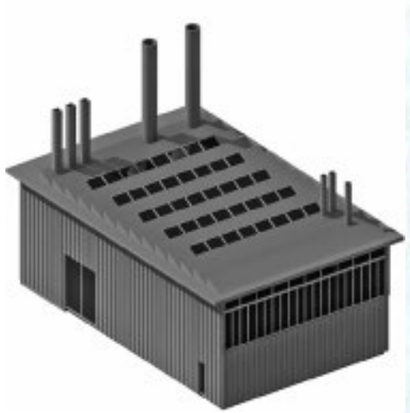


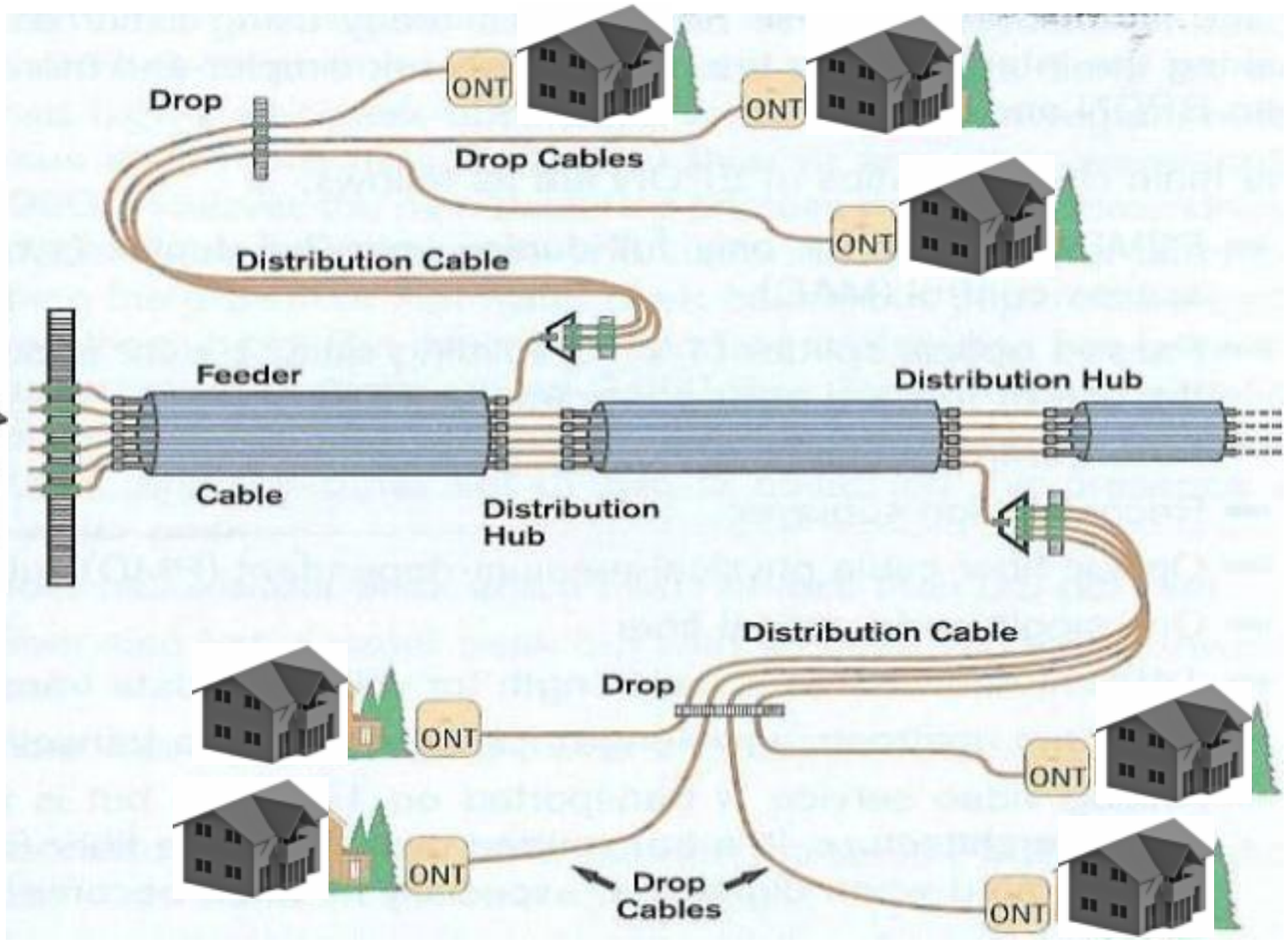


Network Topology P2P



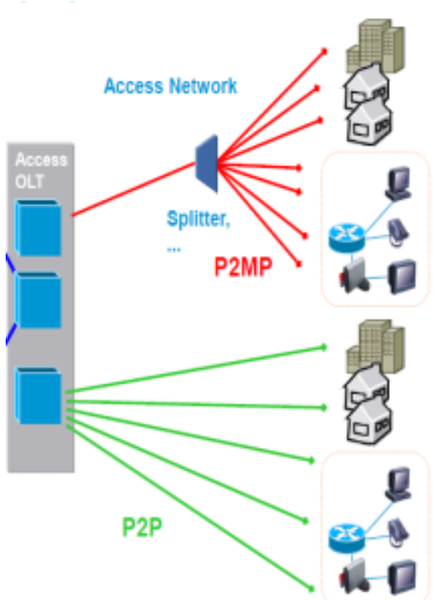
Network Topology P2MP

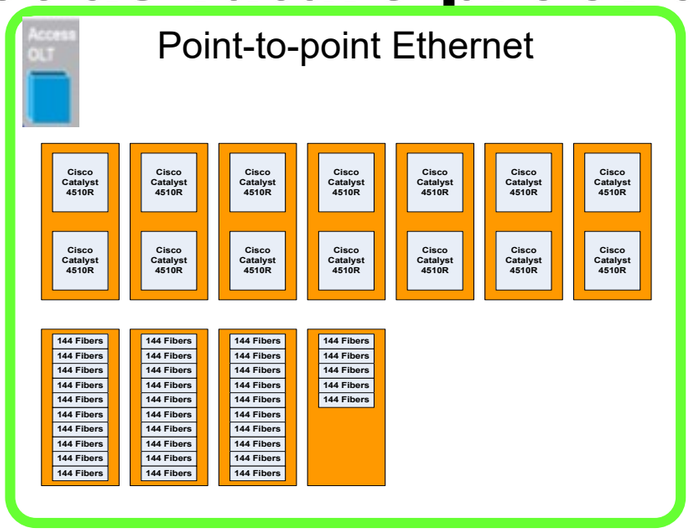


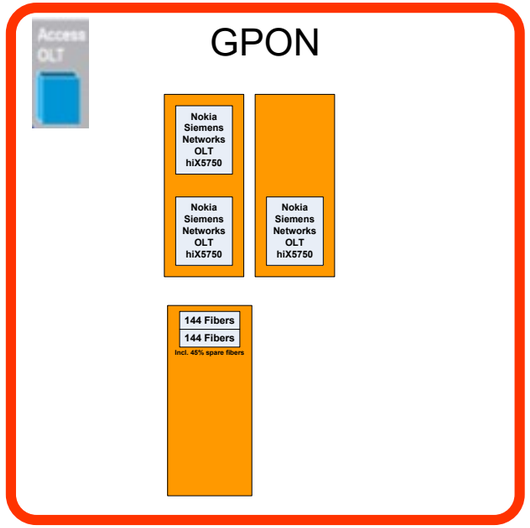


The TCO advantage of P2MP

…but not as future proof as P2P

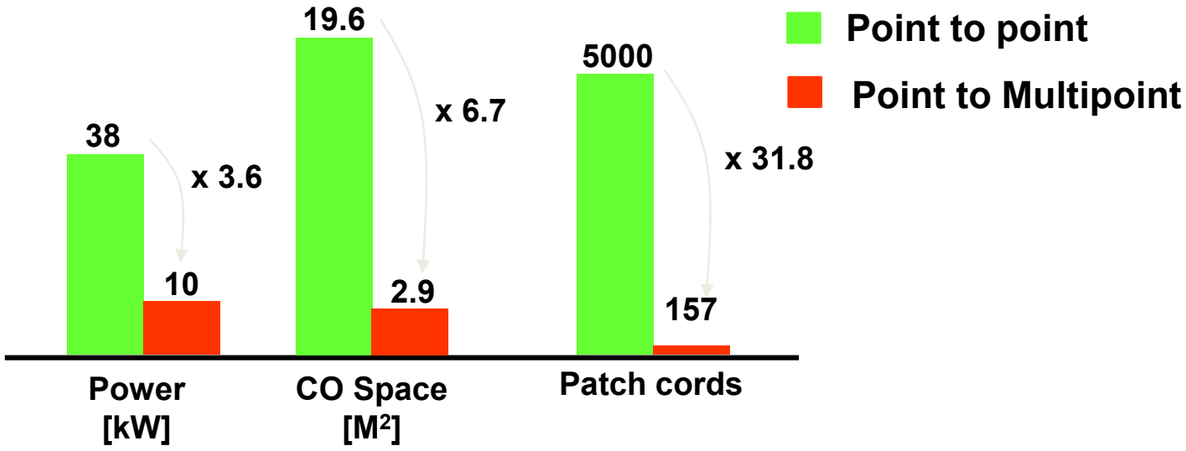






Realistic deployment

- 5000 subscribers connected to CO
- PON splitting ratio 1:32
- Fibre terminations per ODF rack: 1,440 (10 shelves holding 144 fibres)
- Power consumption figures and ports per cage based on real product specs



P2MP or P2P?

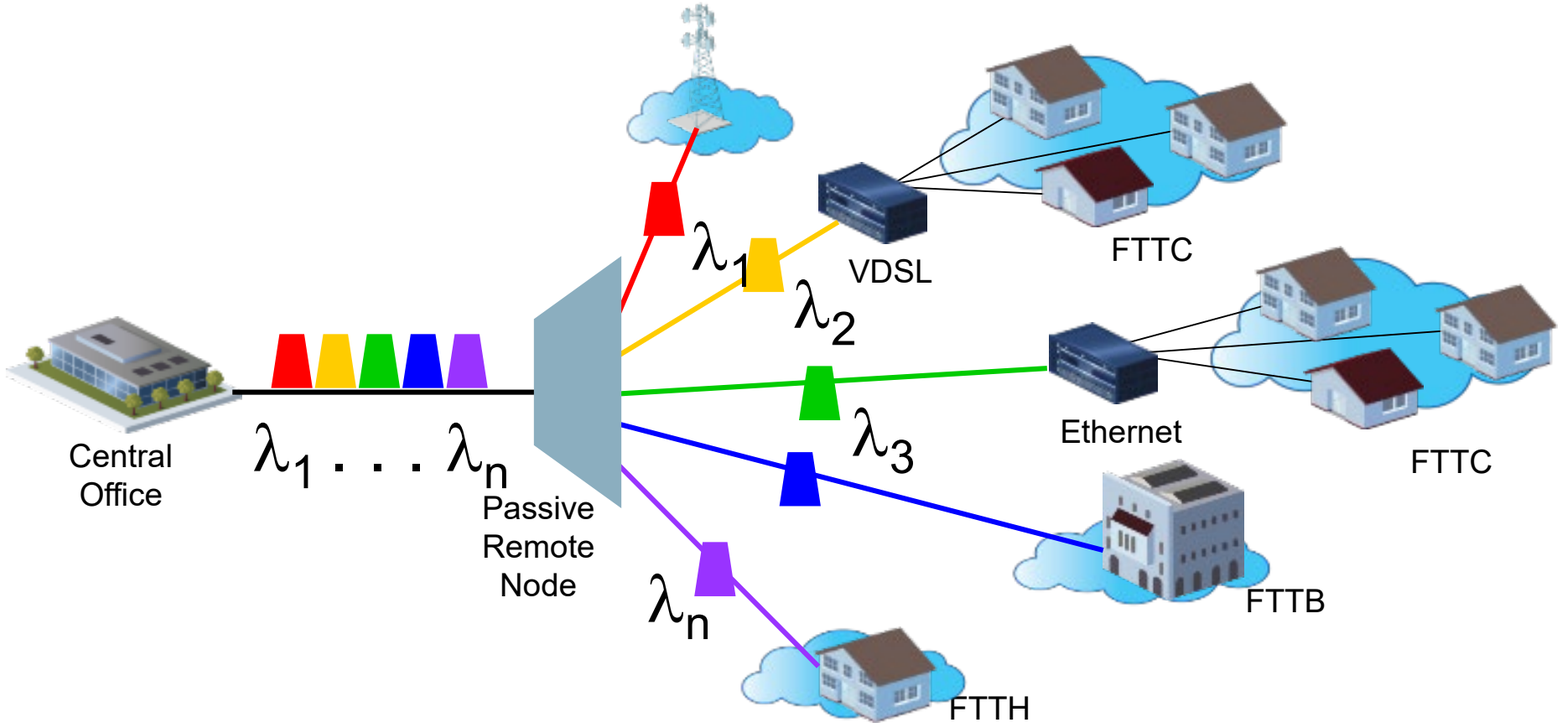
What do the customer need?

- Where is the area in question ?
- How far from central office ?
- Less maintenance ?
- More future proof ?
- Be different or same as most ?
- Space
- …

Network topology

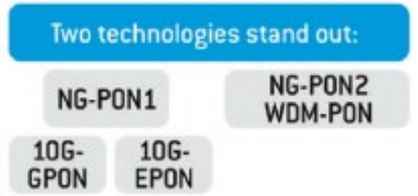
P2P or P2MP decision (maybe both – but in this case we have to know for each subscriber how they are going to be connected; for example if it is a residential area it can be completely P2MP, for a business park it could be P2P)

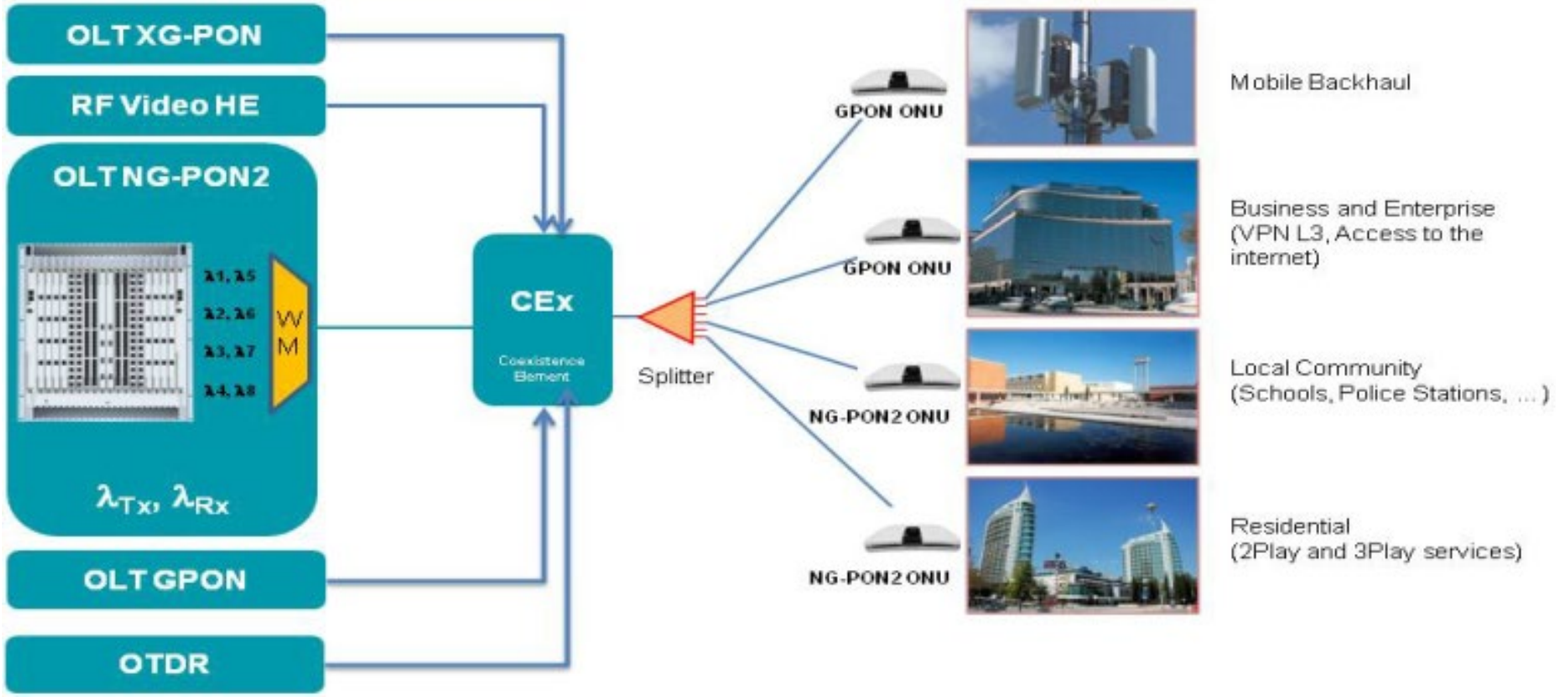
WDM PON network architecture



Each wavelength in a WDM-PON network is effectively a P2P link to the Customer, allowing each link to run a different speed and protocol for maximum flexibility and pay-as-you-grow upgrades.

FTTx Future

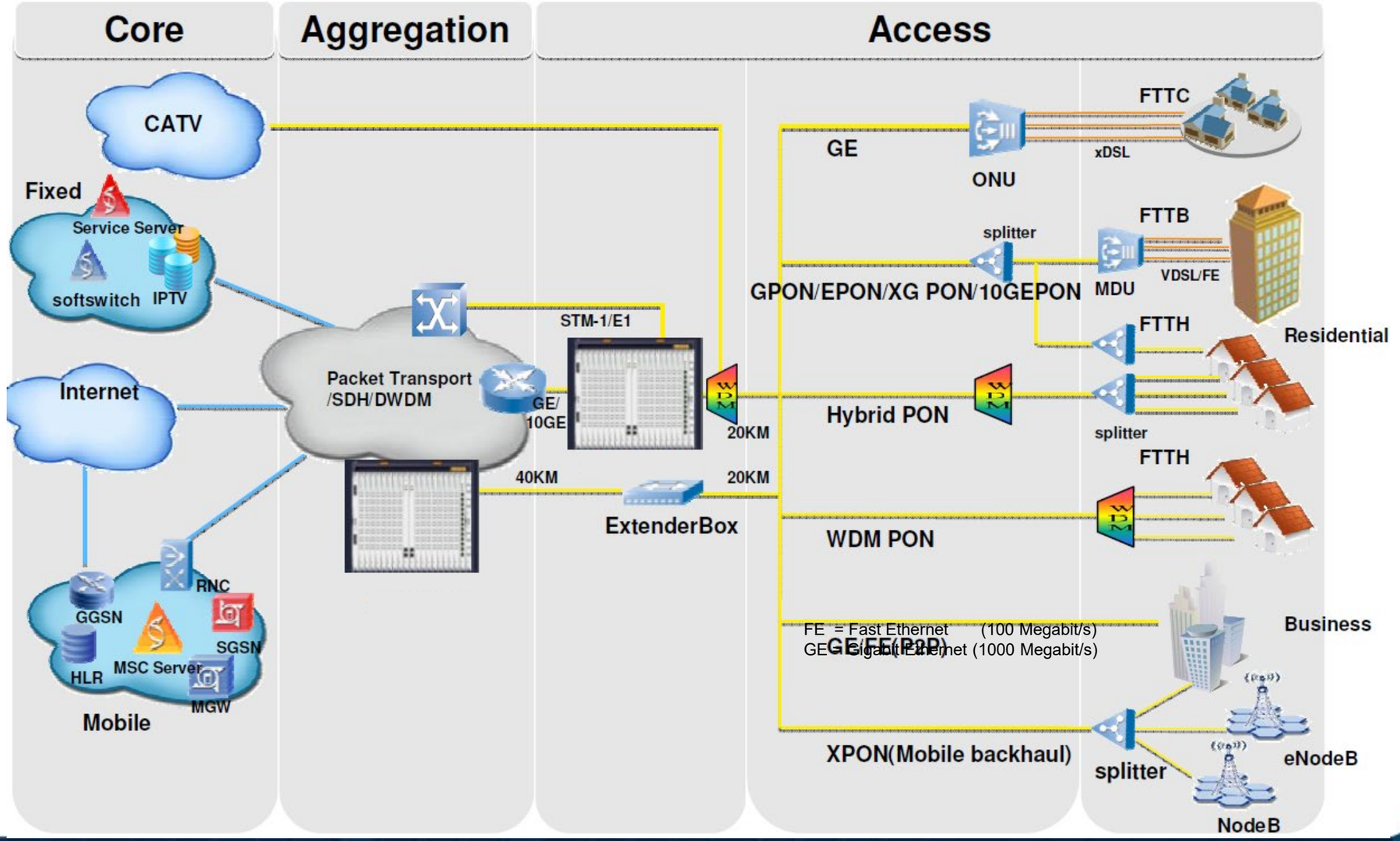




- **Promising Technologies**

•Among all technologies that could possibly allow service providers to increase the bandwith per user, two currently stand out to become the technology of choice for Next Generation Networks : NG-PON1 and NG-PON2 .

Unified xPON Access Platform



Two technologies stand out:

NG-PON1 | NG-PON2 WDM-PON | 10G-GPON | 10G-EPON

NG-PON Standards

Service Providers who have already deployed FTTx, will be able to reuse the same high-quality-network (ODN) and therefore protect their current investment.

Type		10G-GPON		10G-EPON		WDM-PON	
Standard	Units	G.987		802.3av™		**ITU-T G.989***	
Protocol		Ethernet, TDM, TDMA		Ethernet		T.B.C.	
Services		Voice/data - Triple-play -File exchange/remote learning/IPTV/ VOD		-Voice/data - Triple-play -File exchange/remote learning/IPTV/ VOD		Voice/data - Triple-play -File exchange/remote learning/IPTV/ VOD	
Maximum physical distance (OLT to ONT)	km	Up to 20		Up to 20		**40/60 ***	
Split Ratio		up to 1x64		up to 1x32		**1:256**	
Nominal bit rate *		Downstream	Upstream	Downstream	Upstream	Downstream	Upstream
Asymmetric	Gb/s	10	2,5	10	1,25	Virtually no limits E.g., 1 Gbit/s per user	Virtually no limits E.g., 1 Gbit/s per user
Symmetric	Gb/s	10	10	10	10		
Operating wavelength band	nm	1577 -2, +3	1270 ±10	1577 -2, +3	1270 ±10	**(4 wavelength pairs $\{\lambda_{US},\lambda_{DS}\}$**	
ORL_{MAX}	dB	≥32		≥ 20		**≥ 40**	

PON Future
XG-PON1 (ITU-T G.987)

- XG-PON1is considered a short term evolution of GPON. It uses a single wavelength for the downstream PON signal and a single wavelength for the upstream PON signal. This PON has been standardized by the ITU-T 987.x recommendation series.

- Co-existence of two different technologies over the same fiber: GPON and XG-PON1

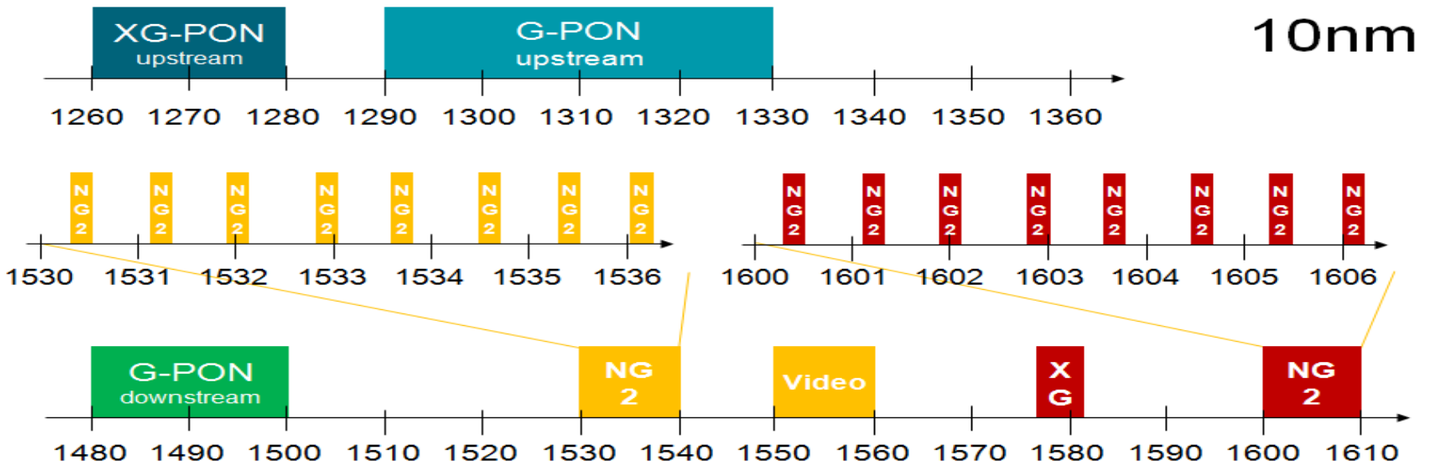
- Downstream: 10 Gbps / Upstream: 2.5 Gbps;

- Co-existence of XG-PON1and GPON on the same fiber infrastructure separated in wavelength domain => introduction of blocking filters at customer premises and of WDM multiplexers in CO

PON Future

NG-PON2 (ITU-T G.989.x)

- NG-PON2 stacks multiple XG-PON1 systems in the wavelength domain
- Standards:
  - G.989.2 => 40-Gigabit-capable passive optical networks (NG-PON2): Physical media dependent (PMD) layer specification
  - G.989.3 => 40-Gigabit-capable passive optical networks (NG-PON2): Transmission Convergence Layer



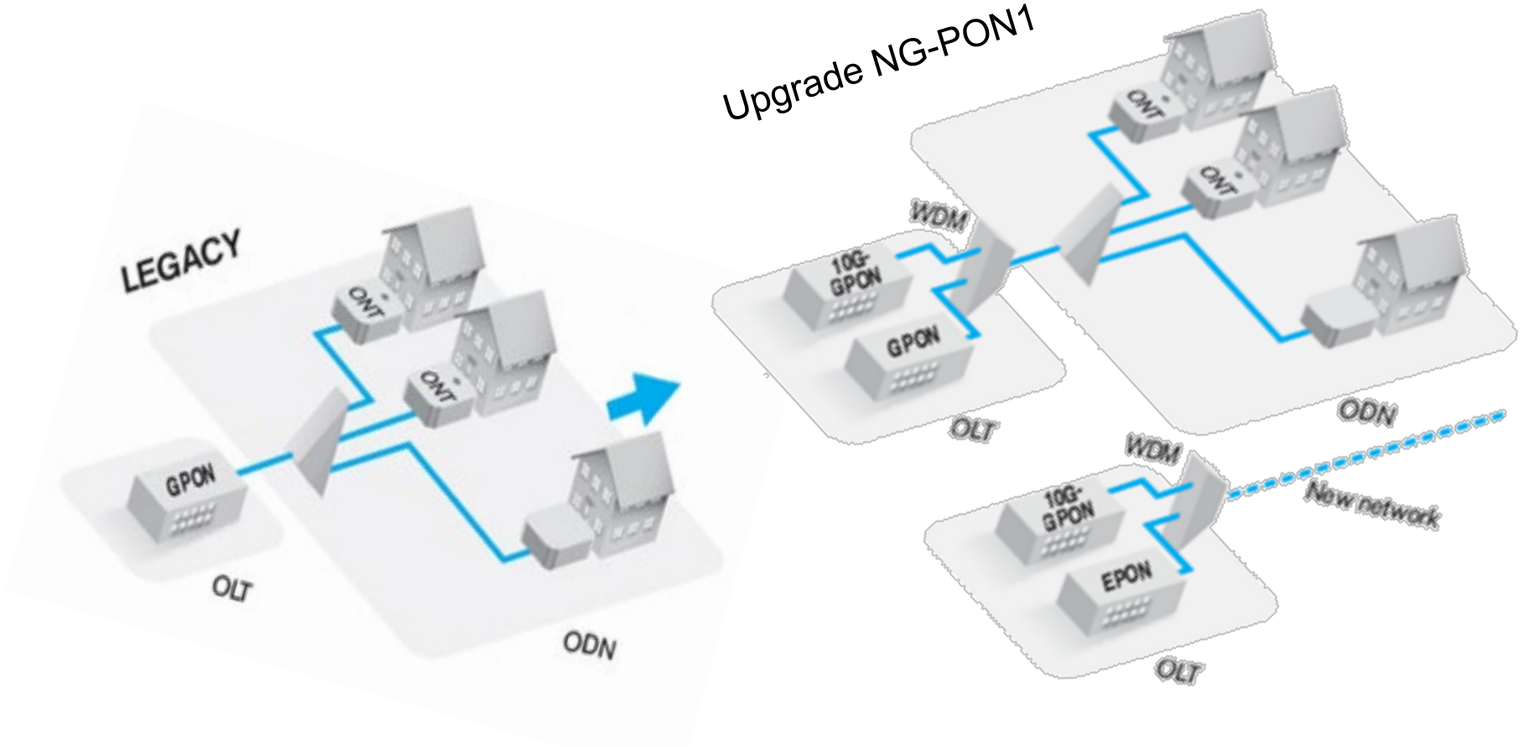
NG-PON Technology Evolution

Two technologies stand out:

NG-PON1 | NG-PON2 WDM-PON

10G-GPON | 10G-EPON

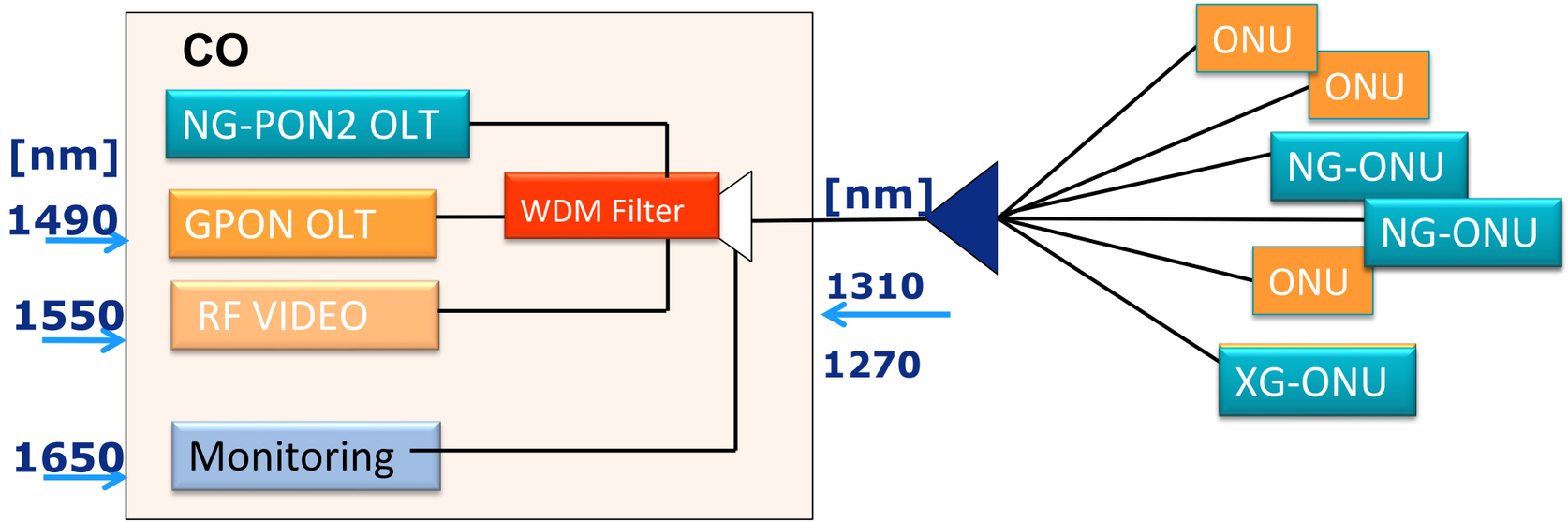
NG-PON1 (10G)



One interesting characteristic of 10G-PON and 10G-EPON is, that the ITU and IEEE committees have defined a «coexistence mindset», allowing for concurent operation with current PON technology. Allows a smoth upgrade using the existing ODN Network.

The Future of FTTH

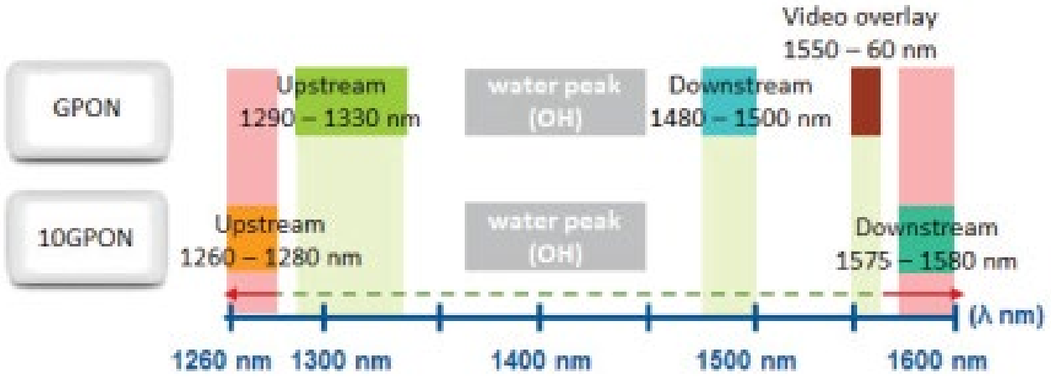
Increase the bandwidth to ≥10 Gb/s DS & US, ie NG-PON2

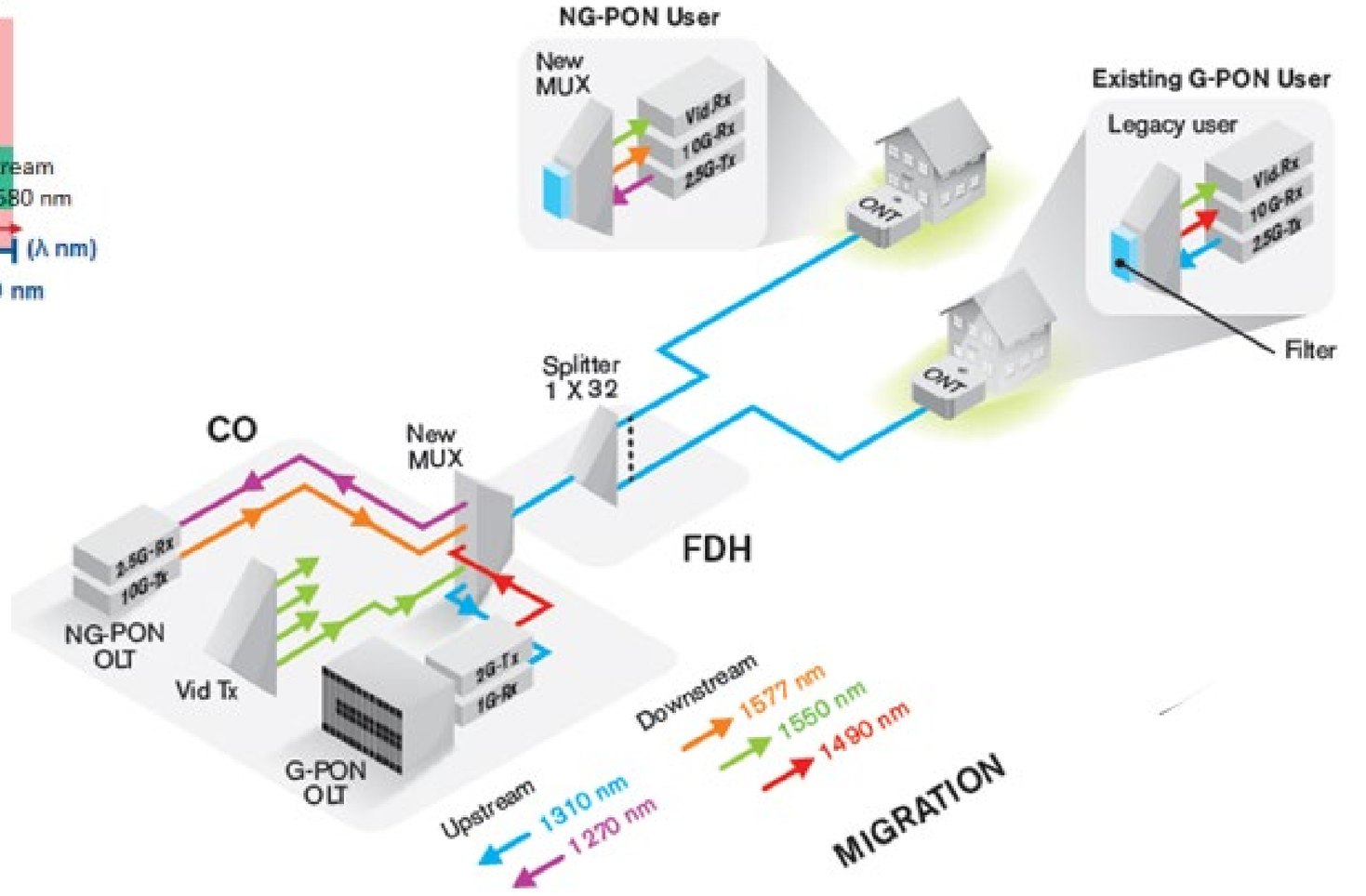


- **NG-PON2 Requirement for coexistence with RF Overlay in GPON scenario:**
  - Support of RF Overlay is needed;
  - Minimize impact on the RF performance;
  - Upgrade to NG-PON with minimal service disruption of GPON clients;

NG-PON Technology Evolution

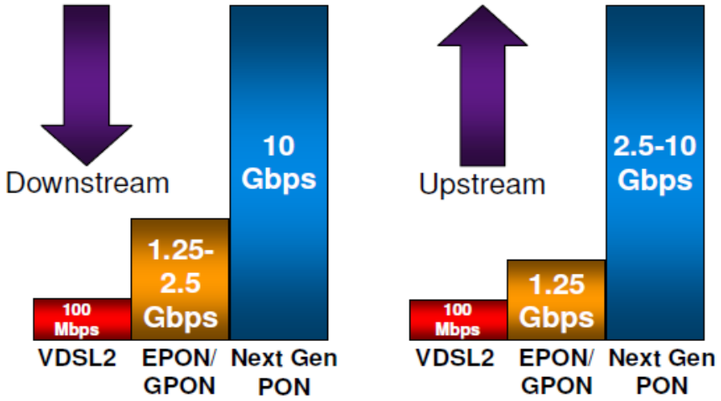
NG-PON1 (10G)





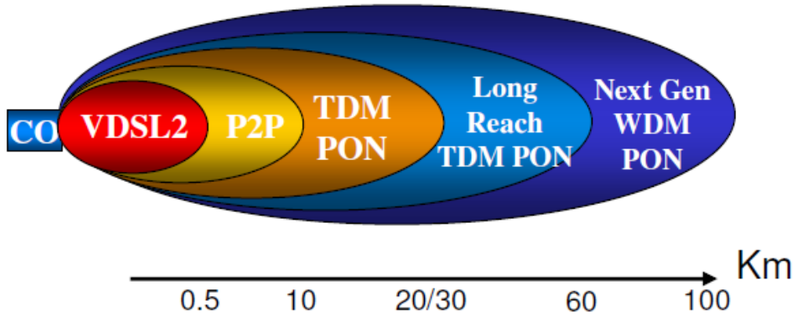
What are Next Gen PON Key Benefits

Increased Capacity



- Increased bandwidth will offer new services and will increase revenues
- Higher ports density with higher splitter ratio will offer more subscribers per central office thus reducing OPEX & CAPEX

Increased Coverrage



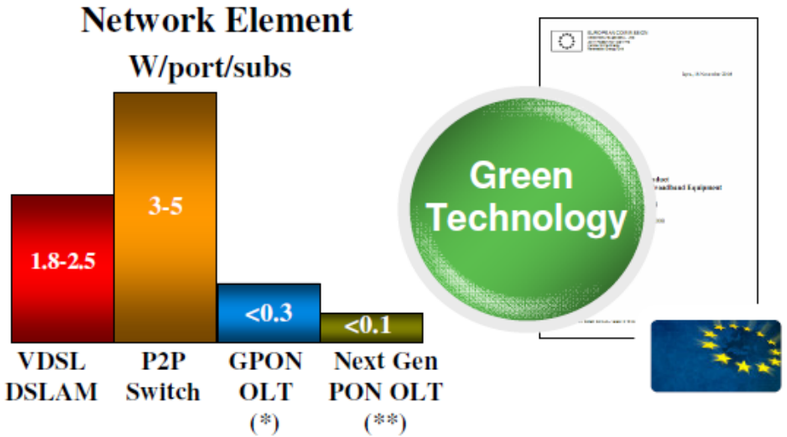
- Increased Coverage will reduce the number of Central offices needed in rural areas thus offering OPEX & CAPEX savings
- Operators can close end remove unneccesary exchanges

(France Telecom could close 95% of its rural COs with Long Reach)

Next Gen PON Networks will Reduce TCO and Increase Revenues

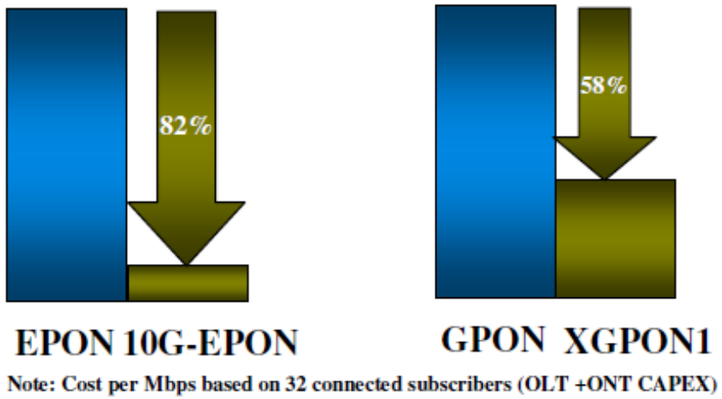
What are Next Gen PON Key Benefits

Green Network Elements



- xPON networks offers lower consumption Levels compared to VDSL and P2P technologies leading to OPEX savings
- Next Gen PON OLTs will offer additional savings based on green innovations and higher split ratio (*) 64 subscribers (**) 128 subscribers

Lower cost per Mbps



Note: Cost per Mbps based on 32 connected subscribers (OLT +ONT CAPEX)

- Next Gen PON Optics costs are higher due to higher performance levels
- The cost of 10G-EPON will decrease compared to EPON
- The cost of XGPON1 will decrease compared to GPON

Next Gen PON Networks will Reduce TCO and Increase Revenues

Benefits of Unified xPON Access Platform

Reduced CAPEX

Cost efficient industrial chain :

- Unified chipsets & modules for different xPON technologies

Flexible Platform:

- Common Chassis & backplane for GPON / EPON /P2P/ 10GE PON / XG-PON 1/ WDM-PON cards

Next Gen PON Readiness :

- Lower upgrade costs: Only 1 new module is needed for the upgrade to 10G-EPON (or XG-PON1 or WDM- PON) compared to a traditional design

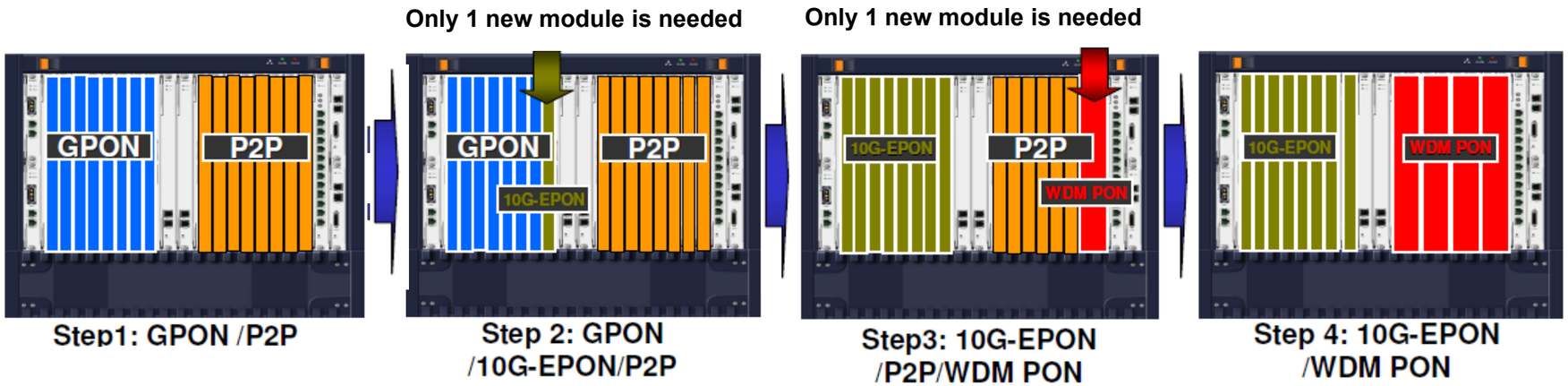
Reduced OPEX

Green Technology:

- Lower power consumption with newest design & innovative features

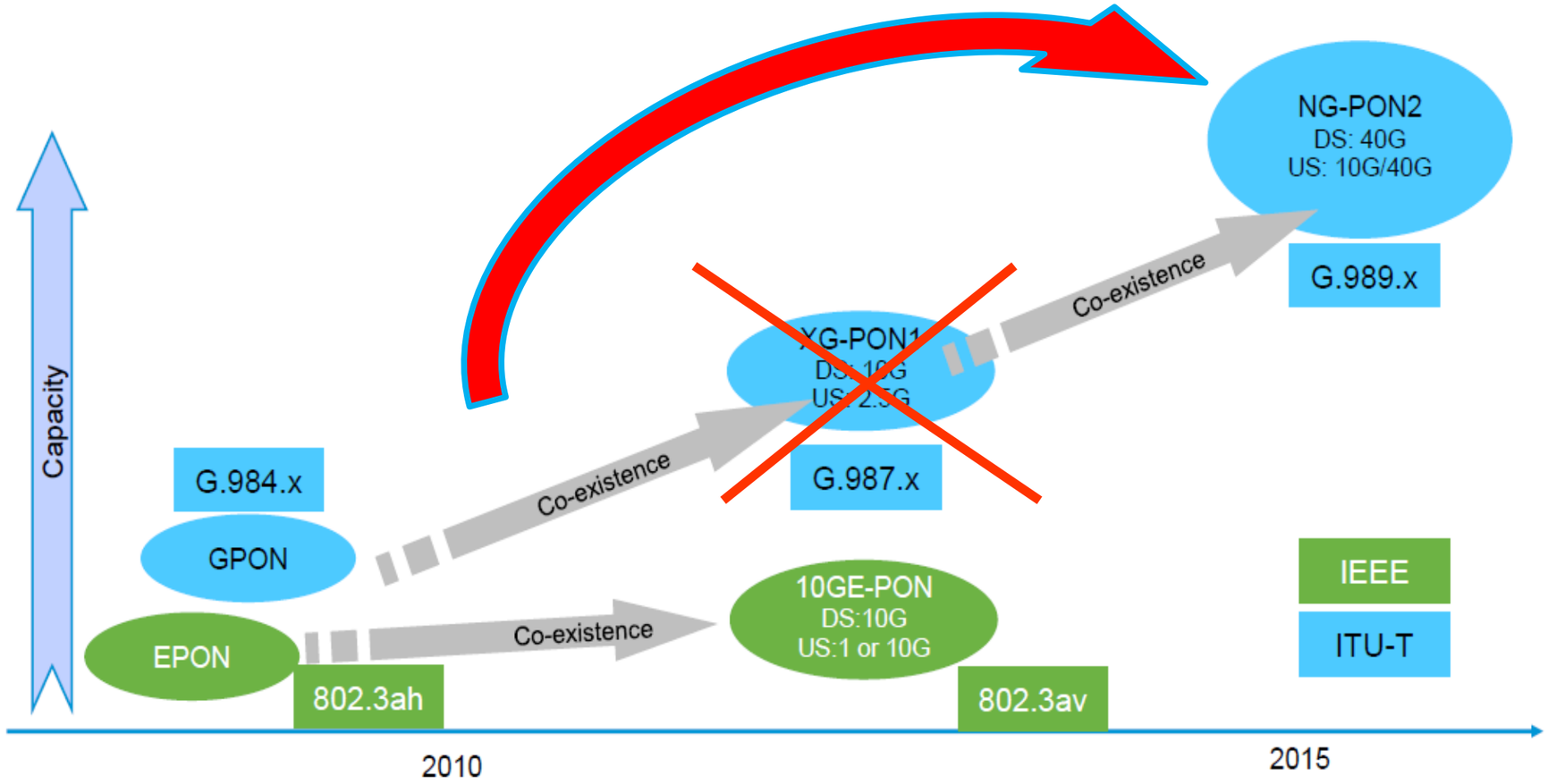
Optimized OAM :

- Unified Operation & Maintenance for different xPON technologies

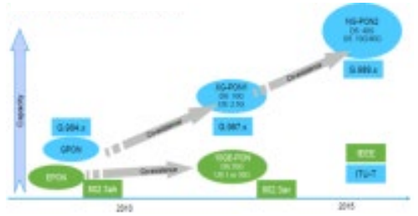


Unified xPON Platform Reduces OPEX & CAPEX and Preserves Initial Investments

The Evolution of PON Technology



Conclusion Network



- Next generation PON's will enable seamless evolution, from existing optical access networks, which are mainly residential-focussed, to converged access networks supporting residential, business, cloud and mobile backhaul services.

- Large investments have been made deploying optical fiber at the access network layer. Any new technology has to use the existing passive fiber infrastructure (e.g. splitter based P2MP plant)

- In terms of bitrates, XG-PON1 technology is the natural successor to GPON, but the need for higher bitrates will lead many operators to upgrade their networks directly to NG-PON2.

- Time and wavelength division multiplexed PON (TWDM-PON) has been chosen as the technical concept for NG-PON2.

Questions…

Thank you for your attention