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

- Intelligent Power Grid
- Virtual companies: on demand enterprises
- Efficient Healthcare
- Next Generation Online Entertainment
- "Knowledge Economy"
- Cloud Computing: all applications online
- Telepresence: High quality video comms
- ...
The demand for bandwidth and services...require High-Quality-Networks

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

B2C services

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

B2B services
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
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

- **2010**
  - DS: ?
  - US: ?
- **2012**
  - DS: 40 Gbps
  - US: 10 Gbps
- **2015**
  - DS: 10 Gbps
  - US: 2.5 Gbps
- **2015**
  - DS: 10 Gbps
  - US: 10 Gbps
- **2015**
  - DS: 2.5 Gbps
  - US: 1.2 Gbps
- **2012**
  - DS: 1 Gbps
  - US: 1 Gbps
- **2015**
  - DS: 10 Gbps
  - US: 10 Gbps
- **2020**
  - DS: 40 Gbps
  - US: 10 Gbps
- **2020**
  - DS: 10 Gbps
  - US: 2.5 Gbps
- **2015**
  - DS: 10 Gbps
  - US: 10 Gbps
- **2015**
  - NG PON2
  - DS: 10 Gbps
  - US: 10 Gbps
- **2020**
  - NG PON3
  - DS: 10 Gbps
  - US: 2.5 Gbps

Timeline:

- GPON (ITU-T G.984)
  - DS: 1 Gbps
  - US: 1 Gbps
- 10G EPON (IEEE 802.3av)
  - DS: 10 Gbps
  - US: 10 Gbps
- XG PON (ITU-T G.987)
  - DS: 10 Gbps
  - US: 2.5 Gbps
- NG PON2
  - DS: 10 Gbps
  - US: 10 Gbps
- NG PON3
  - DS: 10 Gbps
  - US: 2.5 Gbps

Higher data rate longer reach higher split ratios new multiplexing method.
### Where is the influence for layer 1

<table>
<thead>
<tr>
<th></th>
<th>GEAPON</th>
<th>GPON</th>
<th>10G EPON</th>
<th>XG PON</th>
<th>NG PON2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data Rate DS / US [Gbps]</strong></td>
<td>1 / 1</td>
<td>2.5 / 1.2</td>
<td>10 / 10</td>
<td>10 / 2.5</td>
<td>40 / 10*</td>
</tr>
<tr>
<td><strong>Power Budget [dB]</strong></td>
<td>26</td>
<td>30</td>
<td>30.5</td>
<td>35</td>
<td>~ 40 dB**</td>
</tr>
<tr>
<td><strong>Laser Power US (ONU) / DS (OLT) [mW]</strong></td>
<td>0.8 / 1.6</td>
<td>1.6 / 2.0</td>
<td>2.5 / 3.2</td>
<td>1.6 / 28.2</td>
<td>~1.8 / ~10**</td>
</tr>
<tr>
<td><strong>Physical Reach (typ.) [km]</strong></td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>40</td>
<td>40 / 60*</td>
</tr>
<tr>
<td><strong>Split Ratio</strong></td>
<td>≥ 1:16 Max: 1:32</td>
<td>≥ 1:32 Max: 1:64</td>
<td>≥ 1:32 Max: n.a.</td>
<td>≥ 1:64 Max: 1:256</td>
<td>Must support at least: 1:256*</td>
</tr>
<tr>
<td><strong>Multiplexing Method</strong></td>
<td>TDM</td>
<td>TDM</td>
<td>TDM</td>
<td>TDM</td>
<td>TWDM* (4 wavelength pairs {λUS,λDS})</td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td>IEEE 802.ah</td>
<td>IEEE 802.ah</td>
<td>IEEE 802.3av</td>
<td>ITU-T G.987</td>
<td>ITU-T G.989*</td>
</tr>
</tbody>
</table>
Reason for new Connector Standards

...growth of Bandwidth

- 2.4k (Analog Copper, Voice-Modem Dial-up)
- 64k (Digital Copper, ISDN Dial-up)
- 40M (Enhanced Copper, ADSL Always-on)
- 100M (Hybrid Fiber & Copper, Fiber + VDSL Always-on)
- Pure fiber (1G, FTTH Always-on)

IL 0.2 dB corresponds to 4.5% loss of Light
New Standards IEC 61755 & IEC 61753

IEC 61755

• Grade A = Singlemode (high-end performance)
• Grade B = Singlemode (advanced performance)
• Grade C = Singlemode (standard performance)
• 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 1310 nm and 1550 nm (dB)**

<table>
<thead>
<tr>
<th>Attenuation grade</th>
<th>Attenuation (≥ 97%)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≤ 0.15</td>
<td>≤ 0.07</td>
<td>Reserved for future application</td>
</tr>
<tr>
<td>B</td>
<td>≤ 0.25</td>
<td>≤ 0.12</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>≤ 0.50</td>
<td>≤ 0.25</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>≤ 1.0</td>
<td>≤ 0.50</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> 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 1310 nm and 1550 nm (dB)**

<table>
<thead>
<tr>
<th>Return loss grade</th>
<th>Return loss (mated)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>≥ 00</td>
<td>≥ 65 dB in unmated condition (APC only)</td>
</tr>
<tr>
<td>2</td>
<td>≥ 45</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>≥ 35</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>≥ 25</td>
<td></td>
</tr>
</tbody>
</table>

original chart out of IEC standardization
IL Values

Grade B: ≤0.25dB for 97%

≤0.12dB mean,
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

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!
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

<table>
<thead>
<tr>
<th></th>
<th>BPON</th>
<th>EPON</th>
<th>GPON</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
<td>ITU G.983</td>
<td>IEEE803.2ah</td>
<td>ITU-T G.984</td>
</tr>
<tr>
<td><strong>Data Packet Cell Size</strong></td>
<td>53 bytes (48 payload and 5 overload)</td>
<td>1,518 bytes</td>
<td>Variable size, from 53 bytes up to 1,518</td>
</tr>
<tr>
<td><strong>Maximum Bandwidth</strong></td>
<td>1.2 Gbit/s downstream; 622 Mbit/s upstream</td>
<td>Up to symmetric 1.25 Gbit/s</td>
<td>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</td>
</tr>
<tr>
<td><strong>Downstream Wavelength</strong></td>
<td>1480nm to 1500nm</td>
<td>1550nm</td>
<td>1480nm to 1500nm</td>
</tr>
<tr>
<td><strong>Upstream Wavelength</strong></td>
<td>1260nm to 1360nm</td>
<td>1310nm</td>
<td>1260nm to 1360nm</td>
</tr>
<tr>
<td><strong>Traffic Modes</strong></td>
<td>ATM</td>
<td>Ethernet</td>
<td>ATM, Ethernet, TDM</td>
</tr>
<tr>
<td><strong>Voice</strong></td>
<td>TDM</td>
<td>VOIP or TDM</td>
<td>Native TDM</td>
</tr>
<tr>
<td><strong>Video</strong></td>
<td>1550nm overlay</td>
<td>1550nm overlay</td>
<td>Either as RF or over IP</td>
</tr>
<tr>
<td><strong>ODN Classes Supported</strong></td>
<td>A, B, and C</td>
<td>A and B</td>
<td>A, B, and C</td>
</tr>
<tr>
<td><strong>Max PON Splits</strong></td>
<td>32</td>
<td>16</td>
<td>64</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th></th>
<th>Class A</th>
<th>Class B</th>
<th>Class B+</th>
<th>Class C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum loss</td>
<td>5 dB</td>
<td>10 dB</td>
<td>13 dB</td>
<td>15 dB</td>
</tr>
<tr>
<td>Maximum loss</td>
<td>20 dB</td>
<td>25 dB</td>
<td>28 dB</td>
<td>30 dB</td>
</tr>
</tbody>
</table>

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

P2P
Point to Point

P2MP
Point to Multipoint

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

B2C services

WDM-PON
Wave Division Multiplexing

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

B2C / B2B

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

Central Office

OLT

ASIC

Tx

Rx

downstream

upstream

1x n

Power Splitter

Users

ONU

RX

Tx

ASIC

n

0 to 20 km

Upstream data

Downstream data

Downstream RF Video

1260

1360

1450

1550

λ (nm)

Flavors

BPON

EPON

GPON

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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

Central Office
ONU ODF

Local Convergence Point

Customer premises
ONT

28 dB GPON Budget

Indoor Loss
0.82 dB
Repair & Maintenance
1.5 dB

Outdoor Loss
23.9 dB

Link Loss (dB)

Cable Splitter Splices Connectors Indoor Loss
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

<table>
<thead>
<tr>
<th>Power [kW]</th>
<th>CO Space [M²]</th>
<th>Patch cords</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>19.6</td>
<td>5000</td>
</tr>
<tr>
<td>10</td>
<td>2.9</td>
<td>157</td>
</tr>
<tr>
<td>3.6</td>
<td>6.7</td>
<td>31.8</td>
</tr>
</tbody>
</table>

Point to point
- Point to Multipoint

GPON

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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)
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.
• Promising Technologies
  • Among all technologies that could possibly allow service providers to increase the bandwidth 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

**Core**
- CATV
- Internet

**Aggregation**
- Packet Transport /SDH/DWDM
- ExtenderBox

**Access**
- GE
- ONU
- FTTC
- xDSL
- FTTH
- Residential
- FTTB
- MDU
- Gigabit Ethernet (1000 Megabit/s)

**Services**
- Fast Ethernet (100 Megabit/s)
- Gigabit Ethernet (1000 Megabit/s)
- XPON (Mobile backhaul)
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.

<table>
<thead>
<tr>
<th>Type</th>
<th>10G-GPON</th>
<th>10G-EPON</th>
<th>WDM-PON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>G.987</td>
<td>802.3av*</td>
<td>ITU-T G.989*</td>
</tr>
<tr>
<td>Protocol</td>
<td>Ethernet, TDM, TDMA</td>
<td>Ethernet</td>
<td>T.B.C.</td>
</tr>
<tr>
<td>Maximum physical distance</td>
<td>Up to 20</td>
<td>Up to 20</td>
<td>40/60*</td>
</tr>
<tr>
<td>(OLT to ONT)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Split Ratio</td>
<td>up to 1x64</td>
<td>up to 1x32</td>
<td>1:256</td>
</tr>
<tr>
<td>Nominal bit rate *</td>
<td>Downstream</td>
<td>Upstream</td>
<td>Downstream</td>
</tr>
<tr>
<td>Asymmetric</td>
<td>10 Gb/s</td>
<td>2.5</td>
<td>10</td>
</tr>
<tr>
<td>Symmetric</td>
<td>10 Gb/s</td>
<td>10</td>
<td>1.25</td>
</tr>
<tr>
<td>Operating wavelength band</td>
<td>1577 -2, +3</td>
<td>1270 ±10</td>
<td>1577 -2, +3</td>
</tr>
<tr>
<td>OLR_{MAX}</td>
<td>≥22 dB</td>
<td>≥20 dB</td>
<td>≥40 dB</td>
</tr>
</tbody>
</table>
PON Future
XG-PON1 (ITU-T G.987)

• XG-PON1 is 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-PON1 and 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
One interesting characteristic of 10G-PON and 10G-EPON is, that the ITU and IEEE committees have defined a «coexistence mindset», allowing for concurrent operation with current PON technology. Allows a smooth 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;
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 Coverage**
- Increased Coverage will reduce the number of Central offices needed in rural areas thus offering OPEX & CAPEX savings
- Operators can close end remove uneccesary 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 offer 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

Next Gen PON Networks will Reduce TCO and Increase Revenues

- 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.
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

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

- **GPON** (G.984.x)
  - 2010
  - Co-existence with EPON

- **EPON** (802.3ah)
  - 2010

- **10GE-PON** (IEEE 802.3av)
  - 2015
  - Co-existence with EPON

- **XG-PON1** (G.987.x)
  - 2010
  - Co-existence with GPON

- **NG-PON2** (IEEE 802.3av)
  - 2015
  - Co-existence with XG-PON1
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