Next Generation PON System  
-Access Platforms Integration-

Feb. 25, 2008  
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System Platforms Research Labs,  
NEC Corporation
Outline

1. Optical Access Technology and market
2. Next Generation Access (NGA)
   1. Requirements for NGA
   2. NGA Standardization Status
      – Topics, Direction, Status, Feature
3. R&D activities in NEC group
   1. Key optical devices for NGA(10G, WDM)
   2. WDM Access Transport System
   3. OWI Protection
4. Summary
Optical Access Technology Evolution

- Optical access technology enables HDTV distribution to home.
- Higher bandwidth/capacity more than Giga PON technologies make it possible to come in new attractive services.

- Bandwidth/capacity is increasing.
- We can now fully enjoy the benefits of Gigabit class service.
• Broadband subscriber is steadily increasing.
• FTTH subscriptions surpass 10 Million (Sept. 2007)
• Meanwhile, DSL subscriptions declined.

Source: Ministry of Internal Affairs and Communication of Japan and Yano Research Institute, Ltd. November 2007
Current Optical Access Architecture

- PON OLT
- Optical Splitter
- Leased line
- Mobile base station
- Plural users share fiber and OLT.
- Single star
- VDSL
- Apartment

Consumer Service

Business Service

Wireless Service
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## Requirements and Key Technologies for NGA

### Requirements
- Higher bandwidth/capacity than current system
- Coexistence with installed system
- Limited floor in CO
- Limited power supply in CO
- Wider coverage area
- Fixed and wireless integration
- Higher Reliability
- Security

### Key Technologies
- TDM (e.g. 10Gbps/\(\lambda\))
- WDM (e.g. colorless ONU)
- Dual-rate Burst Receiver
- High-power optical transmitter and high-sensitivity optical receiver for higher-speed (10Gbps) transmission
- FEC
- Integrated access platforms (10GE-PON system)
- WDM repeater
- FTTx/Wireless Integration
- FTTx/WiMAX Protection
- Cryptosystem (e.g. QKD)
IP-TV Service Trend

Require *much* more bandwidth

<table>
<thead>
<tr>
<th>Service Offerings</th>
<th>Today</th>
<th>Near Future (2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast</td>
<td></td>
<td>Time-shifted / narrowcast</td>
</tr>
<tr>
<td>Video-on-Demand</td>
<td></td>
<td>All-channel personal video recorder</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Picture-in-picture / split screen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Digital cinema distribution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Personal multimedia publishing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Residential and business digital video surveillance</td>
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</table>

<table>
<thead>
<tr>
<th>Bandwidth per Channel</th>
<th>Today</th>
<th>Near Future (2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Definition TV (SDTV)</td>
<td>2 Mbps per channel</td>
<td>High-Definition TV (HDTV)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~10 Mbps per channel</td>
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<tr>
<td></td>
<td></td>
<td>Large Screen Digital Imagery (LSDI)</td>
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<tr>
<td></td>
<td></td>
<td>Standardized by ITU-T J.601</td>
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<tr>
<td></td>
<td></td>
<td>40 to 160 Mbps per channel</td>
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</table>

<table>
<thead>
<tr>
<th>Number of Channels</th>
<th>Today</th>
<th>Near Future (2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 ~ 100 channels</td>
<td>1000 or more channels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mix of SDTV, HDTV, LSDI</td>
</tr>
</tbody>
</table>

Maximum utilization of installed ODN

Coexistence with current system

1. Compatible fiber plant with current system
   - Fiber plant which is constructed for current system, must be used for NGA.
     - G.652 SMF
     - Power budget (30 dB and penalty < 1 dB, or 29 dB without penalty)
     - 20km reach
     - More than 32 split ratio

2. Coexistence with current system.
   - NGA must avoid to interfere with existing current system in a same fiber.
   - Optical overlay of RF video must be also supported.

Source: http://www.ieee802.org/3/10GEPON_study/public/may06/otaka_1_0506.pdf
Optical Access For Wireless Back-Haul

- 4th Gen mobile communication will be ubiquitous
  - Bandwidth: ~30Mbps/user, 100M~1Gbps/access point
  - Access point coverage will decrease
  - Number of access points will increase
  - PON is a natural back-haul solution for the 4th Gen access points

- Next generation wireless back-haul
  - 802.11n: up to 100 Mbps per device
  - 802.16e: up to 70 Mbps per access point

Requirements and Key Technologies for NGA

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- FTTx/WiMAX Protection
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Access Platforms Integration over 10GEPON

FTTx/WiMAX solution to provide high reliability and extend reach.

Integrate PON subscriber

WDM access transport to extend reach and provide wider bandwidth.

xDSL/POTS/Wireless Access over 10GEPON
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# Standard Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010~</th>
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<tbody>
<tr>
<td><strong>IEEE802.3av 10GEPON</strong></td>
<td></td>
<td>▼ Nov.</td>
<td>▼ Feb.</td>
<td>▼ Jul.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D1.0</td>
<td>D1.1</td>
<td>D2.0</td>
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<tr>
<td><strong>Technical Discussion</strong></td>
<td></td>
<td>May</td>
<td>Nov.</td>
<td>Last Feature</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Last</td>
<td>Technical</td>
<td>Change</td>
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<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td>PMD Spec.</td>
<td>MPCP Extension</td>
<td>U/S 1G/10G Coexistence</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Power Budget</td>
<td>-Wavelength</td>
<td>-FEC</td>
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<tr>
<td><strong>Extension, Option</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Development of FSAN NG-PON white paper</strong></td>
<td></td>
<td>Continuation to study NG-PON2 (tentative)</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NG-PON1 Standardization in conjunction with ITU-T</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Technical Discussion</strong></td>
<td></td>
<td>Long-reach</td>
<td>WDM-PON</td>
<td>XG-PON</td>
</tr>
</tbody>
</table>

*Joint Meeting for Harmonization*
10GEPON –Objectives–

- Support subscriber access networks using point to multipoint topologies on optical fiber

- PHY(s) to have a BER better than or equal to $10^{-12}$ at the PHY service interface

- Provide physical layer specifications:
  - PHY for PON, 10 Gbps downstream/1 Gbps upstream, single SM fiber
  - PHY for PON, 10 Gbps downstream/10 Gbps upstream, single SM fiber

- Define up to 3 optical power budgets that support split ratios of 1:16 and 1:32, and distances of at least 10 and at least 20 km.

### Table: Power Budget Classes

<table>
<thead>
<tr>
<th></th>
<th>1:16</th>
<th>1:32</th>
</tr>
</thead>
<tbody>
<tr>
<td>10km</td>
<td>PR10, PRX10</td>
<td>PR20, PRX20</td>
</tr>
<tr>
<td>20km</td>
<td>PR20, PRX20</td>
<td>PR30, PRX30</td>
</tr>
</tbody>
</table>

**PR:** 10G/10G  
**PRX:** 10G/1G
10GEPON – Features –

Coexistence with GE-PON, RF-video

**Loss budget = 29 dB (PR30/PRX30)**

**Upstream: TDMA**

**Downstream: WDM**

**Wavelength Allocation**

**Key Device: High-sensitivity APD, High-Power LD**
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Key Device for 10GEPON High-Power Transmitter

1.3μm AlGaInAs BH DFB-LD
  - AlGaInAs MQW
    • High relaxation oscillation frequency even at high temperature
  - BH structure with semi-insulating current blocking layer
    • Reduce parasitic capacitance by Fe doped InP for high-speed (>10GHz) operation

High-power (+4dBm) 10Gbps operation was confirmed.
Key Device for 10GEPON High-Performance Receiver

- Two type of high-performance APD have developed.
  - Mesa-type APD
    - Simple Mesa structure is suitable for mass production and low cost.
    - Tolerant for high-power.
    - High reliability.
  - Waveguide APD
    - Waveguide structure realizes high quantum efficiency and high sensitivity.
    - WG structure is suitable for surface mounting and PLC.

Frequency Response
A back-illuminated mesa APD. High reliability with thin multiplication and two-step absorption layer.

Received Sensitivity
An asymmetric waveguide APD with thin SAM structure. High input power operation with asymmetric structure.

*SAM : Separated absorption and multiplication structure
## Colorless ONU Technology for WDM-PON

<table>
<thead>
<tr>
<th>Technique</th>
<th>Local Emission</th>
<th>Wavelength Supply</th>
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</thead>
<tbody>
<tr>
<td><strong>ONU configuration</strong></td>
<td><strong>Tunable</strong></td>
<td><strong>Spectrum Slicing</strong></td>
</tr>
<tr>
<td><strong>WDM Rx</strong></td>
<td><strong>TLD</strong></td>
<td><strong>WDM Rx</strong></td>
</tr>
<tr>
<td><strong>Modulation</strong></td>
<td>Direct/External</td>
<td>Direct</td>
</tr>
<tr>
<td><strong>Rate</strong></td>
<td>10Gbps</td>
<td>1.25Gbps</td>
</tr>
<tr>
<td><strong>Location of US light source</strong></td>
<td>ONU</td>
<td>ONU</td>
</tr>
</tbody>
</table>

TLD: Tunable Laser Diode, BLS: Broadband Light Source, RSOA: Reflective Semiconductor Optical Amplifier

Full band Tunable LD

- Full band Tunable LD
- SOA
- Double-ring resonator
- AR coating
- HR coating
- TO heater (on the ring waveguide)

160nm tuning range

- S-band
- C-band
- L-band

Fiber coupled intensity [dBm]

Wavelength [nm]

Year

Tuning range [nm]


OFC2008 San Diego
WDM Access Transport System

- WDM access transport to extend reach and provide wider bandwidth
- The system multiplexes burst optical signal and behaves as a repeater as well.
  - Effective use of access network fiber by reducing number of fibers
  - Extend optical reach beyond 20km with using repeaters to 60km
  - Compatible in mixed deployment with PON, point-to-point or other systems

Extend reach (20km)

Multiple wavelengths over single fiber
FTTx/ WiMAX Protection

• Optical access will become social infrastructure
• High reliability, at the same time low-cost is indispensable

Existing technology

Without integrated FTTH/Wireless redundant system
• Requires external switch fabric for protection switching
• Requires explicit addressing management for redundant path, SDH like protection scheme is preferable to implicit redundant path management

Can not provide flexible redundant system.

Our solution

PON/WiMAX Redundancy
• Realizes PON/WiMAX line card protection
• Switching will be done by IGU (Integrated Gateway unit)
Summary

- Requirements and trends for next generation optical access technologies are presented.
  1. Requirements for NGA
  2. NGA Standardization Status
- R&D activities in NEC are introduced.
  1. Key optical devices for NGA
  2. WDM Access Transport System
  3. OWI Protection System
- I believe that these technologies lead to realizing 10GEPON-based integrated optical access.
For “Next” Next Generation Access

- New technologies (e.g. OFDM, OCDM) are expected for realizing more higher bandwidth and flexibility.
- However, it is difficult to remove legacy system
- Coexistence architecture with legacy system is desired
- Coexistence technology will be technical issues.
For Higher Capacity

- In order to enlarge bandwidth/capacity, we have options, WDM, TDM and etc.
- Now 10Gbit/s continuous transmission technology is mature, e.g. 10Gigabit Ethernet.
- TDM, especially 10Gbit/s PON technologies will be available around 2010.

1st step: 10Gbit/s PON
2nd step: WDM PON

![Graph showing the evolution of data transmission technologies from 1998 to 2010](image_url)

- **Bit/s**: 100K, 1M, 10M, 100M, 1G, 10G, 100G
- **Data Transmission Technologies**: STM-PON, B-PON, G-PON, GE-PON, 10GE-PON, NGA, FSAN, ITU-T

10Gbps/λ x N