Programmable Optical Networks

Martin Nuss
VP & Chief Technologist

Internet2 – Arlington, VA – April 25, 2007
Why do Optical Networks still look like Mainframes

Everybody else is still building the next Mainframe:

- faster, bigger, telecom-specific ASICs
- Proprietary, highly integrated optics with low volumes
- Line cards and functionality tailored to a specific protocol/task

What we really want is the “PC Equivalent” of Optical Transport:

- Fully programmable line cards that can be reprogrammed to any need and application
- Pluggable optics from a wide variety of vendors (just like 3rd-party PCI cards)
- Taking advantage of datacom logic + processors
- APIs so that 3rd parties can write applications (e.g. special encryption engines)
What are the Technologies that allow us to finally build “Optical Transport PCs?”

→ Programmable Gate Arrays as engines
→ Pluggable Optics (the equivalent of PCI cards)
→ Taking advantage of Datacom economics and volumes
→ Can I have it?
Telecom HW: FPGAs are taking over ASICs

- FPGA Technology rapidly approaching the capabilities of ASICs
- Allows to build hardware with Software defined functionality
  - Ciena’s FlexSelect technology is an example where Transponder, muxponder, ring add-drop, sub-wavelength grooming, and cross connect can be SW-configured
  - Less planning, fewer cards, configurations, and spares
- Investment Protection and Future-proofing
Pluggable optics changes the way we build HW

- Everything becomes pluggable & tunable
- More suppliers, lower costs, more innovation

New innovative products:
- T1 or DS3 Circuit Em SFPs
- 10G DWDM 40-ch Tunable XFP
Ciena FlexSelect Architecture
A software approach to WDM transport

"Traditional approach"

"FlexiPort approach"

VS.

Any Service
Any Speed
Any Port
Any Time

Network or Client

The FlexiPort advantage

- Lower costs, higher profitability
- Future-proofing
- Easy Migration to Ethernet/IP and/or InfiniBand
- Less planning, engineering, spares, truck rolls

© Ciena Confidential and Proprietary
Programmable HW & Pluggable Optics finally get Telecom onto the same curve as Datacom

<table>
<thead>
<tr>
<th>Year</th>
<th>System capacity</th>
<th>Bandwidth cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>2.5</td>
<td>2,080</td>
</tr>
<tr>
<td>1994</td>
<td>2.5</td>
<td>1,140</td>
</tr>
<tr>
<td>1995</td>
<td>10</td>
<td>429</td>
</tr>
<tr>
<td>1996</td>
<td>40</td>
<td>153</td>
</tr>
<tr>
<td>1997</td>
<td>100</td>
<td>85.7</td>
</tr>
<tr>
<td>1998</td>
<td>320</td>
<td>36.4</td>
</tr>
<tr>
<td>1999</td>
<td>480</td>
<td>32.0</td>
</tr>
<tr>
<td>2000</td>
<td>960</td>
<td>24.2</td>
</tr>
<tr>
<td>2001</td>
<td>1,600</td>
<td>17.5</td>
</tr>
<tr>
<td>2002</td>
<td>1,600</td>
<td>10.7</td>
</tr>
<tr>
<td>2003</td>
<td>1,600</td>
<td>$3.58</td>
</tr>
<tr>
<td>2004</td>
<td>1,600</td>
<td>$2.80</td>
</tr>
<tr>
<td>2005</td>
<td>1,600</td>
<td>$1.43</td>
</tr>
</tbody>
</table>

Source: RHK Inc.

Note: Equipment cost excludes fibre plant; analysis based on long point-to-point system with fully utilised capacity

Moore’s Law...

10G Convergence

OTN
Pluggable Optics
40G / 100G
Once united at 10G…
why should LAN and WAN separate again?

**Ethernet LANs**
- 100 Gbps
- 10 Gbps
- 1 Gbps
- 100 Mbps
- 10 Mbps

**PDH/SONET/SDH & 10GE WANs**
- 100 Gbps
- 40 Gbps (for how long??)
- 10 Gbps
- 2.5 Gbps
- 622 Mbps
- 155 Mbps
- 34-45 Mbps
- 1.5-2 Mbps
Efficient optical coding for 100G Ethernet

→ 100G parallel
  → 4λ x 25G for LAN
  → 10λ x 10G for MAN, compatible with 40/80 km requirement from 10GbE
  → 10 lanes (copper/fiber) x 10G, for (HPC) interconnect, SAN or LAN

→ 100G serial with Advanced Modulation Format

recent Bell Labs demo demonstrating 10λ @ 107G (100 + 7% EFEC) – Raybon ECOC 2006
Standards Based OIF & G.ASON Architecture are key to take advantage of programmable networks

- **User-Network Interface (UNI):** signaling interface for clients to request services from optical network
- **External Network-Network Interface (E-NNI):** signaling and routing interface providing call/connection control and topology
- **Domain edges provide interworking between vendor-specific Internal NNI (I-NNI) and OIF UNI-N/E-NNI protocols**

- Domains can be advertised as
  - Multiple exposed border nodes with virtual intra-domain links (vendor 1) or
  - Single abstract node (vendor 2)
But what we really want are probably SIP-enabled control planes.

Applications

- Application Network Interface (for middleware)
- Value-added services, AAA, back-office functions
- Common service platforms, customer profiles
- Create services and connectivity over disparate networks

Carrier Apps

3rd Party Apps

SIP Session Control

Ethernet

Photonic

SDH/OTN

SIP User Agents

Transport control planes
- Connection-less + GVRP
- G.ASON/GMPLS
- G.ASTN
Advances in Technology enables a new class of Optical Transport gear that is fully programmable.

Taking advantage of datacom economics and Ethernet volumes guarantees that we can evolve along Moore’s law – both speed and cost.

Ports, line cards, functionality, and entire networks can be reconfigured on the fly.

Enables Flexibility, rapid configuration, ability to support new protocols, and Peace-of-Mind.
Thank you