Delivering 100G per wavelength with today’s DWDM infrastructure
Motivation, Experiments and Standards
RIPE 55, Amsterdam

Michael Finkenzeller, IPT DWDM
Agenda

Motivation and Some Background Information

100G transmission: Experiments and Trials

Standards: 100GbE, Carrier Ethernet Transport

Conclusion
Historical Volume Growth AMS-IX

Every 30 months traffic increased with factor 10.

source: AMS-IX
WDM - Wavelength Division Multiplexing

- Each “coloured” wavelength represents one WDM channel
- Multiplexing of separate signals on same fiber
Signal Quality Degradation in Optical Systems

- Attenuation
- Noise
- Dispersion
- Non-linear effects

Bit rate increase to 100Gb/s

- Chromatic dispersion tolerance decrease
- Polarization Mode Dispersion tolerance decrease
- OSNR tolerance decrease
- Non Linear Effects

- New transmission techniques
- New optical modulation schemes
- New dispersion management techniques
- New components
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2006: 107 Gbit/s transmission over 160km

Transmission line:
- 2x80-km field NZDSF, 19.7 dB attenuation per span
- Direct optical 107 Gb/s generation and additional filtering
- Electrical processing of 107 Gb/s in single chip after photo diode
- Q-factor: 10.4dB btb, 9.6dB after 160km

Field trial using ETDM sender and receiver.
Technology Trends in 40G/100G

Enabling technologies:
- Modulation formats (DPSK, DQPSK)
- Polarization-Multiplexing (PolMux)
- Coherent receivers
Modulation formats: multiple bits per symbol

- **DPSK**: 1 bit/symbol
- **DQPSK**: 2 bits/symbol
- **POLMUX-DPSK**: 4 bits/symbol
- **POLMUX-DQPSK**: 4 bits/symbol
2007: 10 x 111 Gbit/s transmission over 2375 km

Experimental setup:
- 10 channels with 111Gbit/s each (100GbE + EFEC) on a 50GHz grid
- Alternative modulation format POLMUX-RZ-DQPSK
- Completely electronic modulation and demodulation
- 2375km of SSMF and 5 add-drop nodes
- Coherent detection and equalization for polarization recovery and high chromatic dispersion tolerance

As broad as 10G → same infrastructure usable!

Possible to use today’s 10G infrastructure for 100G/λ transmission
COHERENT 111-Gbit/s POLMUX-DQPSK (CP-QPSK)

- Very narrow spectral width => Use of existing 50Ghz grid WDM systems
- High spectral efficiency 4 bits per symbol (27.75Gbaud)
- Use of low spec 40-G electrical components
- Chromatic dispersion and PMD are compensated electrically (1st time for 100Gb/s)
- Coherent detection allows electrical polarization de-multiplexing

111-Gbit/s POLMUX-(N)RZ-DQPSK transmitter:
**Polarization multiplexing**

POLMUX-(N)RZ-DQPSK receiver:
**Coherent detection**
## Native transport versus concatenated within DWDM layer

<table>
<thead>
<tr>
<th>Native 40/100G (serial)</th>
<th>Concatenated nx10G (parallel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>☑ optimal use of network capacity</td>
<td>☑ less optical impairments</td>
</tr>
<tr>
<td>☑ easy service routing</td>
<td>☑ more easy to obtain higher reach</td>
</tr>
<tr>
<td>☑ easy to implement services in meshed network</td>
<td>☑ routing as bundle of wavelengths necessary</td>
</tr>
<tr>
<td>☹ high reach might be available later</td>
<td>☹ congests network (especially cumbersome in partially filled meshed network)</td>
</tr>
<tr>
<td>☹ potentially more regeneration points</td>
<td>☹ latency cannot be avoided</td>
</tr>
<tr>
<td></td>
<td>☹ doesn’t scale in OpEx/CapEx</td>
</tr>
</tbody>
</table>

Native transport is the better choice. Better scalability and simple maintenance: “One service, one port”
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100GbE: IEEE and ITU-T are different worlds.

**IEEE World**
- 10M, 100M, 1G, 10G Interfaces
- 10G Interfaces
- Distances 100m … 10/40km
- 100M, 1G, 10G Interfaces

**ITU-T World**
- 155M, 622M, 2.5G, 10G, 40G Interfaces
- 10G / 40G in OTN
- Distances 2km - nx1000km
- 155M, 622M, 2.5G, 10G Interfaces

The IEEE world is short range and used factor 10 in the past. The ITU-T world is long range and used factor 4 in the past.
Status 100GbE Standardization

- Status IEEE 802.3 Higher-Speed Study Group (HSSG)
  - Attendance predominantly interested in cost-efficient, mature transceiver alternatives for short-reach applications, transport networking vendors / service providers represent a minority. New: data center and server operators.
  - Data rate and de-skewing procedure are defined in study groups today.

- Status ITU SG15 Q6 / Q11:
  - Several OTU-4 proposals in G.709 are under discussion (111 - 112 Gb/s or 130Gb/s), new revision of G.709 including 100GbE transport capability planned for Feb 2008.

<table>
<thead>
<tr>
<th>Line Data Rate</th>
<th>Client Interface</th>
<th>Line Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>111-112Gb/s</td>
<td>100GbE (9-10 x 10Gb)</td>
<td>1(\lambda), 2(\lambda)</td>
</tr>
<tr>
<td>130Gb/s</td>
<td>100GbE</td>
<td>(1(\lambda), 2(\lambda), 3(\lambda))</td>
</tr>
<tr>
<td></td>
<td>3 x 40Gb/s (9 ..12 x10Gb/s)</td>
<td></td>
</tr>
</tbody>
</table>

Data rate 130G would delay 100GbE products availability for 2 years.
Close coordination is needed for 100G and 40G.
Mapping of 10GbE: Example where standard didn’t much help …

For 10GbE two different line interfaces (over-clocking).
Pre-Standard 100G?

AT&T, Verizon Have Optical Wishes
JUNE 08, 2007

... In a keynote on Wednesday, AT&T's Peter Magill said his company would need 100 Gig sooner rather than later.

...

Magill says that AT&T is committed to meeting bandwidth demands, however, and in an interview after his keynote, he said that AT&T would deploy pre-standard 100-Gig technology if it had to, as long as it made economic sense.

source: Light Reading, October 03, 2007
Provide native End-to-End Ethernet Services
New 100GbE traffic will require an optimized Carrier Ethernet Transport (CET)

- DWDM infrastructure will transport 100GbE native interfaces
  => New transmission techniques to use existing WDM infrastructure
- Evolve from point-to-point DWDM to an optical meshed network with PXC & ROADM
- Introduce GMPLS control plane in transport layer to optimize operation

R&D efforts

Offload core IP Routers of transit traffic
IP/MPLS routers just were really required

Combine L2 & L1 technologies for a cost-effective connection-oriented switching for Carrier Ethernet Transport (CET)

Use cost-effective L1 optical switching where possible
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1. Motivation and Some Background Information
2. 100G transmission: Experiments and Trials
3. Standards: 100GbE, Carrier Ethernet Transport
4. Conclusion
Conclusion

• Demand for 100G is real.
  – IP based applications are main driver.
  – Main payload will be Ethernet based services.

• 100G: Technology is on the right track.
  – Operation of 100G native on 10G infrastructure is feasible.
  – 100GbE standardization is key factor for products in 2010.

• Standardization Issues
  – Transport: client side and line side have to be synchronized
  – Carrier Ethernet Transport (CET) provides simplification and cost savings for future
Thank you …

… Questions?