Making DCI work in GÉANT

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Current GÉANT pain points

Problems with current architecture:

- OTN layer expensive
- OTN chassis running out of slots in central PoPs
- OTN useful for protection switching and multihop but traffic is 70% unprotected and next hop
- OTN chassis are DC powered full rack cost is very high in some PoPs
- Proliferation of IP/MPLS
Current GÉANT pain points

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Part 1: GÉANT fibre and ONSR characteristics
**GÉANT fibre infrastructure**

**Fibre types**

- Typical span is 65-85km
- 74% of fibre is Original LEAF or TWRS
- 95% of links <100km
- 99% of links <120 km
GÉANT fibre infrastructure
Fibre insertion loss vs. Distance

Insertion loss (dB)

Span Length (km)

0.33 dB/km
0.22 dB/km
0.18 dB/km

>30dB
GÉANT fibre infrastructure  
Q-factor and preFEC BER

- Forward (●) and reverse (●) Q-factors on 20 routes
- All modulation is currently DP-QPSK
- Link pre-FEC BER clustered between: 1e-4 → 1e-8
- Operational margin determined by the grade of FEC deployed on the link
- SD FEC deployed on newer/longer links
GÉANT fibre infrastructure
Q-factor vs. distance

- 20 routes shown
- No ROADMs, just 4 physical bypasses
- Bulk of routes are 400-800km
- Worst Q is 9.75
- Best Q is 14.7
GÉANT fibre infrastructure

OSNR measurement problem in coherent system

- OCG1 from Geneva (1548.915nm), measured after receiver amp
- +9dBm/-9dBm
- OSNR = 18dB
- OSA measures 22.3dB
- OSA measurement of OSNR is not reliable
GÉANT fibre infrastructure
Measured DWDM ONSR

- OSNR measurements from OSA compared to modelling
- There seems to be a reasonable match to the ‘total (required) OSNR’ from the modelling
- Coriant G30 gives an OSNR measurement... this is probably the most reliable.

<table>
<thead>
<tr>
<th>Node A</th>
<th>Node Z</th>
<th>Min OSNR (dB)</th>
<th>Total (Required) OSNR</th>
<th>measured OSNR at input to OAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lon</td>
<td>Ams</td>
<td>19.41</td>
<td>19.16</td>
<td>16.61</td>
</tr>
<tr>
<td>Lon</td>
<td>Bru</td>
<td>20.72</td>
<td>21.38</td>
<td>19.13</td>
</tr>
<tr>
<td>Gen</td>
<td>Lon</td>
<td>16.48</td>
<td>17.87</td>
<td>15.2</td>
</tr>
</tbody>
</table>
Part 2: DCI evaluation and procurement
## DCI pre-procurement evaluation

<table>
<thead>
<tr>
<th>Optics</th>
<th>First Vendor</th>
<th>Second Vendor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia AC400</td>
<td><strong>Equipment:</strong> Facebook Voyager&lt;br&gt;<strong>Status:</strong> Cambridge lab testing&lt;br&gt;Cambridge lab testing&lt;br&gt;GÉANT field trial Lon-Bru&lt;br&gt;NREN evaluation by PSNC and UNINETT</td>
<td><strong>Equipment:</strong> ADVA FSP3000&lt;br&gt;<strong>Status:</strong> Testing under consideration.</td>
</tr>
<tr>
<td>Acacia CFP2 ACO</td>
<td><strong>Equipment:</strong> Juniper DWDM CFP2 100G ACO&lt;br&gt;<strong>Status:</strong> Cambridge lab testing&lt;br&gt;Cambridge lab testing&lt;br&gt;GÉANT field trial Mil-Mar</td>
<td><strong>Equipment:</strong> Coriant Groove G30&lt;br&gt;<strong>Status:</strong> Lab testing in Cambridge</td>
</tr>
<tr>
<td>Acacia CFP2 DCO</td>
<td><strong>Equipment:</strong> Vendor in DWDM stealth mode&lt;br&gt;<strong>Status:</strong> GÉANT field trial on Mil-Mar</td>
<td><strong>Equipment:</strong> Juniper DWDM CFP2 100G DCO&lt;br&gt;<strong>Status:</strong> Testing expected mid 2018</td>
</tr>
<tr>
<td>Ciena WaveServer</td>
<td><strong>Equipment:</strong> WaveServer AI&lt;br&gt;<strong>Status:</strong> Cambridge lab testing&lt;br&gt;Cambridge lab testing&lt;br&gt;Field trial on CESNET fibre Prague to Vienna</td>
<td><strong>Status:</strong> NA</td>
</tr>
<tr>
<td>Infinera</td>
<td><strong>Equipment:</strong> XT3300/3600&lt;br&gt;<strong>Status:</strong> Compatible with GÉANT DWDM system</td>
<td><strong>Status:</strong> NA</td>
</tr>
</tbody>
</table>
Lab test results

- Tested over 100km of fibre lit with Infinera DTN-X
- To get optimal performance wavelength needs to be detuned
- For QP-DPSK the system can work without de-tuning, but several dB of performance penalty.
- Measurements made before understanding Infinera 12.5GHz offset – see next slide
Infinera BMM2C are tuned off by 12.5GHz

- The centre frequency of the Infinera band muxes are tuned off the ITU-T grid by 12.5 GHz
- In this test the best Q-factor is achieved at -12,000 MHz
- 1.7dB Q-factor penalty for not offsetting
- In the field wider baudrate FEC mode fails

Q-factor vs. frequency offset (16QAM) for Groove

*Tests by Karim Boudjemaa
All GÉANT fibre routes – modulation scheme available

- Of the 21 fibre routes in GÉANT, we can expect that most will work with 8QAM modulation.
- Only 1 route will require DP-QPSK
- At least 2 routes will work with 16QAM modulation
AW Field Trials/ Lab conclusions

What did we learn from the evaluation?

• We like the products that we tested, in particular the optical performance is very good.
• Performance of latest generation of DWDM pluggables is very good – 8QAM will work on most (all?) links in GÉANT network and 16QAM on many.
• Very large cost savings in the network.
• Optical power management is critical in an alien wave environment.
• Software selectable modulation makes planning much easier.
• An optical modelling tool will help scale up number of AWs.
• Turning up AWs is best done in small slow steps.
DCI Choice – Coriant Groove G30

• 1 RU stackable

• 4 sleds, each up to 4 x 100G

• Optics are based on Acacia CFP2 ACO
  • 200G up to 1000km with 16 QAM modulation
  • 150G up to 2000km with 8 QAM modulation
  • 100G up to 5000km with DP-QPSK

• Client side is QSFP28

• Next generation to support up to 600Gbps using 64QAM
Part 3: Lab testing the Coriant G30
Lab setup

- Infinera OCG Band mux
- EDFA
- Add span noise
- EDFA
- Infinera OCG Band mux
- VOA 1
- VOA 2
- Plot Rx sensitivity
- Groove G30
- splitter
- 50km SMF
- Groove G30
- splitter
- Infinera OCG
- Coriant 16-QAM

Graph showing Infinera OCG and Coriant 16-QAM signals.
DP-QPSK

pre-FEC BER vs. OSNR

*Tests by Michal Altmann
8-QAM

*Tests by Michal Altmann
16-QAM

pre-FEC BER vs. OSNR

*Tests by Michal Altmann
G30 Input dynamic range
DP-QPSK with SD-FEC 15%

- Good dynamic range in DPQPSK mode with 100km of fibre and 15% SD-FEC
- Infinera over power warning at -11dBm

*Tests by Karim Boudjemaa
G30 Input dynamic range
16-QAM with SD-FEC 25%

Operational sweet-spot

Need to watch this for multiple waves?

*Tests by Karim Boudjemaa
• Automation will allow hundreds of tests to be carried out in a repeatable way
• We need to develop an AW commissioning process.
• Use a modelling tool (TIP?) to predict the expected performance.
• Model will be used to select a modulation type.
• What margin should we allow for ageing?
• During service commissioning the pre-FEC BER should agree with the modelling prediction.
• What performance tolerance should we allow?
Optical software – how much is enough?

### Modelling Tools

- **None** (trial and error)
- **Full model** (Vendor supplied)
- **Open** (TIP)

### Automation

- **Manual** (GUI)
- **Turn-key** (Vendor)
- **Home-grown** (fully open orchestration)
Summary

• GÉANT fibre and the current OSNR have been analysed
• The results are compared to the lab test results of the Coriant G30 equipment
• We need to tune the wavelengths off by half of a 25Ghz spacing
• The Optimal launch power is around -11dBm to -12dBm. The system margin is good at this launch power
• We will automate our lab bench to achieve fine-grained data set
• The output of these will be used to validate the TIP modelling tool and define the Coriant A/W turn up procedure.
Thank you

Any questions?

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