Capacity, Flexibility, Reliability: what do we really need in our future optical networks?

Andrew Lord (Head of BT Optical Research)
Talk Outline

• 5G / BT network drivers
• Optical network architectures in the light of 5G
• EU Metro-Haul project
• Core network considerations
• Conclusions

• Acknowledgements
  • My BT team
  • Metro-Haul FIJ project partners
Inter/Intra data centre traffic

Data Center IP Traffic 2015 to 2020
(Exabytes per year)

Source: Cisco CGI, 2015-2020

BT still reporting 40%+ traffic growth

CAGR 27%
CAGR 32%
CAGR 24%
Growth of aggregate core traffic continues and is slowing slightly

40% + growth is mirrored around the world
BT 21CN Network (2017)

Converged core

IP/MPLS/WDM

Content

Call Servers
WWW

~110 sites

Multi-service access

DSL

Ethernet aggregation

Copper
Fibre
Wireless

~5.5k sites

End User

~5.5k sites

~110 sites
Network bottle-necks / challenges

SDN-based Control / Orchestration

5G Access
- Multiple CPs
- Tb/s switching
- Remote storage / compute
- NfV
- Dynamic config
- Whitebox
- Cost, power, space premium
- Gb/s access
- Wireless femtocells
- Deep fibre
- 5G KPIs
- Convergence
- Infrastructure cost

Metro Transport
- 10–25G or coherent? transport
- Many wavelengths
- Cost-effective flexibility
- 20km – 50km – 100km
- Cost, power, space premium
- 100s / 1000 nodes

Metro Core
- Multi Tb/s switching
- Data centre functions
- Multi layer 1-3
- ROADM
- Sliceable spectrum
- Dozens of nodes

Photonic Core
- > 1Tb/s per fibre – multiple bands / fibres / SDM
- Increased flexibility
- Cost less critical
- Elastic Optical Networks

Security, Monitoring, Resilience

Millions of nodes

© British Telecommunications plc
5G PPP published KPIs and Use Cases

• 1000 times higher mobile data volume per geographical area
• 10 to 100 times higher typical user data rate
• 10 times lower energy consumption
• End to end latency < 1ms
• Scalable management framework enabling fast deployment of novel applications
• Reduction of the network management OPEX by at least 20% compared to today

https://5g-ppp.eu/kpis/
Access Metro Edge Node (AMEN) – multiple ubiquitous access technologies, cloud enabled (storage, compute)
Metro Transport Network – metro node: pure transport
Metro Core Edge Node (MCEN) – Larger cloud capabilities
Metro Control Plane – full orchestration
Metro networks – ripe for innovation

- Vast numbers of femtocells needed to provide future 5G bandwidth
- Backhaul = deep fibre
  - Potentially hundreds of 10G + circuits over shortish range (20km typical)
- Requirements will be
  - Ultra cost effective optical transport (Facebook talk about 1Gb/s = 1$ for IDC.)
  - Short reach DWDM
  - Some dynamic / optical switching capability
- Existing WSS WAY too expensive
- Recent research starting to focus on this critical area
  - PON-based technology?
  - New modulation schemes – PAM4 and others – focused on chromatic dispersion tolerance
  - Novel optical filters
  - Filtered and filterless (and hybrid) networks
  - Fixed vs tunable lasers? G.Metro?

But we will need v low cost, short range, flexible high speed DWDM
Types of metro optical network

- Main requirement here is **very low cost** 10G–25G WDM with limited reach (<50km) and some switching. Low cost coherent 100G transport also needs deep research.

- **Architecture**
  - Meshed, chains, horse shoes...
  - Traffic flows expected to be hubbed from the Access Metro Nodes to the Metro Core node
  - Resilience – increased streamed traffic likely to mean increased resilience requirements

- **Flexibility – optical switching technology**
  - Considerable attention to filterless network architectures – requiring coherent transmission
  - Fixed filter approaches AWG etc) or cost effective WSS filters with some flexibility
  - C+L band

---

**Drop & Waste (D&W)**

- Drop stage
- Add stage

**Broadcast & Select (B&S)**

- Drop stage
- Add stage
Integrated silicon photonics

- Ericsson technology
- Integration onto chips will enable huge cost reduction
- Performance doesn’t have to match LCoS-based WSS
- 200 mm wafer realization

With CNIT...turned into a **whitebox** optical switch allowing fast open innovation

4,5 cm x 4,5 cm packaging
Disaggregation penalty not significant in metro

M1E.2 OFC 2018 ‘Margin requirement of disaggregating the DWDM transport system and its consequence on application economics’ Ciena
Telemetry and monitoring

- Management of complex systems requires appropriate monitoring
- In 5G networks, KPI assurance is required, and so monitoring takes on an even more critical role
- Wide range of resources need monitoring
  - Optical layer, Packet layer (L2, 3)
  - 5G clients
  - Data Center functions
- Monitoring requirement becomes real time
- Fast decisions need to be made to respond to dynamic situations (new services or performance variations)
- Monitoring needs to be incorporated into the overall Control architecture
- Metro-Haul has a large topic studying this – headed up by UPC (Universitat Politècnica de Catalunya)
• **MDA agent** collects monitoring data from all the different sources, process them locally and conveys data to the **MDA controller**.
• **COM** = Control, Orchestration and Management
Typical results

1. Traffic projection for Planning purposes

2. Failure localization

MPLS Traffic analysis

3. BER analysis for failure root cause identification

Spectrum analysis

© British Telecommunications plc
**Machine Learning?**

- Huge current hype around this subject
- Concept relates to huge, unpredictable data sets
- Networks have potentially hundreds of nodes, each generating a huge amount of monitoring data
  - Every optical and electrical component on every board
  - Every sub-system, transceiver, EDFA, WSS...
  - Every network component, equipment card, rack, shelf...
- Can all this data be harnessed together to analyse and predict overall network performance
- Potentially TOO much data for a ‘linear’ analysis?
- Machine Learning could assist in optimising performance and providing warnings of future problems
- Issues –
  - Is there sufficient data for the ML algorithm to learn?
  - Is the data available from the DCN control that manages the network
  - If the algorithm makes a wrong prediction, that might be catastrophic for a Carrier Class network
  - Vendors don’t have networks to trial the algorithms they have developed
  - There is no explanation ‘why’ a specific decision is arrived at

**Area needs some careful analysis to see if conventional ‘linear’ analysis isn’t sufficient**
Physical Layer – the core network

- Core network changes for 5G?
  - More capacity
  - Possibly more dynamic – although many of the short time scale variations from 5G might average out
- Edge DC functions (compute, storage etc) intended to reduce latency but also reduce core network load
  - Core might not grow as quickly as the metro
- BT flat core has been a challenge –
  - 100 + metro-core nodes fully meshed
  - Complex Routing and Spectrum Assignment
  - Stranded bandwidth
- Scope for more integrated optical + packet layers
  - SDN based orchestration
Metro-Core Edge – Elastic Optical Networks

Elastic Transceivers

S-BVT module

S-BVT module

S-BVT module

187.5GHz

225GHz

150GHz

Flexgrid Spectrum

4 x 100Gb/s (DP-QPSK)

5 x 200Gb/s (DP-16QAM)

7 x 150Gb/s (DP-8QAM)

LCoS

WSS

32Gbaud carrying 25Gb + FEC:
25Gb x BPSK x 2 pol = 50Gb
25Gb x QPSK x 2 pol = 100Gb
25Gb x 16QAM x 2 pol = 200Gb
25Gb x 64QAM x 2 pol = 300Gb

64Gbaud carrying 50Gb + FEC:
50Gb x QPSK x 2 pol = 200Gb
50Gb x 16QAM x 2 pol = 400Gb
50Gb x 64QAM x 2 pol = 600Gb

And many other options

Future transponders capable of 100Gb – 600Gb in 50Gb increments
Beyond the ‘C’ band

Stacking many parallel fibres =
- Cost, power consumption and space requirements rise linearly with equipment

Extension beyond ‘C’ band – to L, then S etc now receiving significant research attention in the industry
- Require new amplifier and switch technologies and **improved transmission modelling**
  - Now getting real attention in the industry
  - No real work on optimised optical architectures for C + L

Beyond traditional Single Mode Fibre?
- Multicore fibre offers enormous potential but with a huge barrier to entry

**Optical Fibre Spectrum**

- Optical frequency (THz)
- Wavelength (micron)
- Band name

<table>
<thead>
<tr>
<th>Frequency (THz)</th>
<th>Wavelength (micron)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1.36</td>
</tr>
<tr>
<td>1.26</td>
<td>1.0</td>
</tr>
<tr>
<td>1.55</td>
<td>1.675</td>
</tr>
<tr>
<td>1.79</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Conclusions

• Continued bandwidth growth means continued pressure on optical networks
• Focus moved discernibly from core to metro – though both need attention
• 5G requires radical changes to metro networks
  • Intelligence to handle KPIs
  • Dynamic capability
  • Extended monitoring
  • Deep fibre – cost effective transport
  • Power and space challenges are huge
  • Whitebox could definitely have a role in the metro
• Core
  • C band close to exhaustion (will fill up too quickly)
  • Growing interest in multiple bands (eg. Where fibre is exhausted)
  • Multicore a much longer term option
THANK YOU