RAN as one service in a metro optical network

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Fibre – a 21st century global mega project

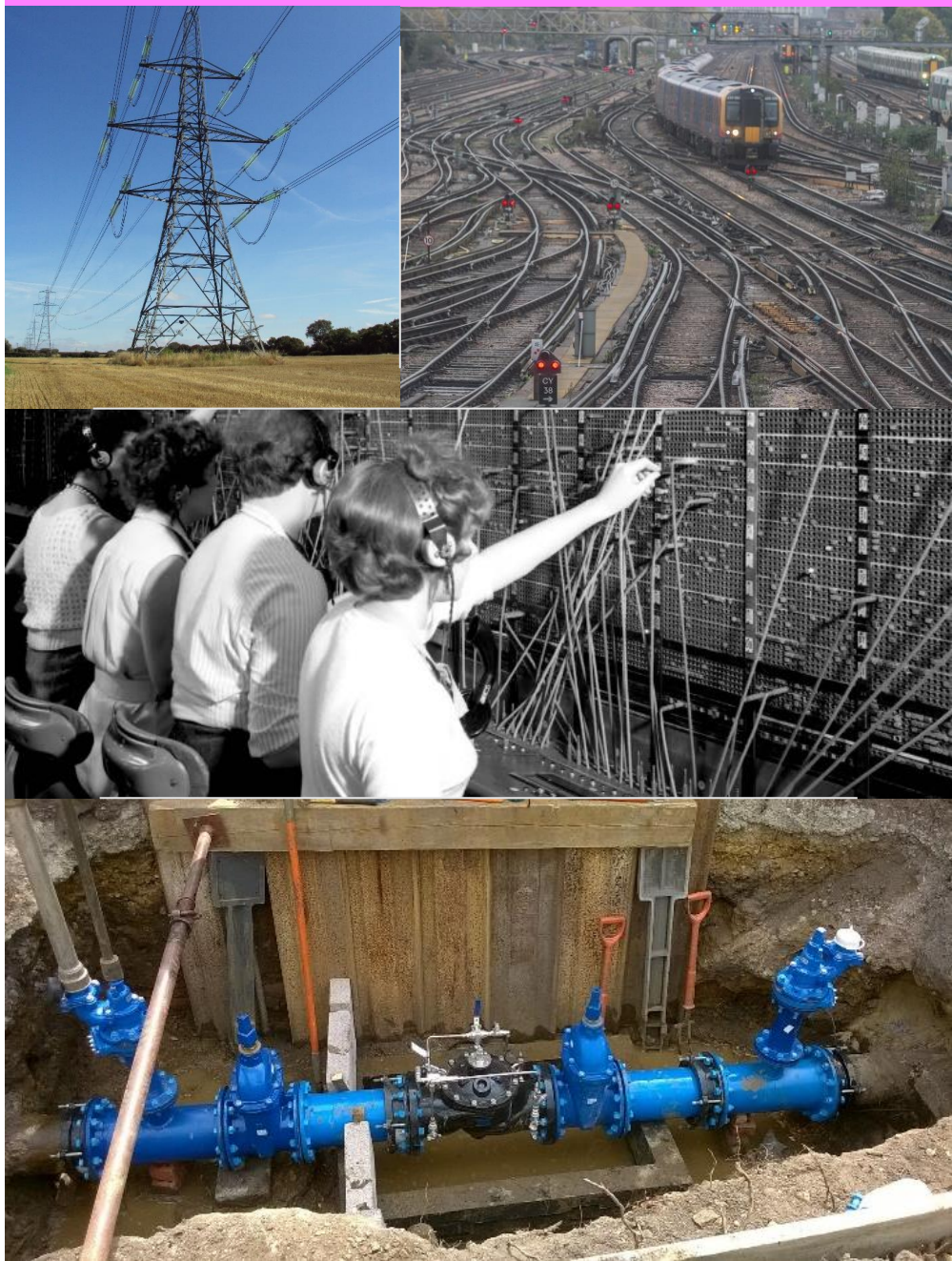
- **19th / 20th Century saw massive world-wide infrastructure projects**
  - Railways, electricity grids, water supplies, telephone networks based on copper

- **21st Century is also seeing massive world-wide build**
  - High bandwidth wireless access
  - Optical Fibre to billions of homes and wireless networks

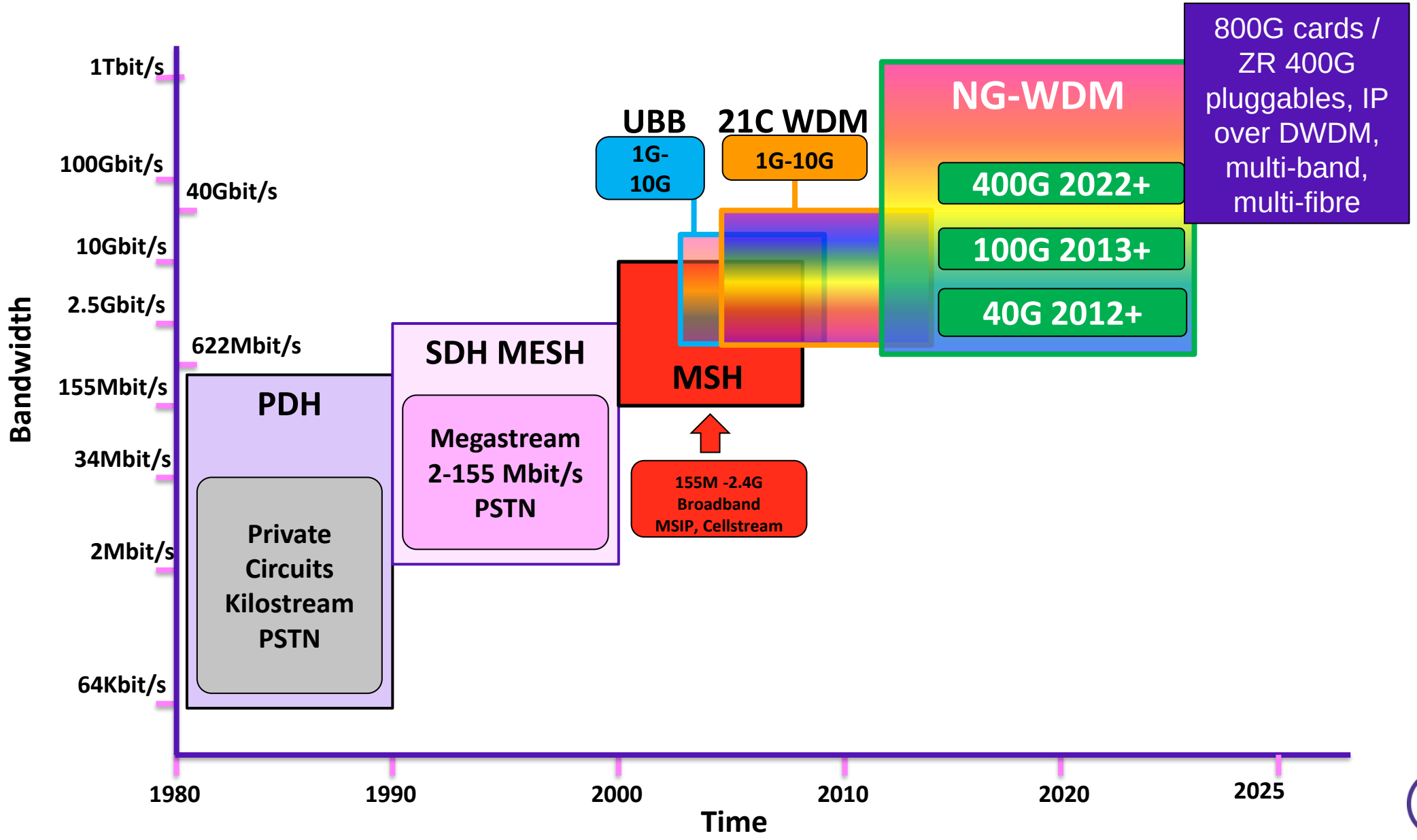
- **The fibre already installed is a small fraction of what is to come**
  - World-wide project will take decades
  - Cost $100s bns
  - Will have to endure for ~100 years or more

- **Optical technology underpins the future**
  - Essential for all future 5G++ networks
  - Essential for all consumer internet
  - Essential for all future smart cities, IoT

Fibre to homes / 5G cells is a century-scale investment with century-scale impact



BT example of multiple network solutions



Evolution of optical networks – elimination of boxes

Past 20 years – complex, multi-layer networks have been stripped back to the Lowest Common Denominator

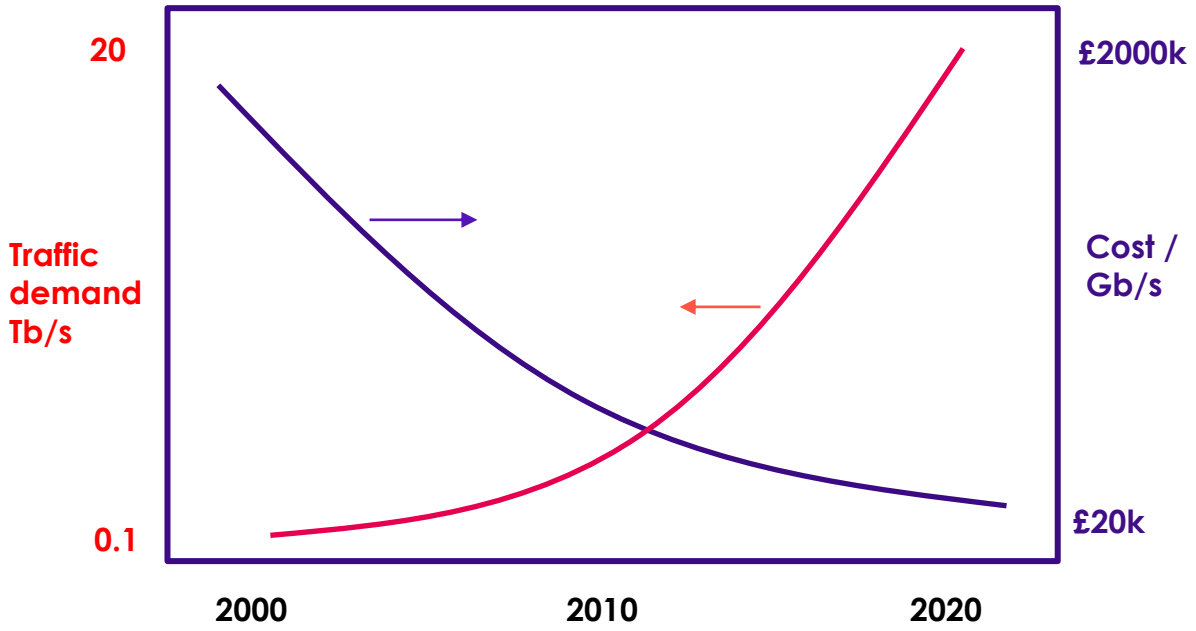
- Cost per bit has fallen by a factor of 10 or more
- Enabled by new technologies and network simplification

Networks perform:

- Access collection
- Aggregation and switching
- Transport

Most of the architectural simplifications have now happened

- Still incremental opportunities
- IP over DWDM reduces grey optics and assists with power and space
- Photonic integration fuelling current high speed optical solutions
- Photonics in routers next?

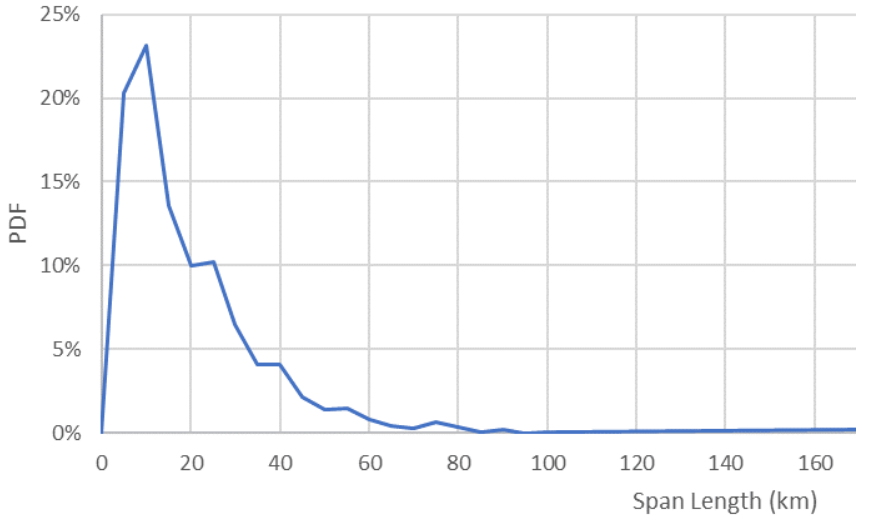


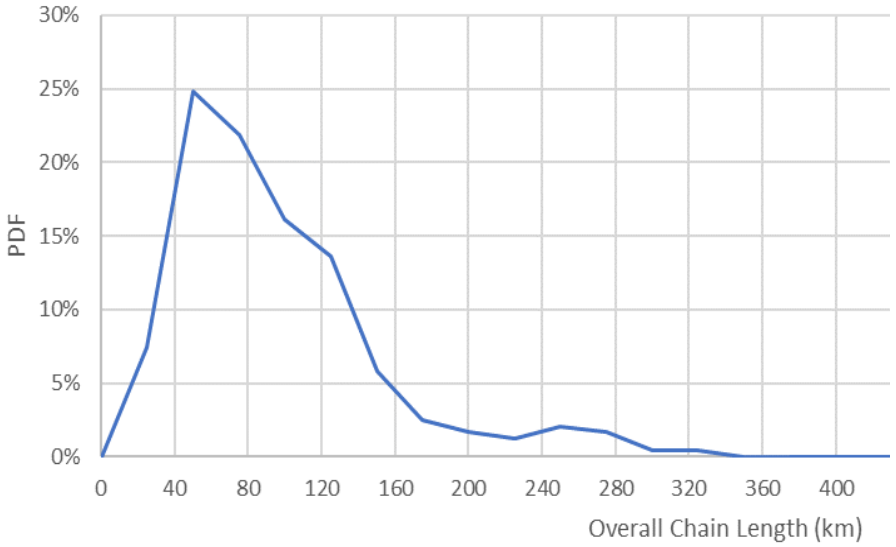
Approximate figures – includes IP layer

Metro topology statistics

- **What does the BT metro look like?**
  - ~1000 local exchange nodes connecting to ~100 metro-core nodes
    Chains of between 5 and 10 nodes (horse-shoe) to two metro-core nodes
- **What is happening to traffic?**
  - Continuing the 30% / year growth curve
- **What will 5G mean for the metro?**
  - One network - metro carries everything – consumer broadband, enterprise traffic, 5G
    Macro cells densifying to small cells… 10Gb/s – 25Gb/s

Distances modest, line-rates approaching the IMDD-coherent watershed, architecture hubbed, highly cost-sensitive part of the network





Some optical transport options

	Non-coherent	Coherent
Point to multi point	▪ PON – GPON far too small for metro ▪ PON – 25 / 50GPON still small but useful for small cells?	▪ PON – coherent / WDM PON ▪ **XR Optics using Digital Subcarrier**
Point to point	▪ 10Gb/s DWDM (legacy) ▪ 25Gb/s DWDM (NRZ) ▪ PAM4 (25 / 50G?) ▪ Kramers Kronig ▪ G.Metro ▪ Pt-pt using PON technology	▪ 100Gb/s DWDM ▪ ZR (400G) – too big? ▪ ZR (100G) – good option ▪ < 100G coherent pt-pt too expensive?

… plus optical switching options ranging from filterless to full ROADM and including 1x2 ROADMs, potentially with photonic integration

Point – Multipoint coherent: XR Optics – blurring boundaries

Technology being introduced by Infinera

Head-end coherent XR 400Gb/s Transceiver

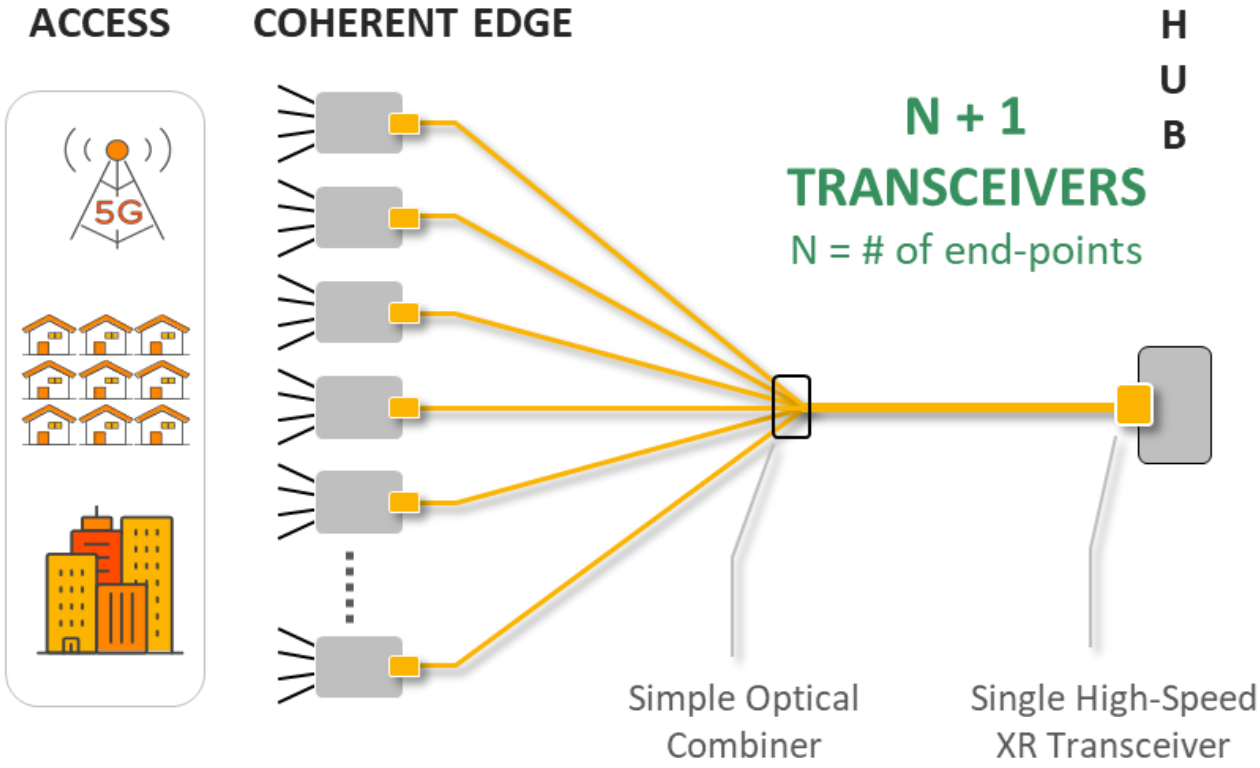
Passive splitter / combiner as with PON

Lower rate edge transceivers (e.g. 25G, 100G)
16 simultaneous coherent optical line systems
DSP-locked spectrum: ***Digital Subcarrier***

Huge reduction in transceiver count for hubbed architectures with asymmetric traffic

Additional benefit of automatic multiplexing

Also provides agile traffic provisioning



Joint modelling work

- Presented at ECOC 2020 and ECOC 2021
- Technology comparisons over typical BT topologies
- Assumptions made on component costs, traffic levels and growth etc – see the papers for details
- Massive savings for XR due to (i) fewer transceivers, (ii) reduced multiplexing

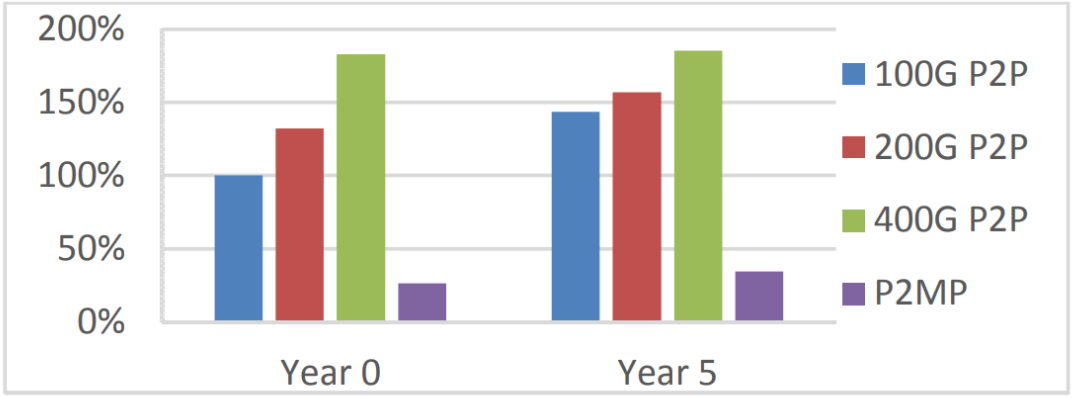
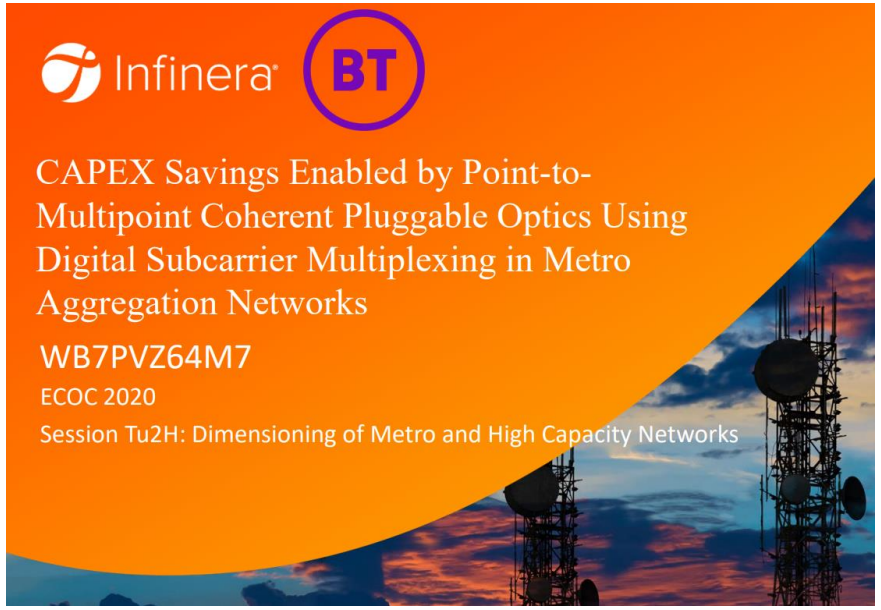
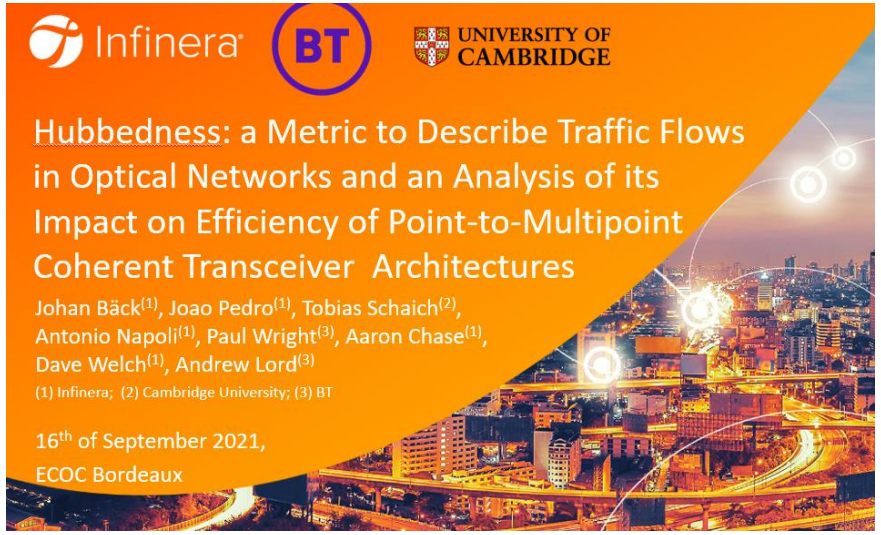


Fig. 2 Normalized cumulative CAPEX for different P2P transponder data rates compared to P2MP transceivers.





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Comments, discussion, conclusions

- Capacity growth running at 30%
- RAN just one service - ~ 1/10 fixed services
  - Consumer internet
  - Business services
- Potential for multiple mobile networks on same fibre
- Macro cells, small cells
- Capacities up at multiple Gb/s – 10G, 25G, 50G, 100G all relevant
- Hubbed
- Flexibility needed but at low cost (not current ROADM technology)

All of this suggests a range of solutions needed
Simple point-point fibre hard to displace
High speed PON attractive e.g. in Small Cell areas
XR handles hubbed aggregation at higher capacities very well
Highly cost competitive part of the network

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