A Vision for Optical Networks in a World of Increased Energy Costs, and Bottlenecks in Electronic Switching and Optical Spectral Efficiency

Andrew Lord
Senior Manager, Optical Networks Research
BT

Fibre – a 21st century global mega project

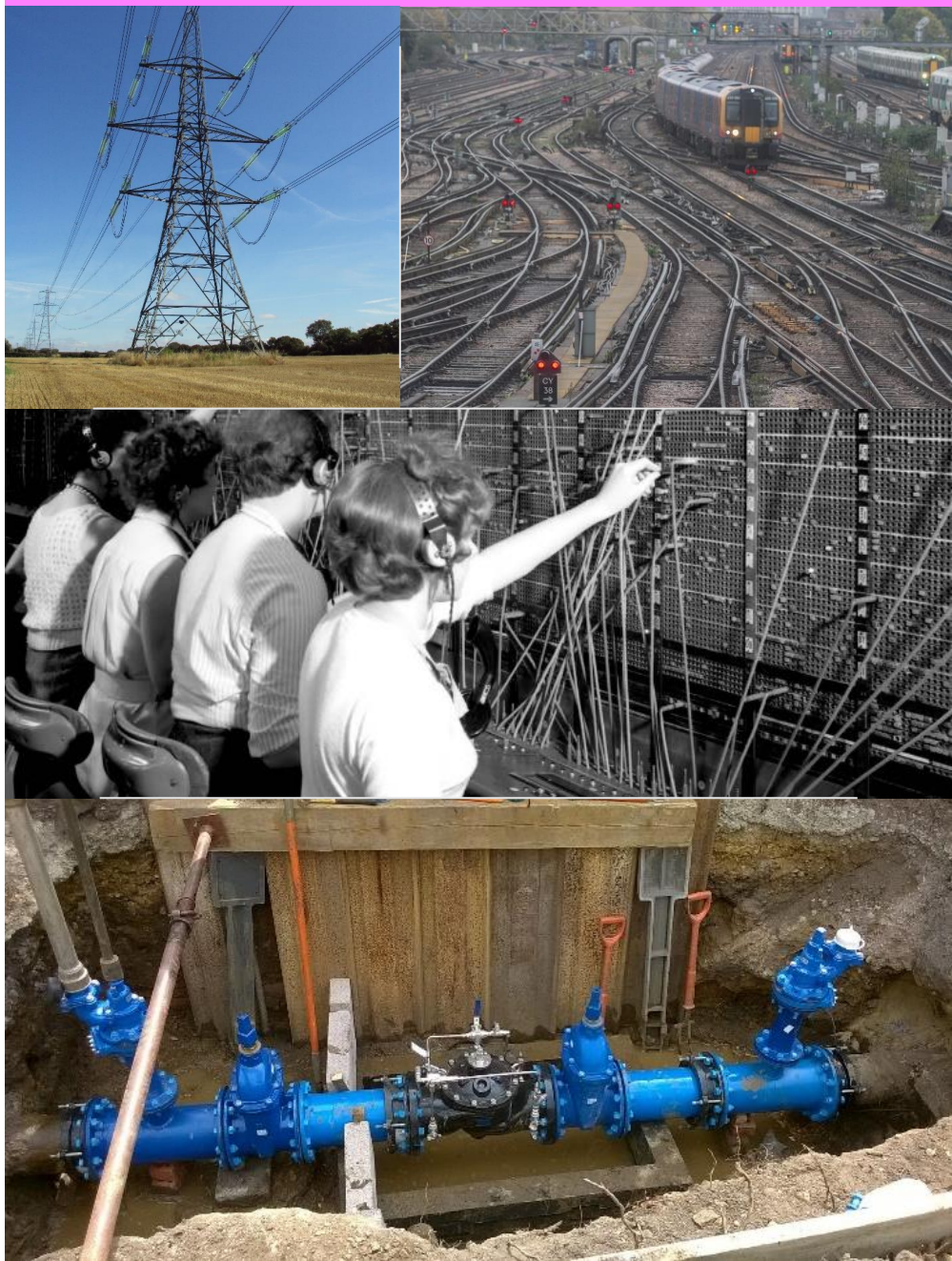
- **19th / 20th Century saw massive world-wide infrastructure projects**
  - Railways, electricity grids, water supplies, telephone networks based on copper

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

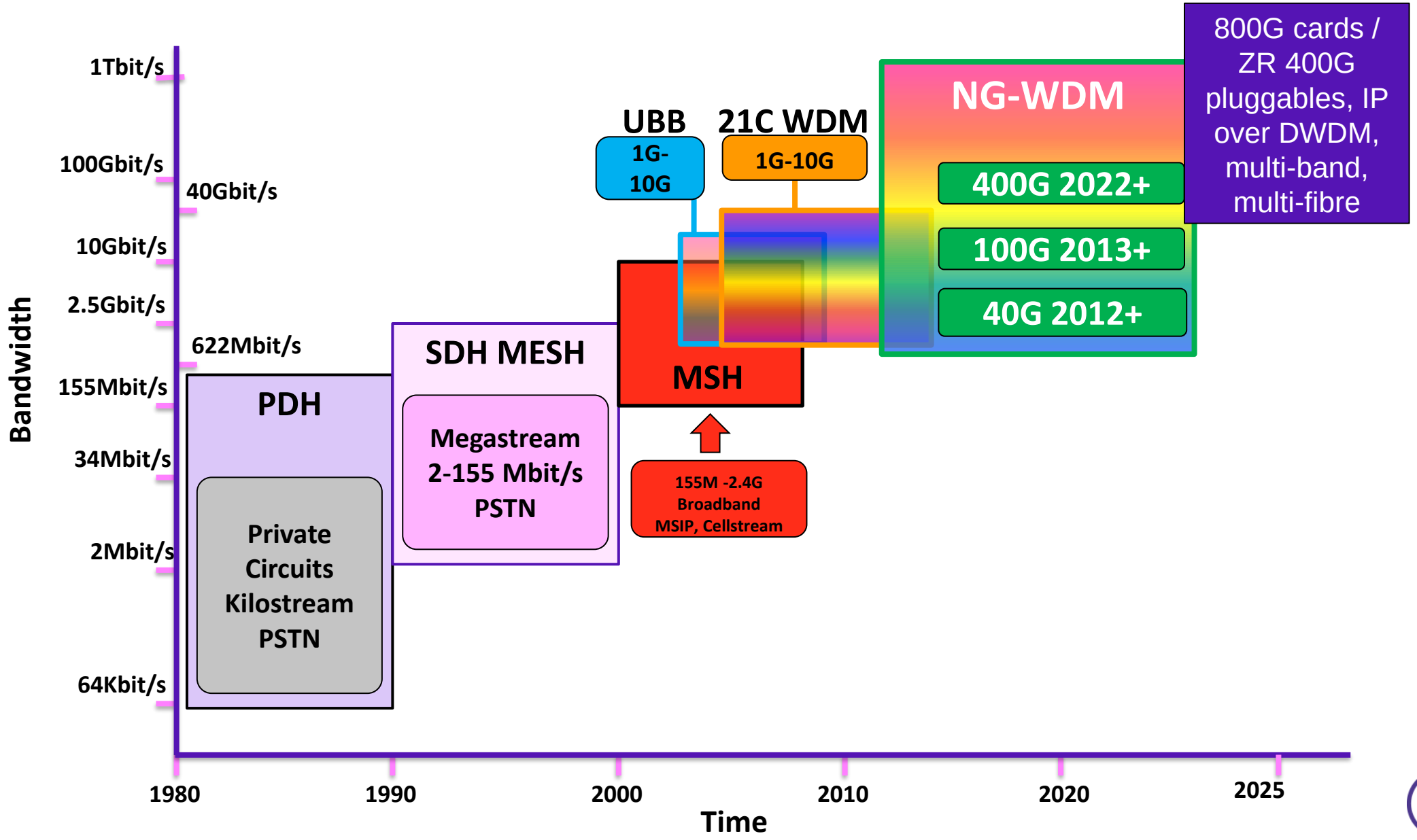
- **The fibre already installed is a small fraction of what is to come**
  - World-wide project will take decades
  - Cost $100s bns
  - Will have to endure for ~100 years or more

- **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

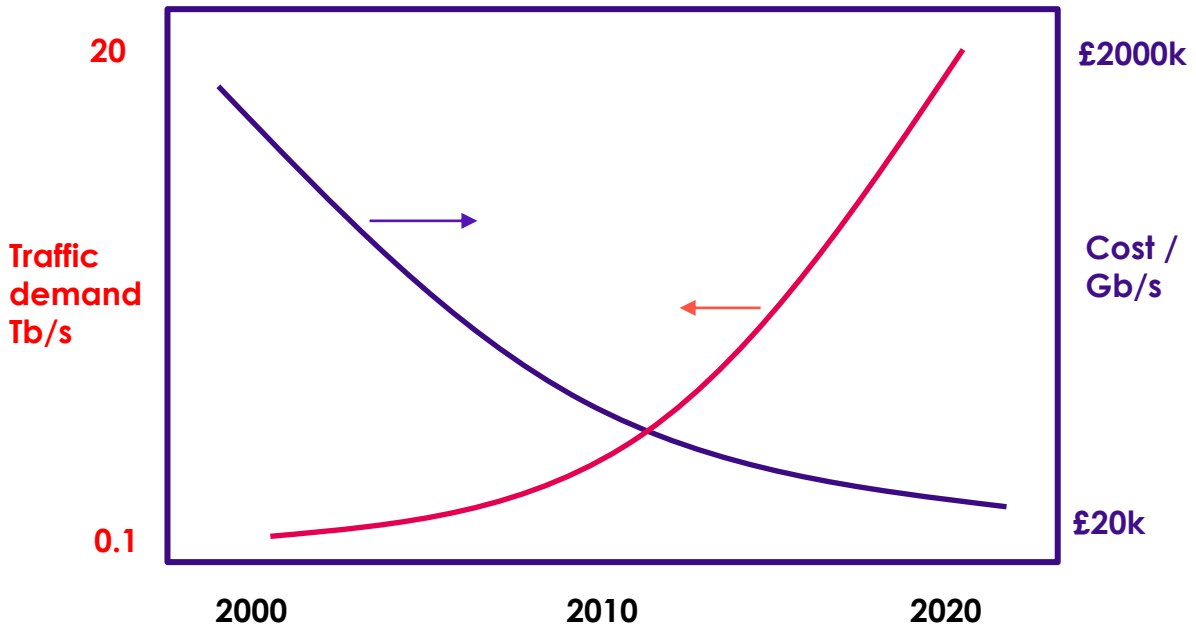
- Cost per bit has fallen by a factor of 10 or more
- Enabled by new technologies and network simplification

Networks perform:

- Access collection
- Aggregation and switching
- Transport

Most of the architectural simplifications have now happened

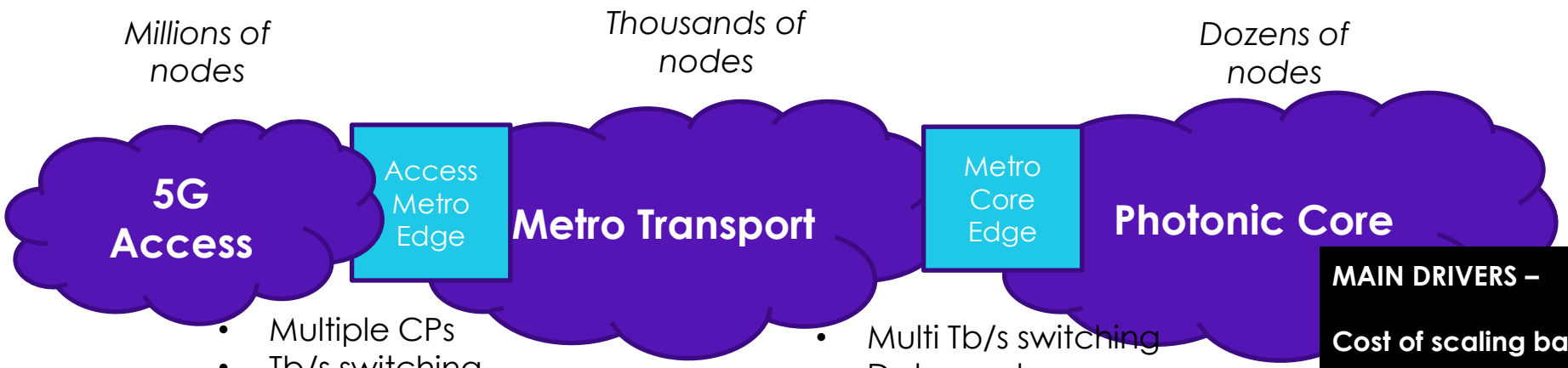
- Still incremental opportunities
- IP over DWDM reduces grey optics and assists with power and space
- Photonic integration fuelling current high speed optical solutions
- Photonics in routers next?



Approximate figures – includes IP layer

Overall network view

SDN-based Control / Orchestration, Security, Energy Consumption



- Multiple CPs
- Tb/s switching
- Remote storage / compute
- NfV
- Dynamic config
- Whitebox

- Multi Tb/s switching
- Data centre functions
- Multi layer 1-3
- ROADM
- Sliceable spectrum

MAIN DRIVERS –

Cost of scaling bandwidth

Appropriate tech for access/metro – modest distances

Energy Efficiency and carbon

Network security

Autonomous operation

- Gb/s access
- Wireless femtocells
- Deep fibre
- Infrastructure cost

- 10-25G transport
- Many wavelengths
- Limited flexibility
- Cheap 10G over 50km

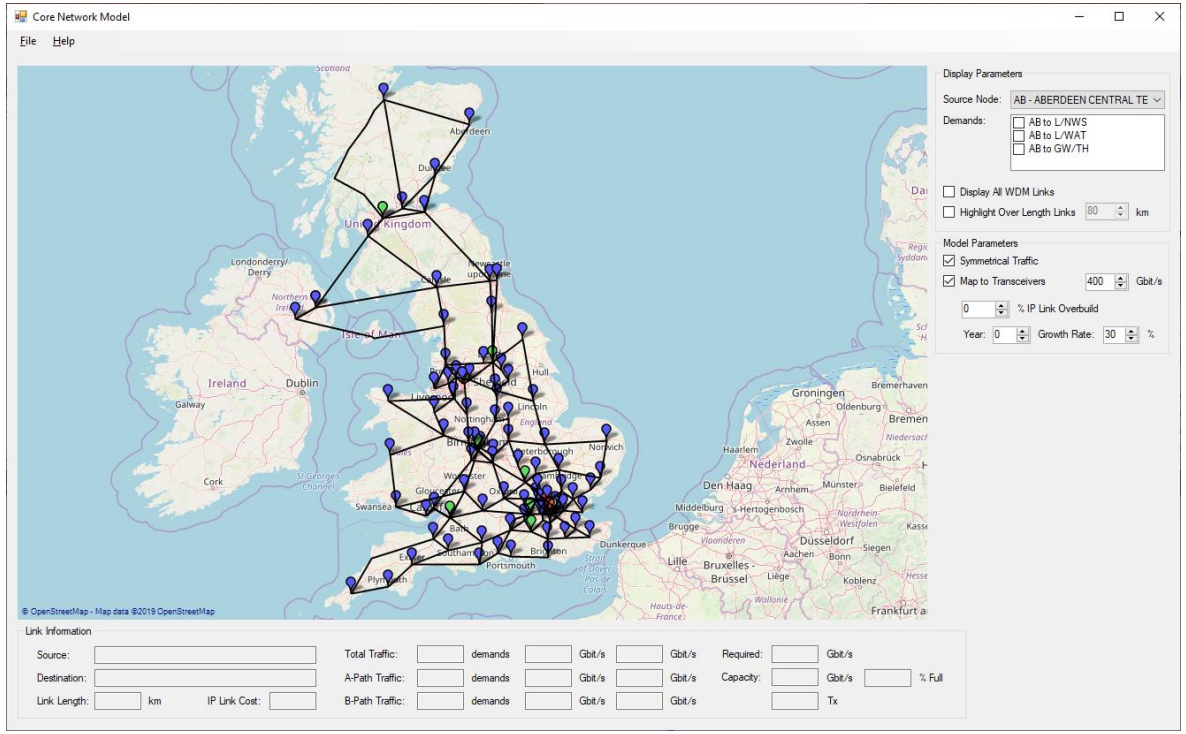
- > 1Tb/s per
- Increased f
- Cost less cri
- Elastic Optical Networks
- Multiband, multifibre networks

BT

400G ZR – the next steps

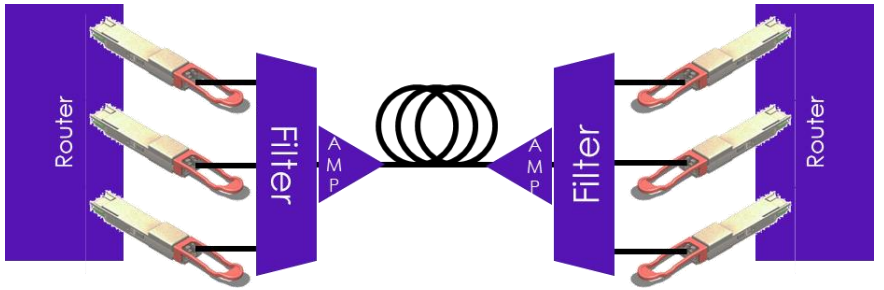
What is it?

- 100Gbit/s migration to 400Gbit/s with a refresh of both the IP and optical layers
- Data centre driven the development of 400G-ZR pluggable
- QSFP-DD interface of 400Gbit/s switches and routers, can reach up to 120km
- For the first time network operators could have IP-optical integration



Hop to hop between routers costs in?

- In places – especially highly dense parts of the network
- Optimum solution is a hybrid of ZR, ZR+ and conventional transponders
- Volume pricing offsets the hop-hop architecture



Multiple ZRs….

- Low power ZR is an issue, especially with ROADMs
- **Now seeing a 'ZR++' high power version to get around this**
- Multiple solutions with ZR including direct fibre, pt-pt WDM, ROADMs, IP over DWDM, grey 400G from routers etc etc

Will the enticing cost advantage of ZR drive operators towards router-router architectures or will higher power ZR+ mean we can carry on using existing ROADM structures?

Point – Multipoint coherent: XR Optics – coherent ‘PON’ is here!

Technology being introduced by Infinera

Head-end coherent XR 400Gb/s Transceiver

Passive splitter / combiner as with PON

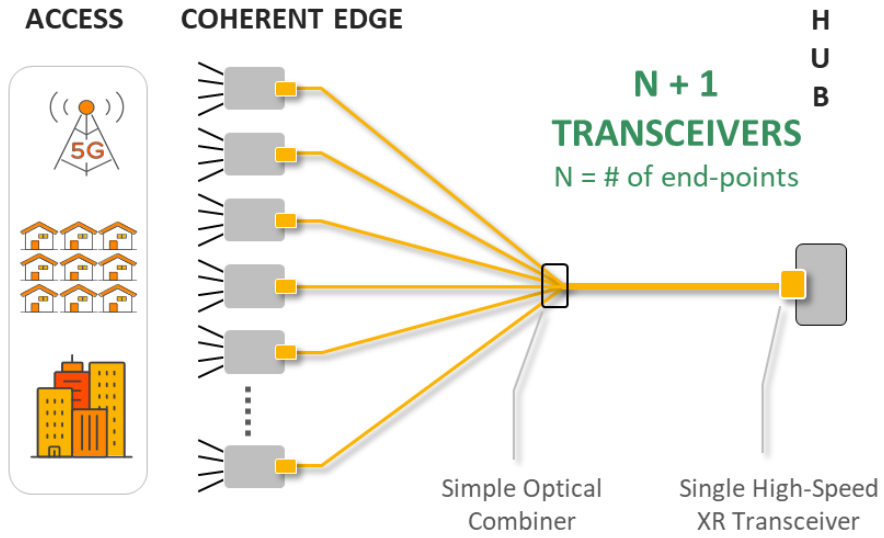
Lower rate edge transceivers (e.g. 25G, 100G)
16 simultaneous coherent optical line systems
DSP-locked spectrum: ***Digital Subcarrier***

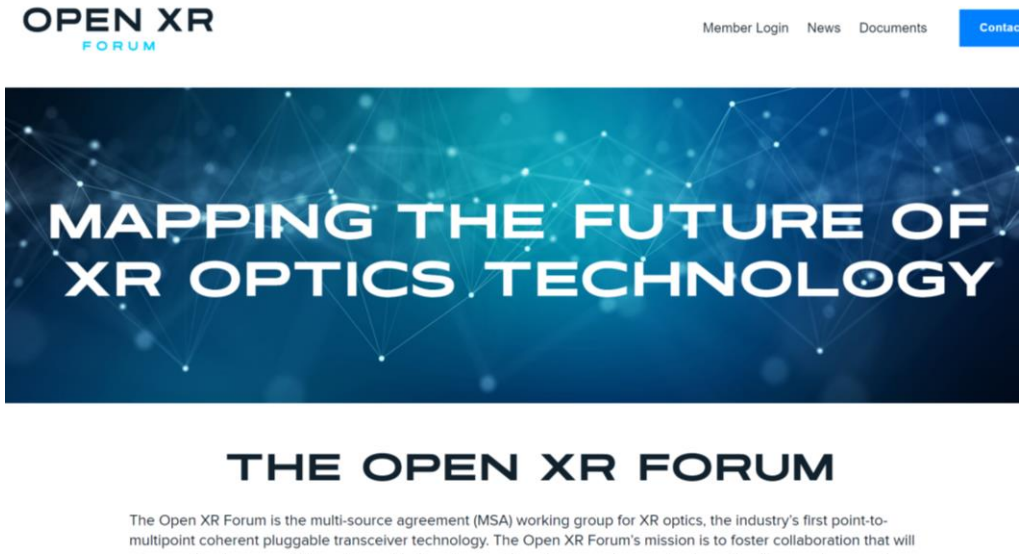
Huge reduction in transceiver count for hubbed architectures with asymmetric traffic

Additional benefit of automatic multiplexing

Also provides agile traffic provisioning

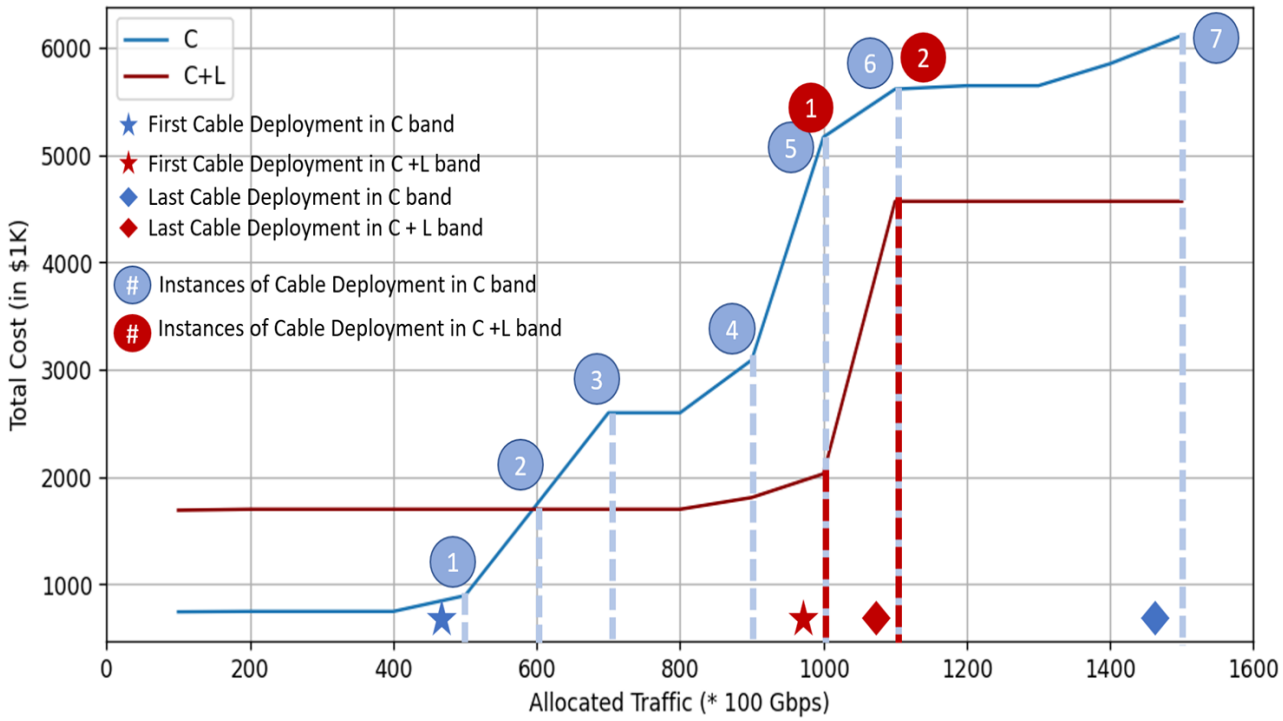
Trials now starting





Once the C-band limit is broken

- Exponential traffic growth is now leading to full C bands
  - With close to maximum spectral efficiency
- De facto option is multiple C bands but with C+L now a viable option
- Research moving on to multiple bands



Paper: We1A.5 (Session: Ultra-wideband Optical Systems)

Multifiber vs. Ultra-Wideband Upgrade: A Techno-Economic Comparison for Elastic Optical Backbone Network

Rana Kumar Jana[1], Md Asif Iqbal[2], Neil Parkin[2], Anand Srivastava[1], Arvind Mishra[3], Jitendra Balakrishnan[3], Phillip Coppin[3], Andrew Lord[2], Abhijit Mitra[1,2]

(1) Dept. of Electronics and Communication Engineering, IIIT Delhi, India,

(2) Applied Research, Adastral Park, British Telecom, UK,

(3) Sterlite Technologies Limited.

September 21, 2022

Comparison of N x C vs (N / 2) x C + L

Modelling program with IIIT Delhi, Sterlite
Is C+L better than C band only?
Network modelling exercise shows longer term benefits in C+L
But more expensive on day 1
Dependent on fibre costs

London quantum-secured metro network services trial

Connecting sites in London's Docklands, the City and the M4 Corridor

- The new network is the world's first commercially viable trial of a quantum network infrastructure that transmits keys and data over a common bearer .
- It will provide a range of quantum-secured services including dedicated high bandwidth end-to-end encrypted links.
- The QKD links will be provided using a quantum network that includes both core and access components, and will be integrated into BT's existing network management operations.
- Toshiba will provide quantum key distribution hardware and key management software.
- The initial trial service will encompass BT-generated keys, encryption and transmission on the key bearing transmission.
- Subsequent trial services will encompass BT-generated keys, encryption, and transmission on other non-key bearing Optical , Ethernet or IPvpn circuits.

Trial quantum secured metro network in central London with connectivity to key customers

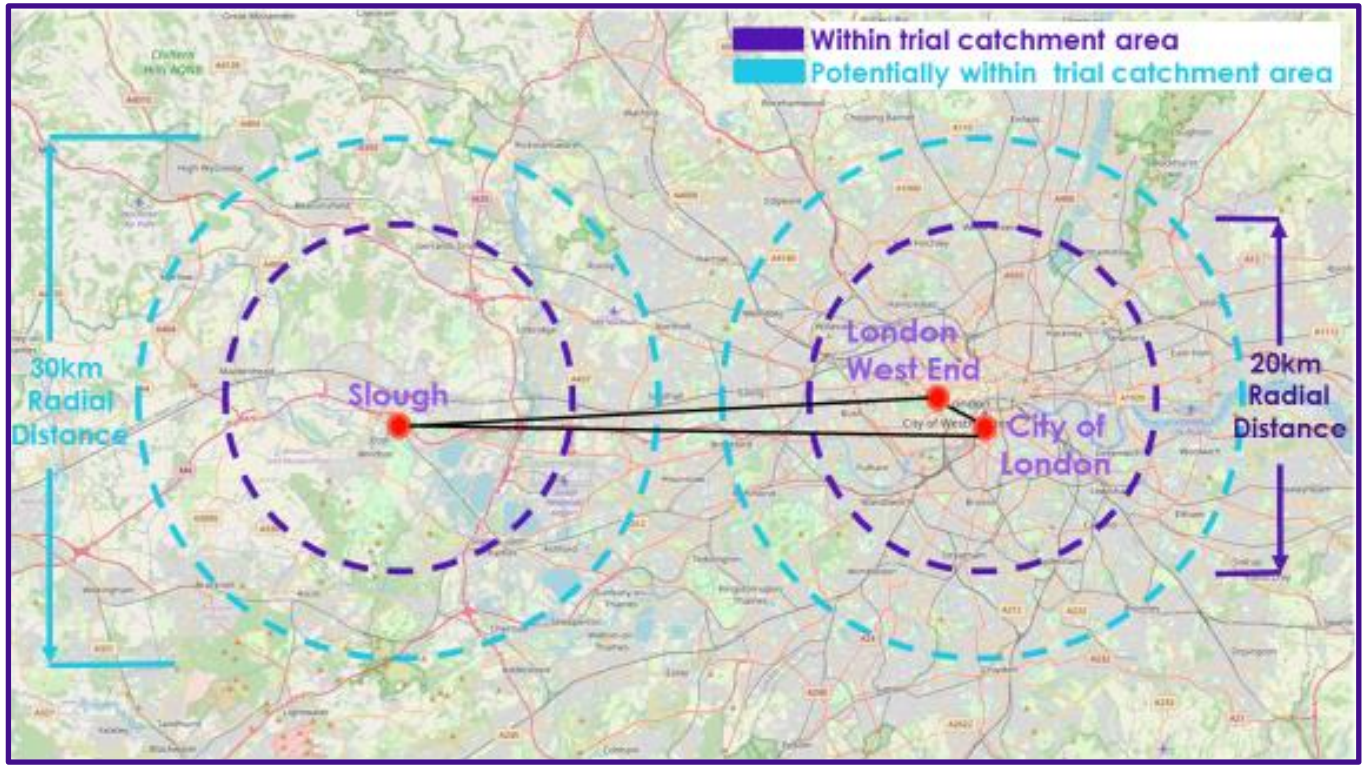
Launched April'22

What:

- 3 year metro-based trial
- 3 node ring with connections to Telehouse and Equinix
- Connections to trial customer sites
- Data services secured with QKD + PQC
- SDN-based network + security management
- Potential to install satellite QKD ground station at one of the trial nodes

Why:

- Acceleration towards a terrestrial UK QKD commercial service
- Design and testing of potential commercial end to end products and services
- Validation of markets and early adopter use cases



Conclusions and discussion

- Combined effect of consistent traffic demands and increased energy costs
  - New technology / innovation needed more than ever
- Network simplification is a one-time trick which has largely played out now
  - IP over optical still largely unused though
- Multiple avenues being explored
  - Reliance on Data Centre tech
  - New optical components (such as PICs)
  - System design (e.g. low margin networks)
  - Network architectures such as Pt-MPt (e.g. XR Optics)
  - Beyond C band transmission
  - Coherent transmission moving to the edge
- As traffic bandwidth increases, the best medium to handle it is optical, but optical solutions need to step up:
  - Cost still high – but with photonic integration and higher volumes coming
  - Solutions not plug and play yet – but progress being made now on monitoring / AI
  - Potentially low energy consumption – still a long way to go here too

Next generation of optical solutions could be high volume, low cost and low energy consumption, enabling the continuation of data consumption for consumers and business

BT