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

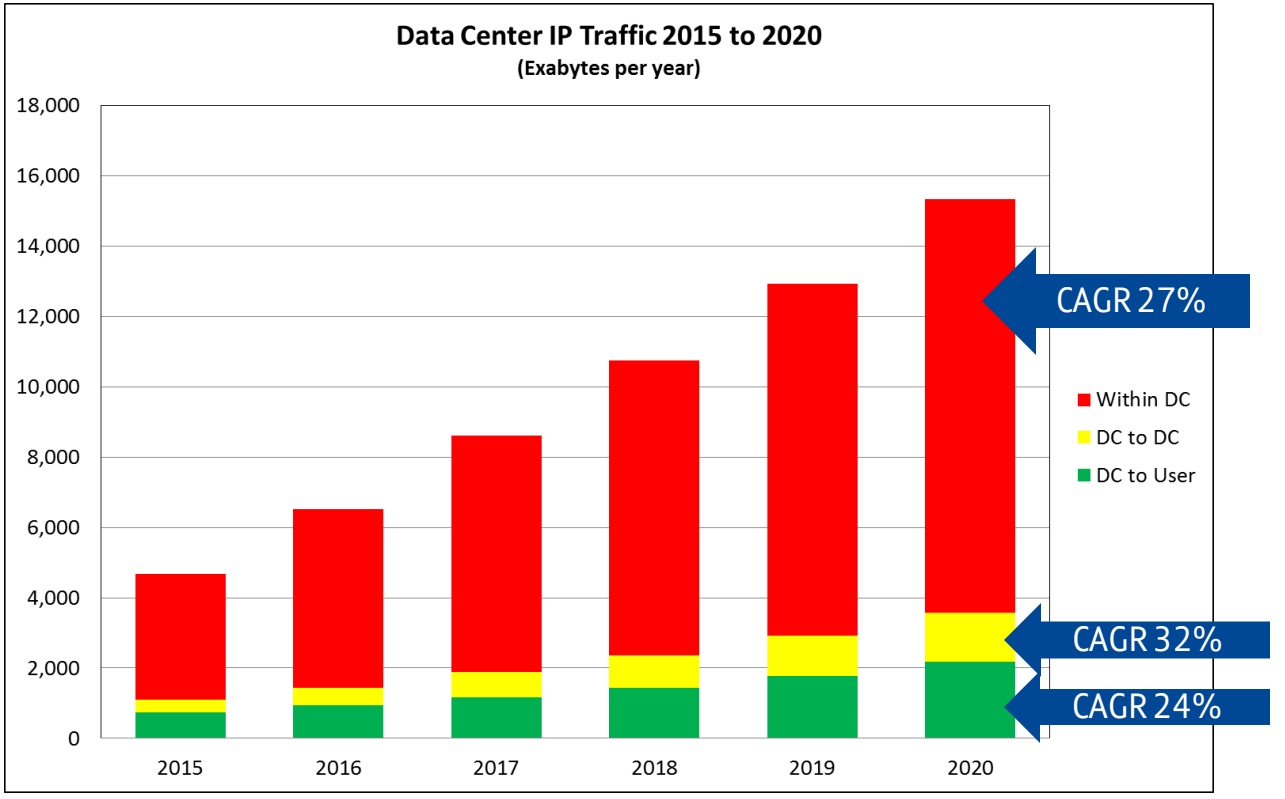
Andrew Lord (Head of BT Optical Research)

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 EU project partners

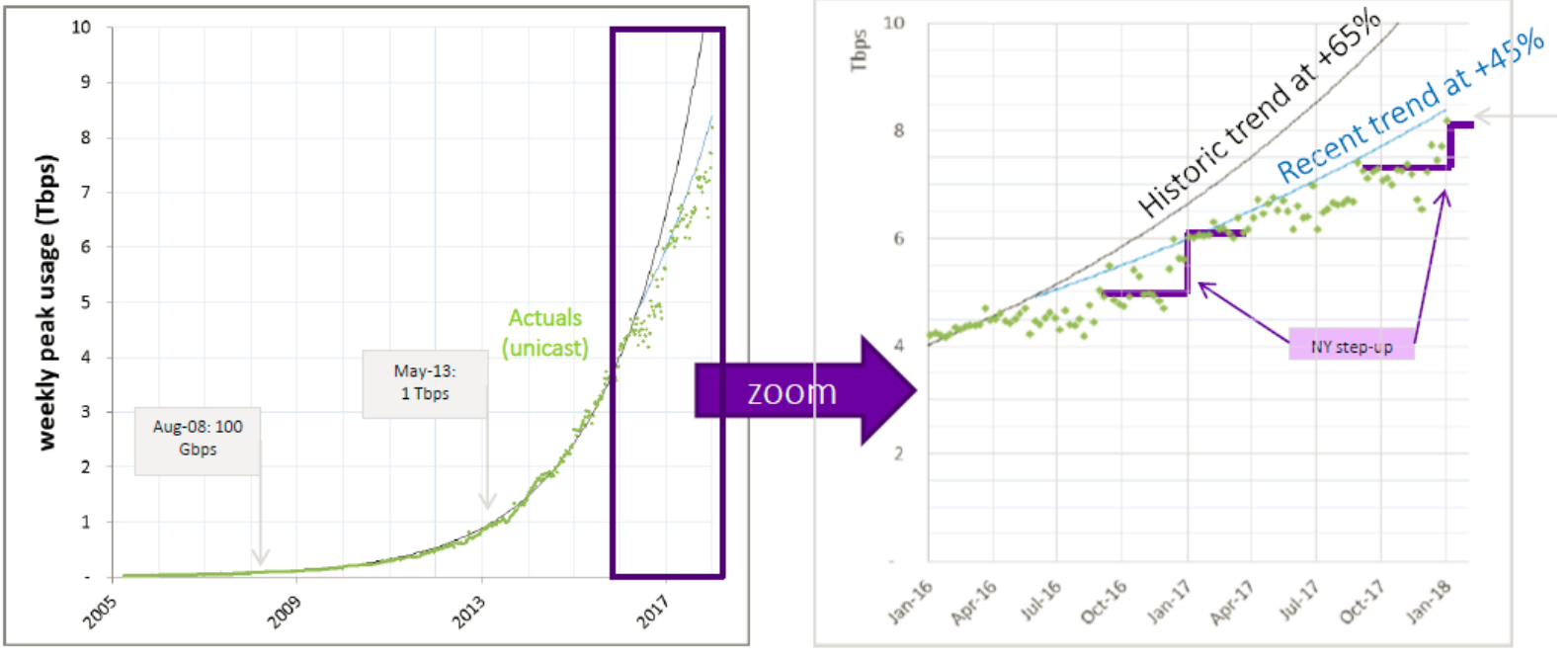
Inter/Intra data centre traffic



Source: Cisco CGI, 2015-2020

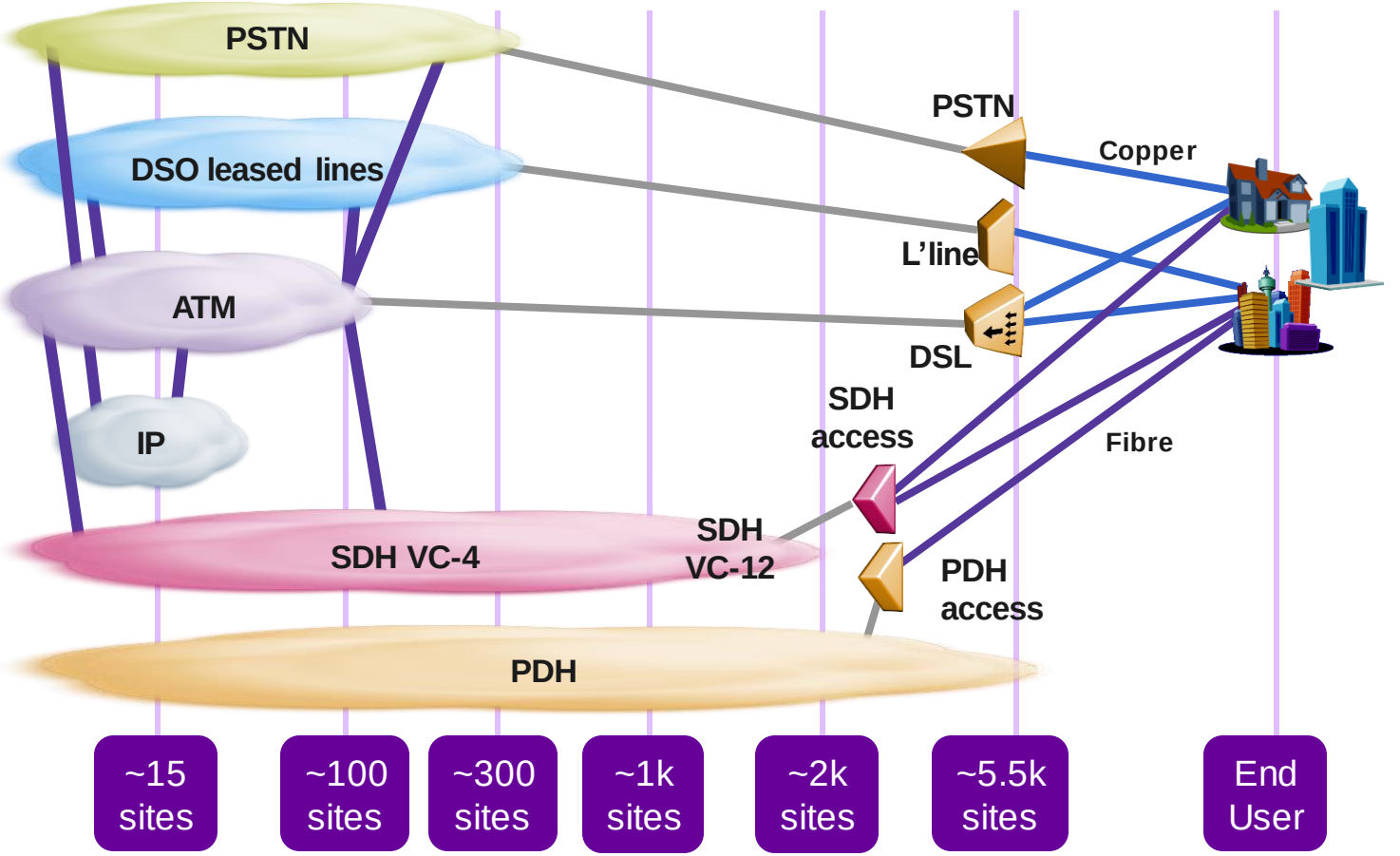
BT still reporting 40%+ traffic growth

Growth of aggregate core traffic continues and is slowing slightly

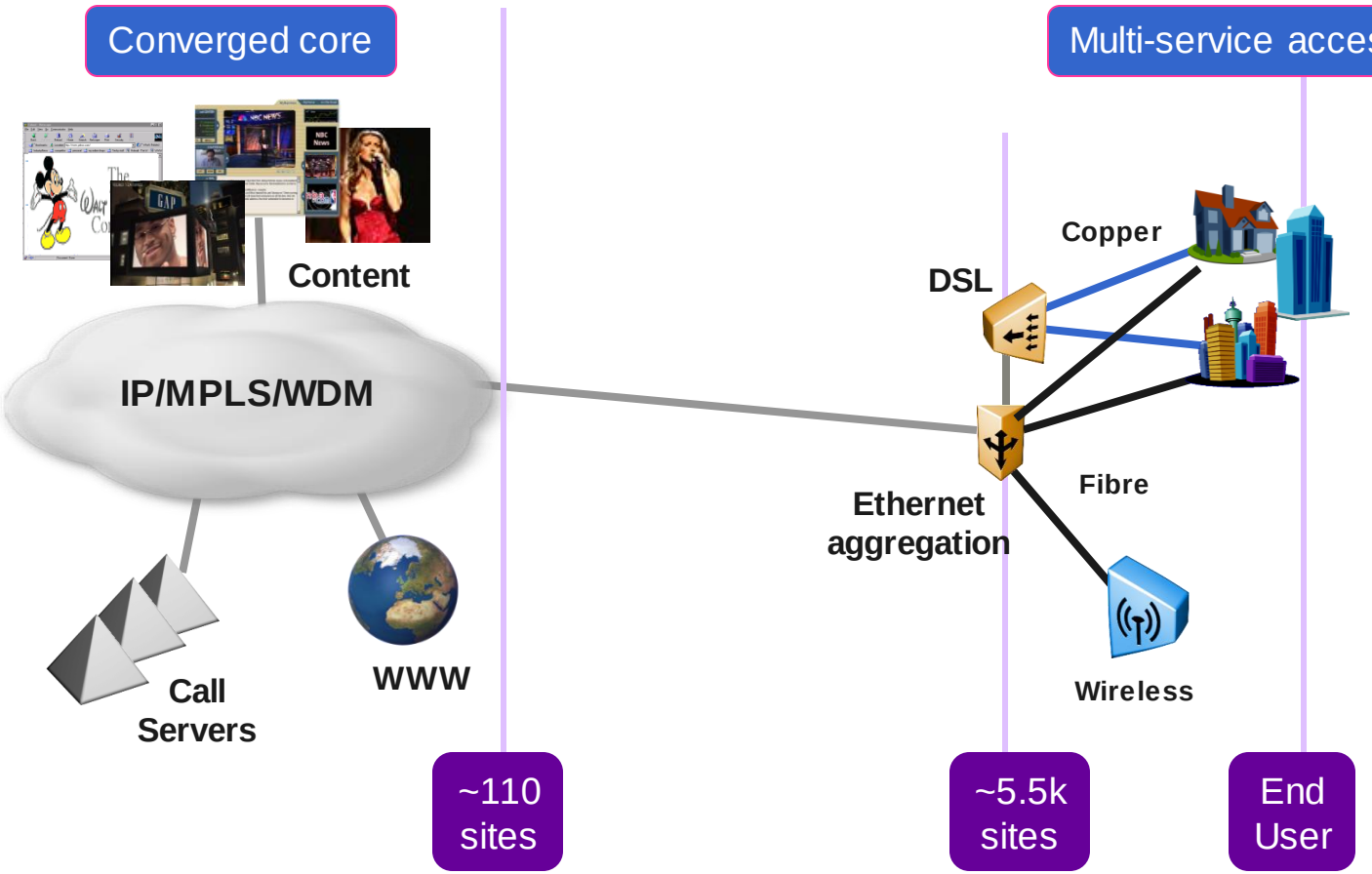


40% + growth is mirrored around the world

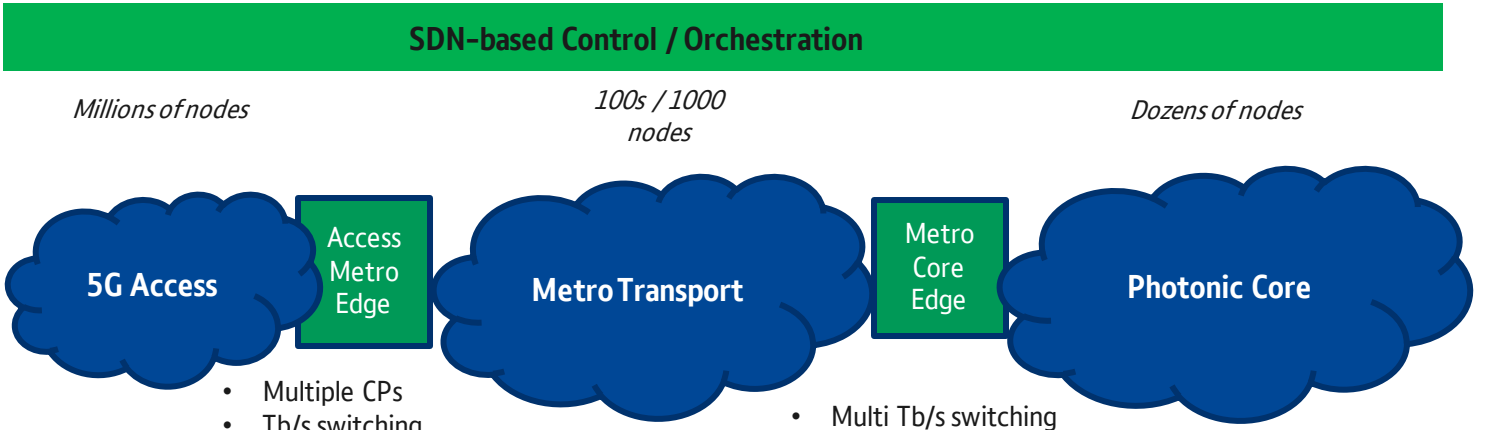
BT Network (2004)



BT 21CN Network (2017)



Network bottle-necks / challenges



- Multiple CPs
- Tb/s switching
- Remote storage / compute
- NfV
- Dynamic config
- Whitebox
- **Cost, power, space premium**

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

- Gb/s access
- Wireless femtocells
- Deep fibre
- 5G KPIs
- Convergence
- Infrastructure cost

- 10-25G or coherent? transport
- Many wavelengths
- Cost-effective flexibility
- 20km – 50km – 100km
- **Cost, power, space premium**

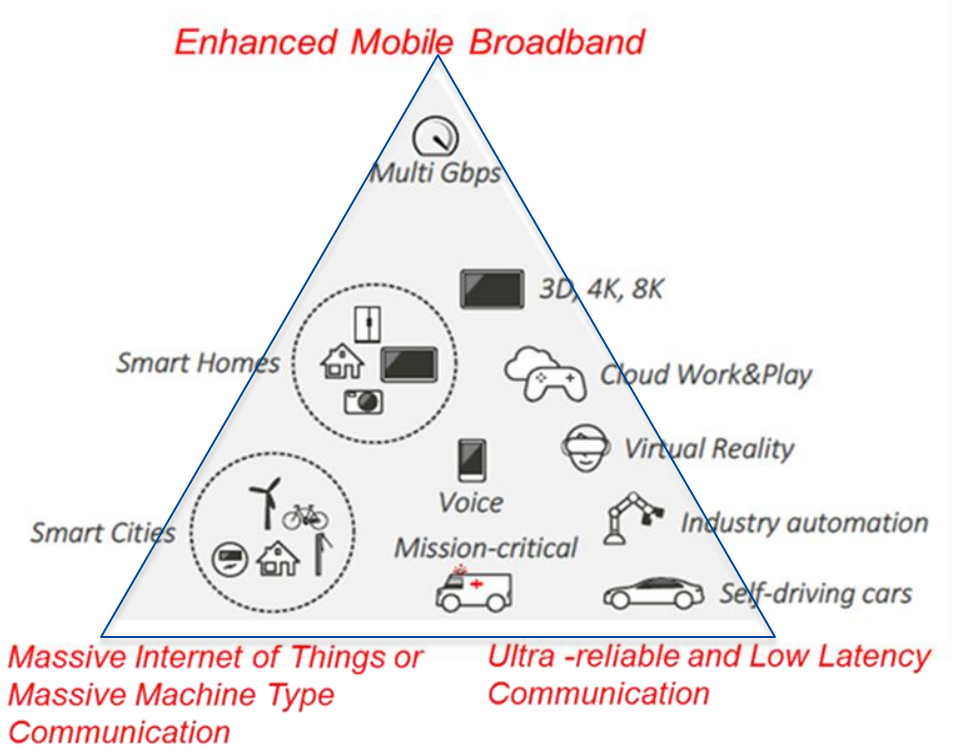
- > 1Tb/s per fibre – multiple bands / fibres / SDM
- Increased flexibility
- Cost less critical
- Elastic Optical Networks

Security, Monitoring, Resilience

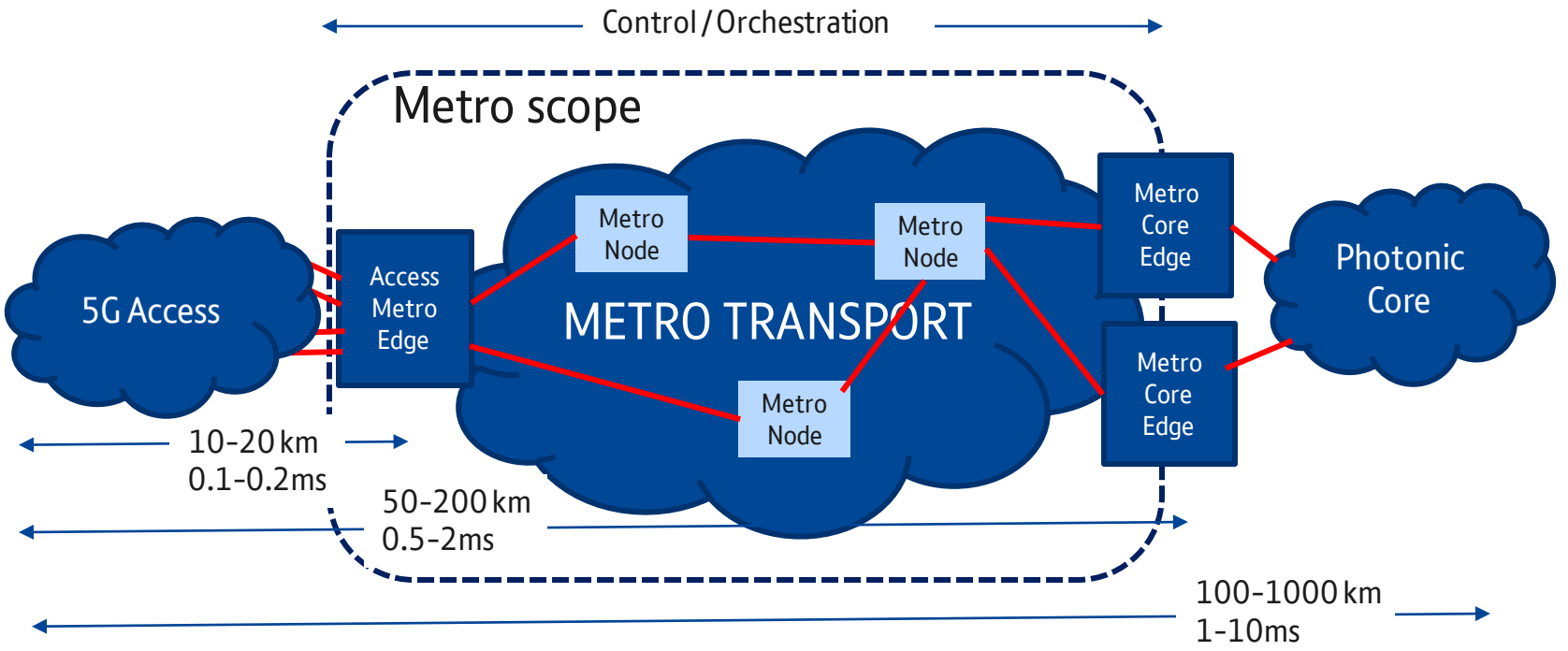
5G PPP published KPIs and Use Cases

- 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/



Metro-Haul architecture and scope



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

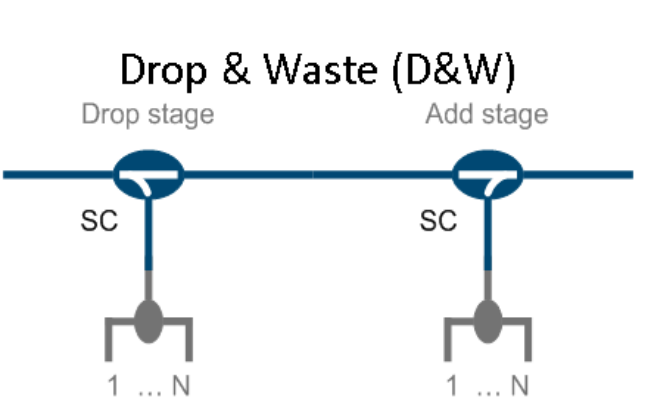
Metro networks – ripe for innovation

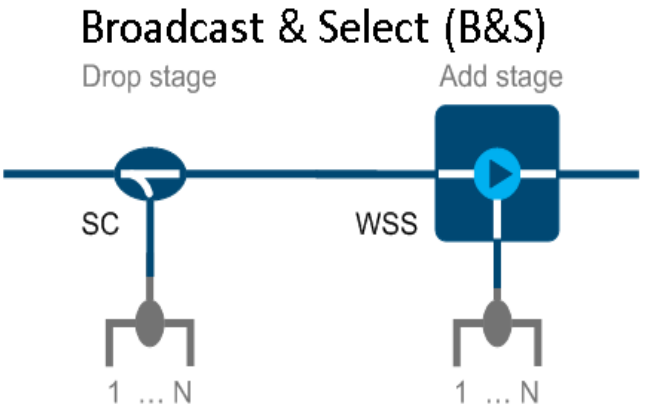
- Vast numbers of femtocells needed to provide future 5G bandwidth
- Backhaul = deep fibre
  - Potentially hundreds of 10G + circuits over shortish range (20km typical)
- Requirements will be
  - Ultra cost effective optical transport (Facebook talk about 1Gb/s = 1$ for IDC.)
  - Short reach DWDM
  - 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

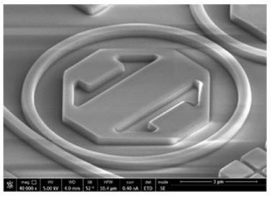
- Main requirement here is **very low cost** 10G-25G WDM with limited reach (<50km) and some switching. Low cost coherent 100G transport also needs deep research.
- Architecture
  - Meshed, chains, horse shoes…
  - Traffic flows expected to be hubbed from the Access Metro Nodes to the Metro Core node
  - 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

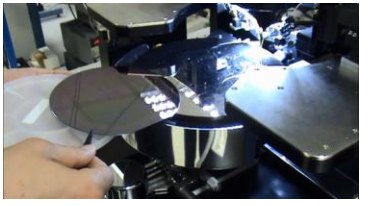


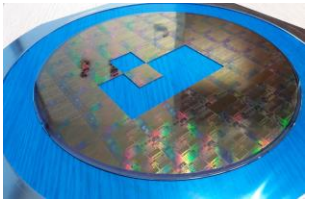


Integrated silicon photonics

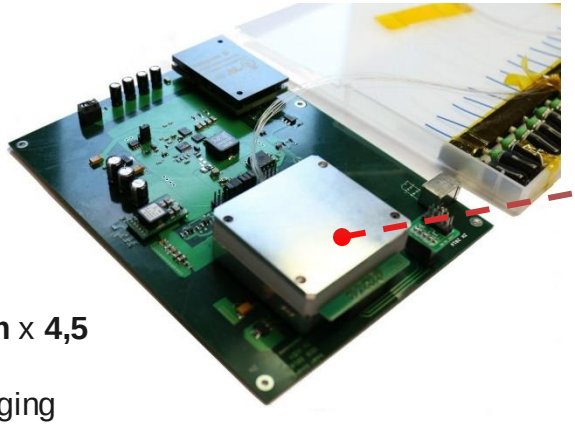
- **Ericsson technology**
- Integration onto chips will enable huge cost reduction
- Performance doesn't have to match LCoS-based WSS
- 200 mm wafer realization



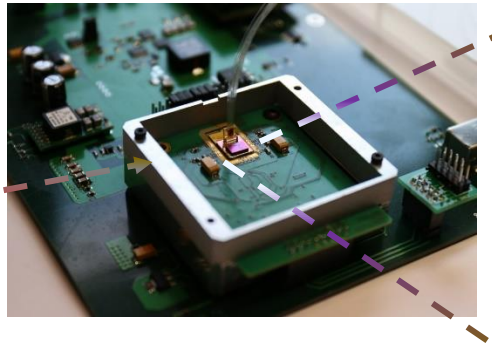


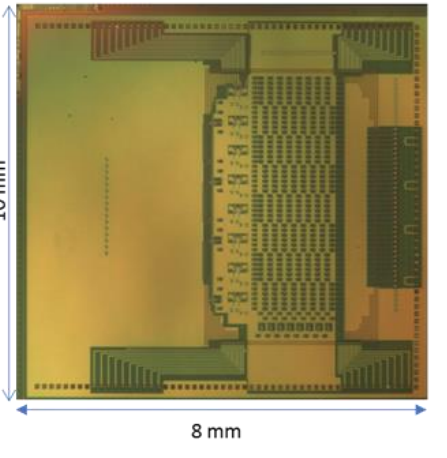


With CNIT…turned into a **whitebox** optical switch allowing fast open innovation

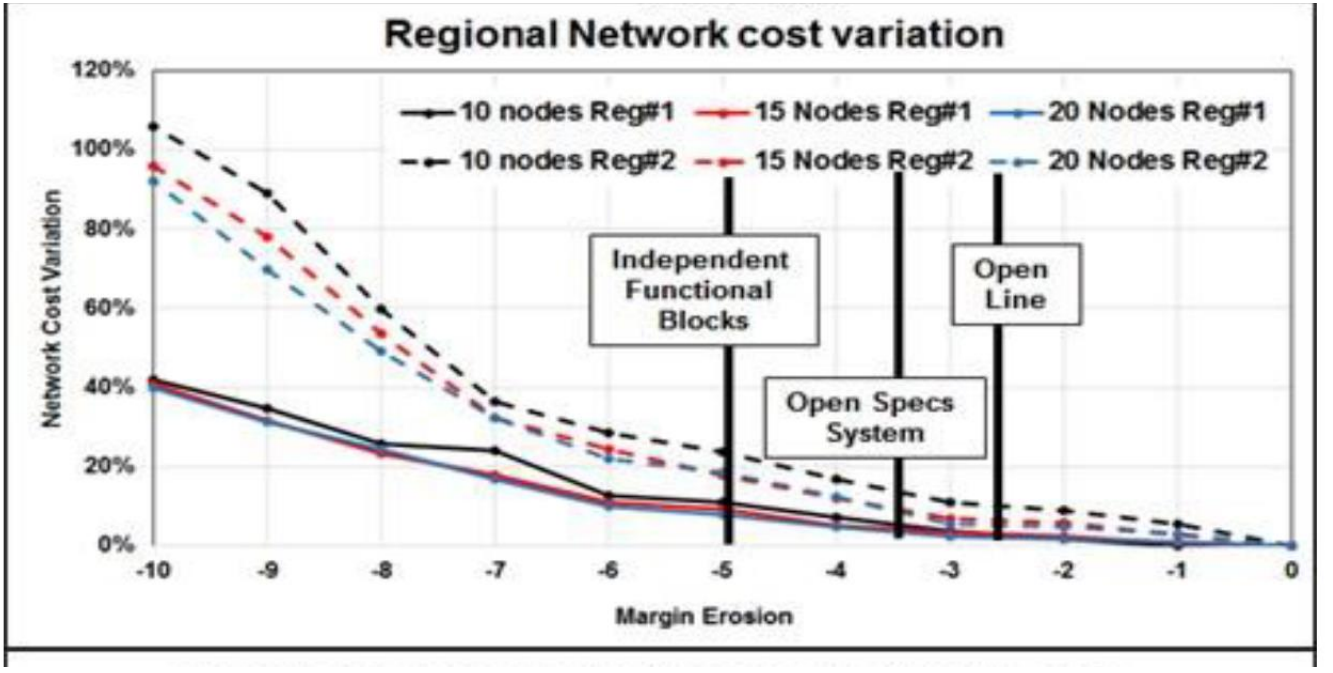


4,5 cm x **4,5 cm**
packaging





Disaggregation penalty not significant in metro

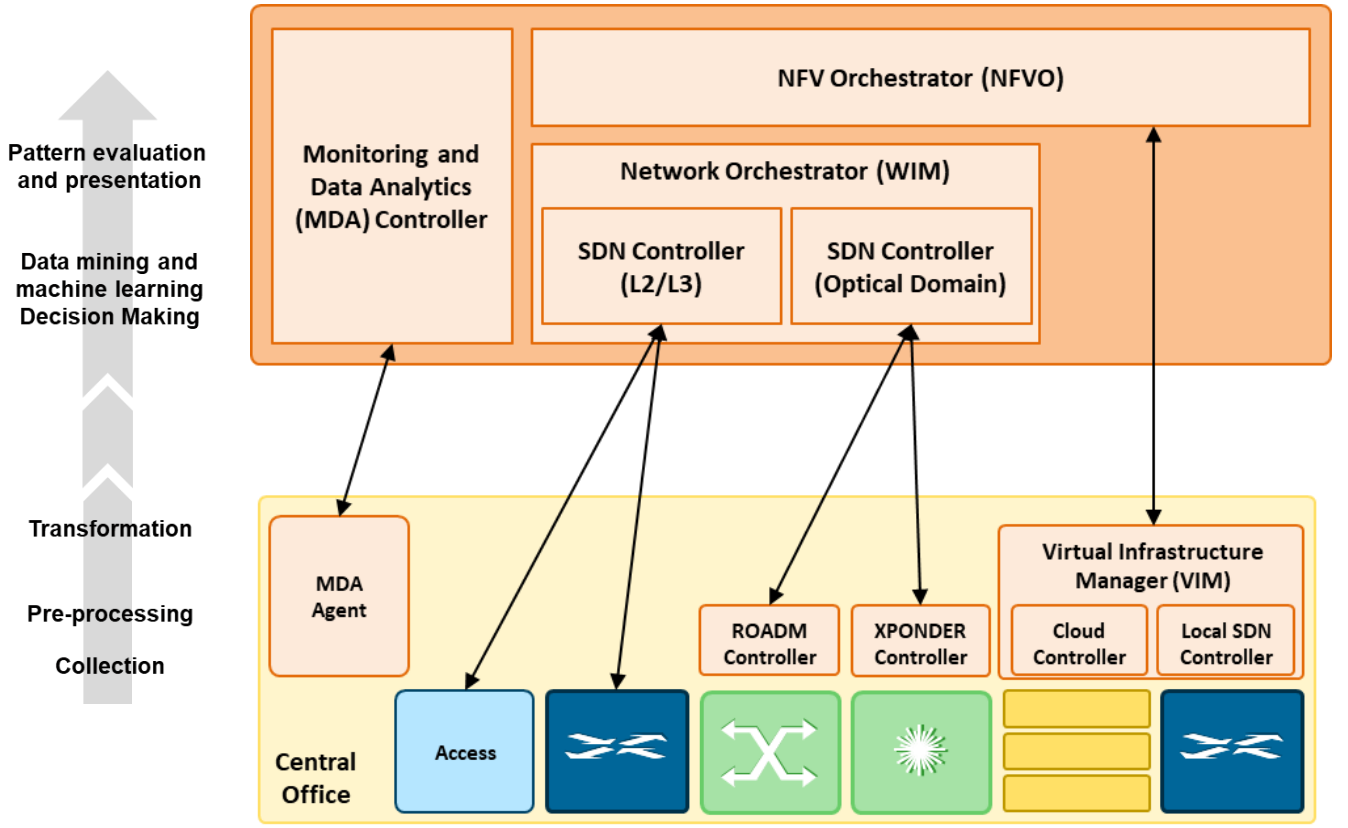


M1E.2 OFC 2018 'Margin requirement of disaggregating the DWDM transport system and its consequence on application economics' Ciena

Telemetry and monitoring

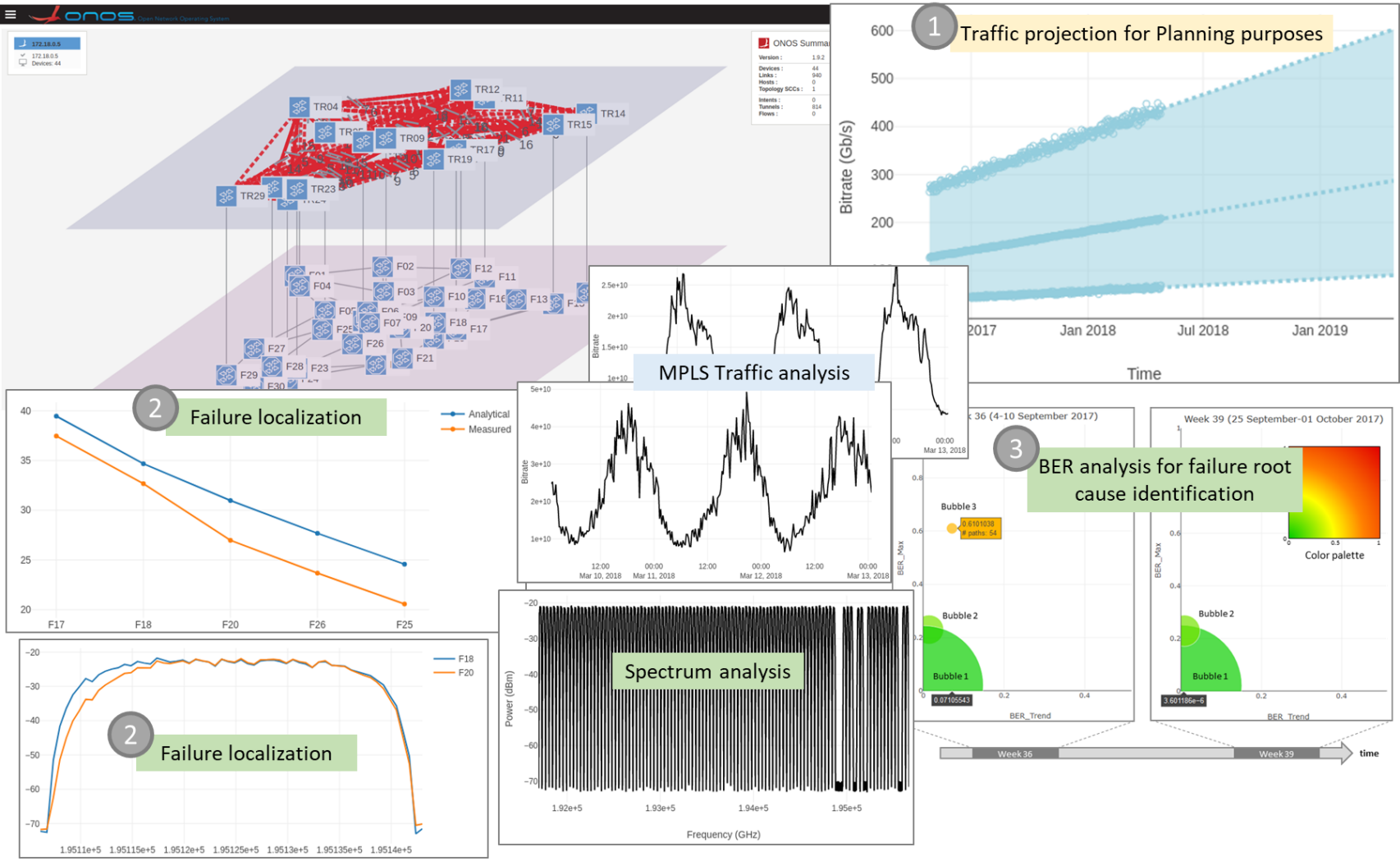
- Management of complex systems requires appropriate monitoring
- In 5G networks, KPI assurance is required, and so monitoring takes on an even more critical role
- Wide range of resources need monitoring
  - Optical layer, Packet layer (L2, 3)
  - 5G clients
  - Data Center functions
- Monitoring requirement 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)**

Conceptual COM Architecture



- **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



Machine Learning?

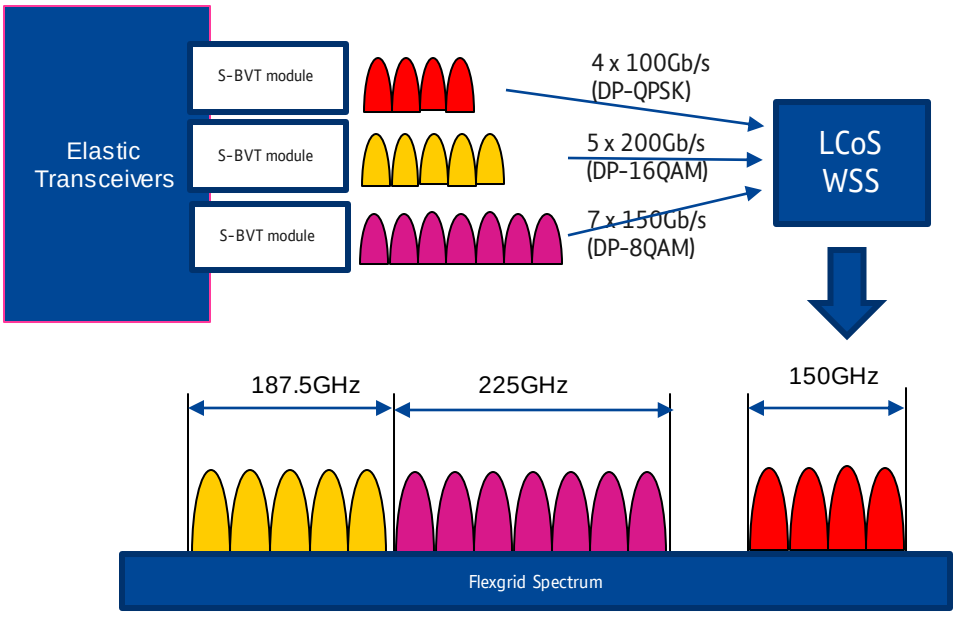
- Huge current hype around this subject
- Concept relates to huge, unpredictable data sets
- Networks have potentially hundreds of nodes, each generating a huge amount of monitoring data
  - Every optical and electrical component on every board
  - Every sub-system, transceiver, EDFA, WSS…
  - Every 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

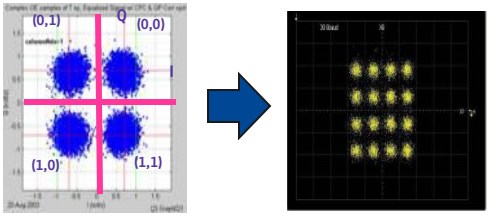
Area needs some careful analysis to see if conventional 'linear' analysis isn't sufficient

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





Future transponders capable of 100Gb – 600Gb in 50Gb increments

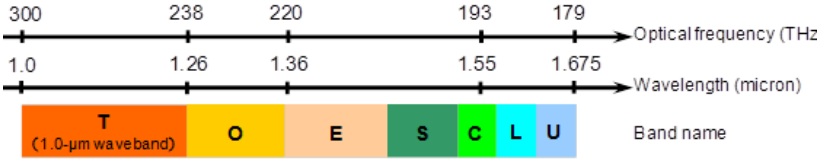
32Gbaud carrying 25Gb + FEC:
25Gb x BPSK x 2 pol = 50Gb
25Gb x QPSK x 2 pol = 100Gb
25Gb x 16QAM x 2 pol = 200Gb
25Gb x 64QAM x 2 pol = 300Gb

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

Beyond the 'C' band

Optical Fibre Spectrum



- 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

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