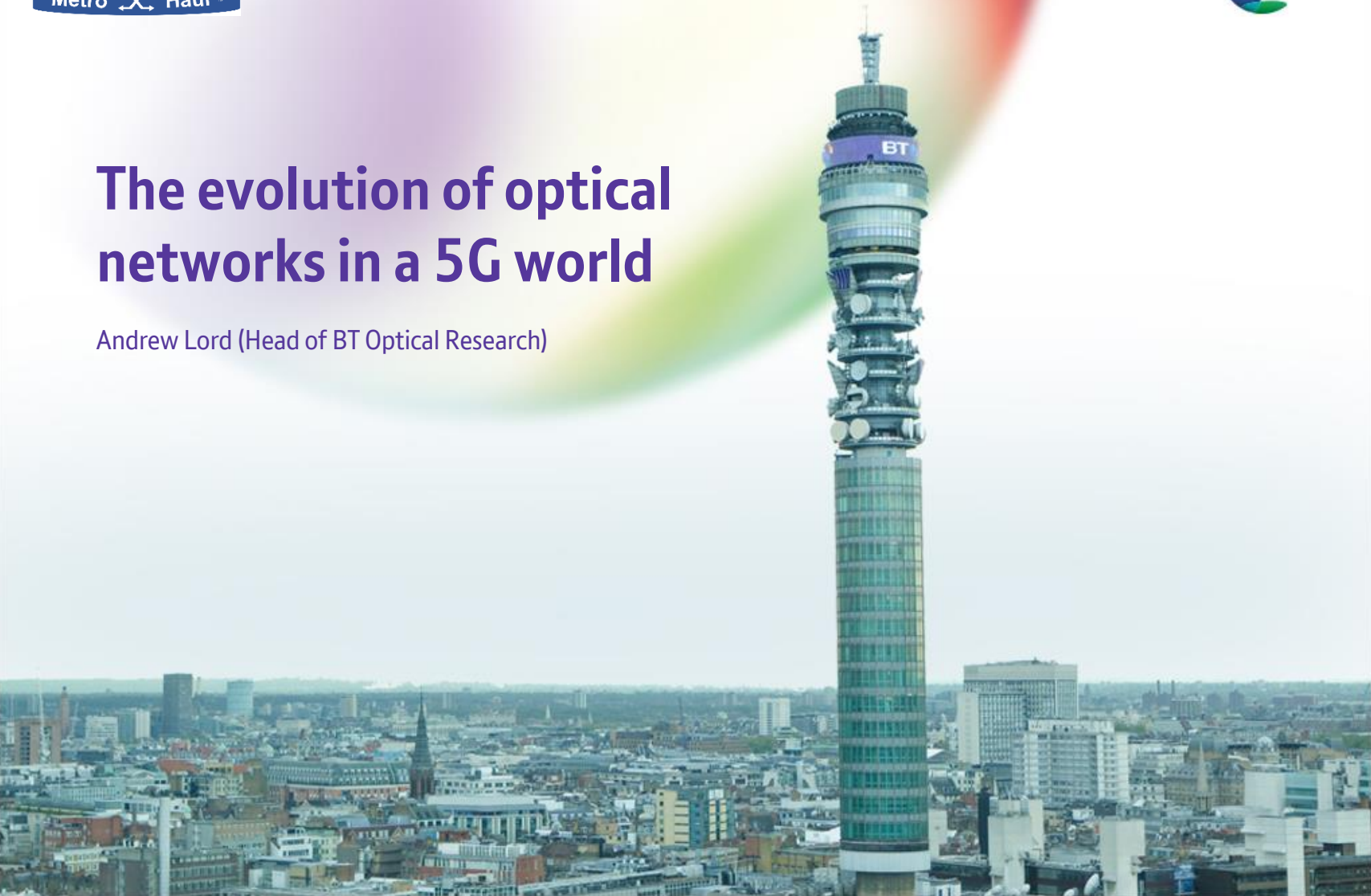
# The evolution of optical networks in a 5G world

Andrew Lord (Head of BT Optical Research)

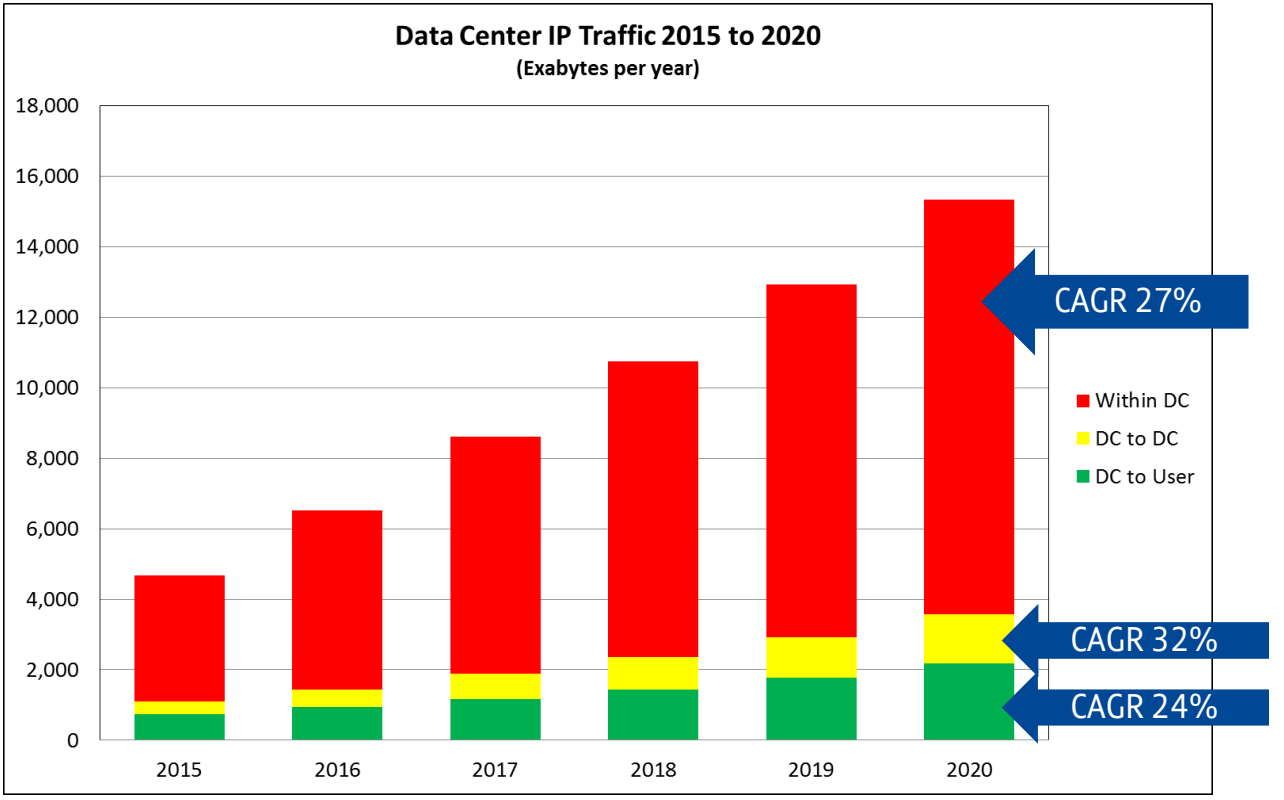


# Talk Outline

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


- Acknowledgements
  - My BT team
  - Metro-Haul EU project partners

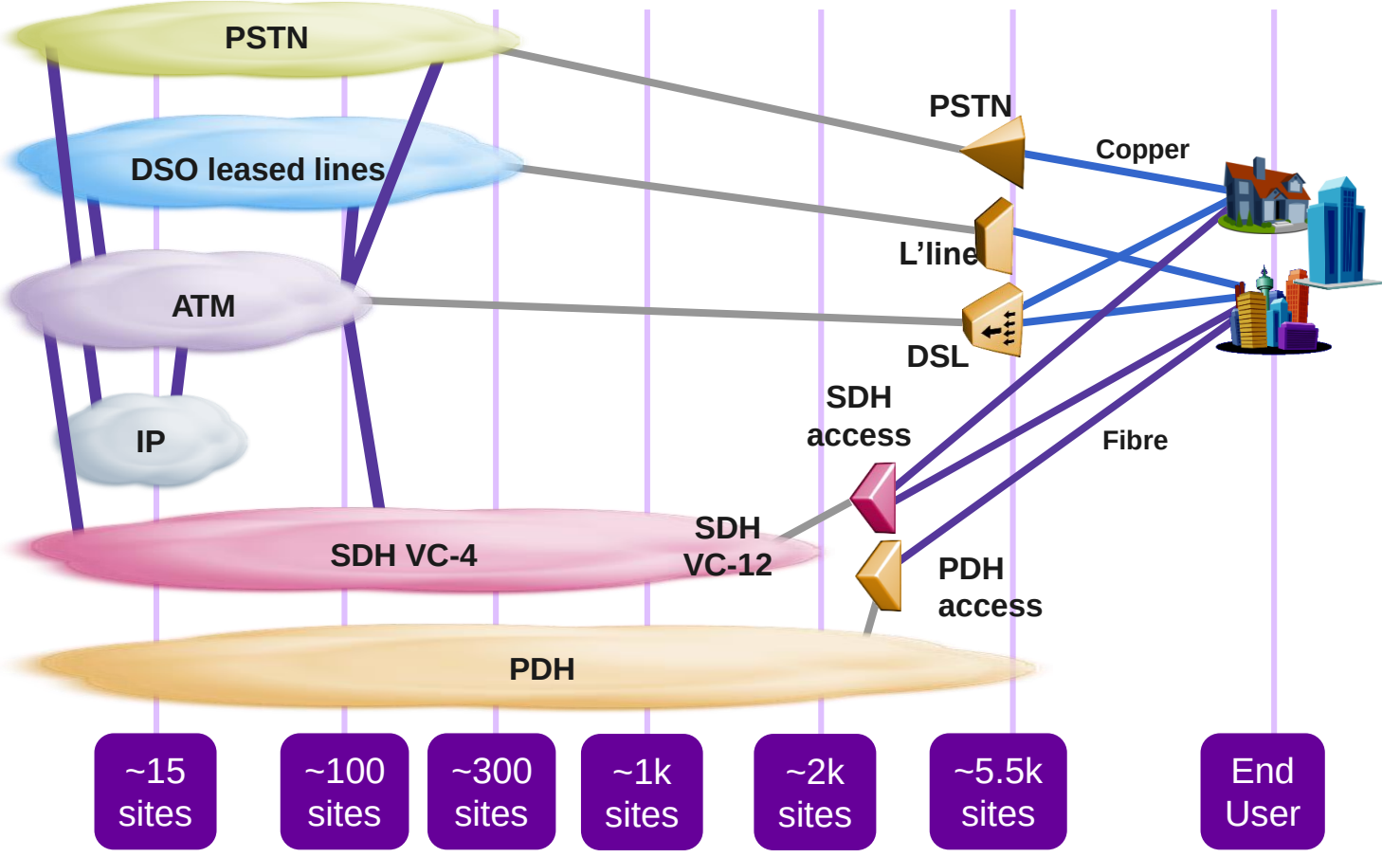
# Inter/Intra data centre traffic



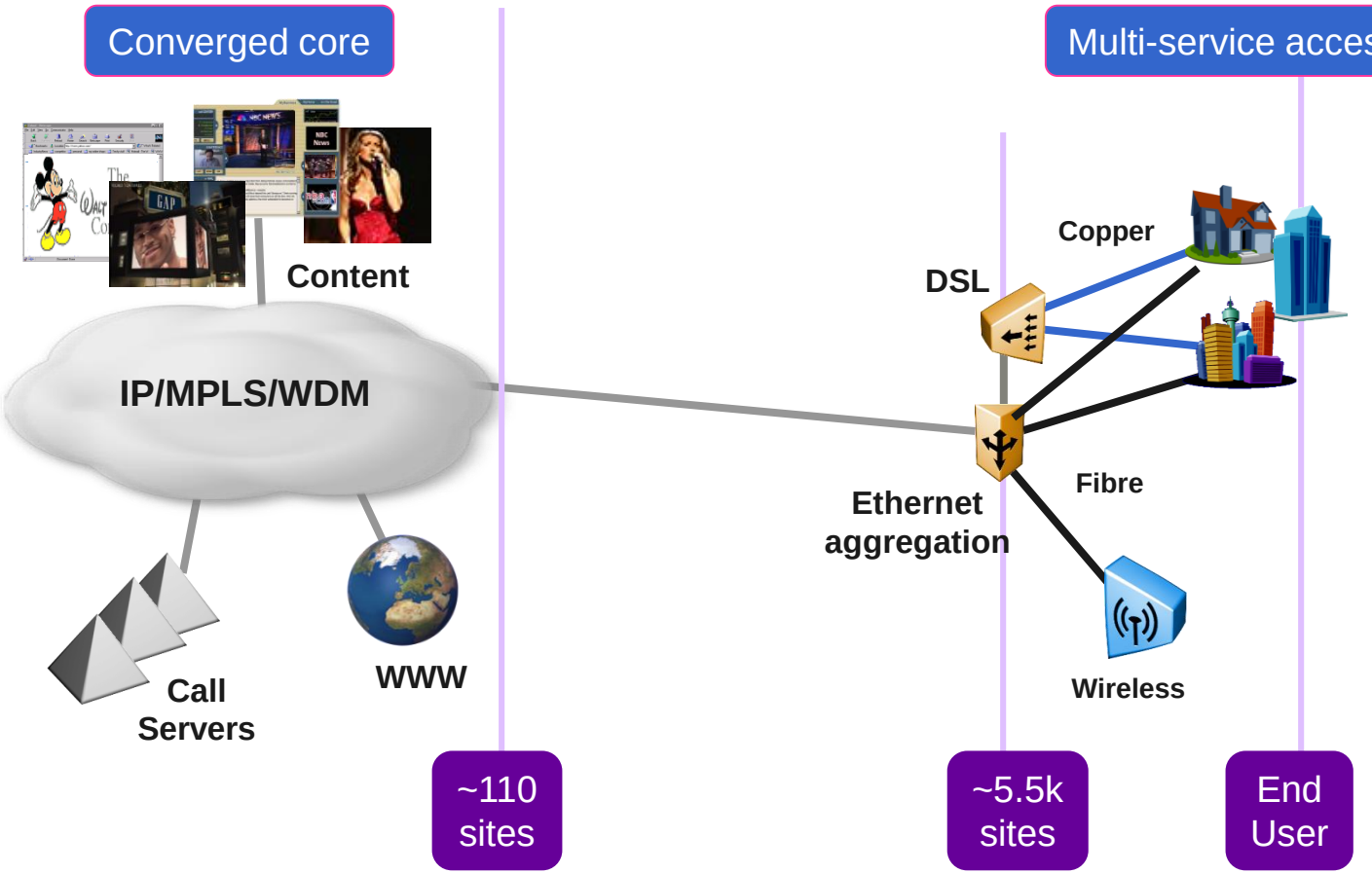

*Source: Cisco CGI, 2015-2020*

BT still reporting 40%+ traffic growth

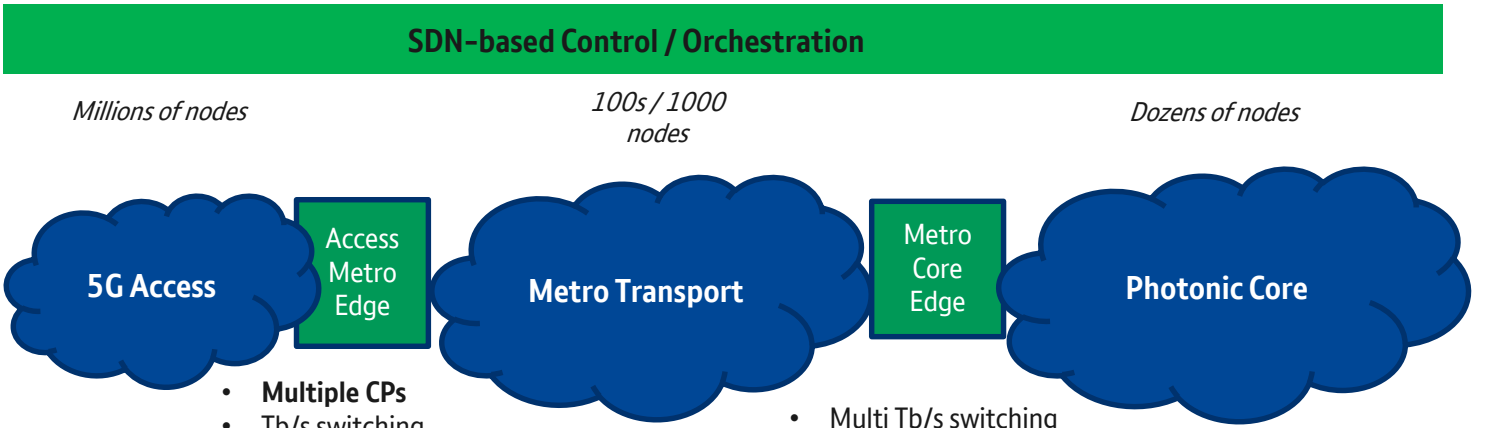
# BT Network (2004)



# BT 21CN Network (2017)



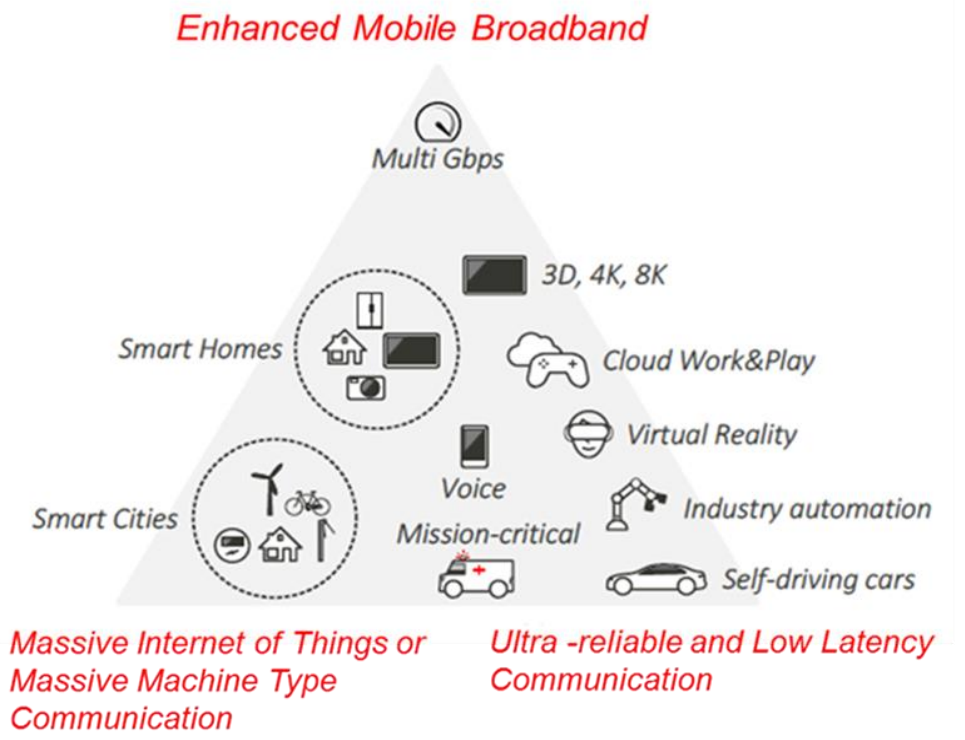
# Network bottle-necks / challenges



# 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/



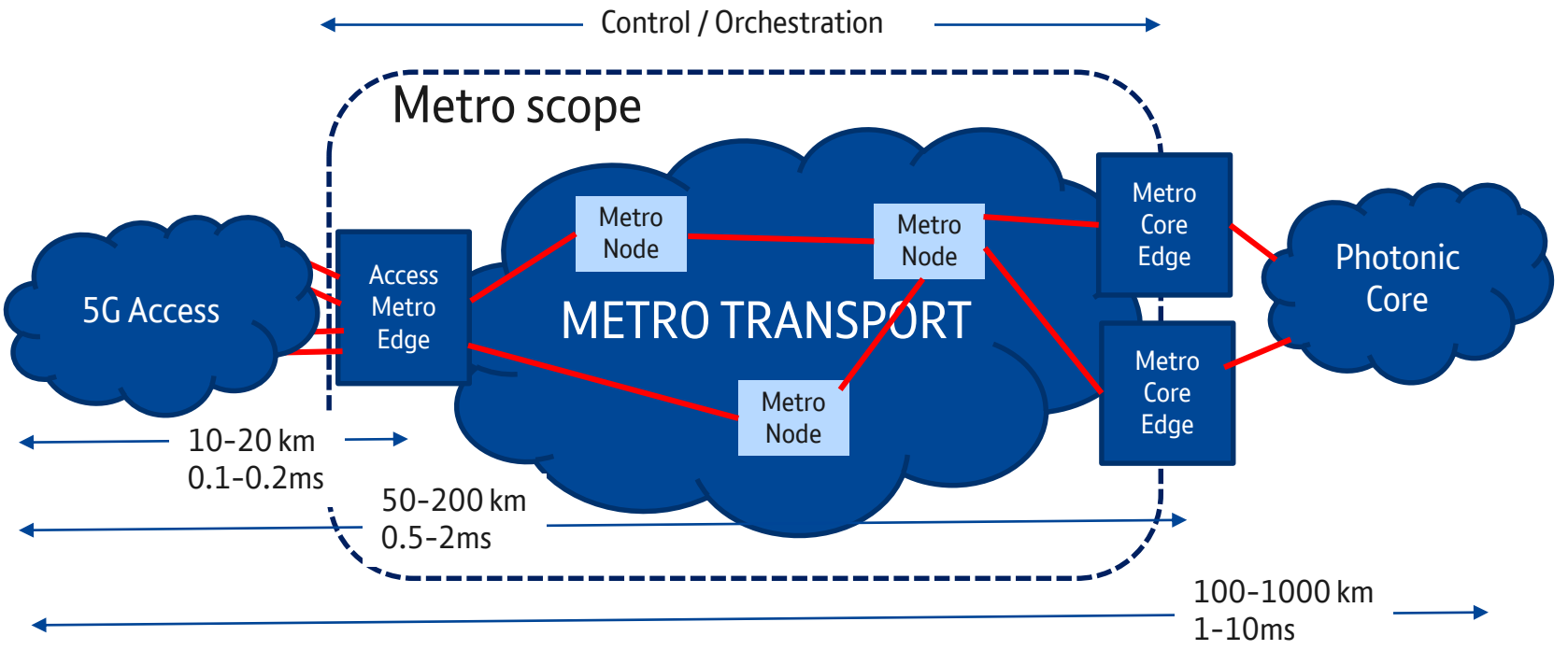
# Metro-Haul EU project

*36 months, started June 2017, BT-led (partners inc. UoB, Telefonica, Tel Ital, Nokia, Adva…) Architect and design cost-effective, energy-efficient, agile and programmable metro networks, scalable for 5G access and future requirements, encompassing the design of all-optical metro nodes (including full compute and storage capabilities), which interface effectively with both 5G access and multi-Tbit/s elastic core networks.*

- 100x more 5G capacity **supported** over the same optical fibre infrastructure
  - Note – this includes metro network bandwidth savings from service offload at the edge
- 10 times less energy consumption
- Latency-aware metro network in which latency-sensitive slices are handled at the metro edge ensuring the metro network adds no additional latency
- End to end SDN-based management framework enabling fast configuration time to set up or reconfigure services handing 5G applications. Specifically 1 minute for simple network path set-up and 10 minutes for full installation of a new VNF and 1 hour for setting up a new virtual network slice.
- Reduction in CAPEX by a factor of 10, plus a reduction in OPEX of at least 20%

Key goal is to demonstrate these 'optical' KPIs and then show how they are essential to achieve '5G' 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

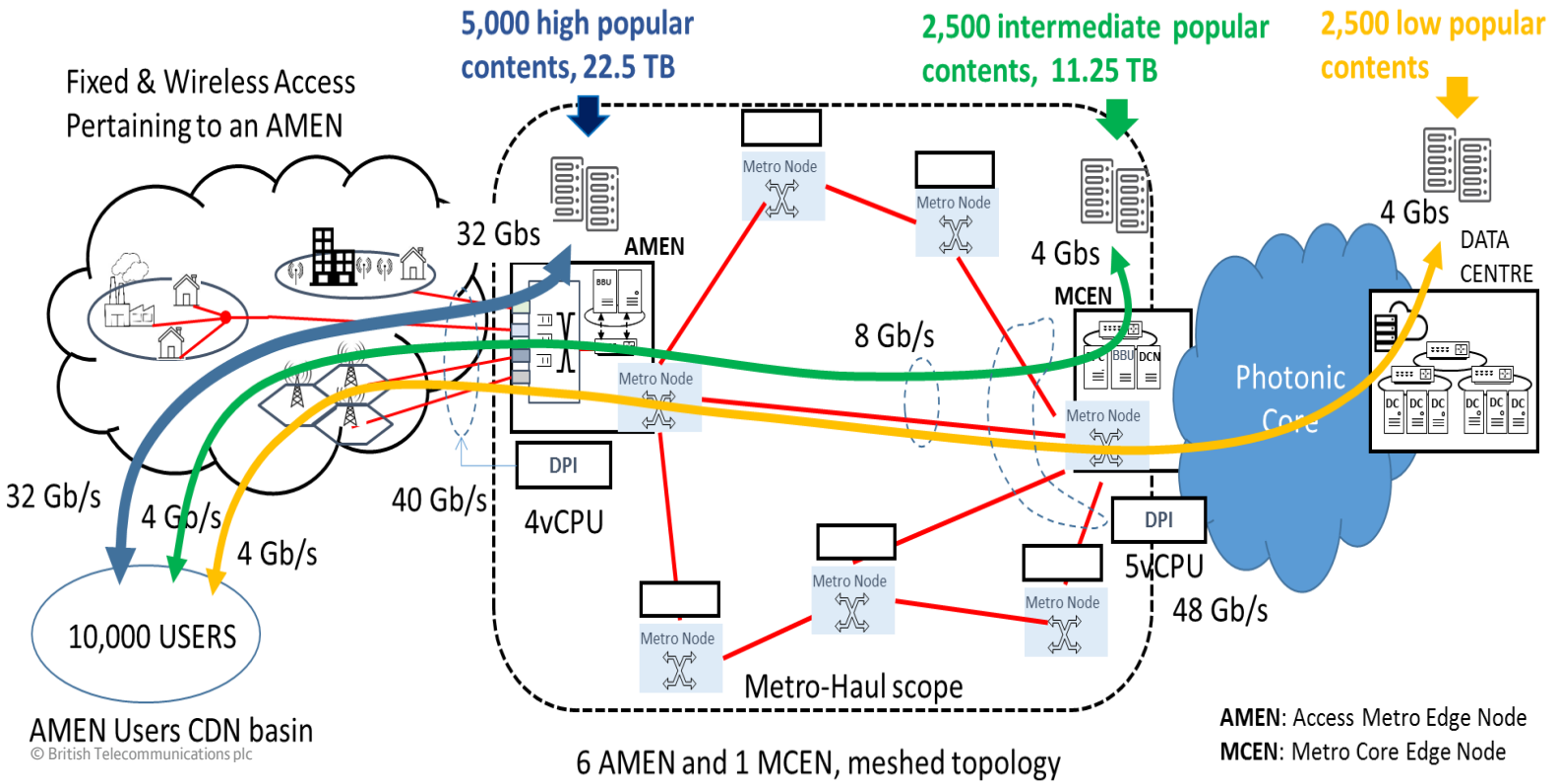
# Metro Haul Use Cases

| Vertical | Use Case | CoS |
|---|---|---|
| Media and Entertainment | Content Delivery Network | eMBB |
| | Live TV Distribution | eMBB + URLLC |
| | 6DoF Virtual Reality | eMBB + URLLC |
| | Crowdsourced Video Broadcasts | URLLC |
| Cloud Services | Service Robotics | eMBB + URLLC |
| | Enterprise Access with NG Ethernet | BB + URLLC |
| Utilities | mIoT Utility Metering | mIoT |
| Automotive | ITS and Autonomous Driving | eMBB + URLLC |
| Industry 4.0 | Smart Factories | eMBB + URLLC + mIoT |
| Public Safety and Environment | RT LL Object Tracking and Security - | URLLC |
| Operator orientated | Secure SDN Control. Video Distribution | BB + URLLC |

- 3GPP definition is assumed
- Enhanced Mobile Broad Band (eMBB)
- Massive Internet of Things (mIoT)
- Ultra Reliable Low Latency Connections (URLLC).

# CDN Use Case example

- In the vision of Metro-Haul network architecture
  - CDN caches popular video contents at AMENs and MCENs.
  - Main functions located at AMENs and MCENs to enable efficient video caching and delivery are Storage capacity, Video interfaces to deliver video contents and Traffic inspection capabilities.

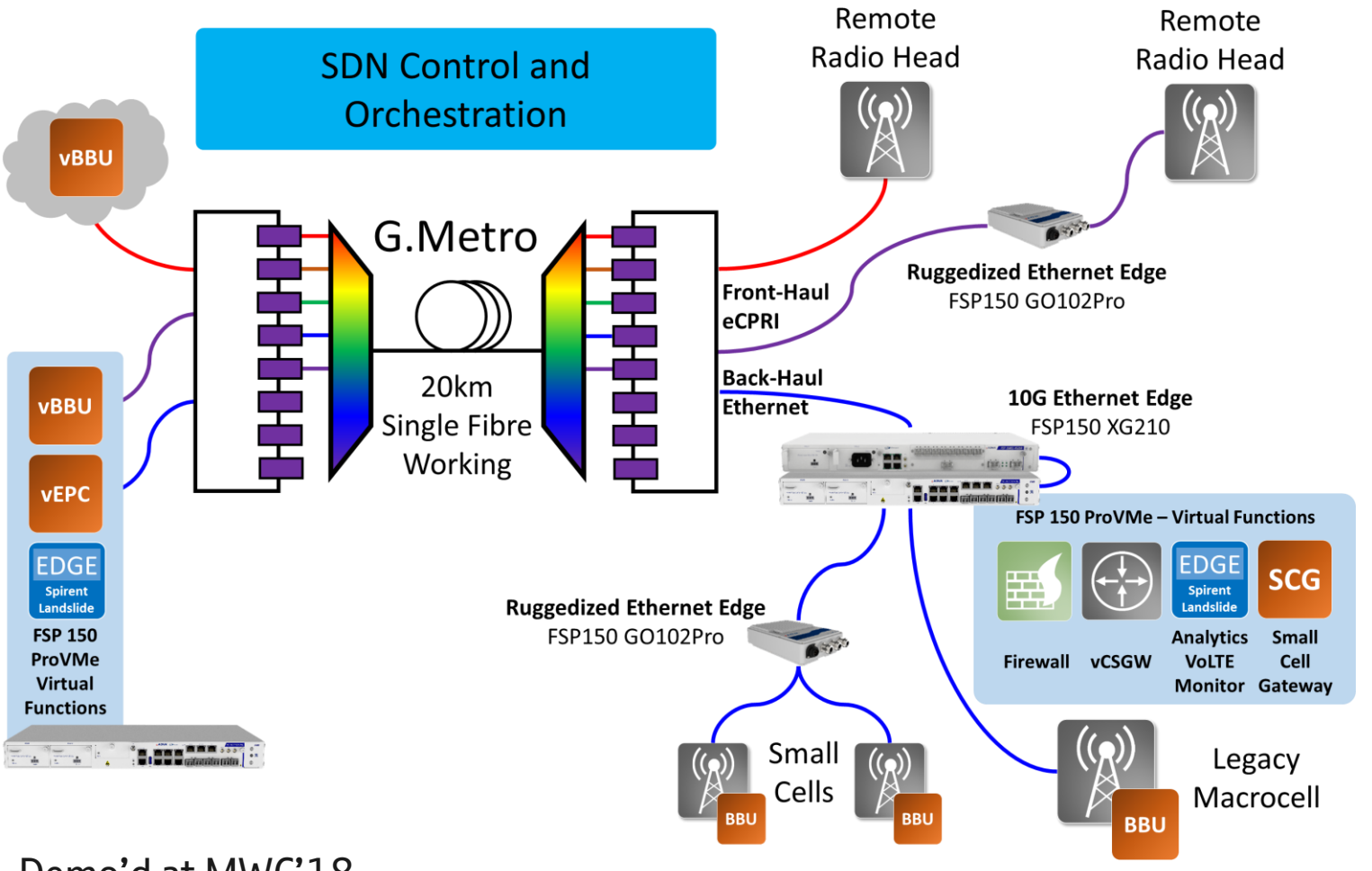


# Mapping onto Metro-Haul architecture

| Task | Throughput | | | Storage | | Computing capacity | |
|---|---|---|---|---|---|---|---|
| | AMEN | MCEN | Optical | AMEN | MCEN | AMEN | MCEN |
| UHD/4K/8K video streaming | 32Gb/s | 24Gb/s | Nx10Gb/s | 22.5TB | 11.25TB | - | - |
| Video traffic inspection, analysis and cache reconfiguration | 40Gb/s | 48Gb/s | 10Gb/s | - | - | 4 vCPU | 5 vCPU |
| Peak-hours/Flash crowd phenomenon | 32Gb/s | 24Gb/s | | - | - | - | - |

| Task | Monitoring and Data analytics | Management, Control and e2e Orchestration |
|---|---|---|
| UHD/4K/8K video streaming | | Fast recovery mechanisms (protection and restoration) |
| Video traffic inspection, analysis and cache reconfiguration | Traffic monitoring for early detection of new popular videos | Local and Global reconfiguration of virtual cache |
| Peak-hours/Flash crowd phenomenon | Traffic monitoring for fast detection of a flash crowd phenomenon | Local and global reconfiguration of virtual cache |

# Early Example – 5G Network Slicing demo




Demo'd at MWC'18

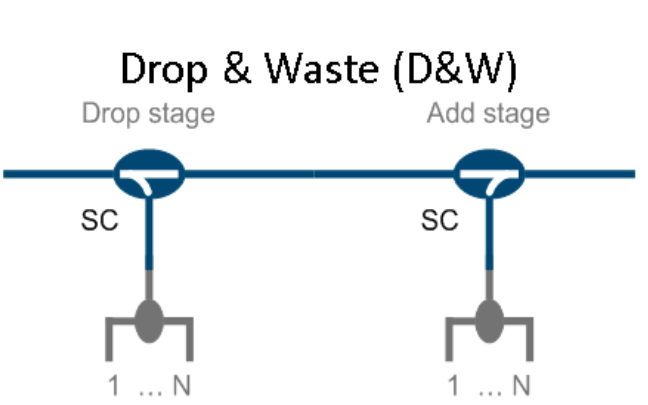
# Metro networks – ripe for innovation

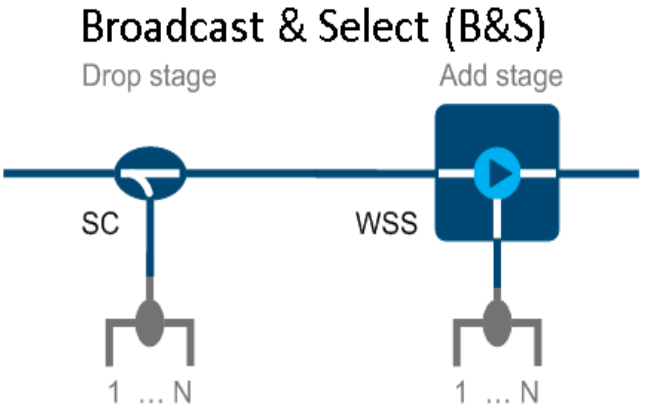
- Vast numbers of femtocells needed to provide future 5G bandwidth
- Backhaul = deep fibre
  - Potentially hundreds of 10G + circuits over shortish range (20km typical)
- Requirements will be
  - Ultra cost effective optical transport (Facebook talk about 1Gb/s = 1$ for IDC.)
  - Short reach DWDM
  -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

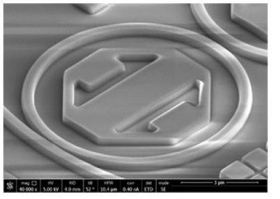
- Main requirement here is **very low cost** 10G-25G WDM with limited reach (<50km) and some switching. Low cost coherent 100G transport also needs deep research.
- Architecture
  - Meshed, chains, horse shoes…
  - Traffic flows expected to be hubbed from the Access Metro Nodes to the Metro Core node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

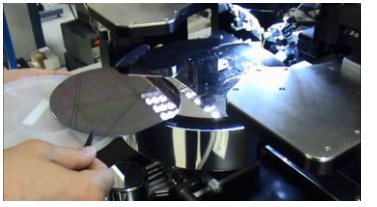


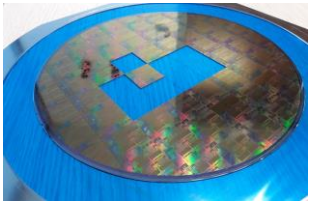



# Integrated silicon photonics

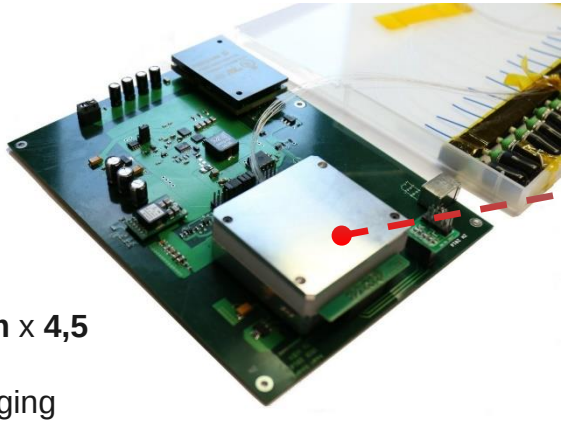
- **Ericsson technology**
- Integration onto chips will enable huge cost reduction
- Performance doesn't have to match LCoS-based WSS
- 200 mm wafer realization



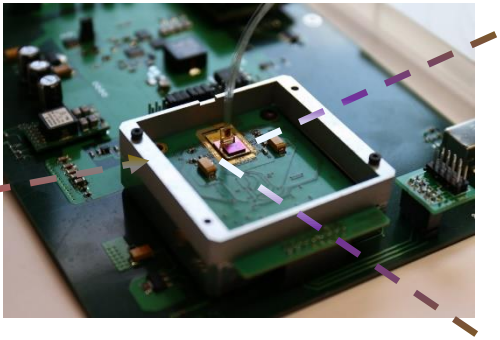


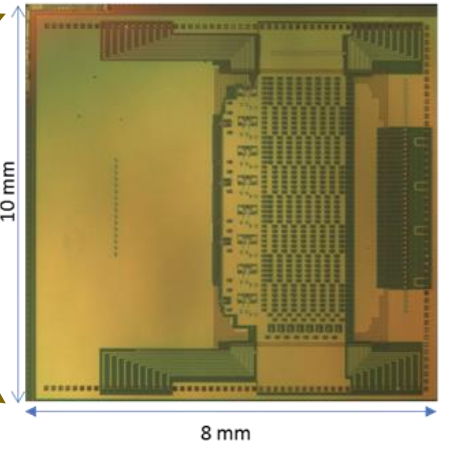


With CNIT…turned into a **whitebox** optical switch allowing fast open innovation

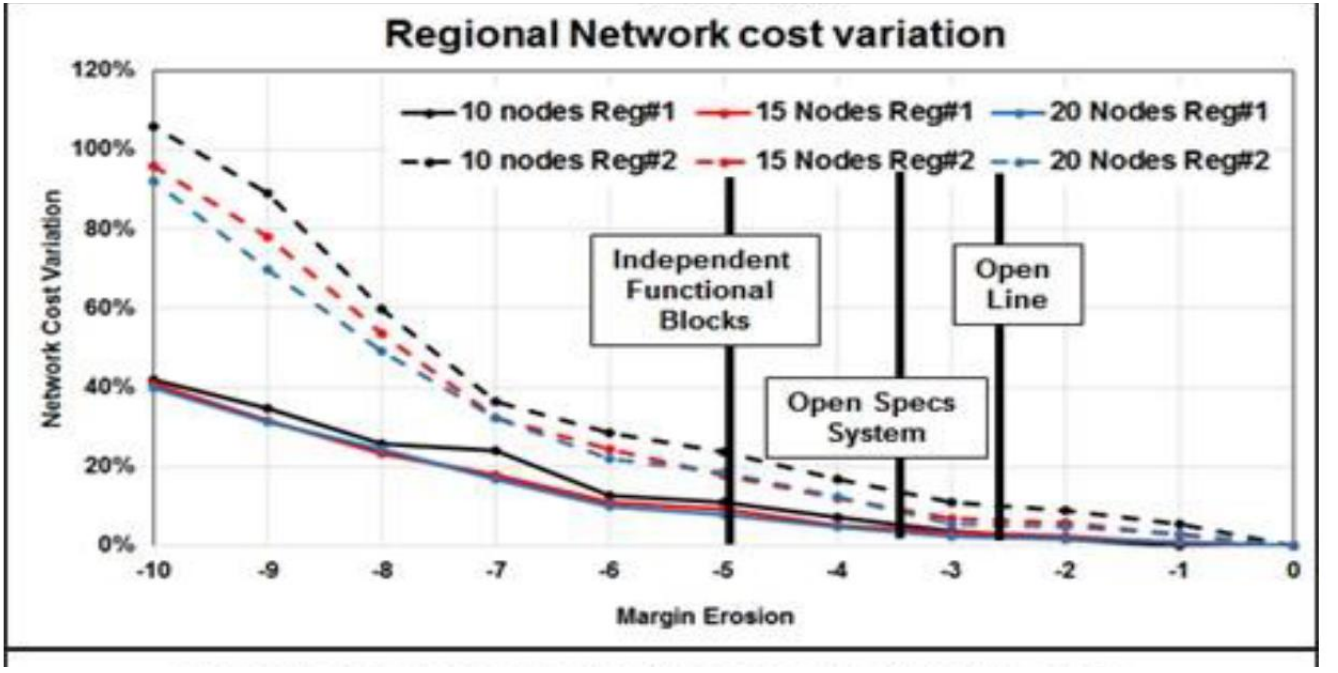


**4,5 cm** x **4,5 cm**
packaging





# Disaggregation penalty not significant in metro

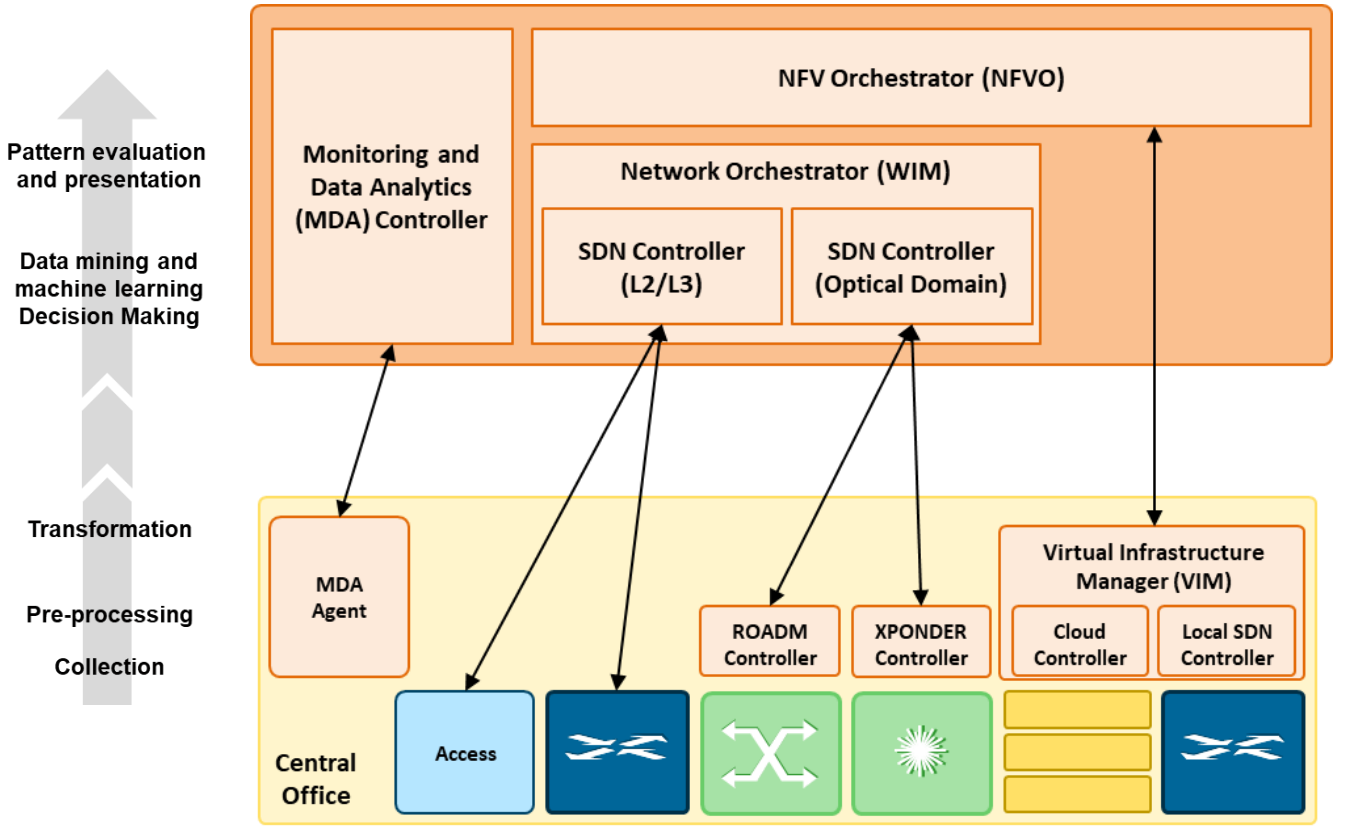



M1E.2 OFC 'Margin requirement of disaggregating the DWDM transport system and its consequence on application economics' Ciena

# Telemetry and monitoring

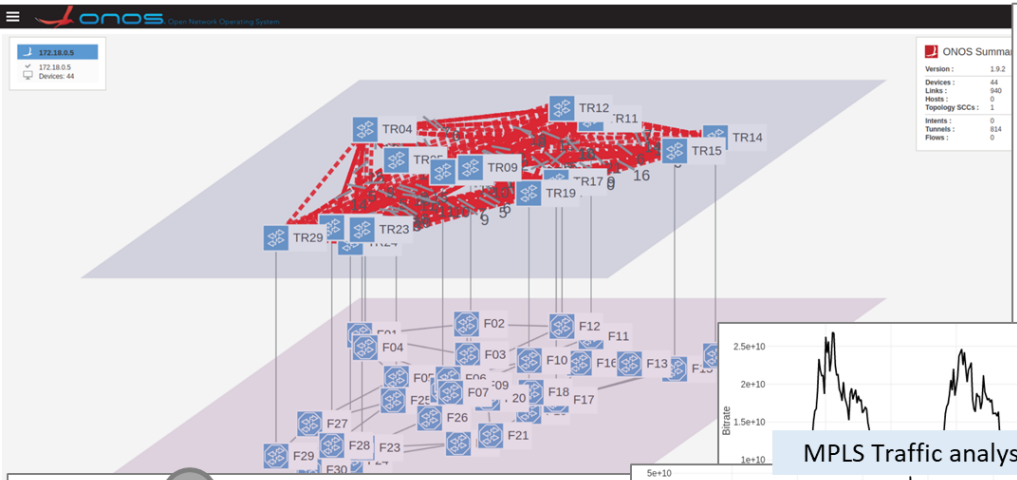
- Management of complex systems requires appropriate monitoring
- In 5G networks, KPI assurance is required, and so monitoring takes on an even more critical role
- Wide range of resources need monitoring
  - Optical layer, Packet layer (L2, 3)
  - 5G clients
  - Data Center functions
- Monitoring requirement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

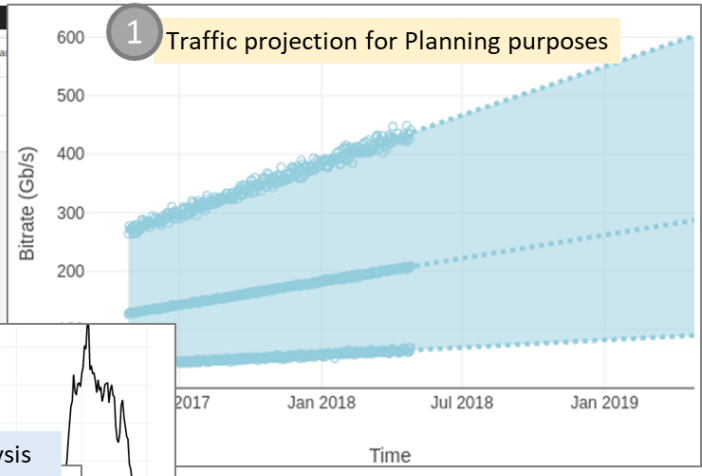
# Conceptual COM Architecture



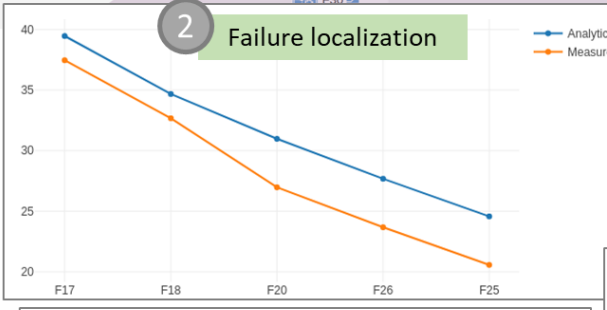

- MDA agent collects monitoring data from all the different sources, process them locally and conveys data to the MDA controller.
- COM = Control, Orchestration and Management

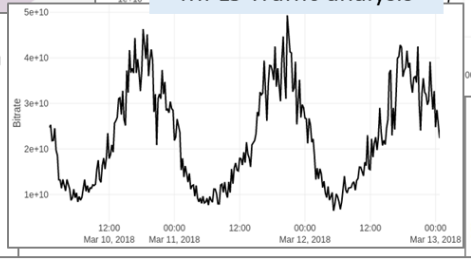
# Typical results

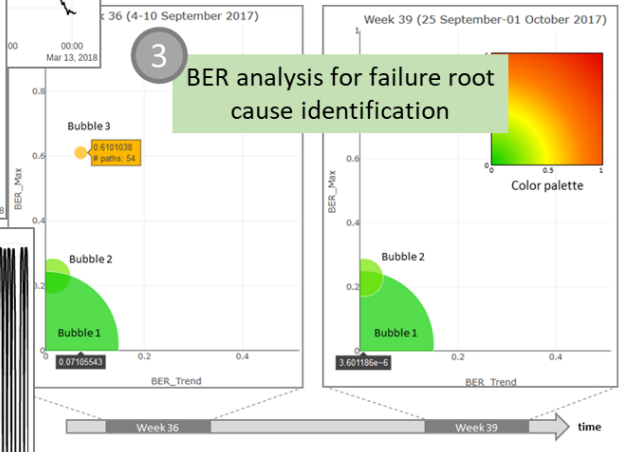


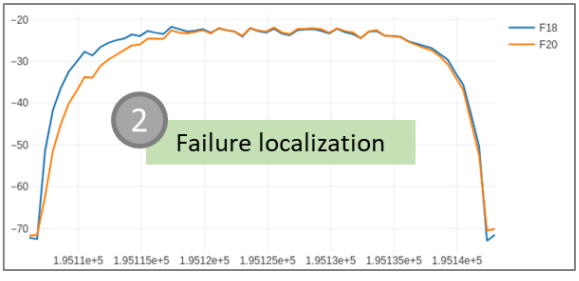



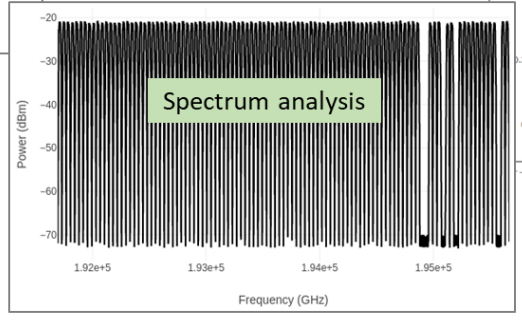




# Machine Learning?

- 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

# 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 networks
  - Intelligence to handle KPIs
  - Dynamic capability
  - Extended monitoring
  - Deep fibre – cost effective transport
- Whitebox could definitely have a role in the metro
- Machine Learning – still not certain

- One thing IS for certain – plenty of optical network research still left to do!

# THANK YOU