# Use cases for SDN and Network virtualisation

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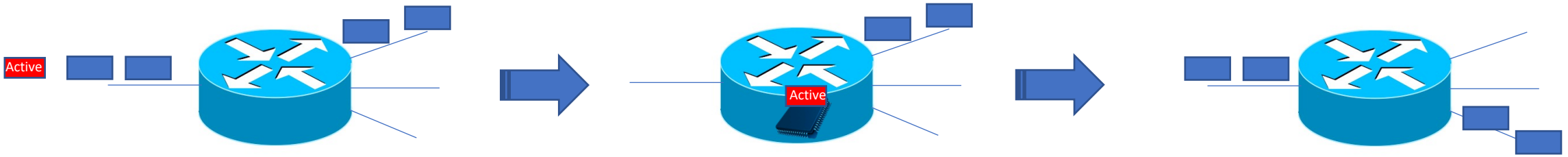
# Lecture content

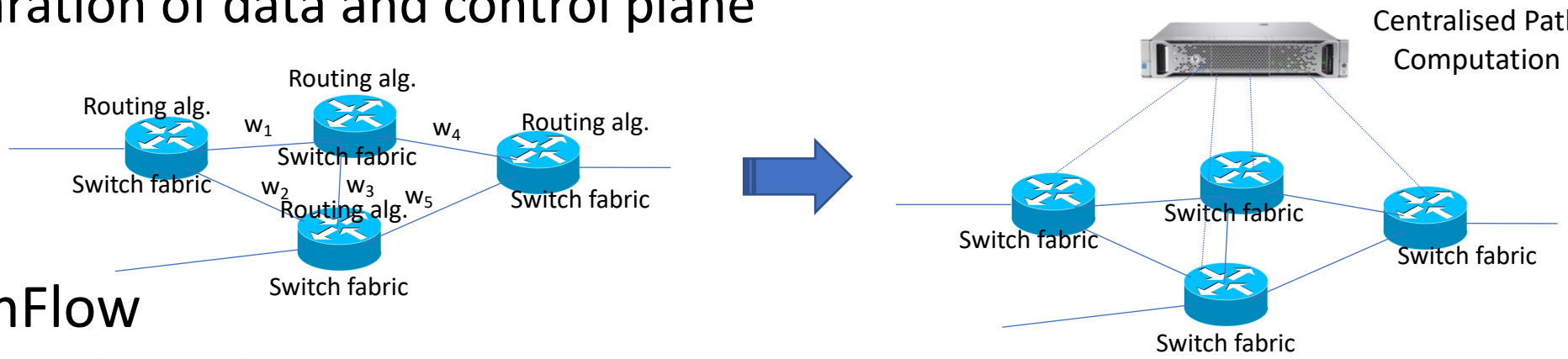
- Next step in history of programmable networks: Network virtualisation
- SDN, NFV, cloud-CO application to future networks
  - Future wireless/optical/cloud use cases
  - Joint fixed/mobile orchestration enabled by virtualisation
- Optical layer disaggregation

# History of programmable networks:

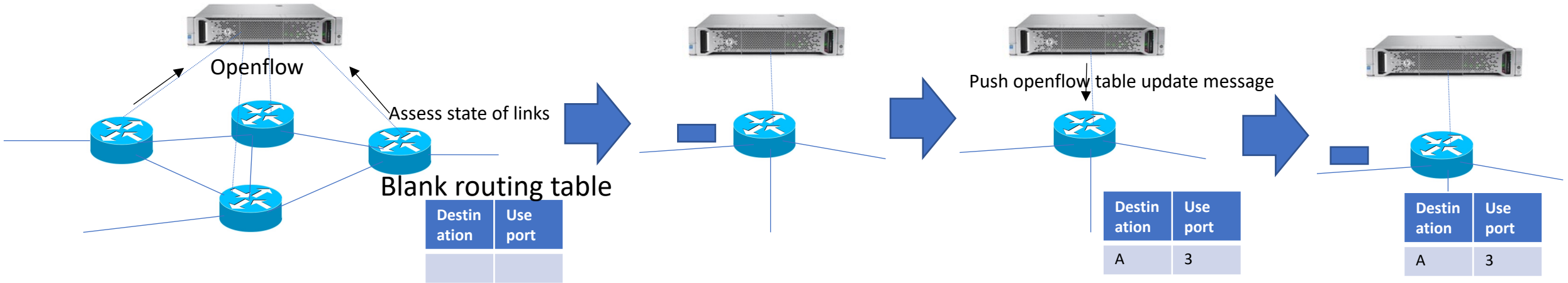
- Active Networks




- Separation of data and control plane

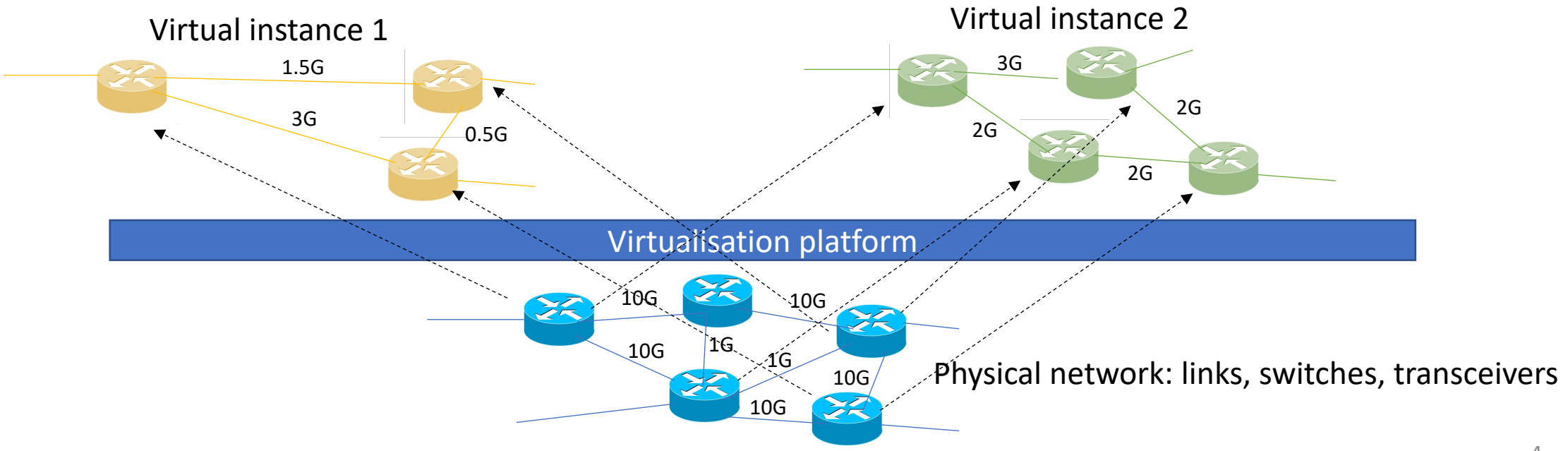



- OpenFlow



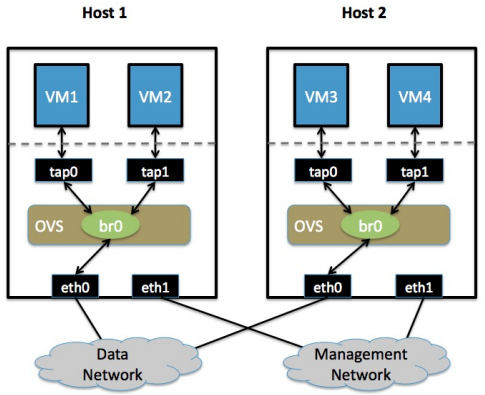
# Next in history of programmable networks: Virtualisation

- Virtualisation is the illusion of obtaining control of a physical entity or resource.
- In networks, virtualisation means abstracting the functionality of a piece of hardware infrastructure into software.
  - provides the ability to instantiate an entire network overlay in software
  - relies on a virtualisation platform to associate the virtual network with real hardware links

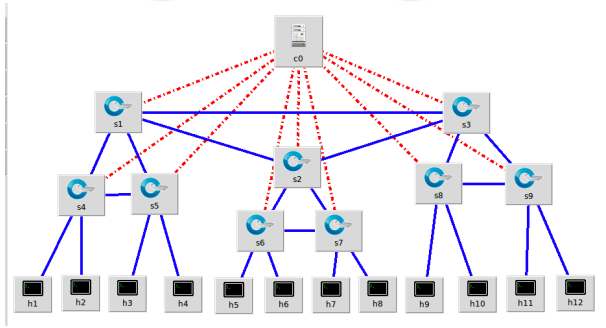


# Some examples of network virtualisation

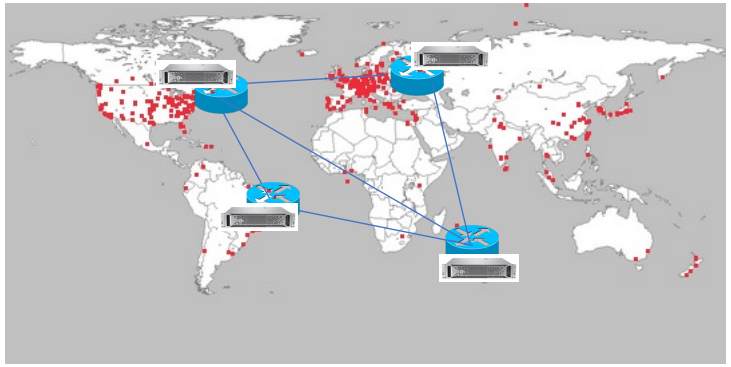
- From local scale:
  - OpenvSwitch (OvS): a virtual packet switch operating in Linux environment




  - Mininet: emulation platform comprising of virtual switches, hosts, and links
    - Can be used to test SDN controllers behaviour



- To global scale:
  - Planetlab applies the idea of virtualisation using nodes and links spread out across the globe

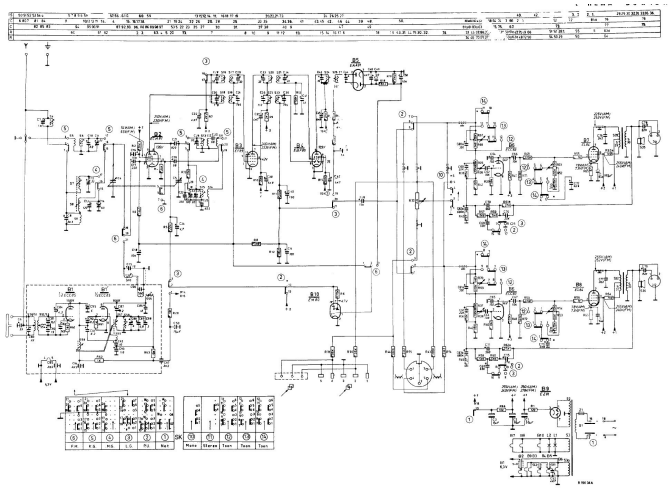


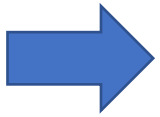
- Today many others exist, including wireless and optical domains

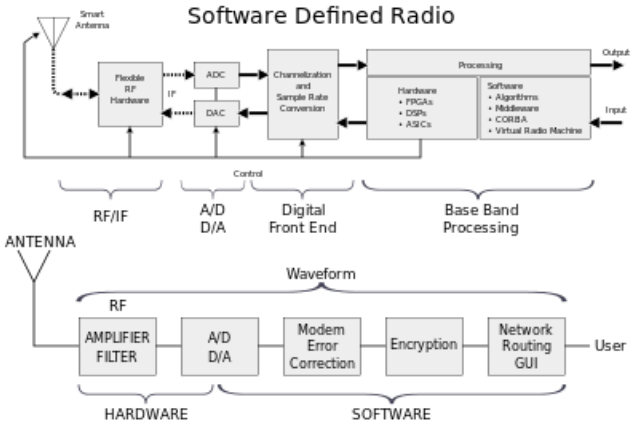
# From virtualisation to network function virtualization (NFV)

- NFV moves functions from dedicated hardware to software running on commodity servers

Software Defined Radio is an early example: GNU radio



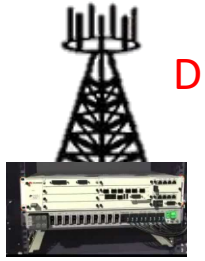





- Advantages:
  - flexibility of adapting transmission format to environment and application
  - coordination with other radios (either distributed or centralized)
  - Integration with other software components…

# SDR in today's telcos

- SDR today stronger than ever:
  - OpenRAN based on SDR ➔ srsRAN, Amarisoft, Flexran, OpenAirInterface, or the implementations based on GNU radio,…
  - Enabling flexibility in resource allocation, statistical multiplexing,…
  - Also, integration with other elements for convergence with other technologies, joint orchestration,…

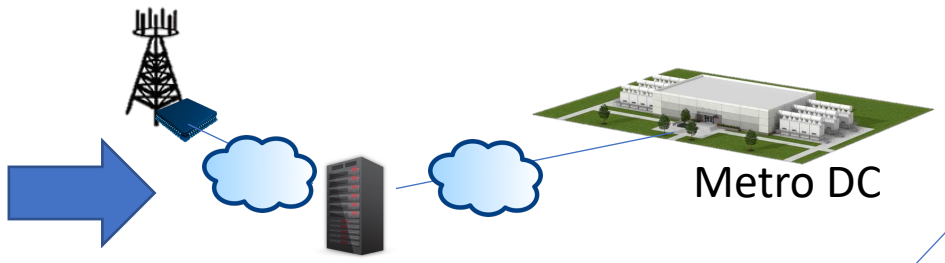


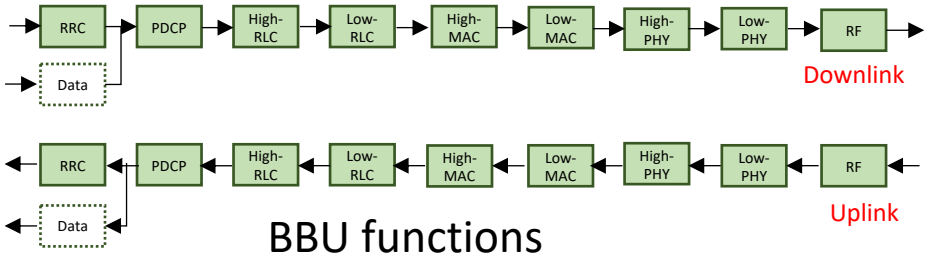
Distributed RAN

Hardware baseband unit (BBU)

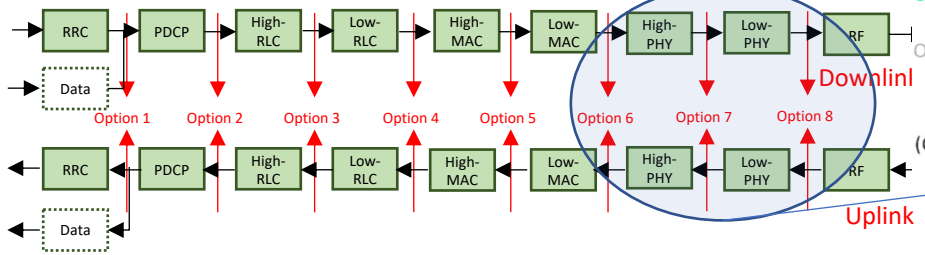
Remote Radio Unit (RRU)

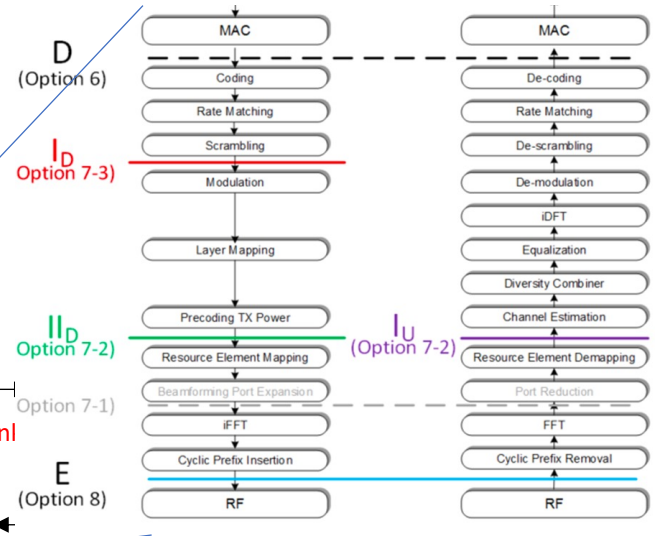
Centralised RAN



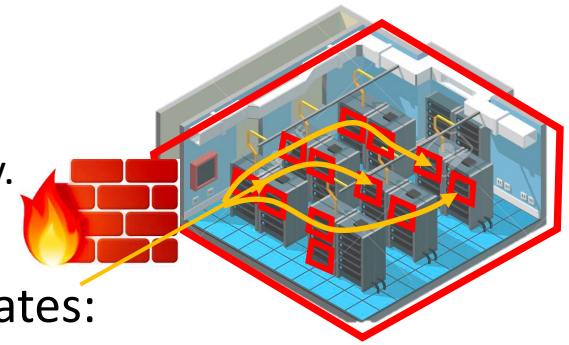

BBU functions




Source: Next Generation Mobile Network (NGMN) alliance. NGMN Overview on 5G RAN Functional Decomposition. Feb., 2018

# Network functions

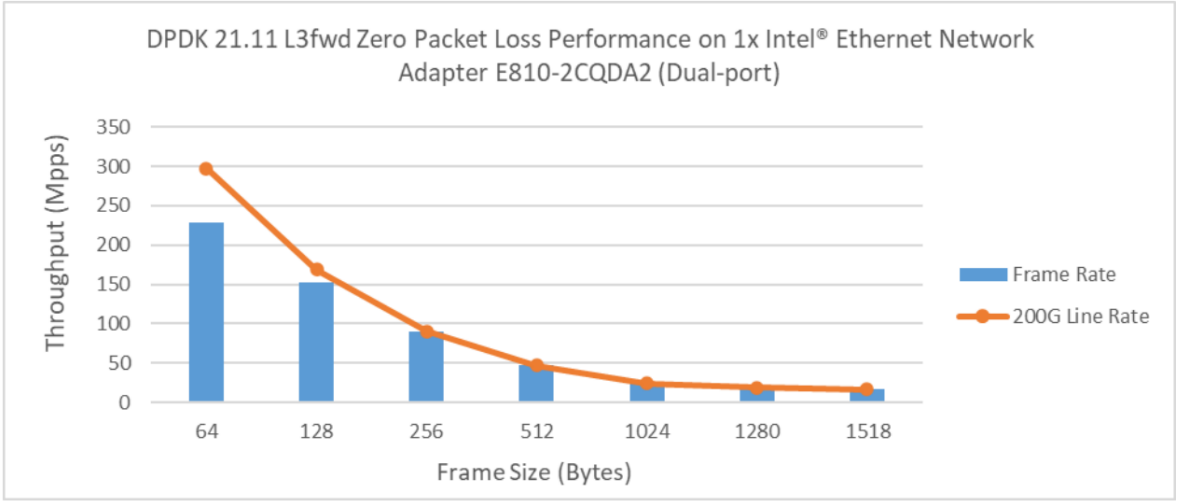


- The NFV concept applies to several other telco functions:
  - Firewall: in VMware NSX it's integrated in each VM, for better customization, flexibility, security.
- In general all functions that require packet processing and switching are good candidates:
  - Service Gateway (vSG): e.g., route the request to the specific service provider
  - Broadband Network Gateway (vBNG o vBRAS): aggregates incoming access connections, enforces QoS, provides layer 3 (IP) connectivity
  - Customer Premises Equipment (vCPE): operates routers, firewalls, VPNs, NAT
- Highly improved packet processing/switching performance (e.g., Data Plane Development Kit – DPDK)

Packet switching performance on Xeon processor

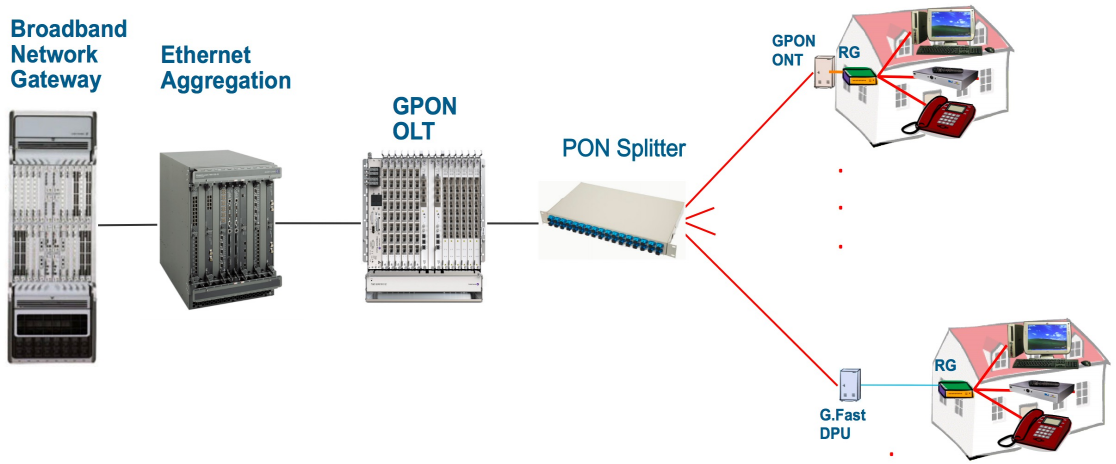
Source: Intel Ethernet's Performance Report with DPDK 21.11 Dec 2021

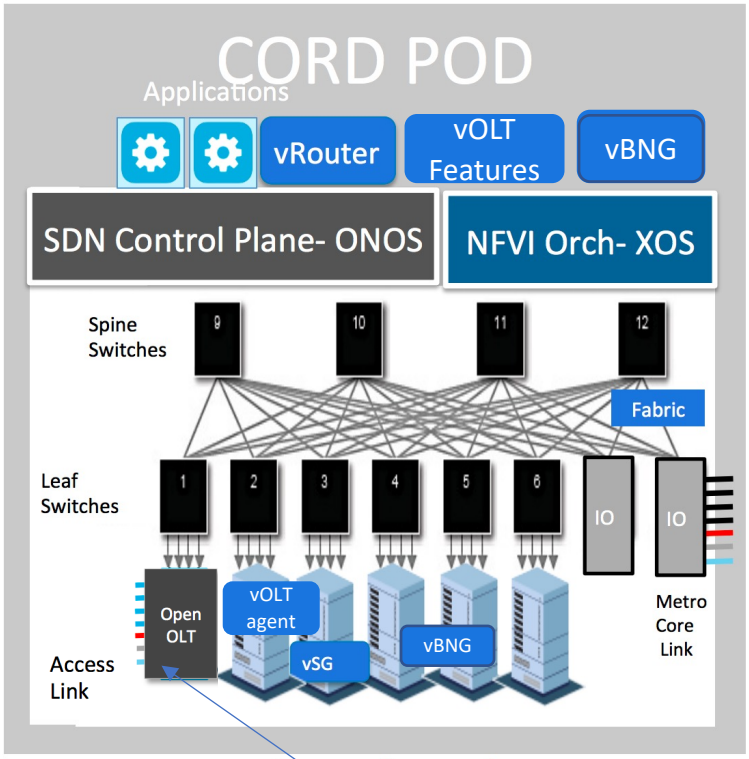
| Frame Size (Bytes) | Line Rate[2x100G] (Mpps) | Frame Rate (Mpps) | % Line Rate |
|---|---|---|---|
| 64 | 297.62 | 228.56 | 76.80 |
| 128 | 168.92 | 152.29 | 90.15 |
| 256 | 90.58 | 90.58 | 100.00 |
| 512 | 46.99 | 46.99 | 100.00 |
| 1024 | 23.95 | 23.95 | 100.00 |
| 1280 | 19.23 | 19.23 | 100.00 |
| 1518 | 16.26 | 16.26 | 100.00 |



# Central Office Virtualisation

- Getting SDN and NFV into the central office:

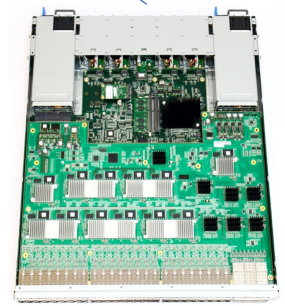


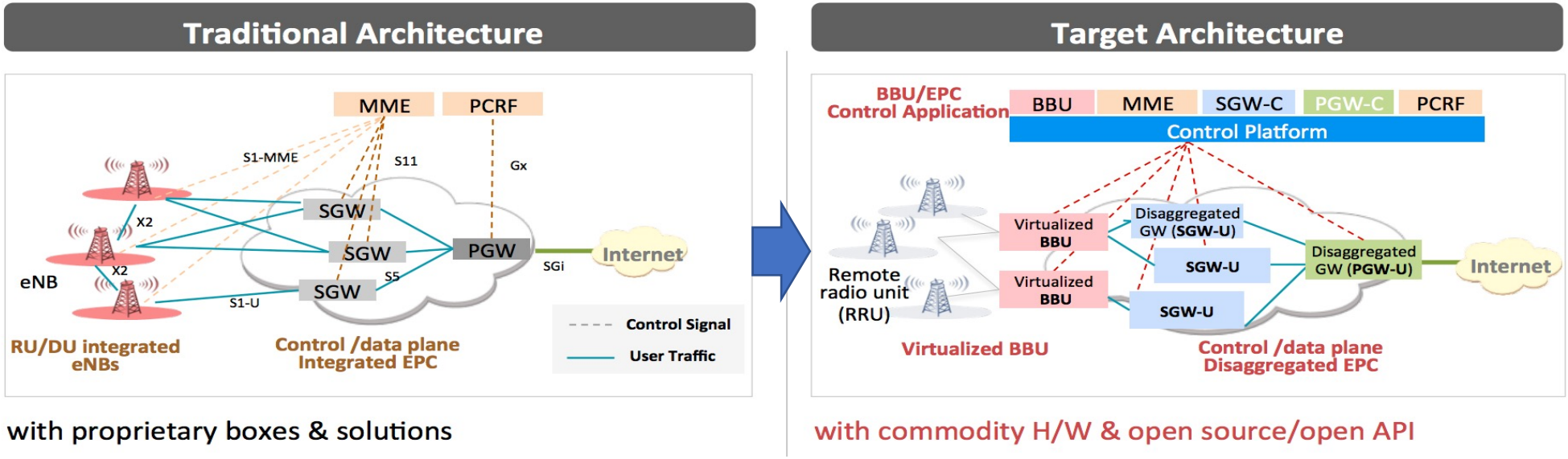

- Driven by development, not by standard
- Being trialed by several operators world-wide
  - E.g., AT&T recently carried out trials on XGS-PON using OLT white boxes

Commodity Hardware

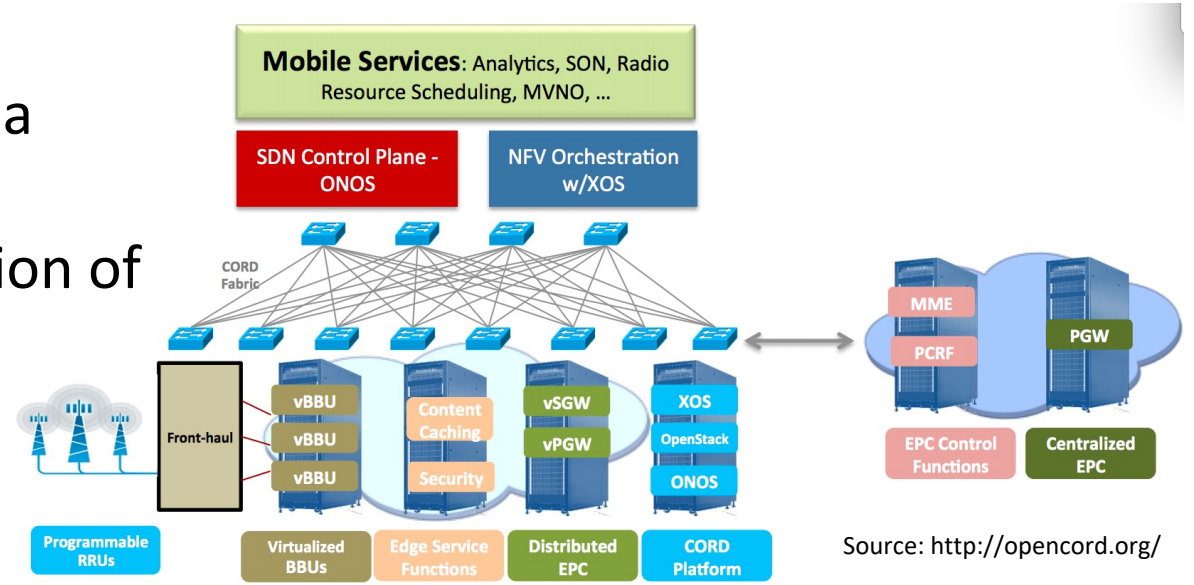
Source: http://opencord.org/



# Multi-service example: Mobile-CORD



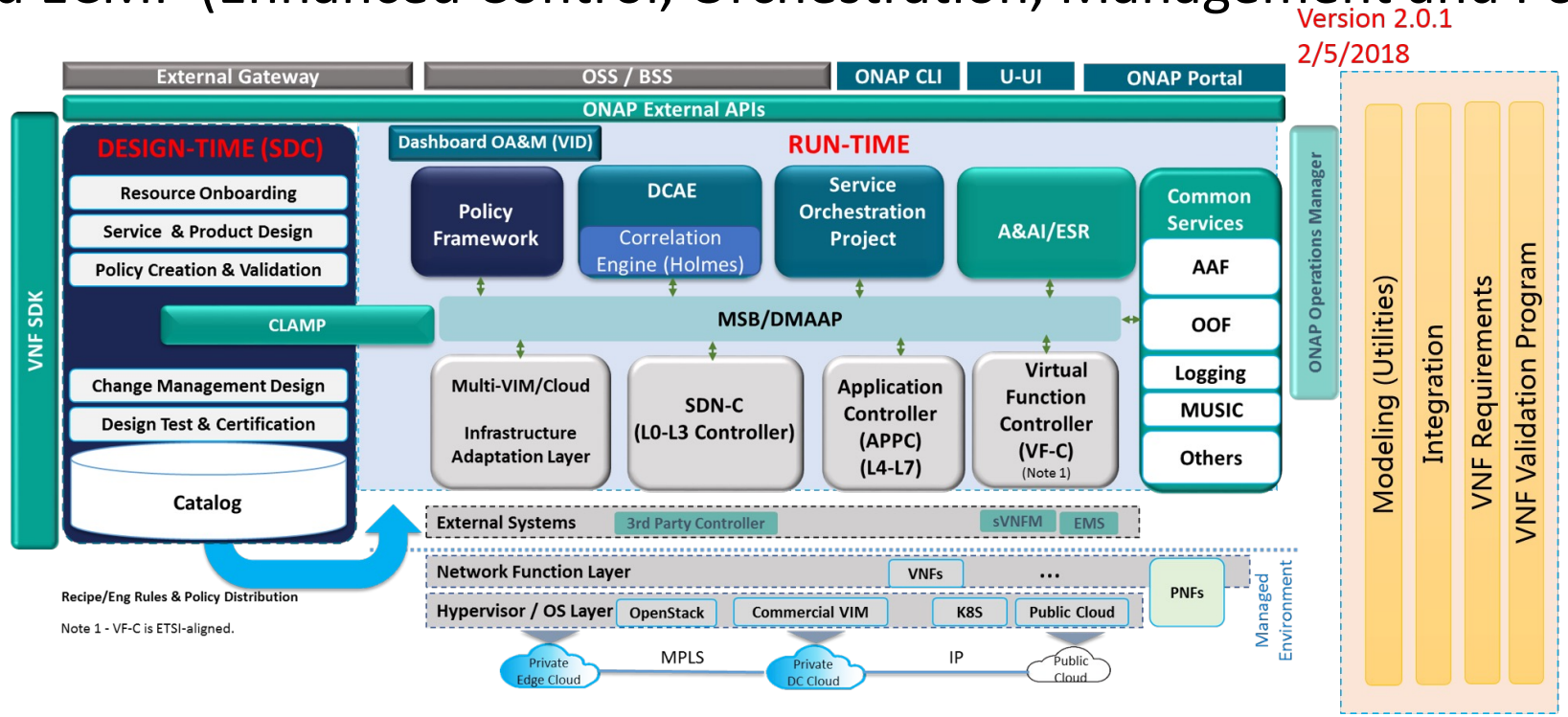

- Software and programmability a main enabler of convergence
- E.g., enables tighter orchestration of resources (see fixed/mobile)




Source: http://opencord.org/

# But there's more to NFV than CORD…

ONAP: The Open Network automation Platform: formed by the fusion of OPEN-O (Open Orchestrator) and ECMP (Enhanced Control, Orchestration, Management and Policy)

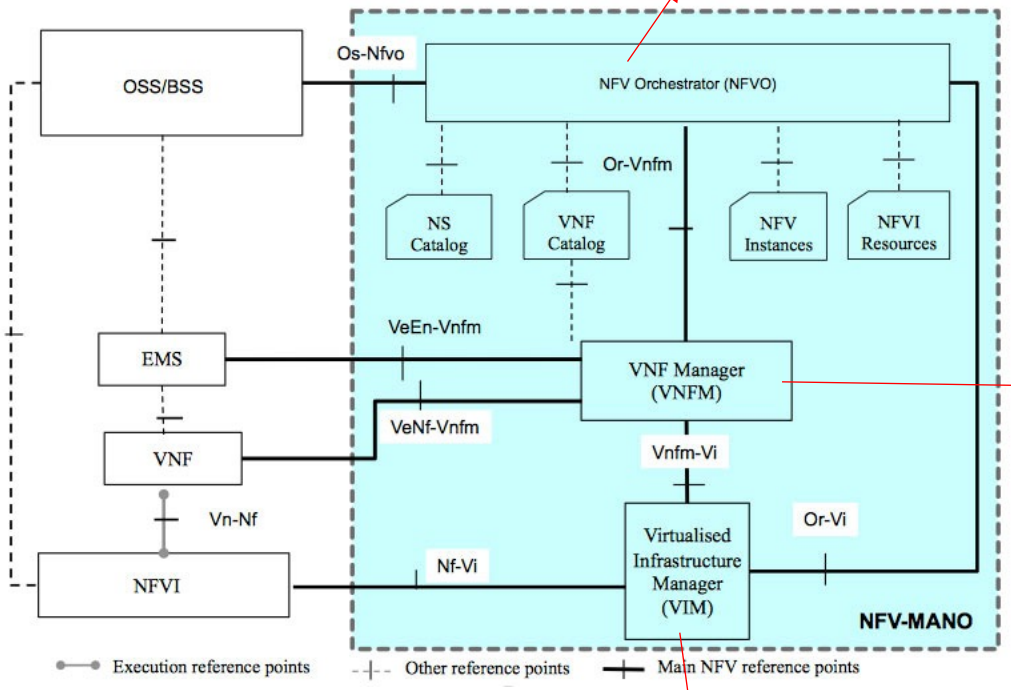



- Focuses on aspects such as data analytics, orchestration, policy, virtual management and network control
  - Ability to specify orchestration and control frameworks to automatically instantiate services
  - Offers analytic framework for monitoring performance associated to the service created

# … much more

- The Open Source MANO (OSM)
  - implementation of the NFV "Management & Orchestration" reference architecture (ETSI)

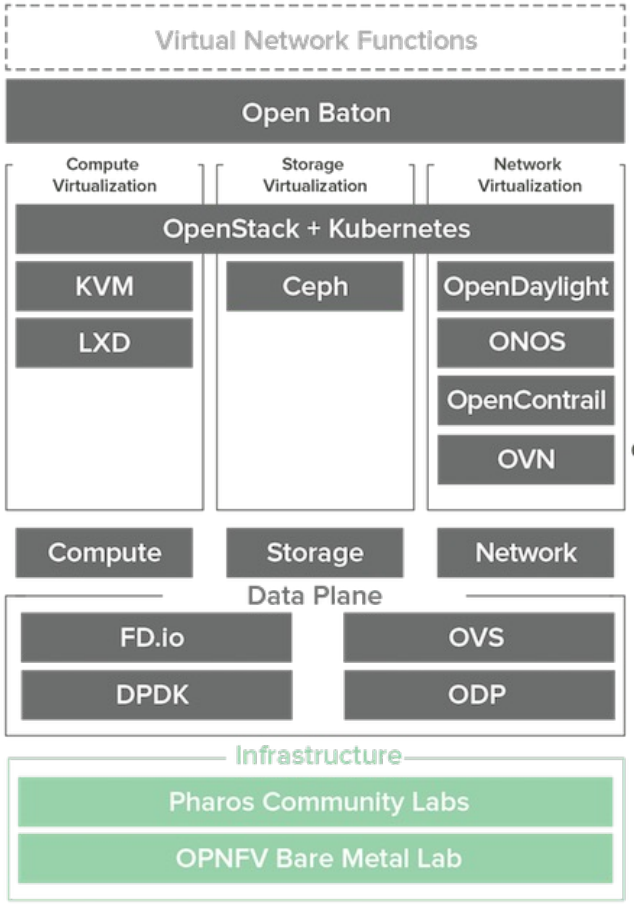
Selection, chaining of VNFs and monitoring to satisfy requested service




VNF lifecycle: instantiate, scale, terminate VNFs

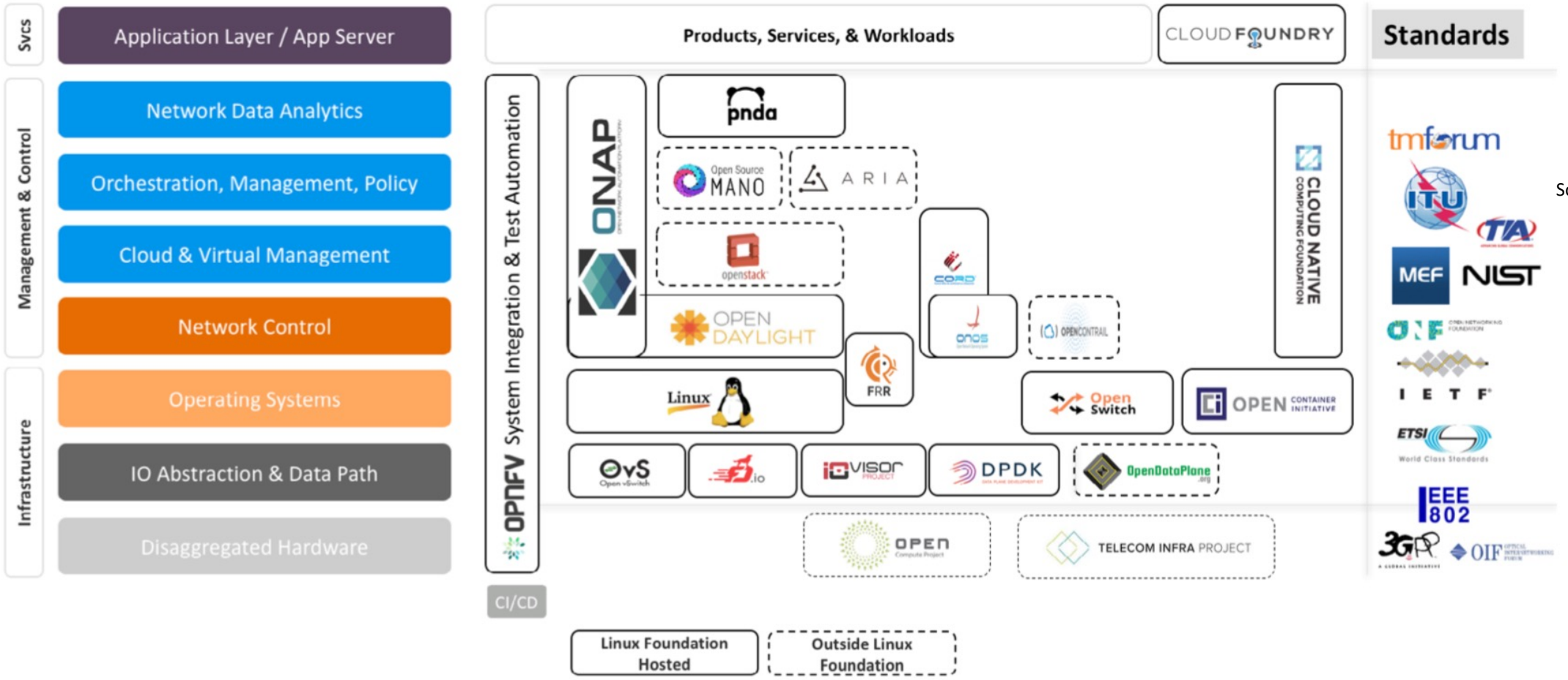
Keeps inventory of physical resources assigned to VNFs

- The Open Platform for NFV (OPNFV)
- Carrier-grade open source reference platform for NFV
- Brings together several NFV components and provides an environment for assuring interoperability and end-to-end testing



# Let’s try to manage the confusion…

- Many activities progressing in parallel across different groups… here’s an overview




Source: the Linux foundation

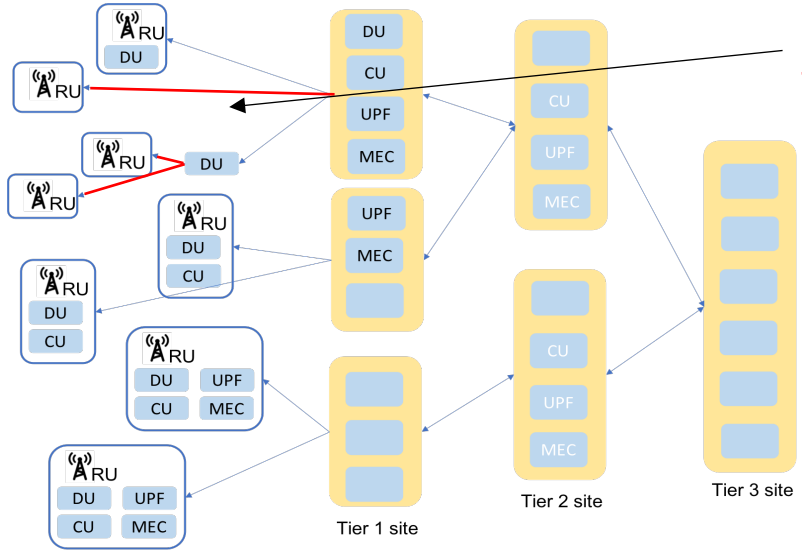
P.S.: This mapping is not part of a masterplan, rather a post-processing mapping exercise to try and show similarity and differences between systems currently being developed

# SDN, NFV and beyond 5G

- Does 5G and beyond need SDN/NFV? Is it a coincidence their occurrence at the same time?
- Did SDN/NFV happen because of the 5G drive? … or vice versa?

- There are signs of mutual influence:
  - 5G initially considered as Radio Access Network (RAN) technology evolution
  - Today the main challenges revolving around 5G now include virtualization and network slicing aspects
  - Fixed/mobile, access/metro convergence are two strong use cases for SDN/NFV in 5G

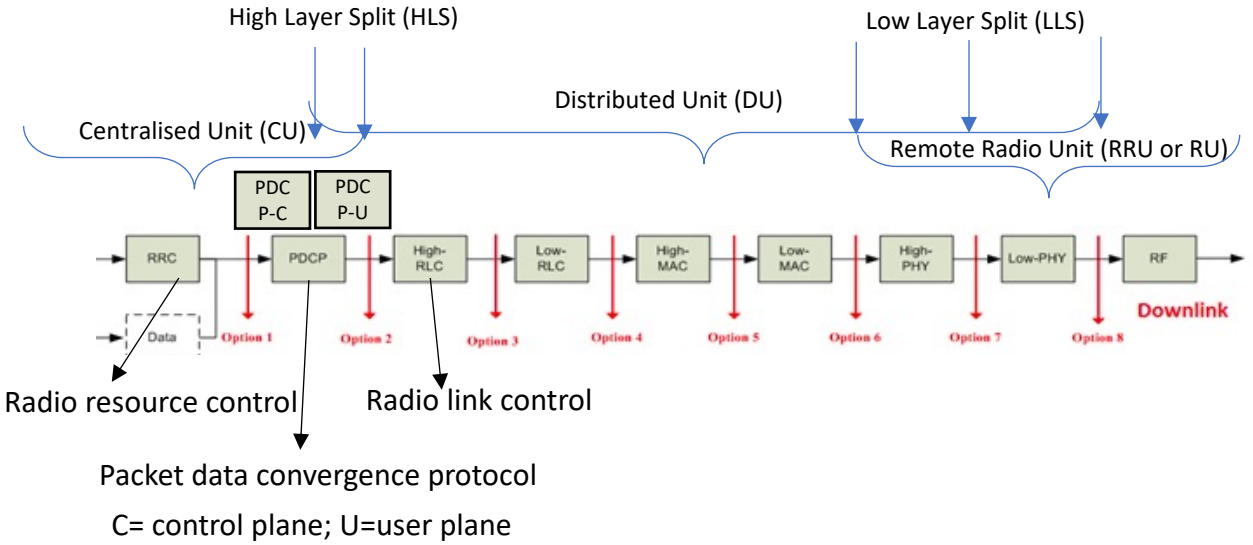
- The SDN/NFV is also reshaping the network architecture…




| UPF Location | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|
| Relative number of sites | 1000 | 100 | 10 |
| Transport latency (1-way) | 0.6 ms | 1.2 ms | 4.2 ms |
| Estimated 5G latency (RTT) | 9.2 ms [eMBB] | 10.4 ms [eMBB] | 16.4 ms [eMBB] |
| | 2.2 ms [URLLC] | 3.4 ms [URLLC] | 9.4 ms [URLLC] |

Source: NGMN

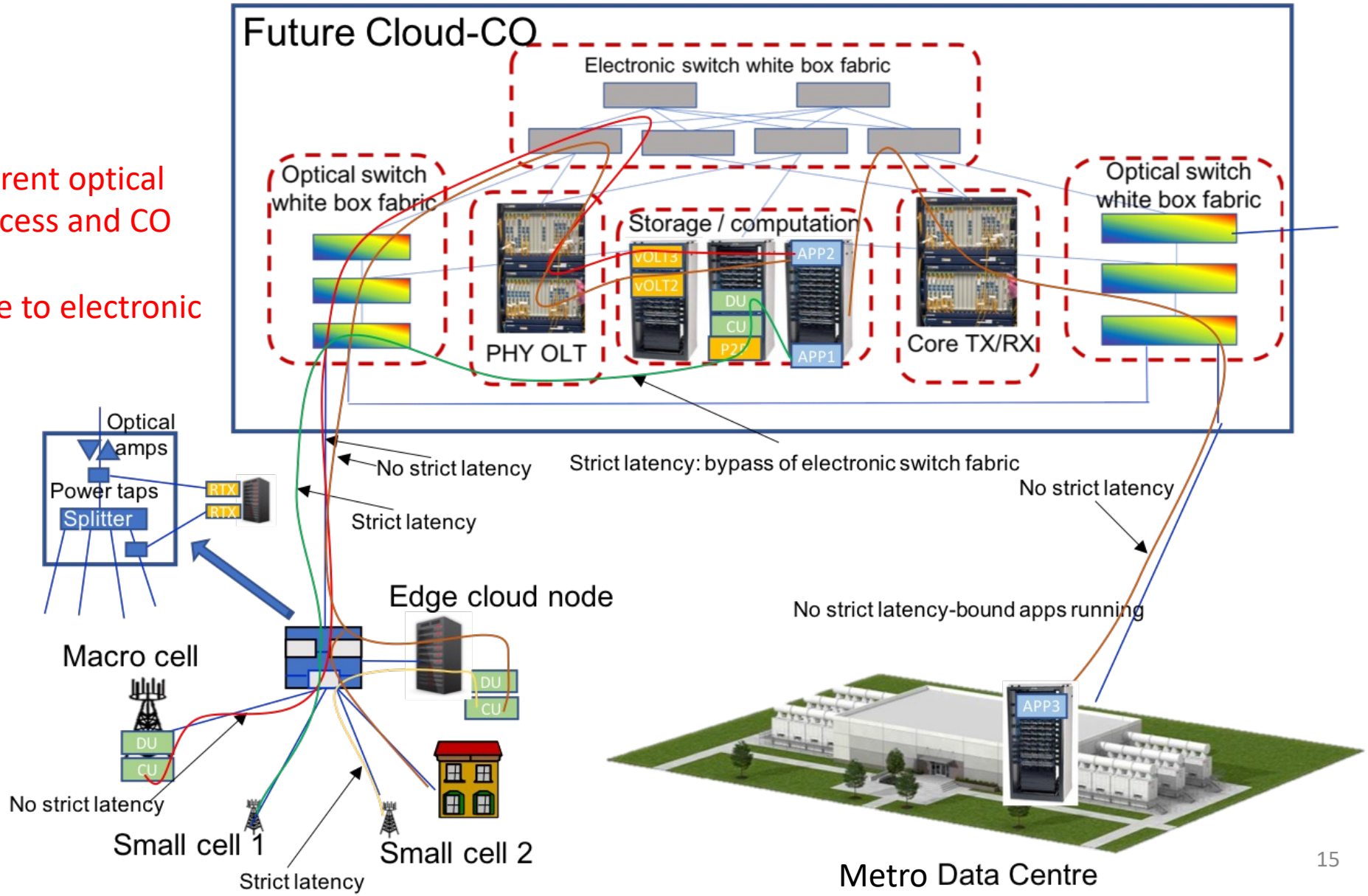
LLS is the low latency interface, between RRU and DU



# Sample use case: convergence of mobile, optical and cloud

Orchestration of transparent optical connections between access and CO

Reduce latency/jitter due to electronic switching, etc.



# Sample use case… cont'd

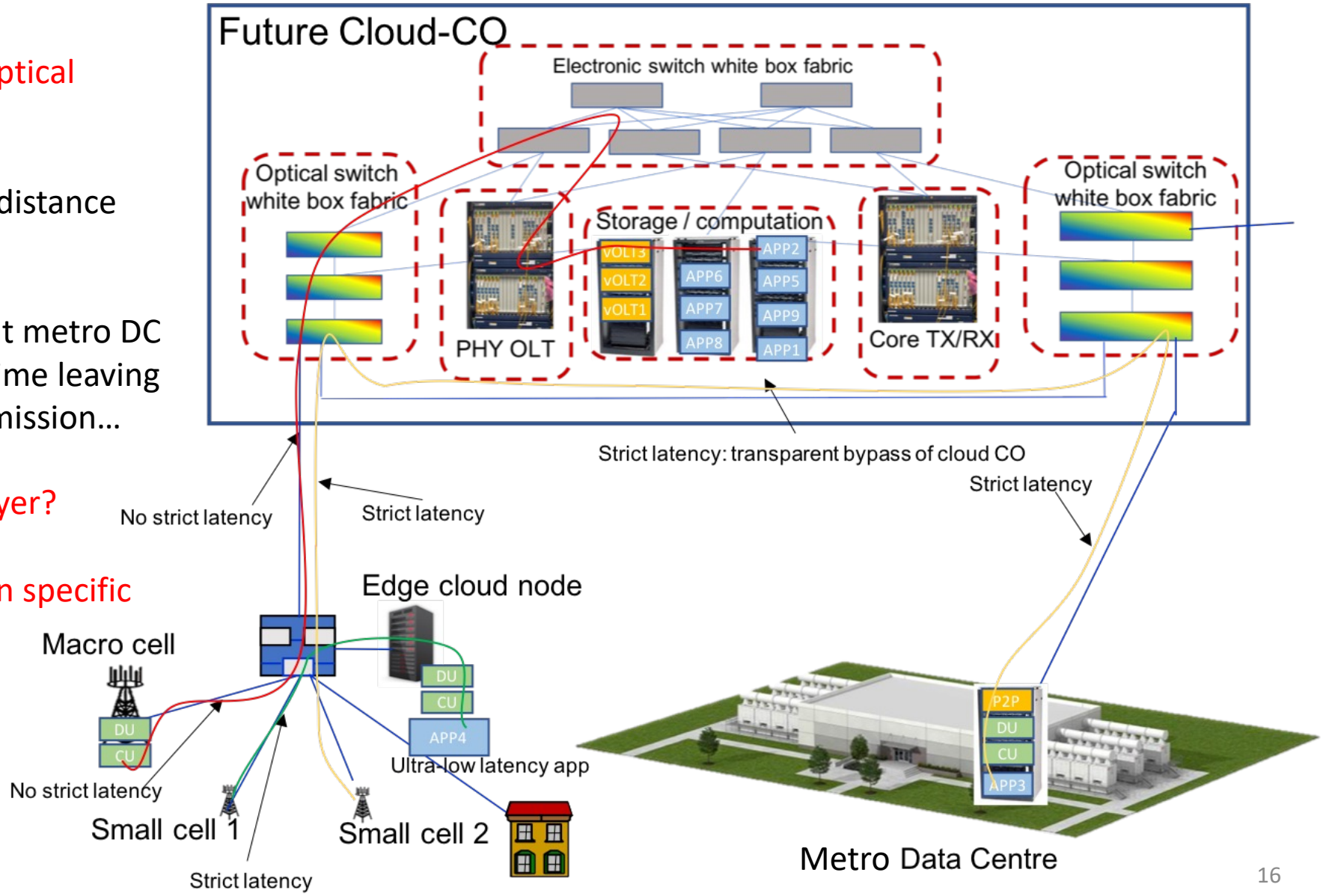
Orchestration of transparent optical connections across the metro

In principle metro data centre distance limited to 40 km by latency…

…but more processing power at metro DC can decrease VNF processing time leaving more latency budget for transmission…

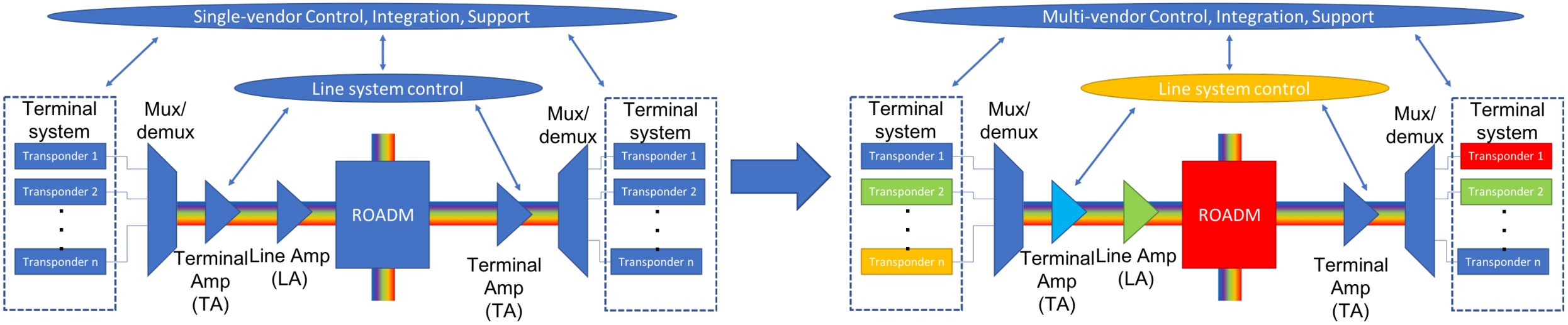
Need to open up the optical layer?

Surely need to be able to assign specific (e.g., powerful) resources as needed



# Optical layer disaggregation

- With CORD, etc. the NFV paradigm was pushed down to the MAC layer of optical technologies (e.g., in PON with the VOLTHA)..
- ..and for wireless technologies down to the physical layer (software radio implementation of LTE)
- So, what about the optical transmission layer?



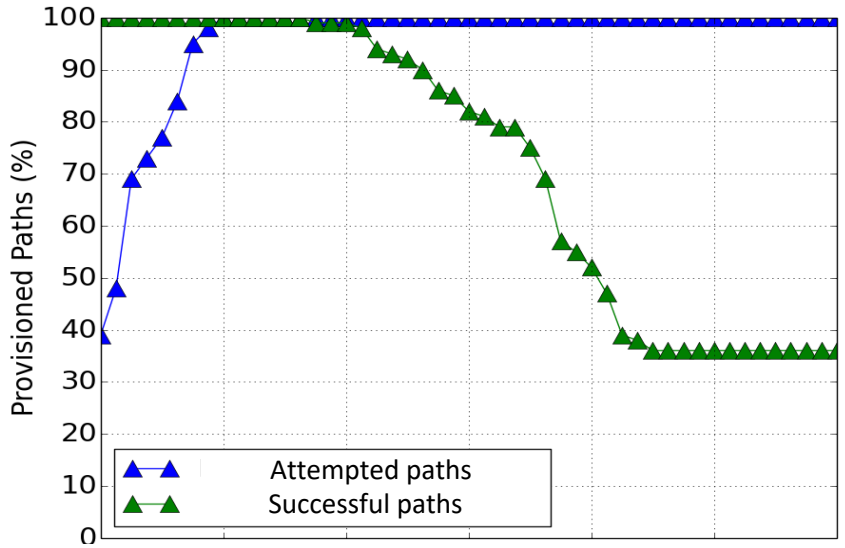

- What it means:
  - Mix and match transponders, amplifiers, ROADMs, control loops, optical control plane …

# Pros and challenges

- Fast evolution: 10 years ago this was deemed unacceptable by most, today is a hot topic..
- Pros:
  - Open market of components from multiple vendors brings cost down
  - No vendor lock-in, faster network upgrades
  - Possibility of full integration with other control layers to achieve dynamic, fast, end-to-end optical re-configurability ➔ previous mobile, optical, cloud use case
- Challenges:
  - Working on analog system with physical parameters and impairments
  - A system engineered by a vendor producing all components is more predictable and stable
  - If opening the systems means higher unpredictability… then need higher optical margins ➔ lower efficiency/higher cost
  - Business-oriented:
    - Who provides system integration?

# Metro vs core

- Meaning of effect on margins:

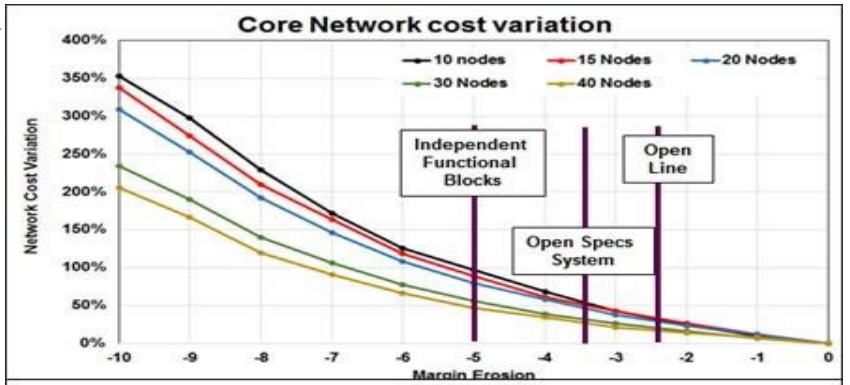


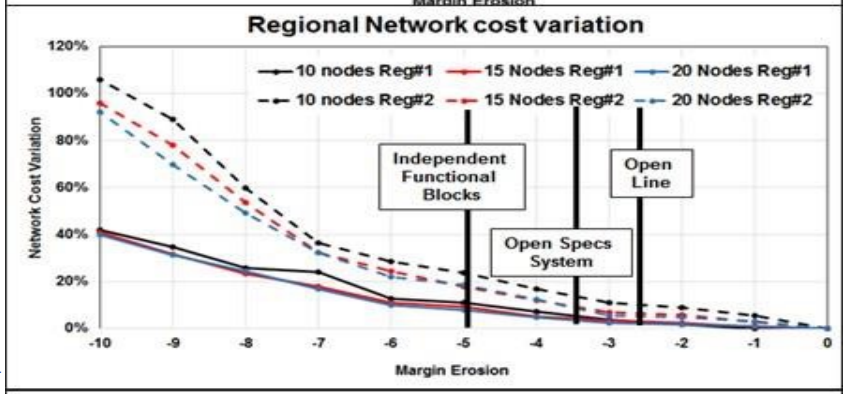

More conservative

More aggressive

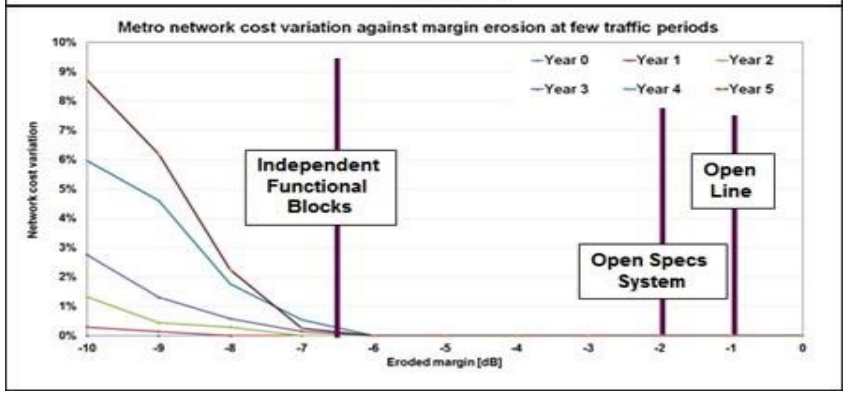
X axis: how conservative are the margins

Effect on cost of core and regional network shown to be substantial due to low available margins




Effect on metro though is negligible, as the metro has larger margins

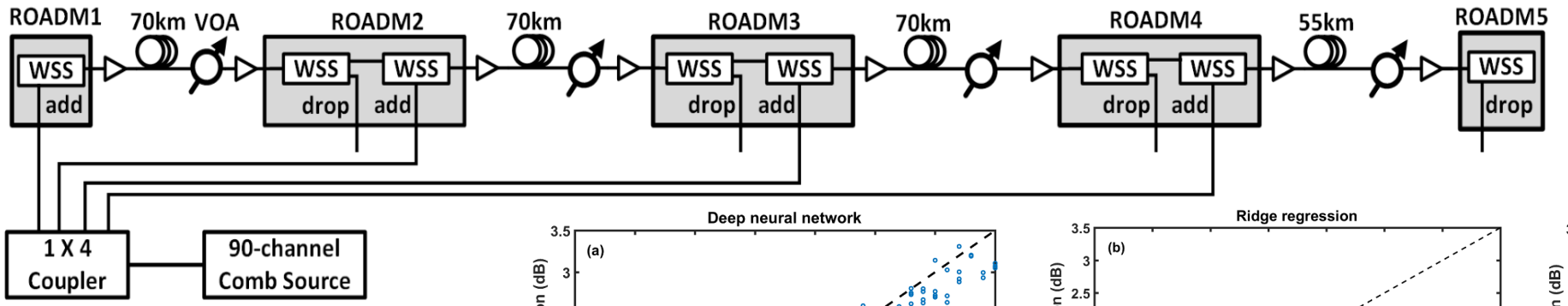



Source: M. Bleanger, M, O'Sullivan and P, Littlewood. Margin requirement of disaggregating the DWDM transport system and its consequence on application economics. M1E.2, OFC '18

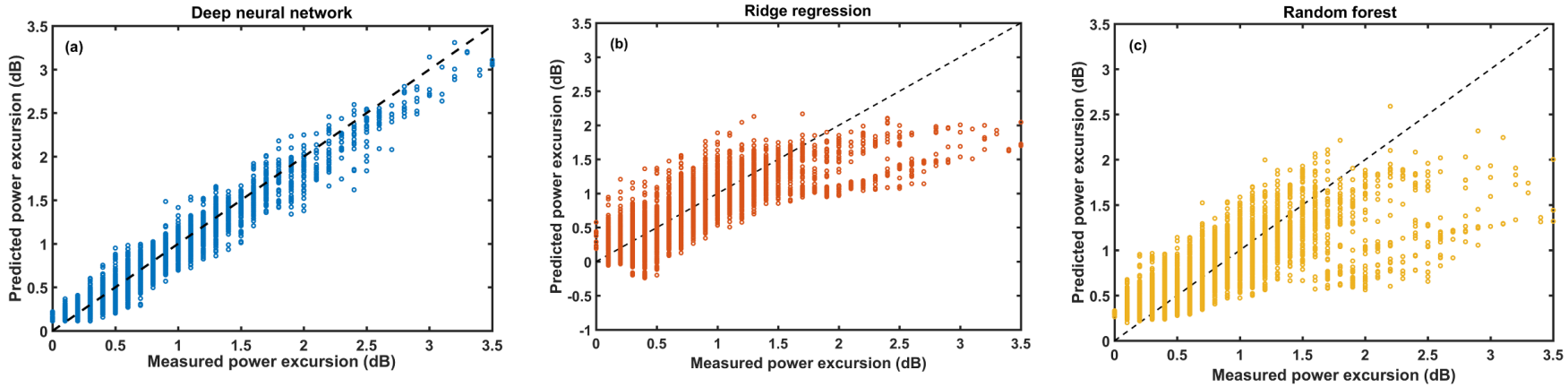
# Machine learning to the rescue…

- Opening up metro network good trade-off, as that's where a dynamic optical layer can provide more benefit..
- … however more work on QoT estimation could change such figures also in regional and core.

- Much work being carried out in the use of machine learning techniques




Amplifier power excursion prediction



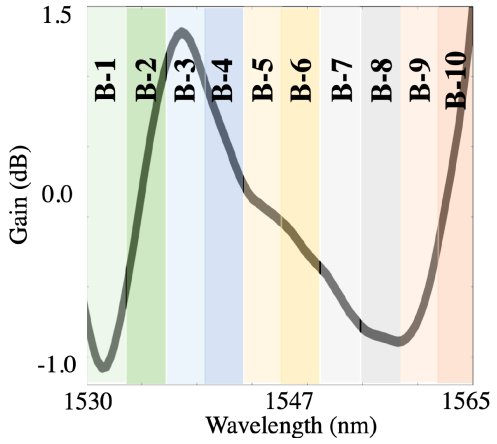

Source: W. Mo,et al., Deep Neural Network Based Wavelength Selection and Switching in ROADM Systems. JOCN Vol. 10, No 10, 2018.

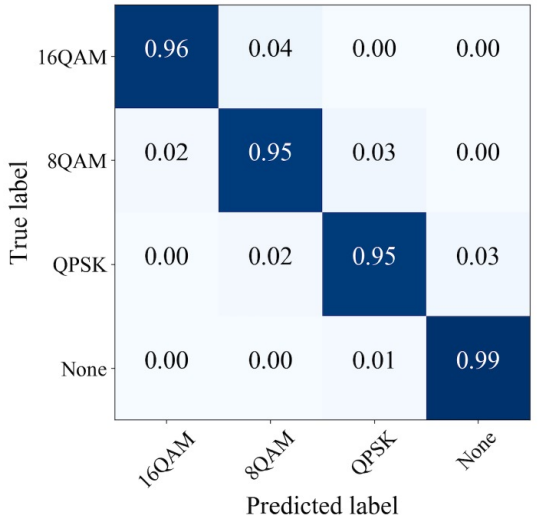
Deep learning (left) shown to accurately predict optical signal power which is main determinant of signal quality, based on the channel configuration alone.

# Use of Machine learning for quality of transmission estimation in optical transport networks

- Dynamic wavelength allocation suffers from impairments in optical amplifiers:
  - Amplifier gain is not perfectly flat across wavelengths and this function is not known and depends on amplifier, working point…

  ➔ Adding a wavelength channel can increase/decrease the power and OSNR of all other channel
- Quality of Transmission estimation is an important research area, and ML techniques have been used to provide such estimation
- Build multi-class SVM classifier to decide what modulation is possible (e.g., related to OSNR) with features: number of nodes, fibre length, launch power, EDFA gain, plus the number of wavelength channels already loaded in each of the 10 bins below.





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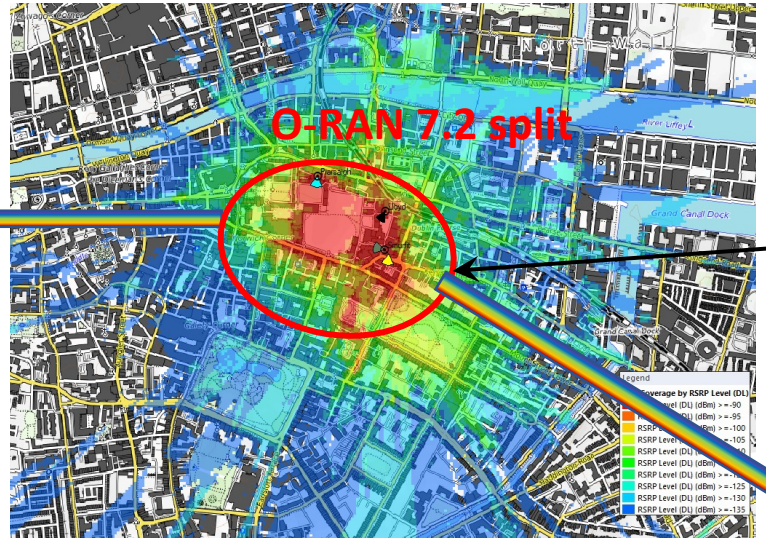
- S. Zhu, C. Gutterman, A. Diaz Montiel, J. Yu, M. Rufini, G. Zussman and D. Kilper. Hybrid Machine Learning EDFA Model. OSA Optical Fiber Communications Conference (OFC), March 2020
- A. A. Dıaz-Montiel and M. Ruffini. A Performance Analysis of Supervised Learning Classifiers for QoT Estimation in ROADM-based Networks. Proc. of Optical Network Design and Modeling conference (ONDM), May 2019
- A. A. Dıaz-Montiel, S. Aladin, C. Tremblay and M. Ruffini. Active Wavelength Load as a Feature for QoTEstimation Based on Support Vector Machine. IEEE International Conference on Communications, May 2019

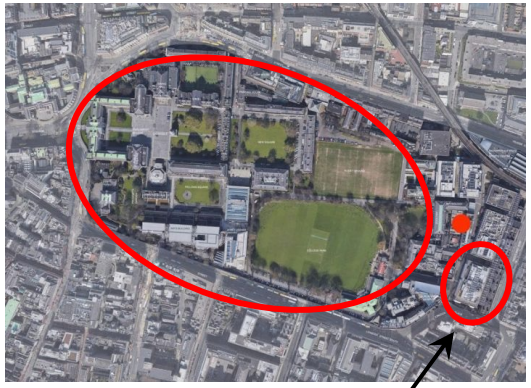
# Open Ireland: Ireland's Open Networking Testbed

www.openireland.eu

Based in Trinity College campus


Optical transmission, analog RoF, mmWave-THz



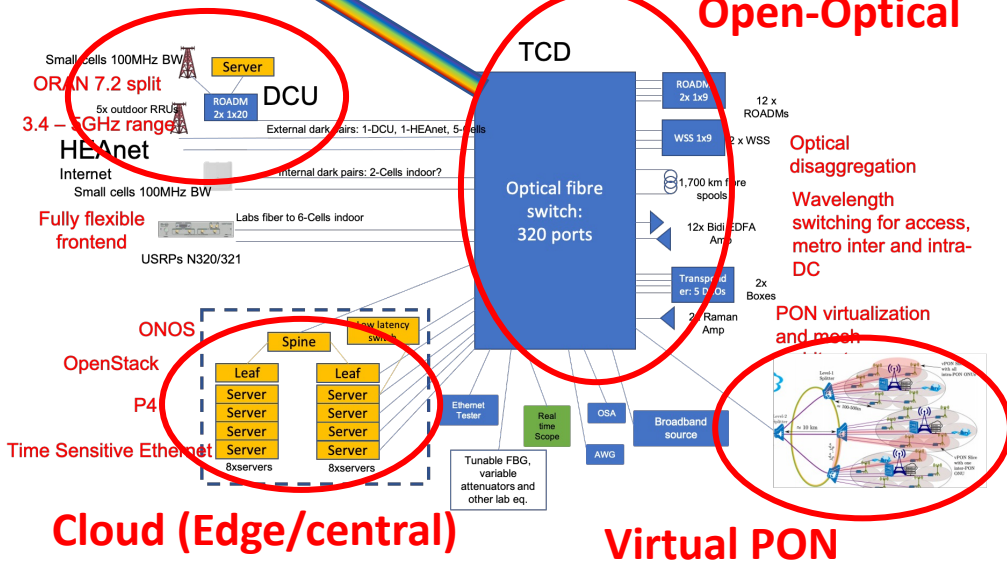



CONNECT research centre building

O-RAN

SDR

Open-Optical




Reconfigurable and **Lego-like** topology reconfiguration with following blocks:

- 1,700km fibre, **SDN ROADMs**, **amplifiers and coherent Tx** (Cassini), virtual PON, OSA, etc.
- **5G O-RAN** (outdoor and indoor); **OpenSource 5G** (OAI and SRS)
- **Edge cloud**, L2 switching, P4 programmability