

The Role of SDN and virtualisation in 5G networks and beyond

Prof. Marco Ruffini

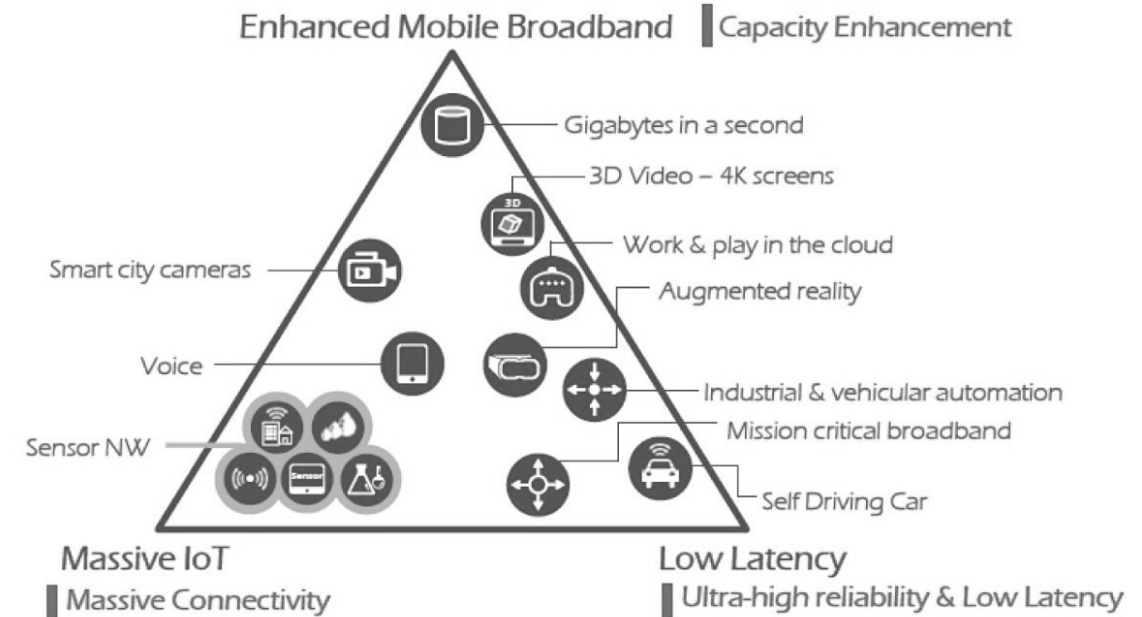
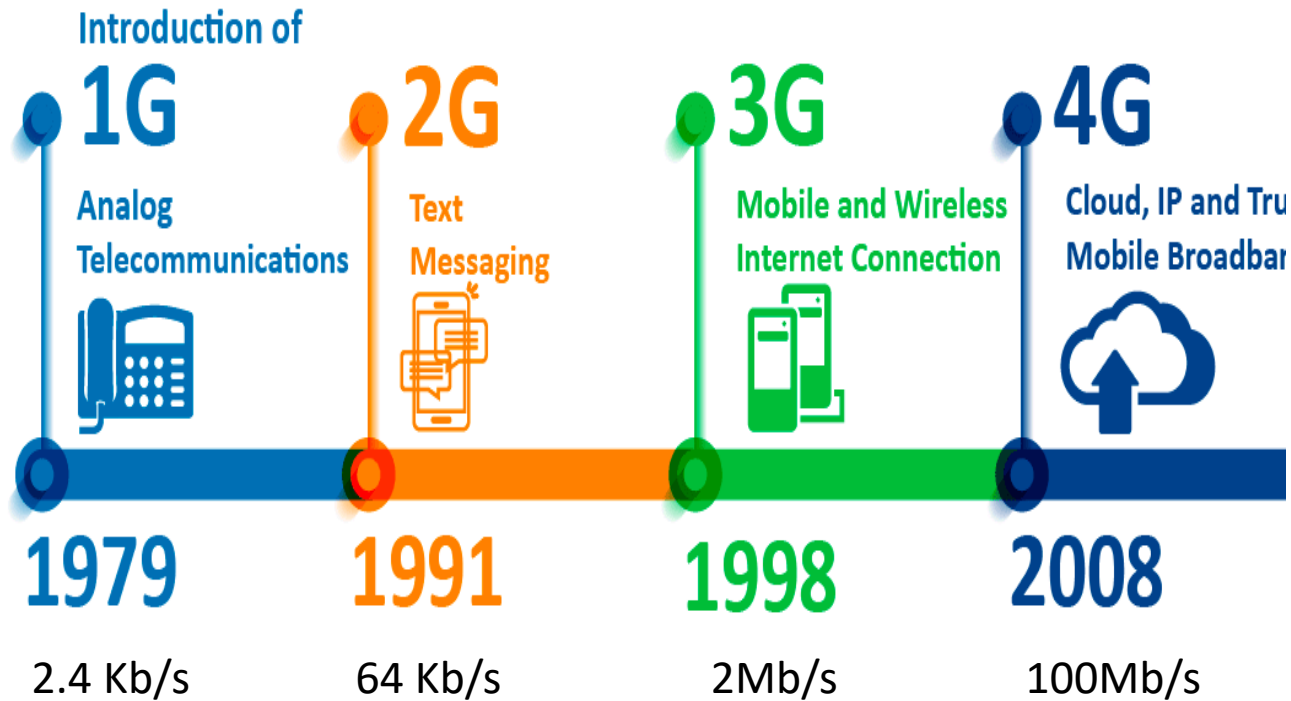
Dept. Computer Science and Statistics, Trinity College Dublin

CONNECT and IPIC (SFI research centres)

Content of the talk

- Introduction:
 - What is 5G?
 - Considerations on network revenues and new revenue sources
- Technology evolution: drive towards automation, cost reduction and flexibility
 - Software Defined Networks
 - Network virtualisation
 - Network Function Virtualisation
 - Network densification and cost-effective connectivity for base stations
 - Practical use case
- Conclusions

5G: what is it and how did we get here?



(Source: ETRI graphic, from ITU-R IMT 2020 requirements)

Who's 5G for?

- Us all!

This we can already do:

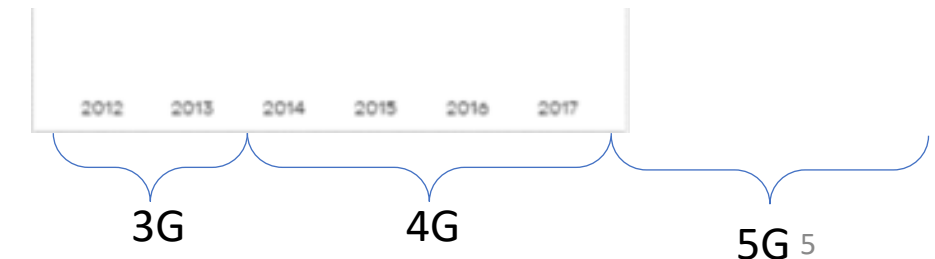
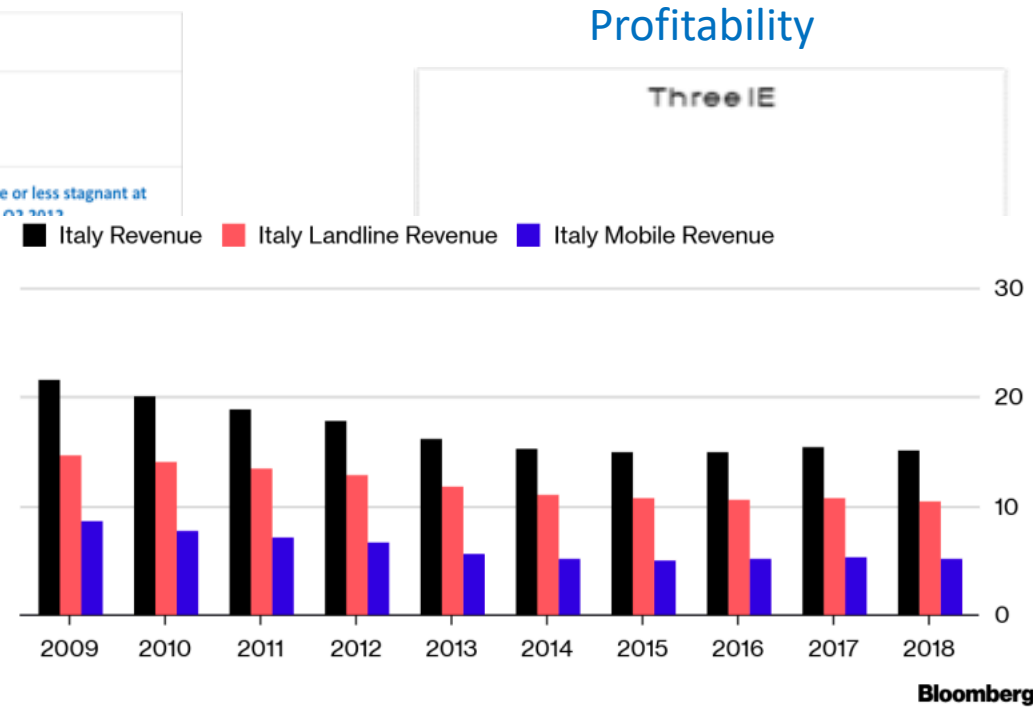
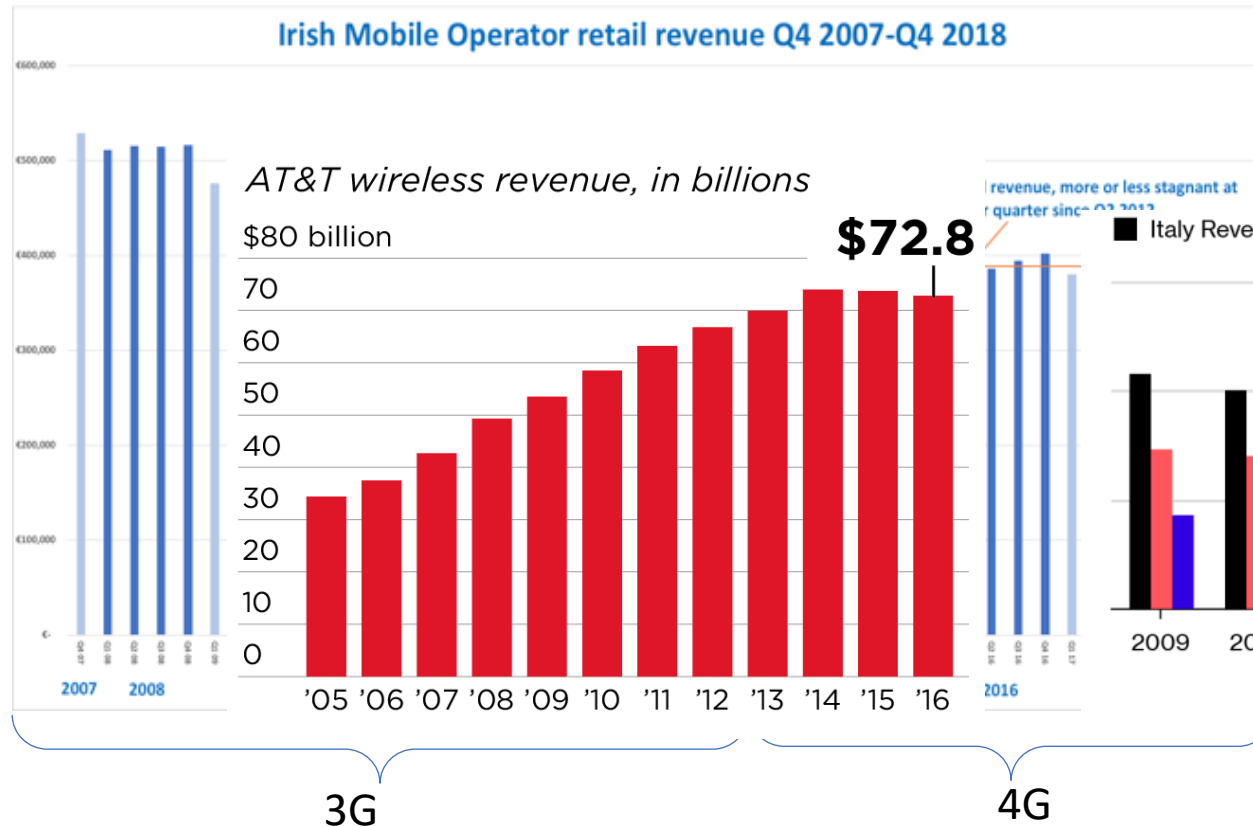


This we will be able to:



One small issue about 5G...

- Broadband revenue generated by retail users is very static (often negative)



Notice that many operators didn't manage to charge 4G more than 3G

Will 5G change this? How??

Surely it should do something different than 3G-to-4G transition:
e.g., not just offering higher bandwidth, at same price

BUT... this is what we see today:



Verizon's 5G network is live in Chicago and Minneapolis.

"...could see speeds between 450 Mbps to 1Gbps and latency connecting to the network less than 30 milliseconds"



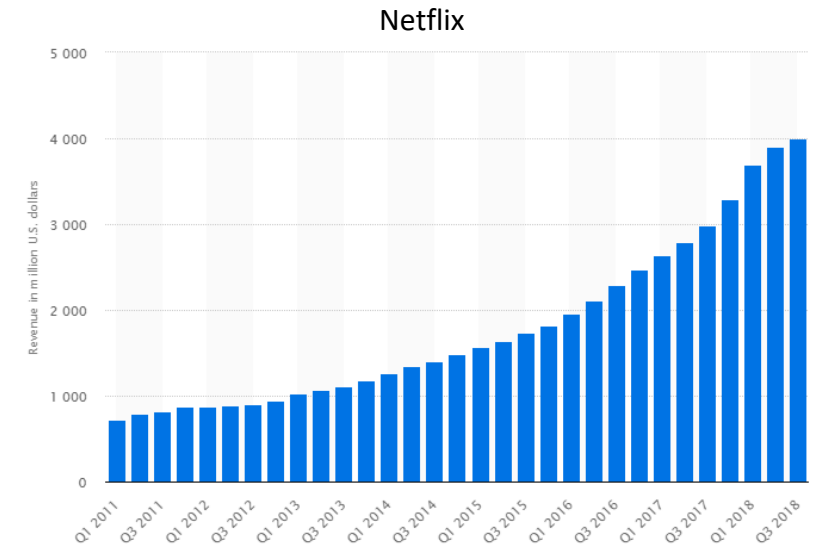
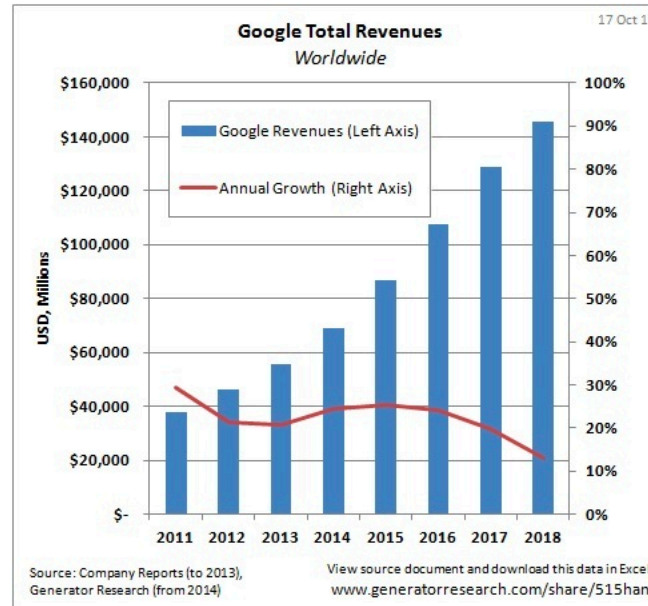
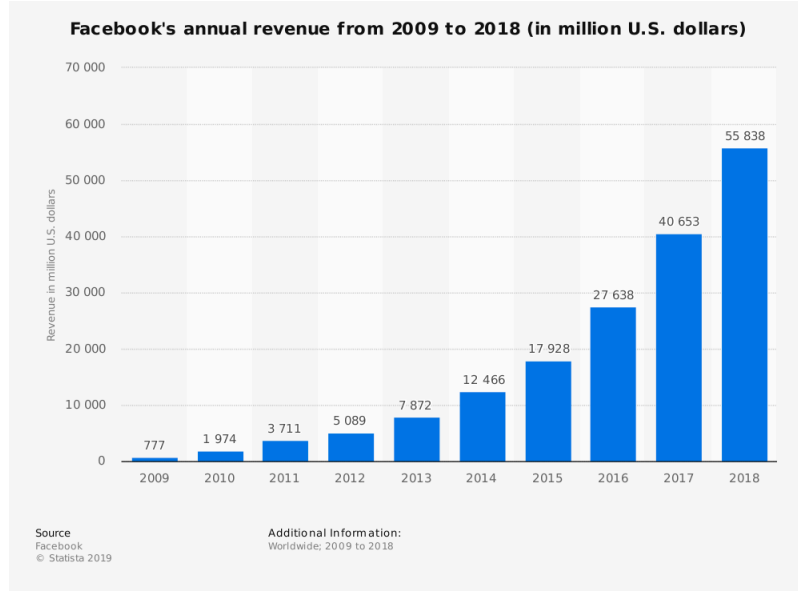
Three to give customers 5G at 'no extra cost'

Current 5G = 4G + 1G

But the 5G community promises that this will change in the next few years..

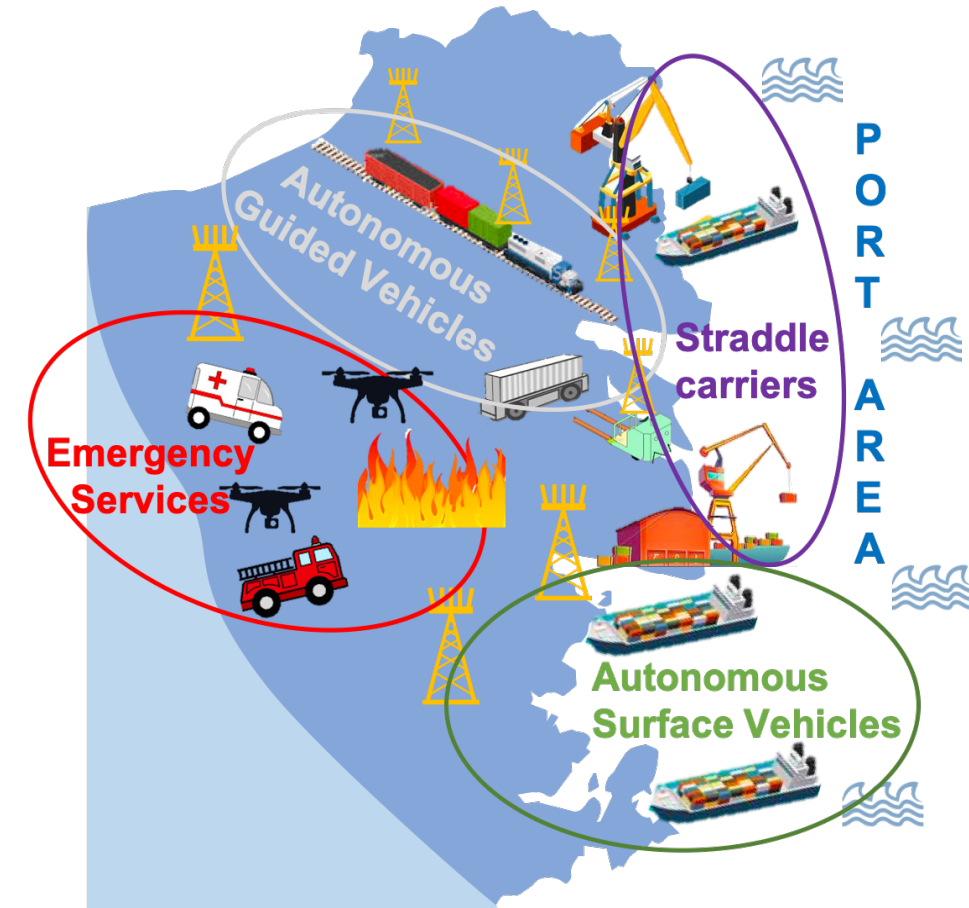
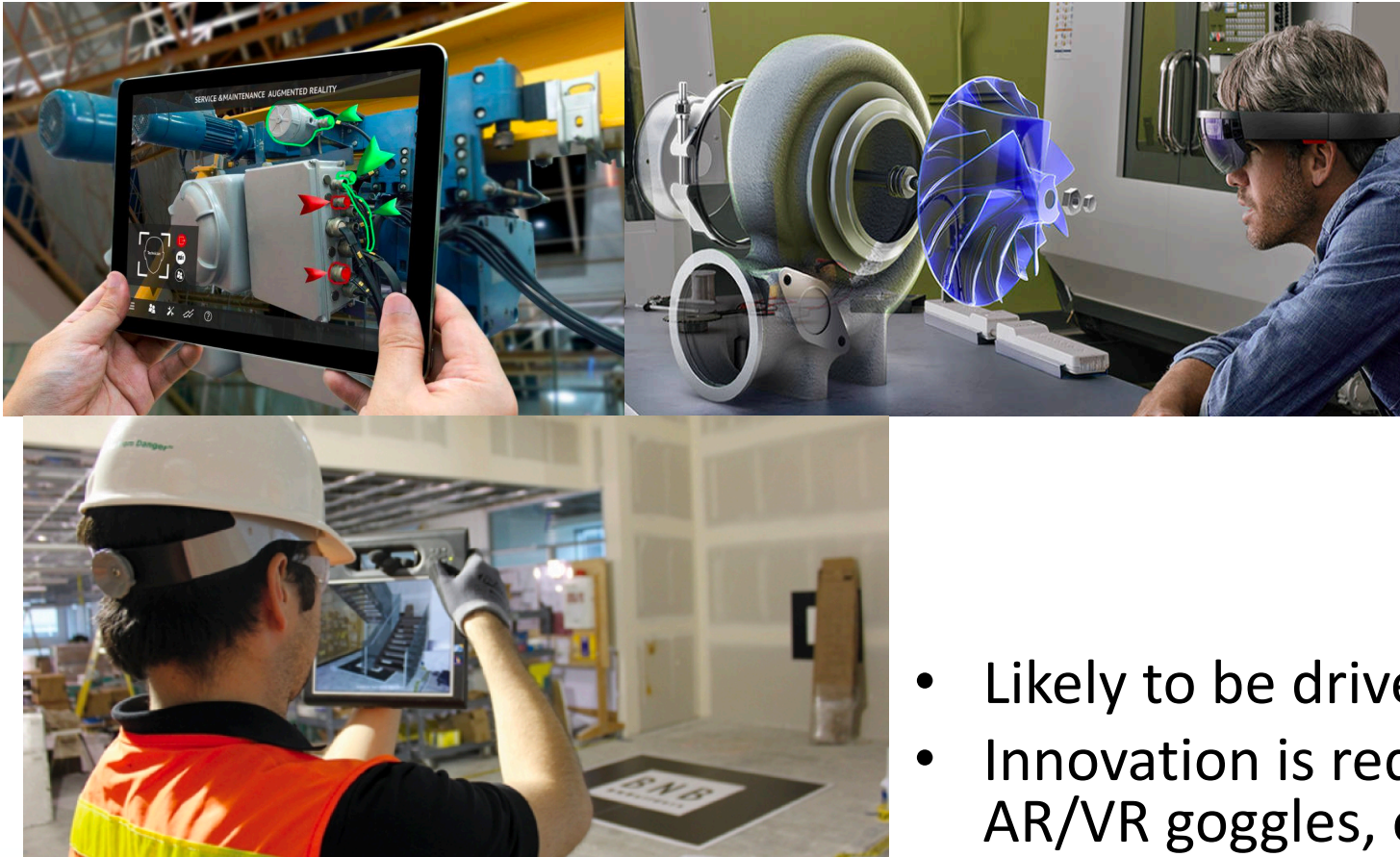
How to fix it?

- For many years we have seen that revenue is in the higher layers, where most of the value is.



New value in new applications: how to attract them?

- Attract new users/businesses by providing new unprecedented features:



- Likely to be driven by Industry 4.0
- Innovation is required also in user devices (e.g., AR/VR goggles, etc.)

From Industry 4.0 to every day's life

- Till the day we'll be fully immersed in the digital world...

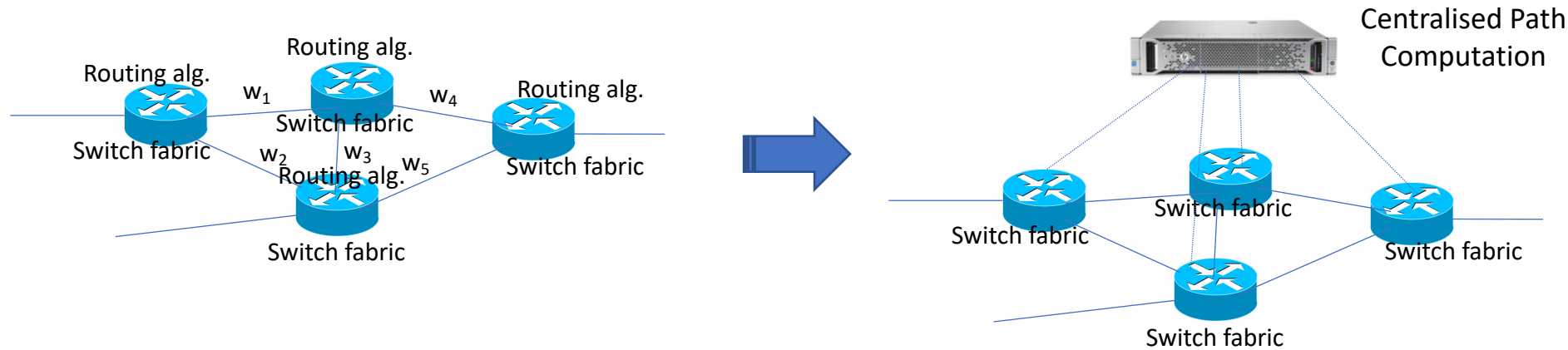


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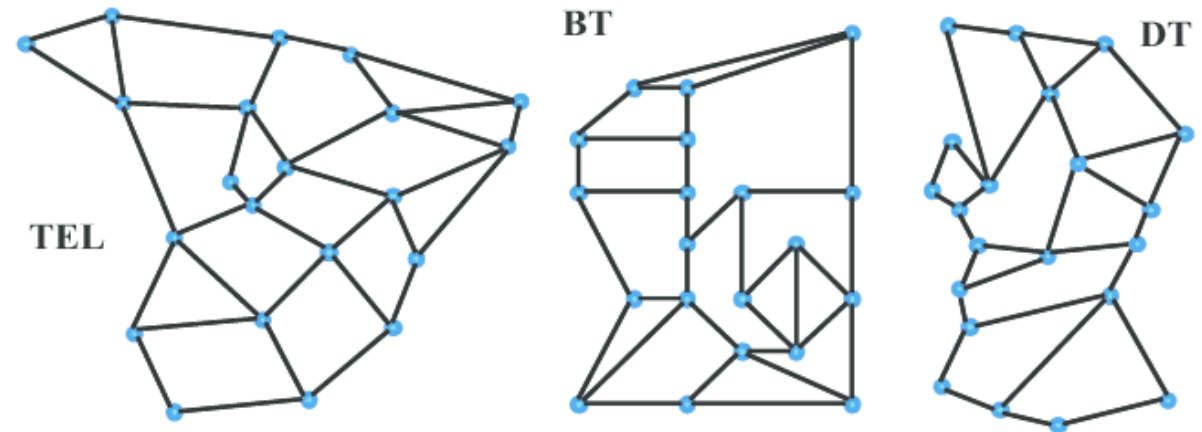
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Software Defined Networks

- Move from a system where routers run independent (but converging algorithms) to a system where all routes are decided by a central entity

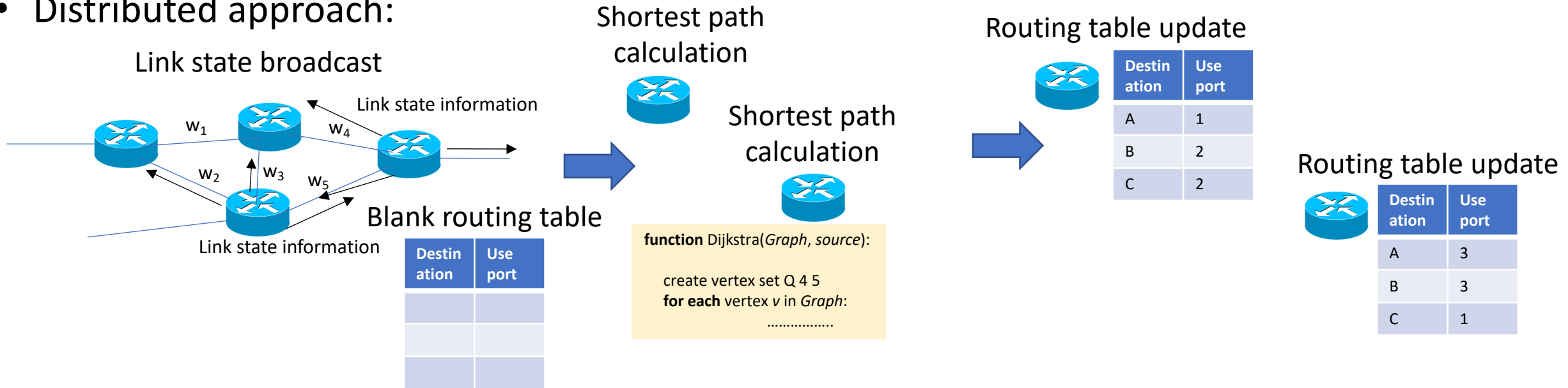


- Advantages:
 - More flexibility in deciding routes
 - The system opens up and facilitate development of integrated software

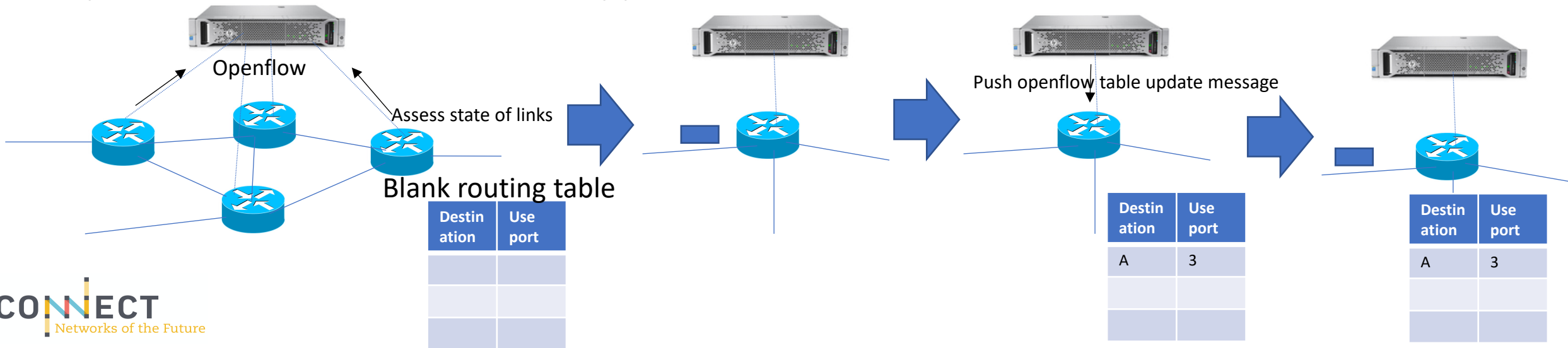


OpenFlow example

- Distributed approach:

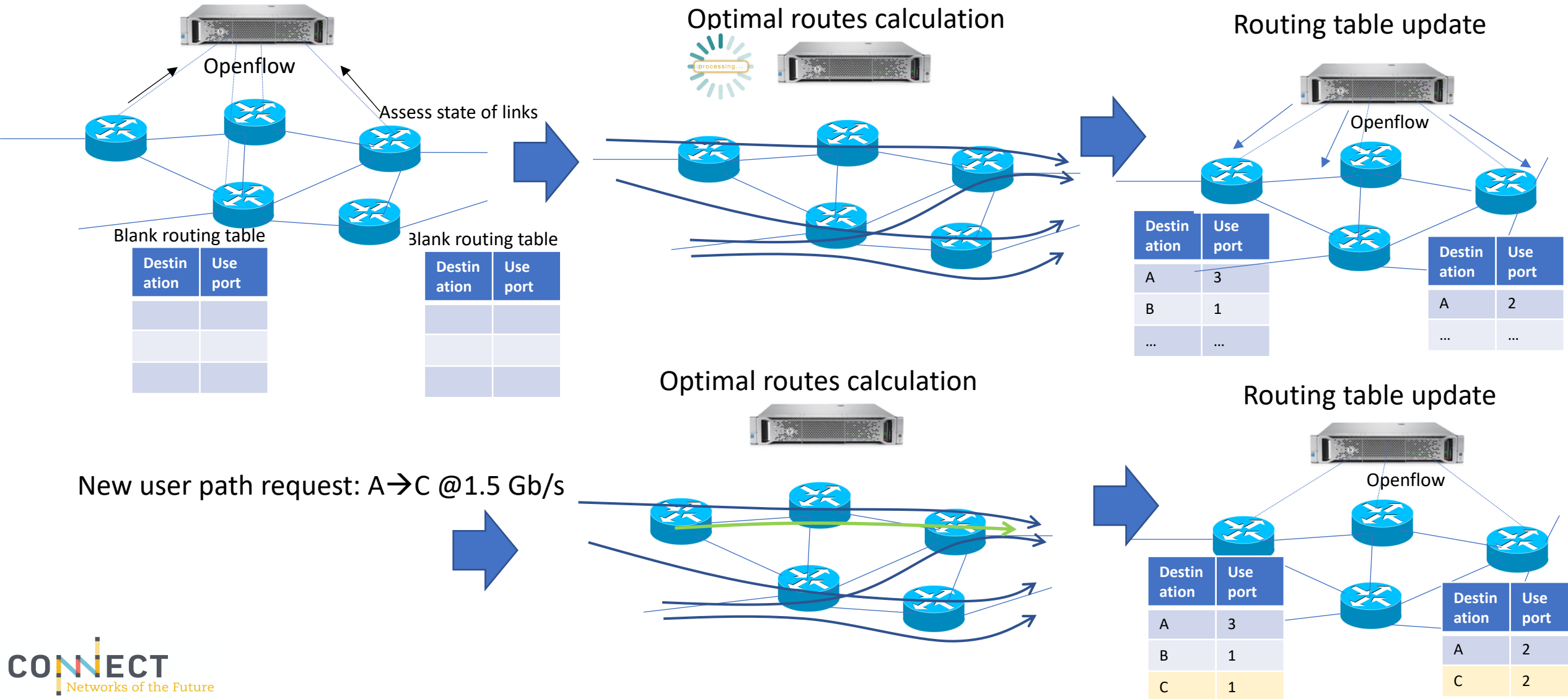


- Openflow centralized (reactive) approach



OpenFlow example

- Openflow centralized (proactive) approach



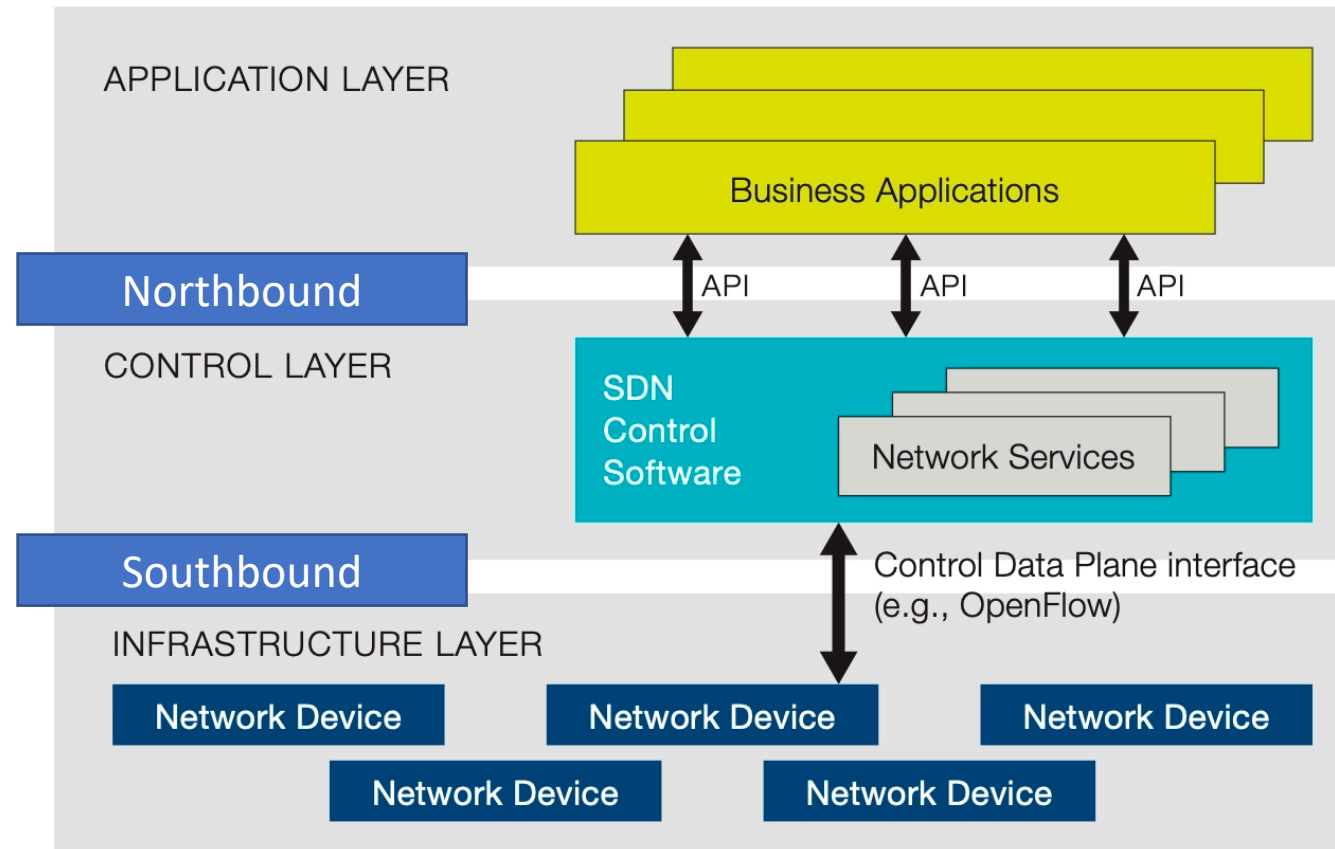
An SDN architecture

The control plane (controller) becomes the Operating System for the network.

Programmability requires well defined and standardized interfaces:

- Southbound interface to send instructions to network devices (think of hardware drivers)
- Northbound APIs are used by applications (e.g., the entity setting up a service) to express their intent

The controller transforms abstract, high-level intents into physical layer commands

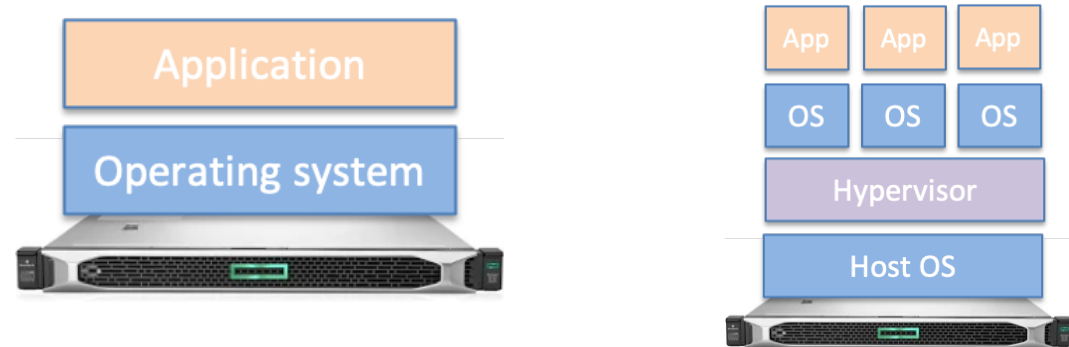


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Virtualisation

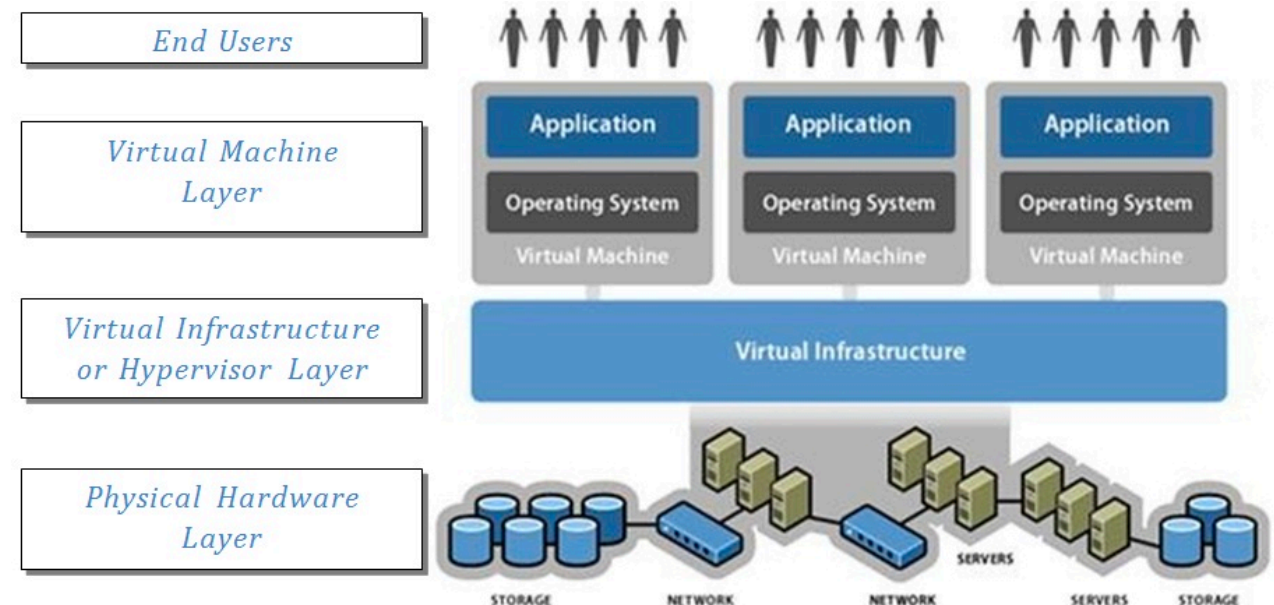
Virtualisation gives the illusion of obtaining control of a physical entity or resource.



In Data centres the principle extends to the whole infrastructure

Completely decouple end user resources from physical hardware resources:

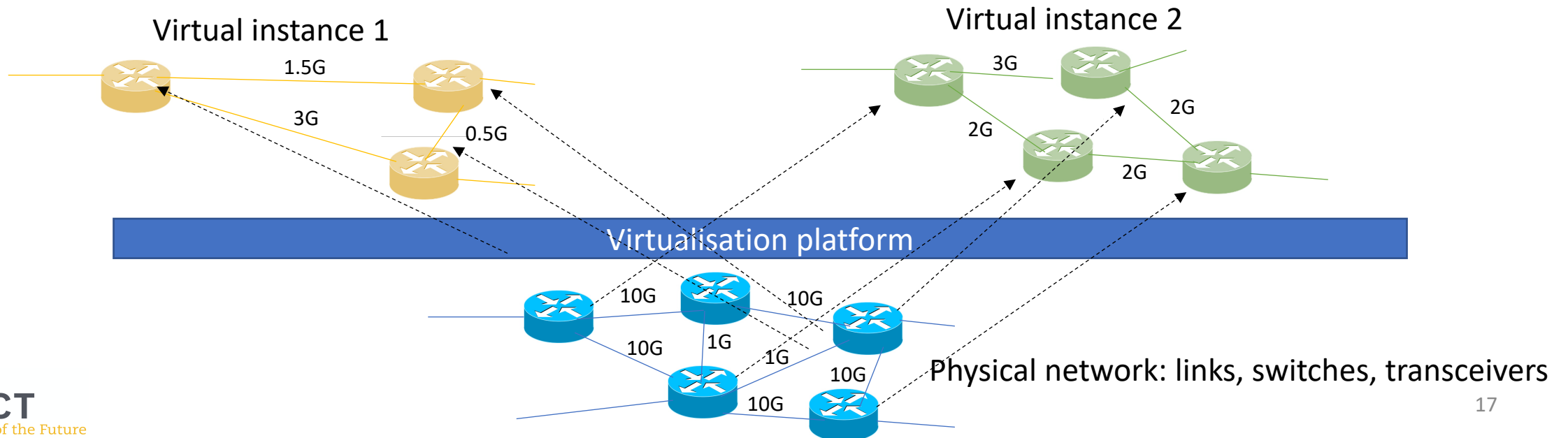
Increase in efficiency, lower energy usage, lower capital costs,...



Network Virtualisation

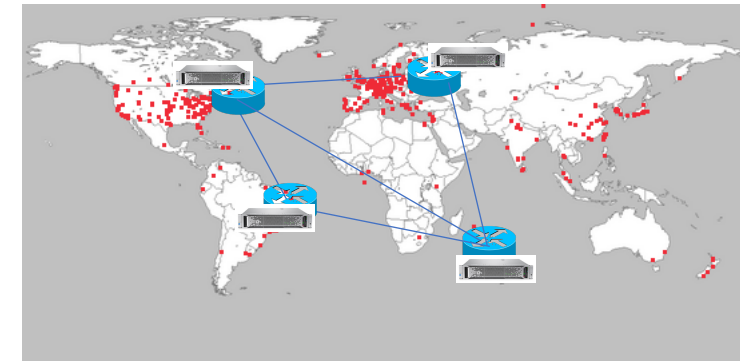
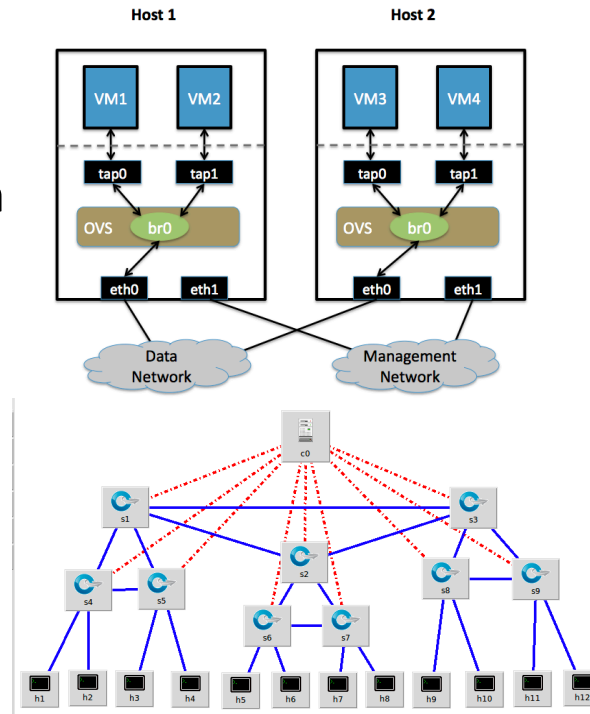


- In networks, virtualisation could be seen as abstracting the functionality of a piece of hardware infrastructure into software.
 - relies on a virtualisation platform to associate the virtual network with real hardware links
 - can provide the ability to instantiate an entire network overlay in software



Some examples of network virtualisation testbeds

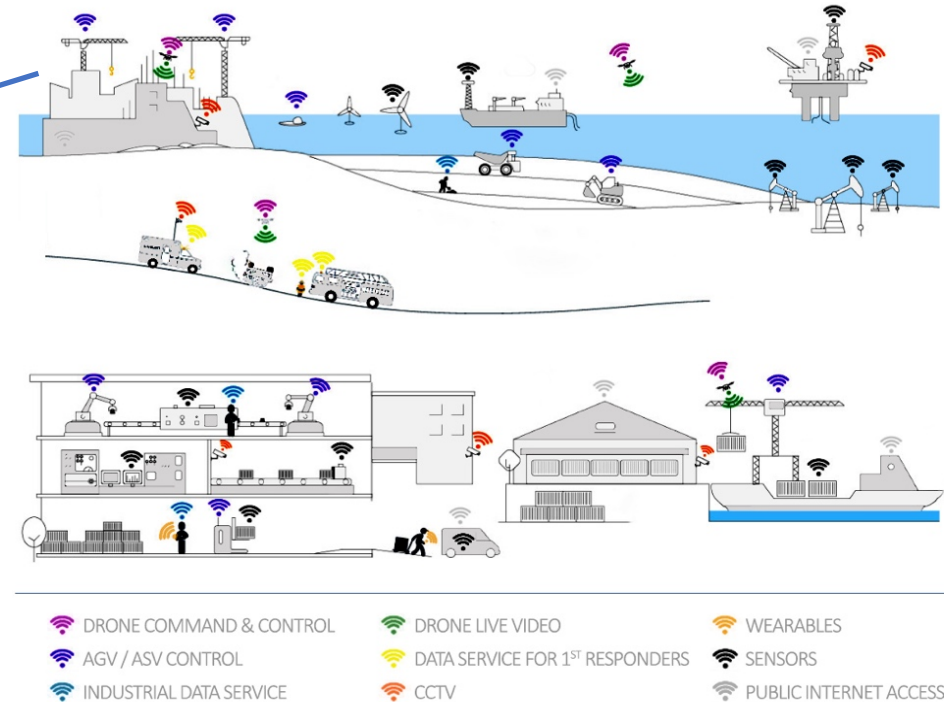
- From local scale:
 - OpenvSwitch (OvS): a virtual packet switch operating in Linux environment
 - Mininet: emulation platform comprising of virtual switches, hosts, and links
 - Can be used to test SDN controllers behaviour
- To global scale:
 - Planetlab applies the idea of virtualisation using nodes and links spread out across the globe
- Today many others exist, including wireless and optical domains



Network slicing

Virtualisation enables slicing, meaning that you can take a network infrastructure and partition it dynamically to serve different use cases and applications.

Private Operator Base Stations: Regional License
Customised Infrastructure Deployment



Public Operator Base Stations:
Nation-wide License, Large-Scale Deployment

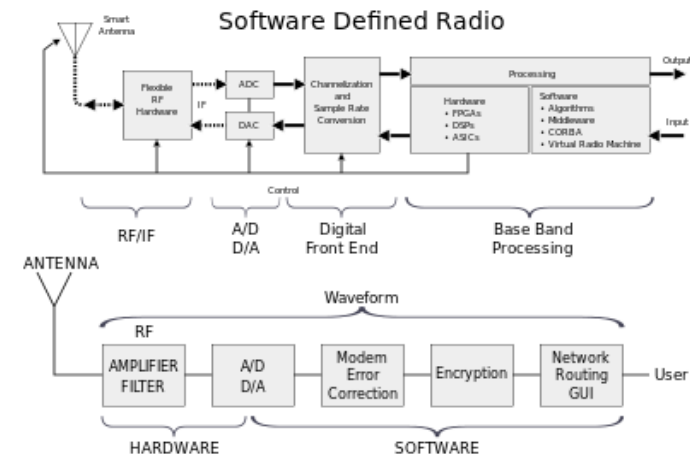
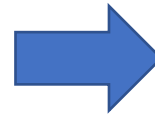
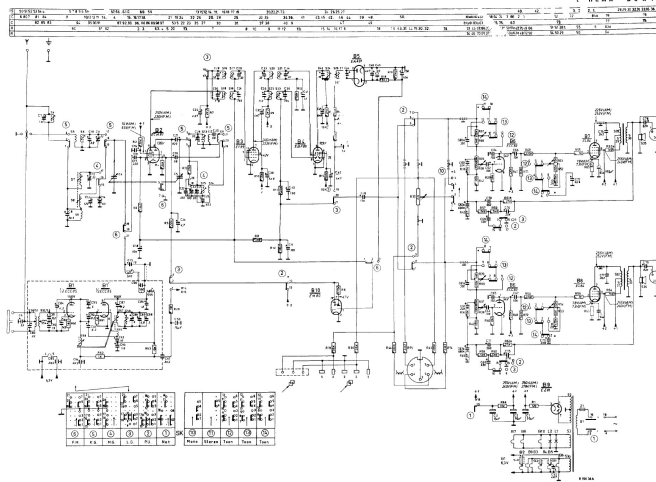
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From virtualisation to network function virtualization (NFV)

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

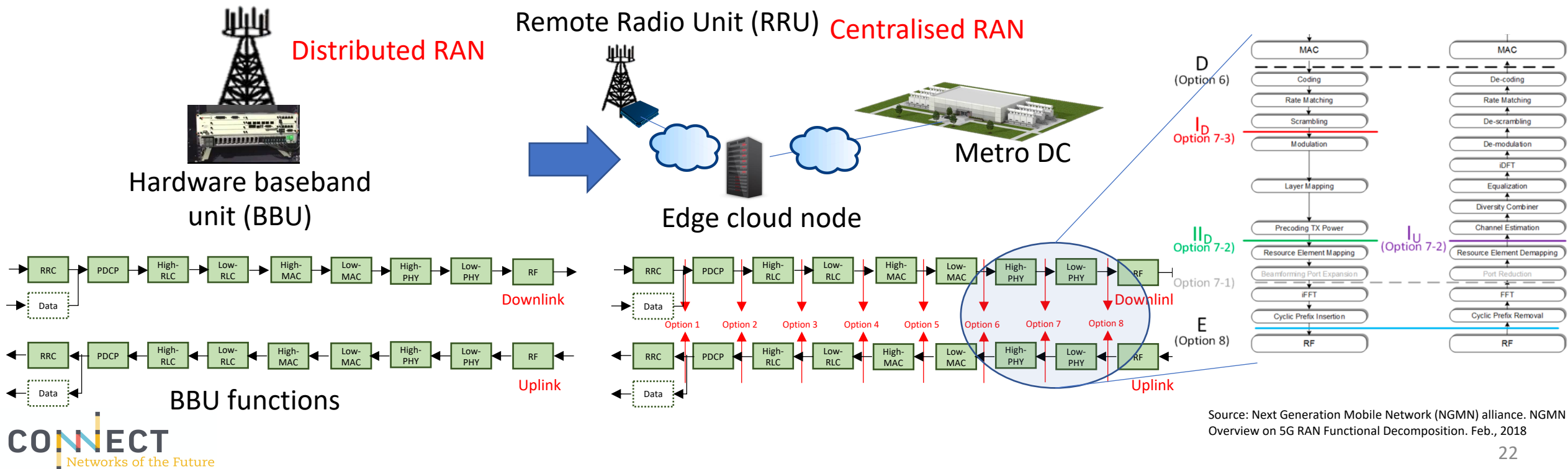
Software Defined Radio is an early example: GNU radio



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

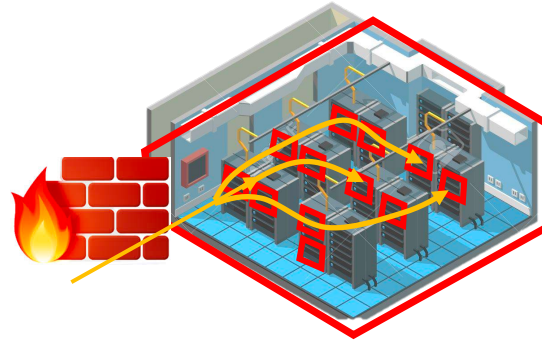
SDR in today's telcos

- SDR today stronger than ever:
 - C-RAN based on SDR → srsLTE, Amarisoft, Flexran, OpenAirInterface, OpenLTE, 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,...



Network functions

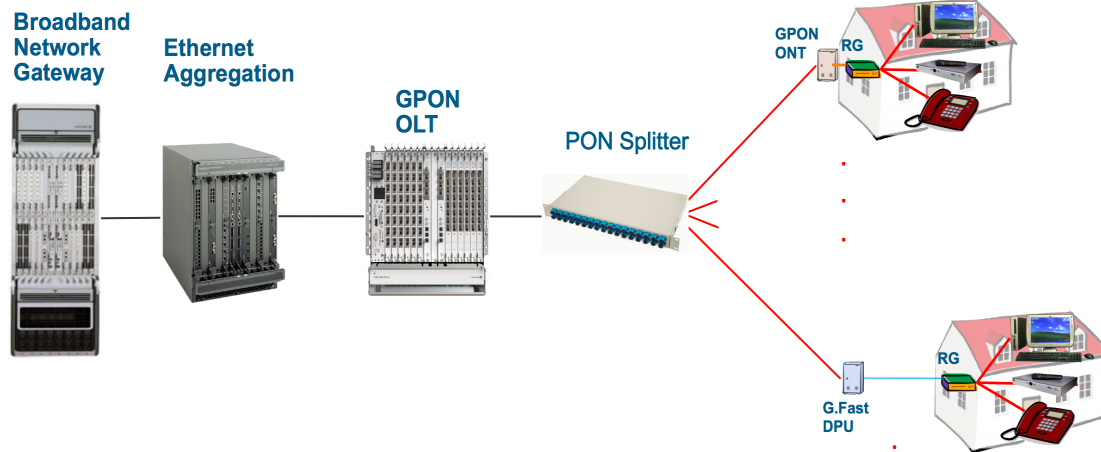
- The NFV concept applies to several other telco functions:
 - Firewall: in VMware NSX it's integrated in each VM, for better customization, flexibility, security.



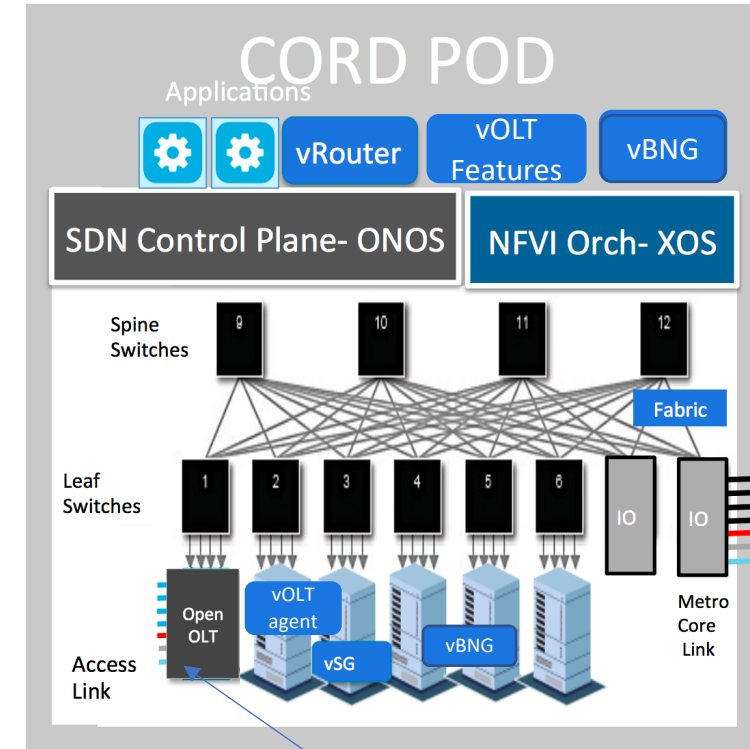
- In general all functions that require packet processing and switching are good candidates:
 - Service Gateway (vSG): e.g., route the request to the specific service provider
 - Broadband Network Gateway (vBNG or vBRAS): aggregates incoming access connections, enforces QoS, provides layer 3 (IP) connectivity
 - Customer Premises Equipment (vCPE): operates routers, firewalls, VPNs, NAT

Central Office Virtualisation

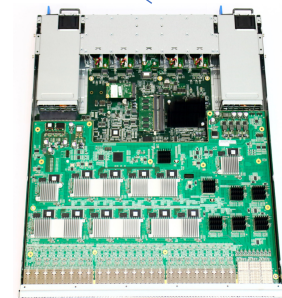
- Getting SDN and NFV into the central office:



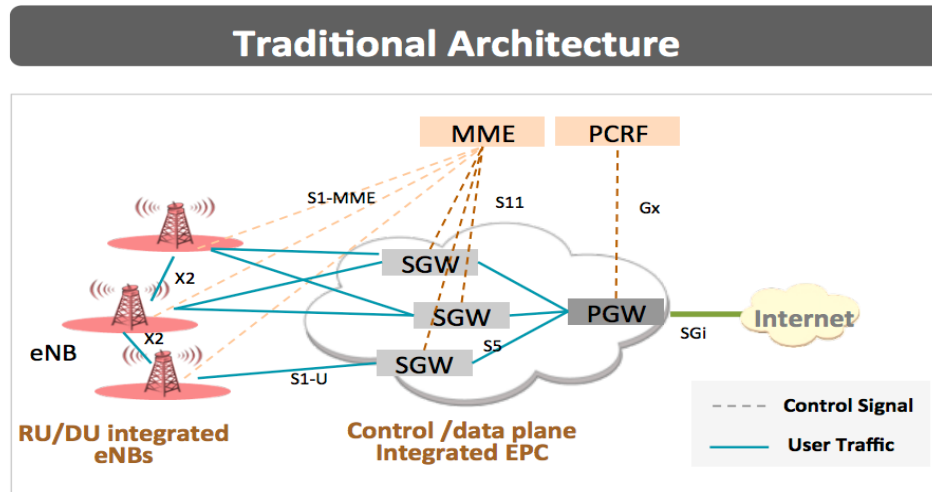
- Driven by development, not by standard
- Being trialed by several operators world-wide
 - E.g., AT&T recently carried out trials on XGS-PON using OLT white boxes



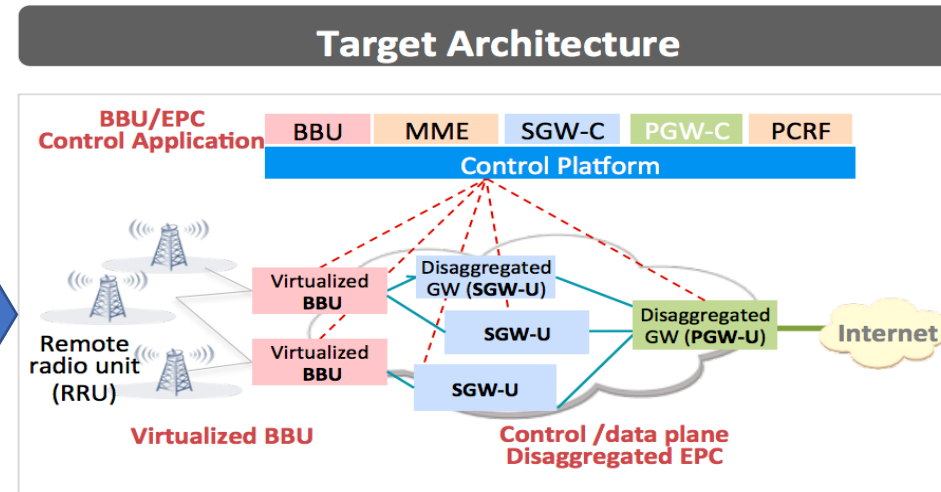
Commodity Hardware
Source: <http://opencord.org/>



Multi-service example: Mobile-CORD

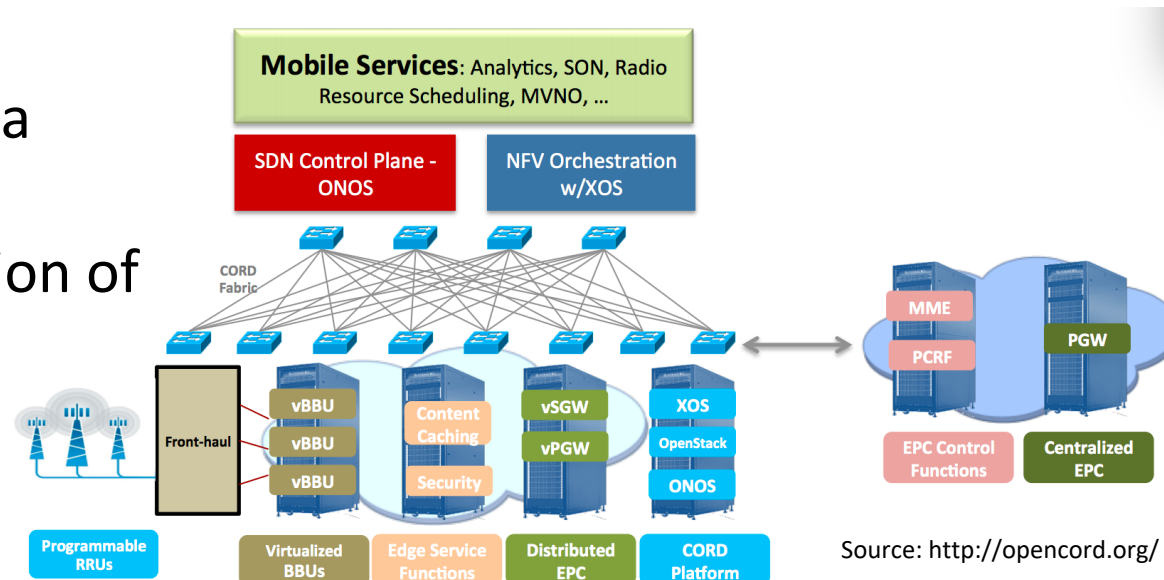


with proprietary boxes & solutions



with commodity H/W & open source/open API

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



Source: <http://opencord.org/>

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How do we increase capacity in 5G?

Question: how to increase mobile capacity by 1000 times (by 2020??)

Some popular estimates of factors for capacity increase:

- Efficiency (MIMO, Smart scheduling, enhanced-CoMP) -> x3
- Spectrum (Carrier Aggregation, New Bands, Authorized Shared Access) -> x2
- **Density (Advanced Macros, HetNet management, Flexible small cells)**

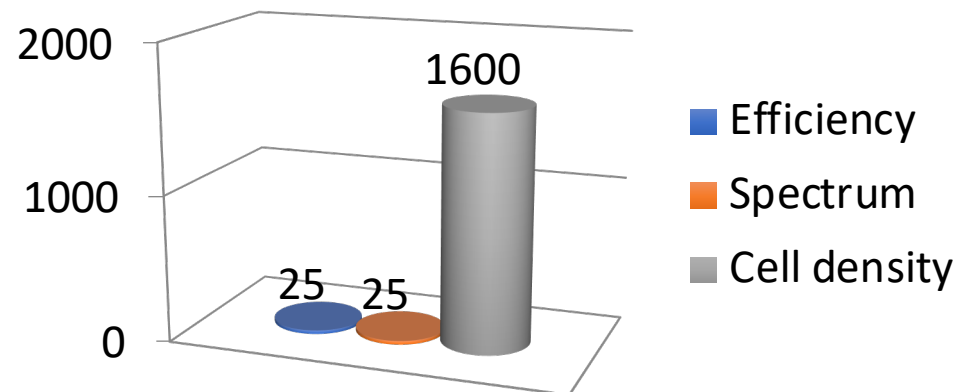


$$\frac{1000}{2 \cdot 3} = 167$$

Source: Nokia, enhance mobile networks to deliver 1000 times more capacity by 2020

This is in line with what happened in the past:

Cooper's law (of spectral efficiency): 1 million times improvement in the past 45 years

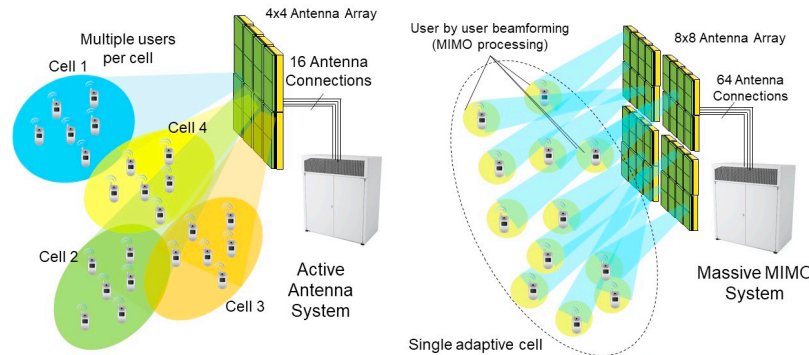


5G (and beyond) wireless technology

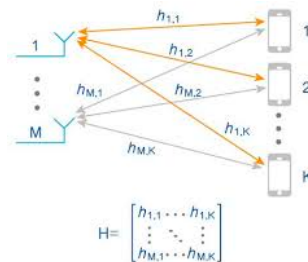
- Higher frequency band: from 20 MHz, to 100, ... to GHz
- Use of additional frequency bands: sub 6GHz, 29GHz, 60 GHz, THz...
- Use of advanced techniques to reduce interference: Coordinated Multi Point (CoMP):
 - coordinated scheduling: coordinate resource allocation across cells (time/frequency)
 - coordinated beamforming: coordinate beams across cells to reduce their interference
 - joint transmission: coordinate transmission from different cells towards the same user (coherent or non coherent)

- MIMO systems for:

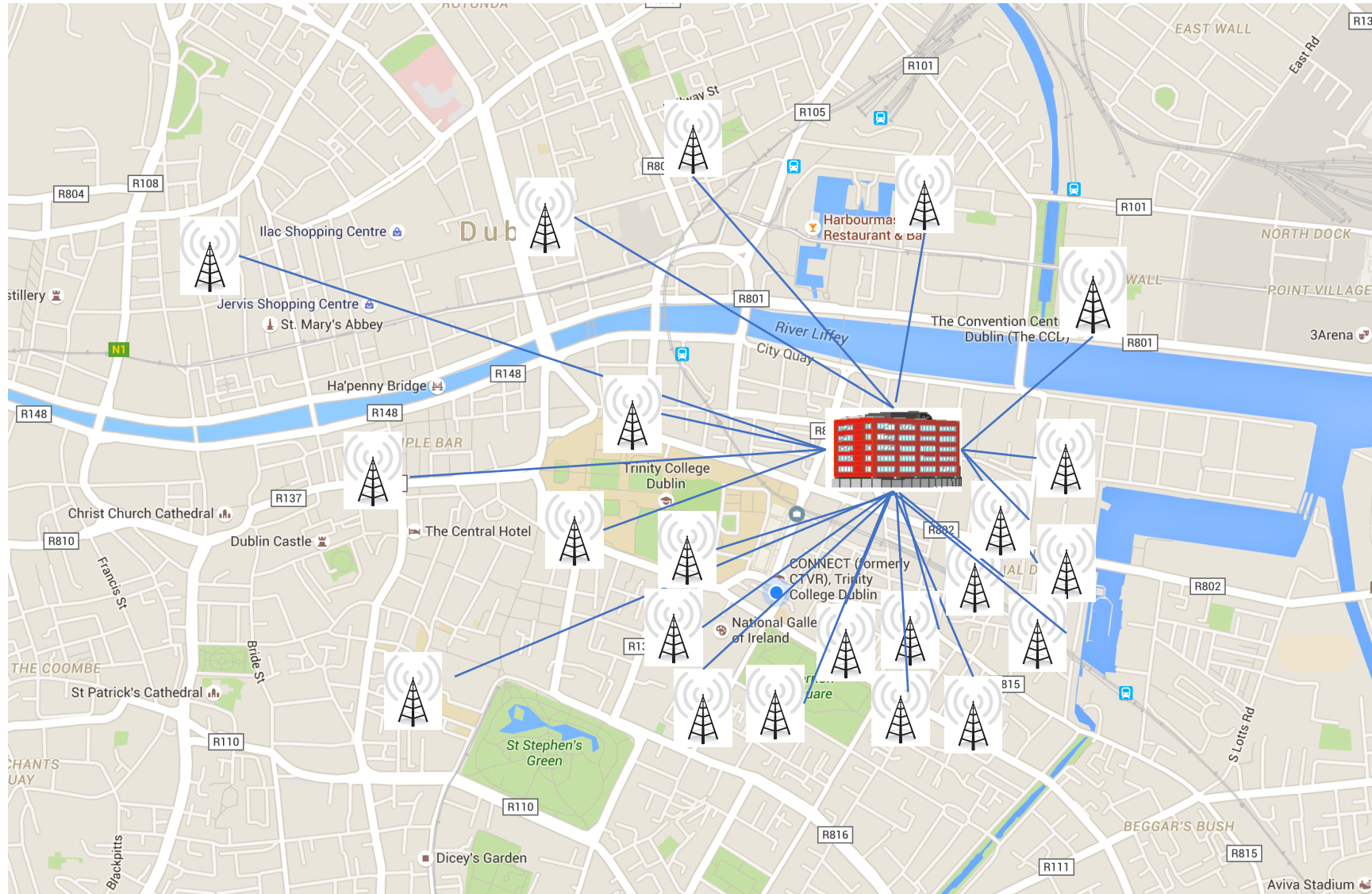
- Beamforming



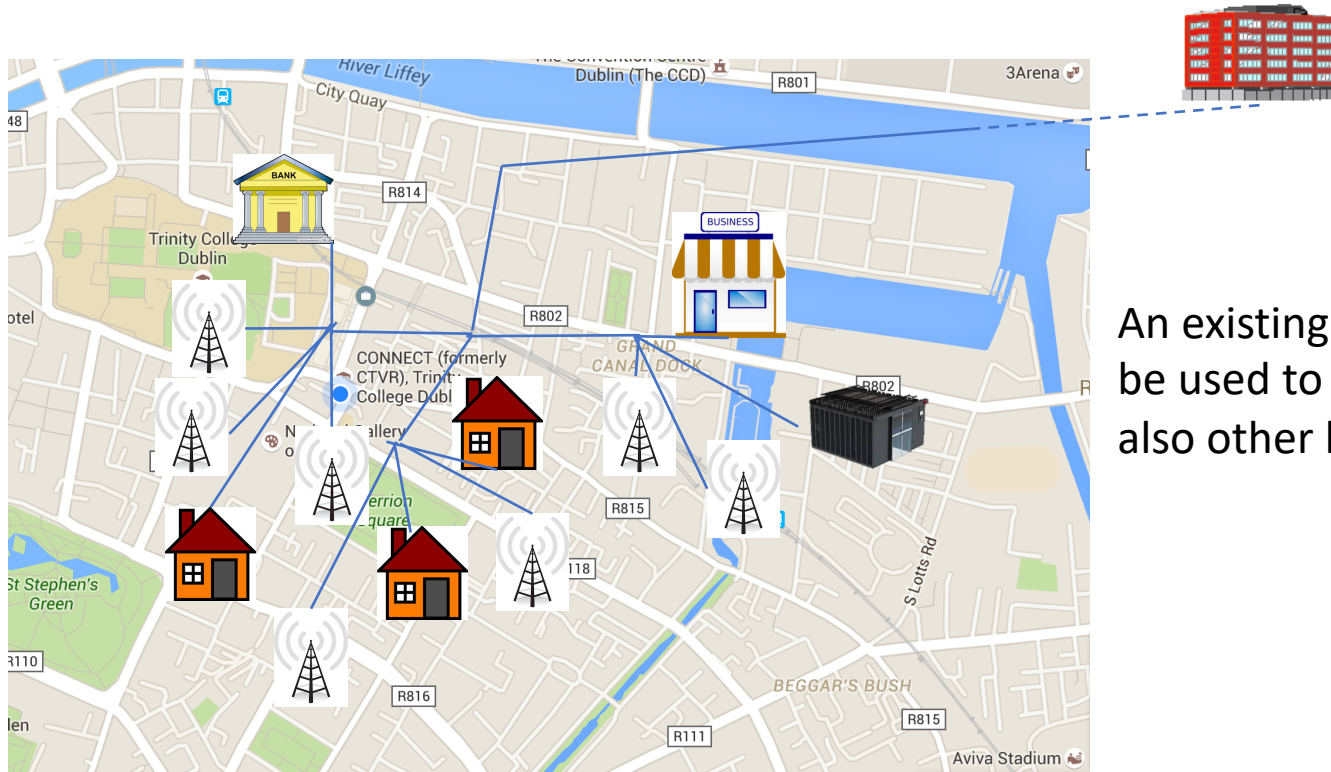
- Spatial multiplexing



The problem with cell densification



Shared PON for mobile backhauling



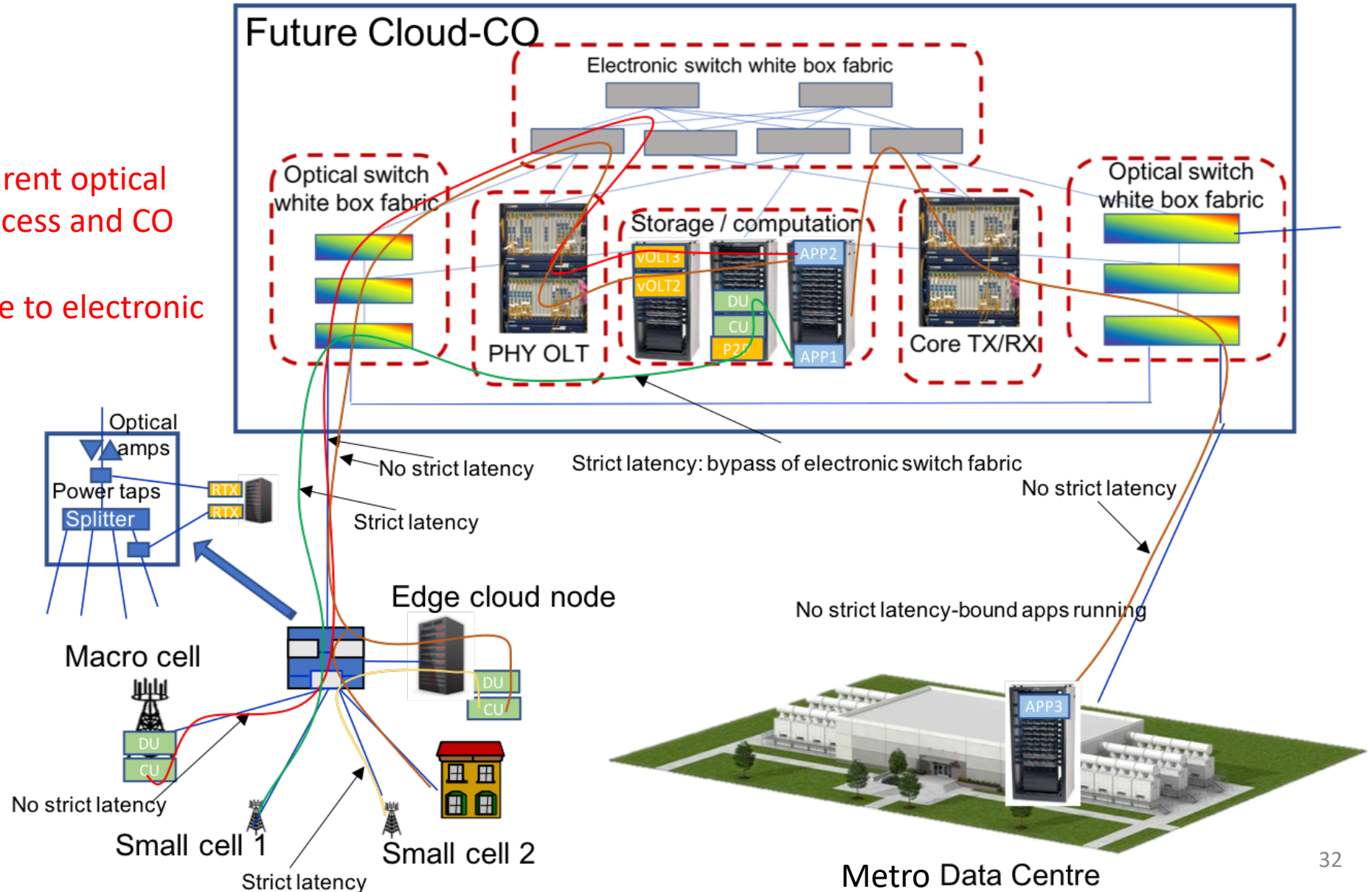
An existing FTTH infrastructure can be used to serve mobile cells, but also other businesses

- An optical access network, if well architected can allow service multiplexing: any access point (a home, a macro cell, a small cell, a business, a micro cache or small data center) can request assured capacity from the low Mb/s to multiple 100s Gb/s.

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

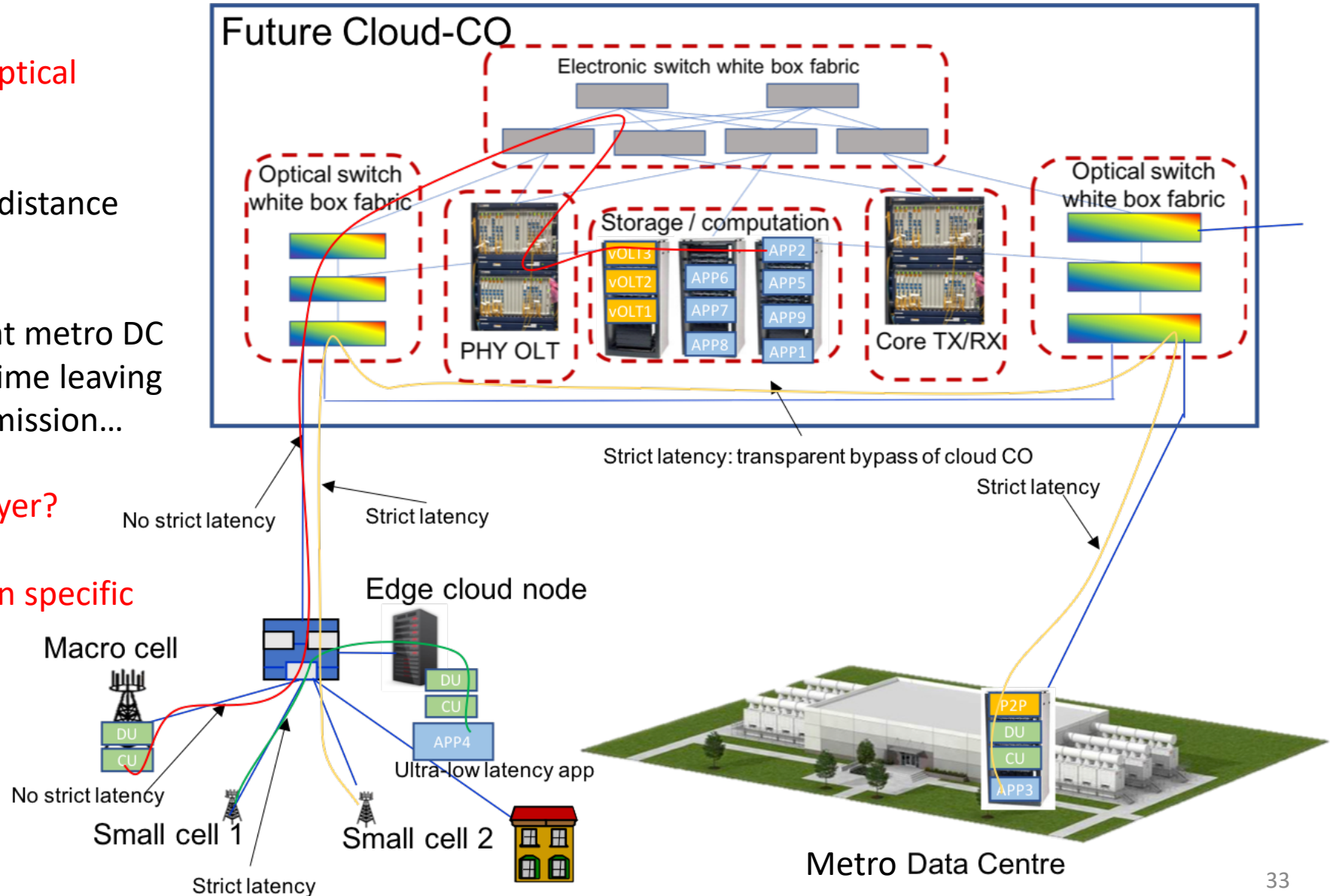
Orchestration of transparent optical connections across the metro

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

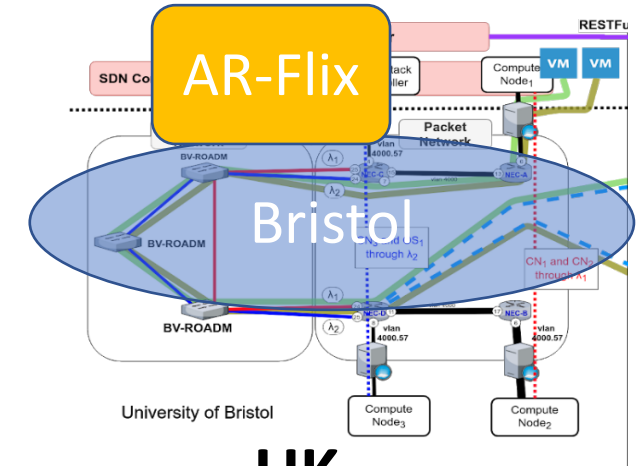


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Practical use case demonstration

- A large UK Operator (Bristol) provides network connectivity to a large content providers (AR-Flix) in the UK. The content provider decides it also wants to access the Irish market and asks Bristol to provide high-QoS connectivity to wireless users in Ireland. Its service require “guaranteed performance” to work seamlessly.

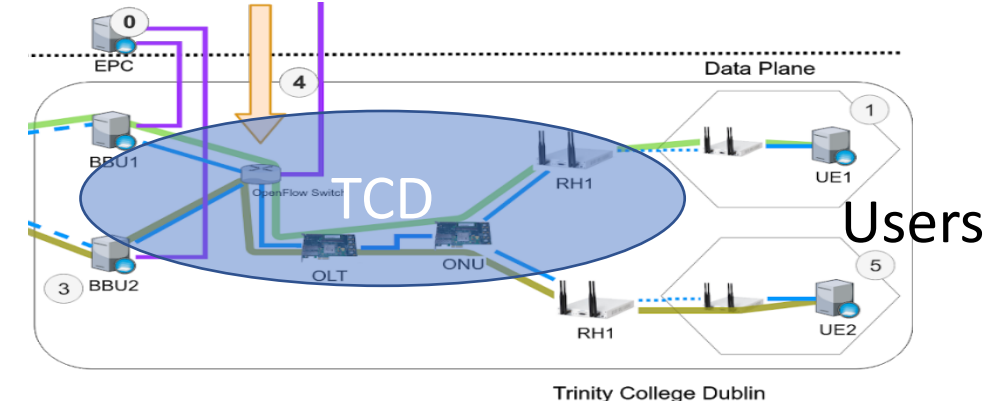


UK



Ireland

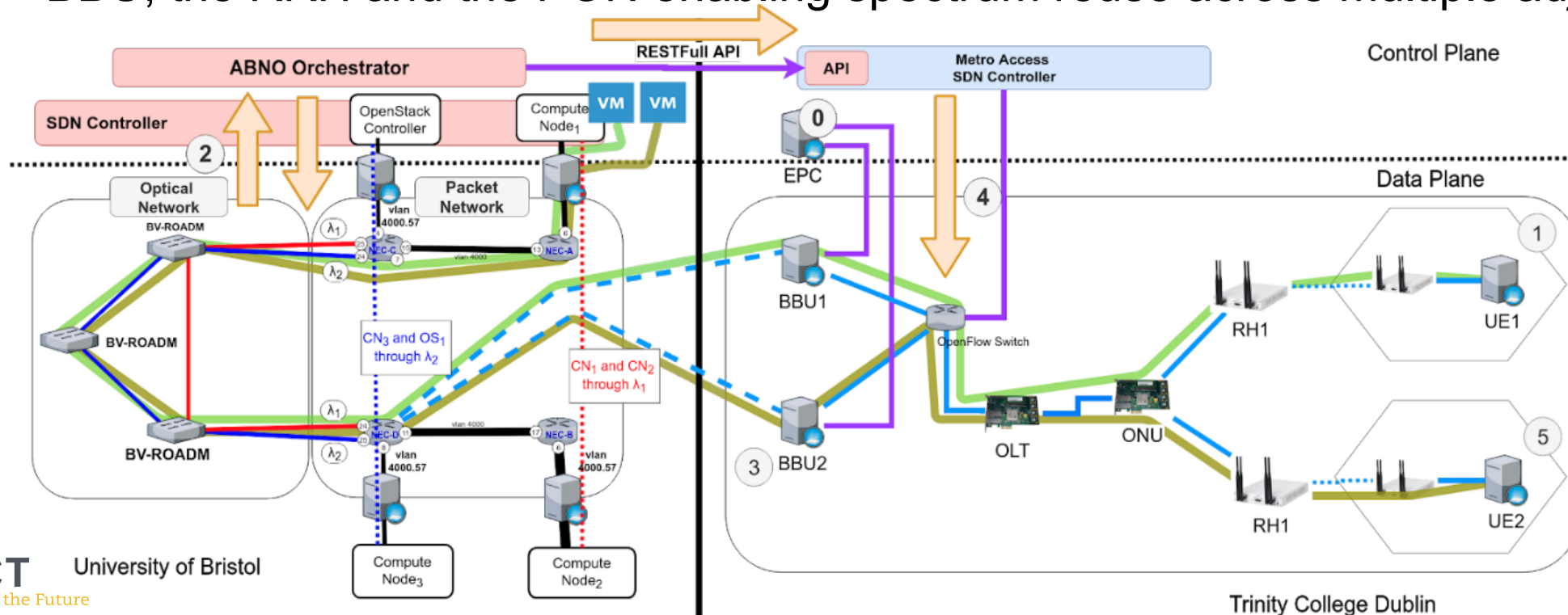
- Bristol thus leases wireless capacity from TCD (which owns the wireless license in Ireland), but it wants to minimise its leasing cost, thus dynamically request only the capacity (wireless spectrum and optical bandwidth) that is actually required by the users, while the remaining is allocated to users of local content.



Trinity College Dublin

DEMO Setup

- Optical core network connected to servers representing content providers (UnivBris)
- Wireless edge network with fronthaul operating over fibre access PON (TCD)
- SDN system controlling:
 - optical core path and computing resources (UnivBris);
 - liaise with TCD controller for configuring TCD access network: adaptation between the BBU, the RRH and the PON enabling spectrum reuse across multiple adjacent cells.



Demo live



<https://www.dropbox.com/s/tvp6il8dbol60em/ECOC%202019%20OW%20Demo.avi?dl=0>

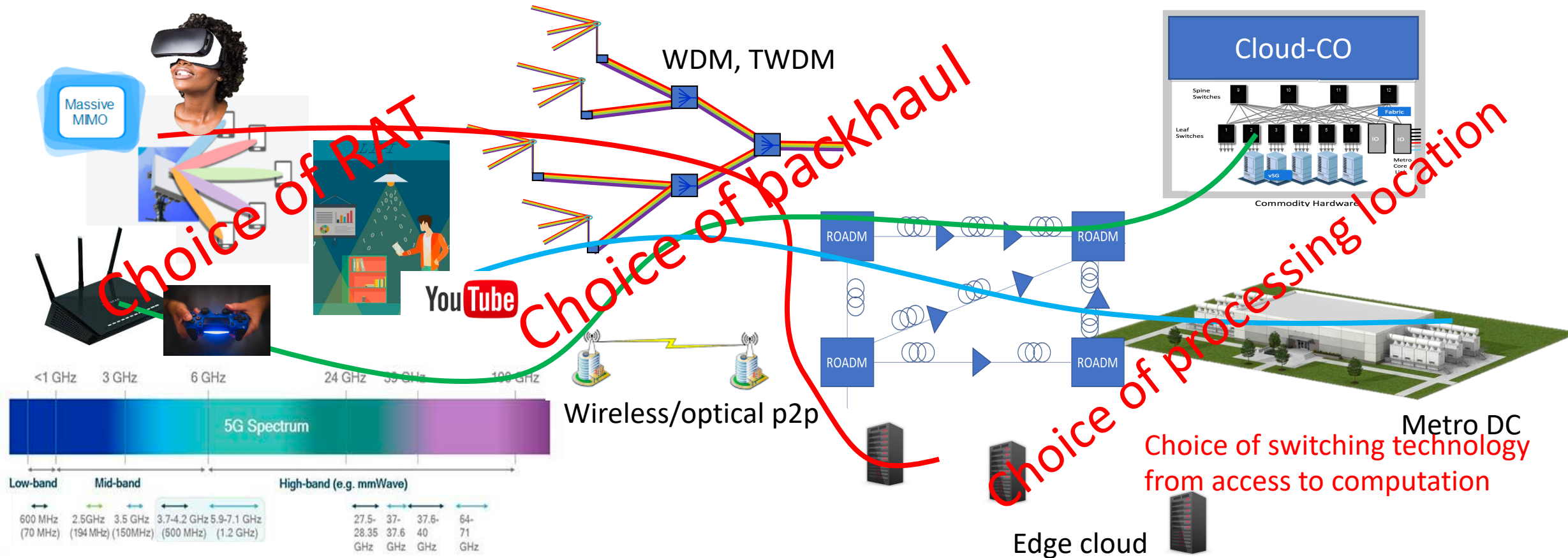
Conclusions and Challenges

- SDN control across all layers can create great opportunities
 - The network really needs new revenue streams (.. to pay for 5G, etc.)
➔ Which new applications and services brought to the network??
- Providing new performance is a good start..
 - Low latency, bounded latency and availability
 - Virtualisation for customization of network service (like in the DC but over the network scale)
- The NFV/SDN approach has the ability to bring this through automation, but...
 - ...Higher reconfigurability brings higher complexity in decision making
 - How to decide and define exact requirements (processing power, latency, bandwidth)?
 - Scalability issues to be addressed
 - How to scale QoS for individual flows?



We are considering the horizontal orchestration

- Interconnect multiple domains, each with multiple technologies



Technologies are so different and variable that end-to-end statistical characterisation might be the only option

What about the vertical orchestration?

In addition to orchestrating physical domains.. orchestrate the protocol stack...

