

# Smart Internet Lab

The UK's First Urban 5G Test-Network  
5G Deployment & Opportunities

24th April 2018



# Topics

- Purpose of Test Network
- Infrastructure & Connectivity
- Cloud Network & 5G Exchange
- Summary of Opportunities
  
- Q/A

## University of Bristol Smart Internet Lab

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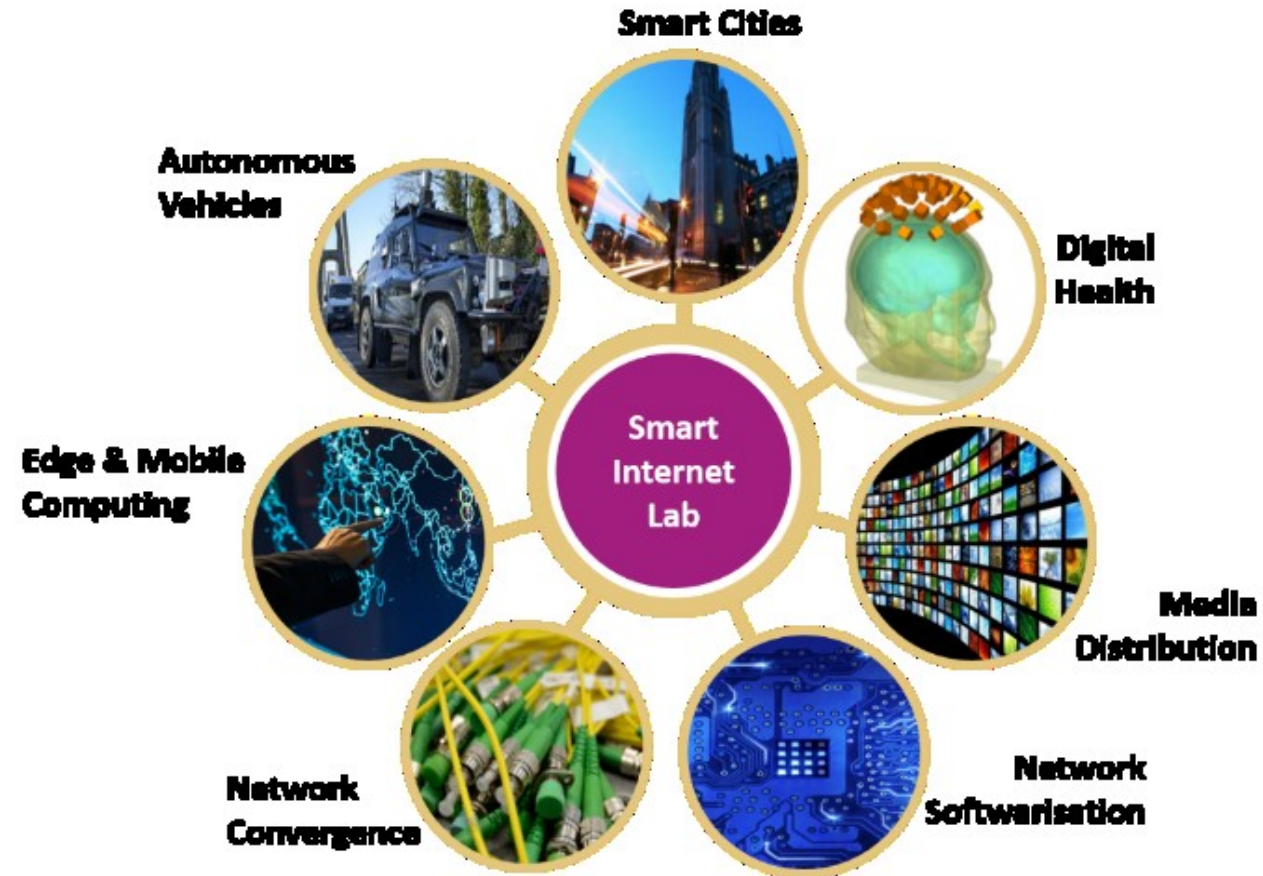
Dr. Hamid Falaki

*Consultant,  
Department of Electrical & Electronic Engineering*

# University of Bristol

## Smart Internet Lab

- Provides a holistic approach to design both hardware and software combined so that it solves critical problems in t' global Internet evolution.
- Brings together end-to-end, wired / wireless network design and optimisation through expertise in:
  - [Communication Systems & Networks \(CSN\) Research Group](#)
  - [High Performance Networks \(HPN\) Research Group](#)
  - [Photonics Research Group](#)



# 5G & UK's Motivation

...we are determined that the UK is a world leader in 5G so that we can take early advantage of the benefits that this new technology offers.

<https://www.gov.uk/government/publications/next-generation-mobile-technologies-an-update-to-the-5g-strategy-for-the-uk>



Department for  
Digital, Culture  
Media & Sport

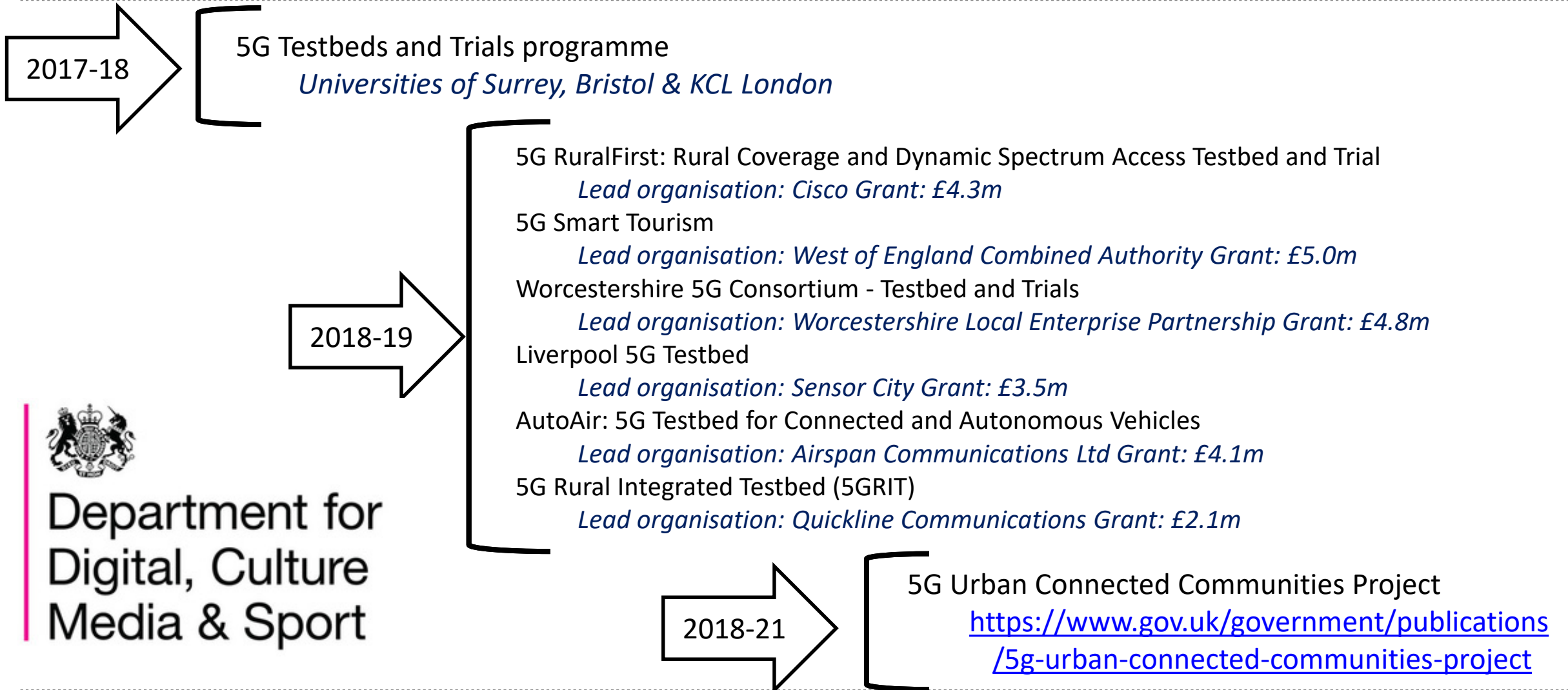


*Matt Hancock*

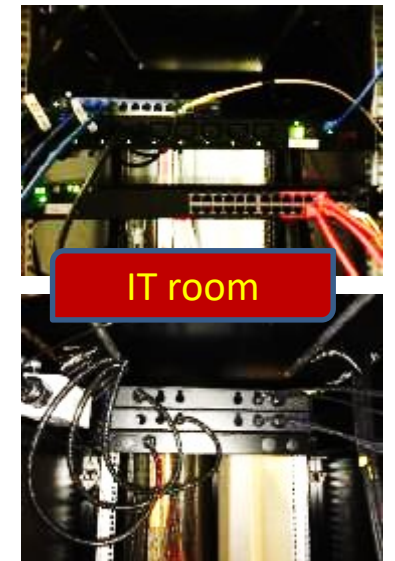
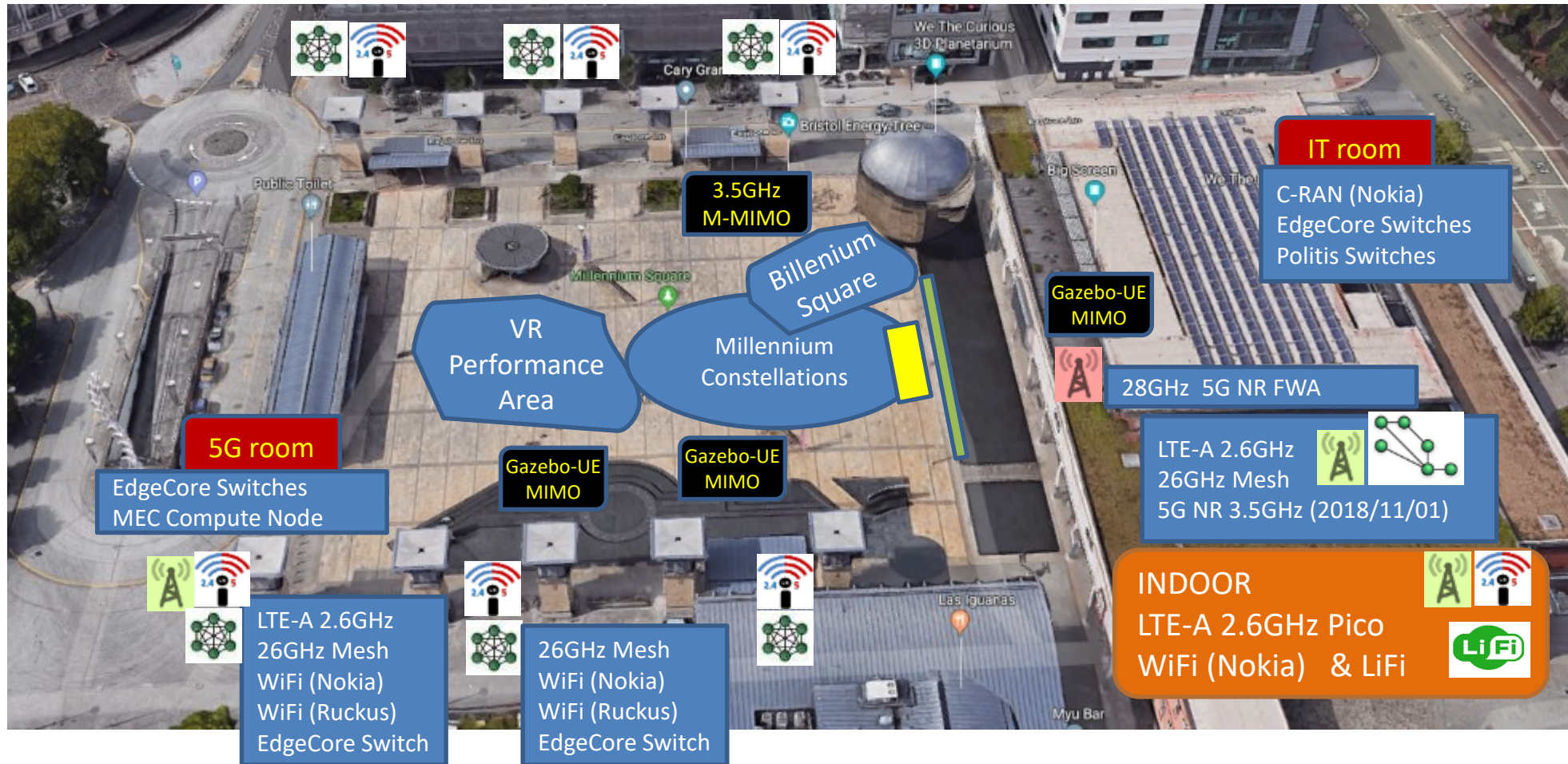
The screenshot shows the GOV.UK website interface. At the top, there is a search bar and navigation links for 'Departments', 'Worldwide', 'How government works', 'Policies', 'Publications', 'Consultations', and 'Statistics'. The main content area features a 'Home' link and a '5G' graphic. The central focus is a 'Press release' titled '£25m for 5G projects on the anniversary of the UK's Digital Strategy'. The text of the release states: 'On the first anniversary of its Digital Strategy, the government has today announced the winners of a £25 million competition to pave the way for a future rollout of 5G technology in the UK.' At the bottom of the release, it is noted as 'Published 10 March 2018' and 'From: Department for Digital, Culture, Media & Sport'.

<https://www.gov.uk/government/news/25m-for-5g-projects-on-the-anniversary-of-the-uks-digital-strategy>

# Project Funding



# University of Bristol 5G Test Network



# 5G Show Case & Demonstrations

## 17-18 March 2018

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### The 5G fellowship programme

- Dimitra Simeonidou - Bristol 5G Testbed: Opportunities for Digital Transformation
- Stuart Nolan - Reaching out - Touch and 5G
- Jake Applebee - What is the future of music as a cultural experience?
- Tim Kindberg - Experiences for Crowds
- Ginger Coons - 5G for Social Good

### Artistic commissions

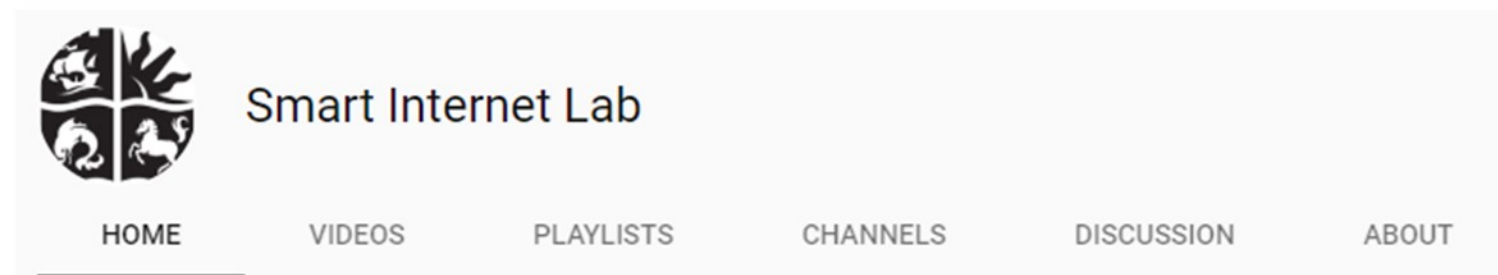
- From the light of the fire, our dancing shadows, by Kaleider Exploring two real world. Virtual Reality Demo
- Billennium Square (After Ballard), from Uninvited Guests and Duncan Speakman. An artist collaborates with participants to imagine possible futures for this public place. Augmented Reality Demo.
- Millennium Constellations, from visual artist Joanie Lemercier Venturing into the heart of a black hole and back out. Data visualisation

### University of Bristol's 5G Technology Demonstrations

- 5G Exchange & Network Slicing between two islands
- Smart City Safety
- 5G in a box
- Car Automation & Data Visualisation
- Radio Frequency Propagation & Visualisation
- 3.5GHz 5G New Radio Massive MIMO Service Demonstration
- 28GHz 5G New Radio service Demonstration
- 26GHz Mesh backhaul network service demonstration

# Smart Internet Lab 5G Showcase

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The 5G Show case link will be placed the Smart Internet Lab YouTube channel.



# UK - Spectrum Auction

Extracts from BBC-Click

<https://www.youtube.com/watch?v=5hfZxsGcWB4>



# 5G UK Test Network

## Infrastructure & Connectivity

- The journey to 5G (a wireless perspective)
- 5G Technologies
- Testbed purpose
- Testbed architecture

# 3<sup>rd</sup> Generation Partnership Programme



- GSM
- Single Carrier
- GMSK
- TDMA
- 9.6 / 9.6 kbps

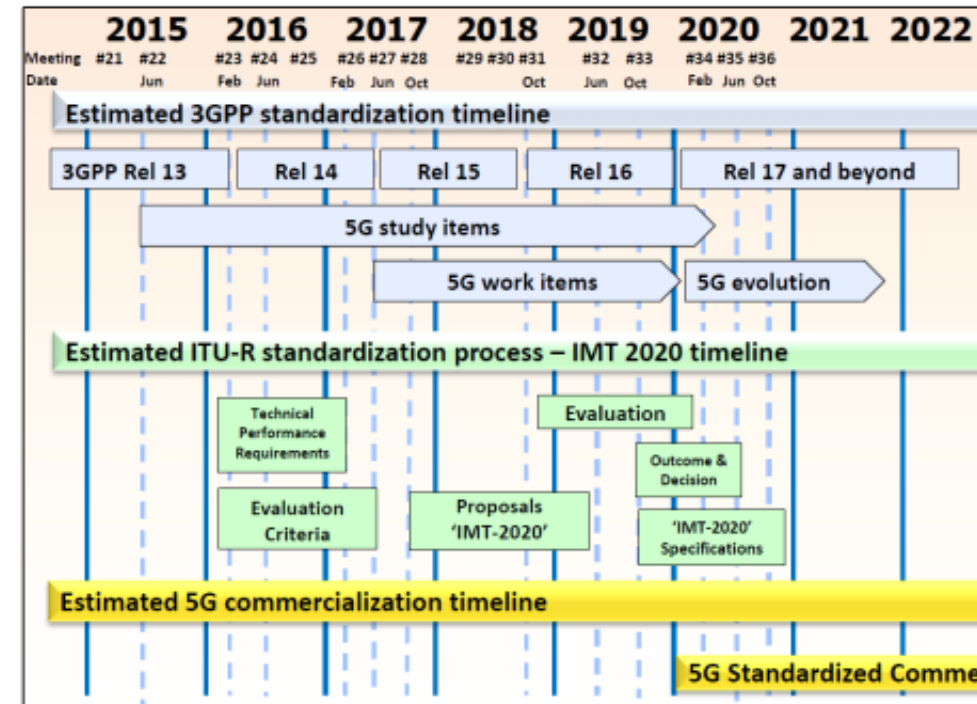
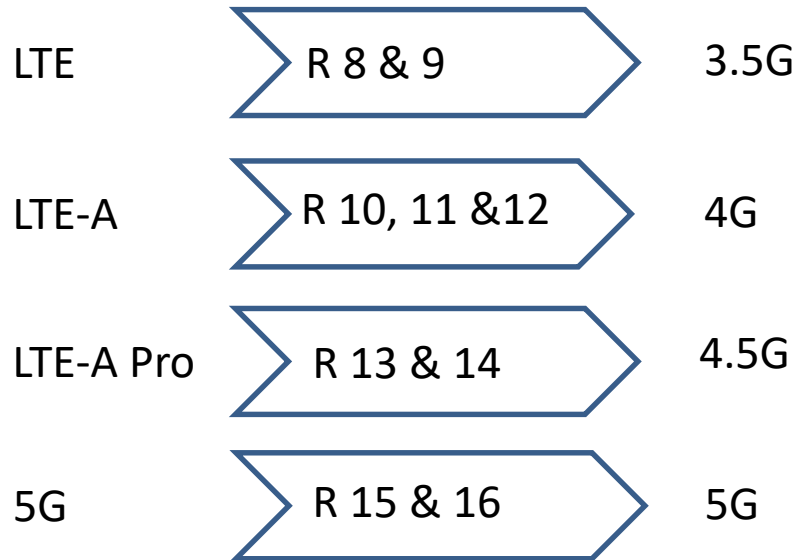
- UMTS
- Single Carrier
- Spread Spectrum
- CDMA
- 14.4 / 5.8 Mbps

- LTE
- Multicarrier
- OFDM (QAM)
- TDMA
- 300 / 75 Mbps

- NR
- Multicarrier
- OFDM (QAM)
- OFDMA
- 1 / 1 Gbps
- MIMO 8x8
- Carrier Aggregation

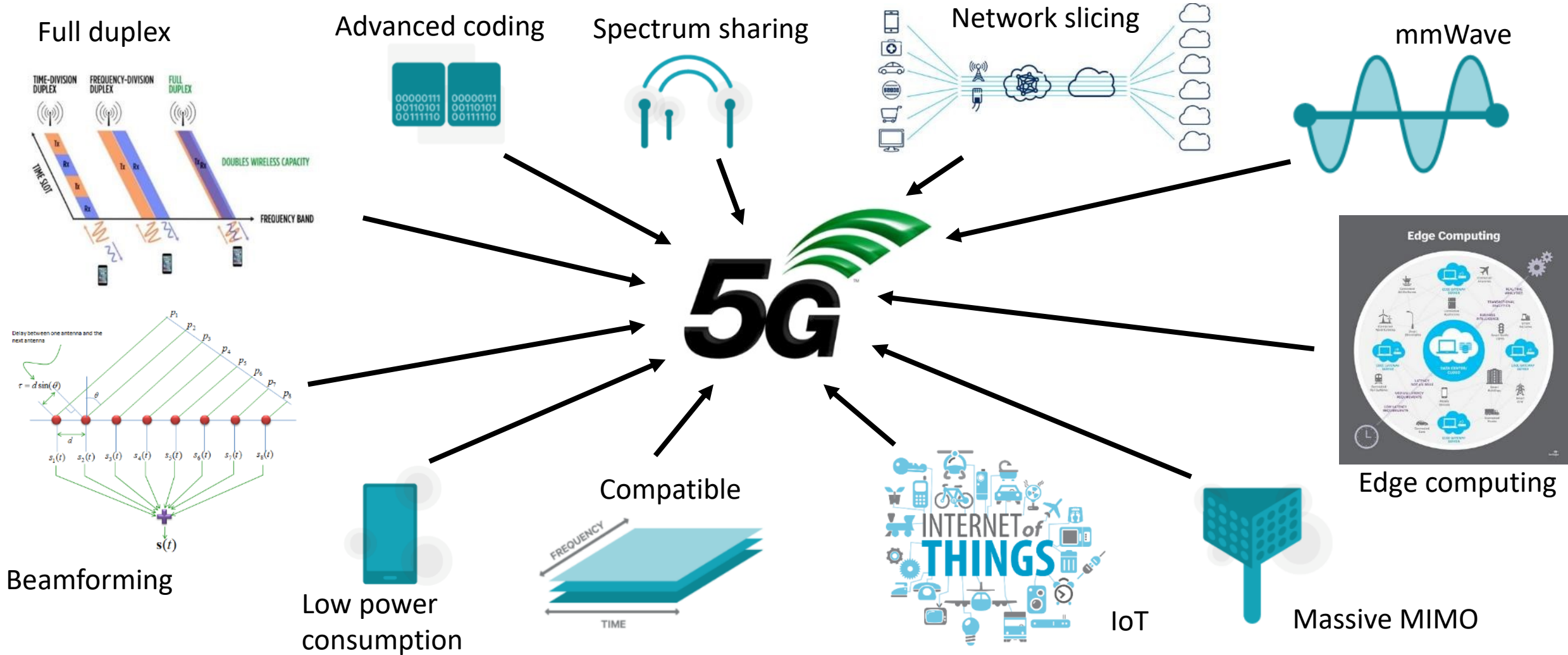
- 5G is the first standard with no fundamental change to air interface
- The trend is towards Multicarrier OFDM systems
- Advances in hardware allow high complexity QAM modulation schemes
- Designed for licensed cellular bands, until now

# 5G NR (new radio)



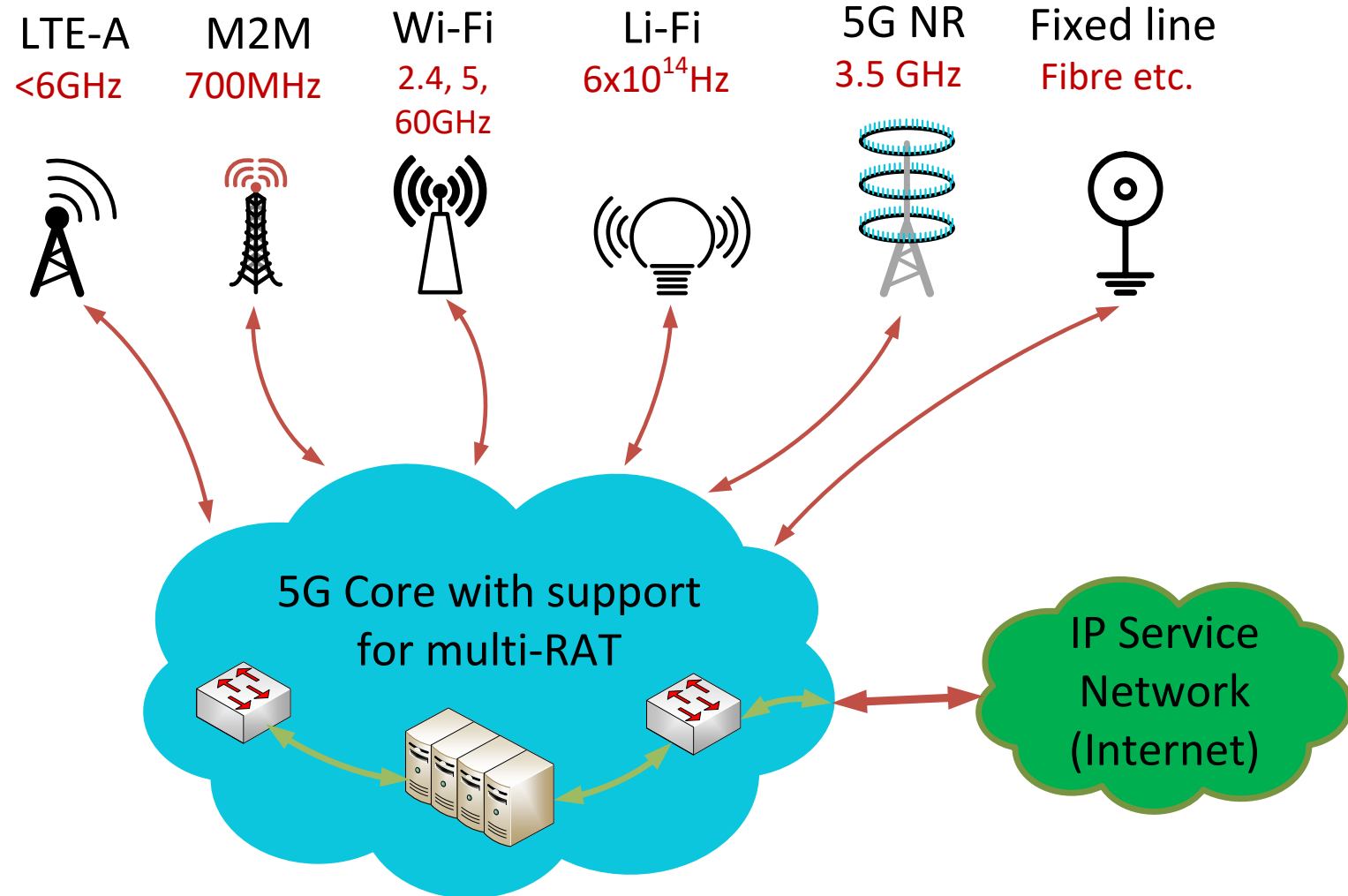
- 5G NR has evolved from Telcos
- Therefore will operate in licensed bands Sub 6GHz and 26-28GHz
- Has OFDM basis – evolved from LTE waveform
- MaMIMO, Beamforming, FD-MIMO, Carrier aggregation, LAA etc.

# Technology



# Heterogeneous Integration

- 5G will be a multi-RAT solution
- All managed by the core network
  - 2G, 3G, LTE, LTE-A
  - 5G NR (massive MIMO & mmWave)
  - Wi-Fi ac and ax, WiGig
  - Fixed line, LiFi, etc
- Evolution from discrete and separately managed networks
- Big step to combine IEEE with 3GPP
- Flexible and adaptive core

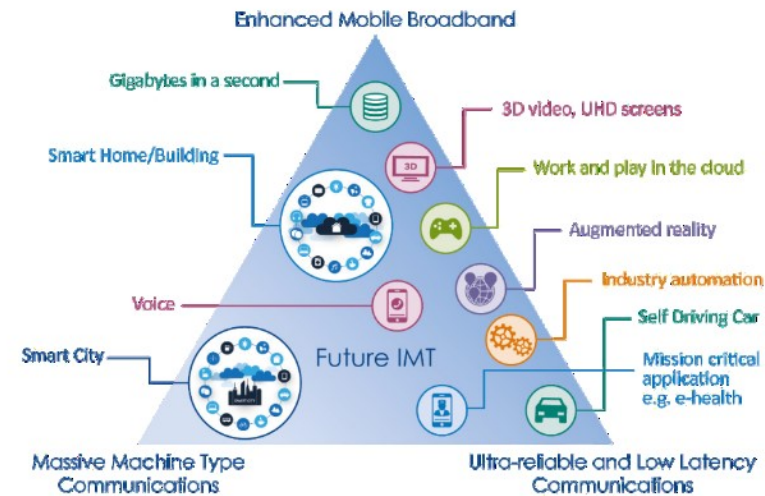


*An intelligent core network is imperative*

# Testbed requirements

“Create a public demonstration and testbed of 5G technologies”

- Showcase 5G technology (wireless and non-wireless)
  - The artistic Layered Realities weekend
  - 3.5GHz Massive MIMO NR demonstrator
  - 5G UK Exchange
- Facilitate 5G experimentation
  - Deploy multiple technology types
  - Create robust/reliable network
  - Design for future proofing and reconfiguration
  - Allow remote access, interconnection and experimentation





# Technology



Dell T630



Corsa DP2100



Polatis 16x16



Ruckus T710



CCS Metnet



SM Fibre



Edgecore AS4610-30P



Massive MIMO

# Massive MIMO (indoor radio propagation)

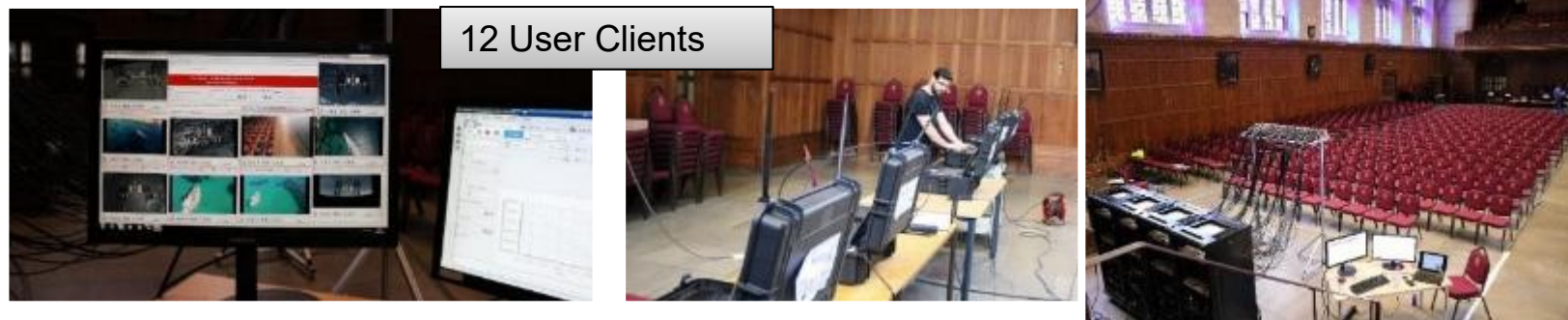
## Testing at Wills Memorial Building

- Evaluated the new Over The Air (OTA) sync method
- Demonstrated 12 video streams in UL & DL
- Ensured Reliability of Service
- Outdoor radio propagation was also carried out before the public demonstration

M-MIMO 3.5GHz Physical Layer



12 User Clients



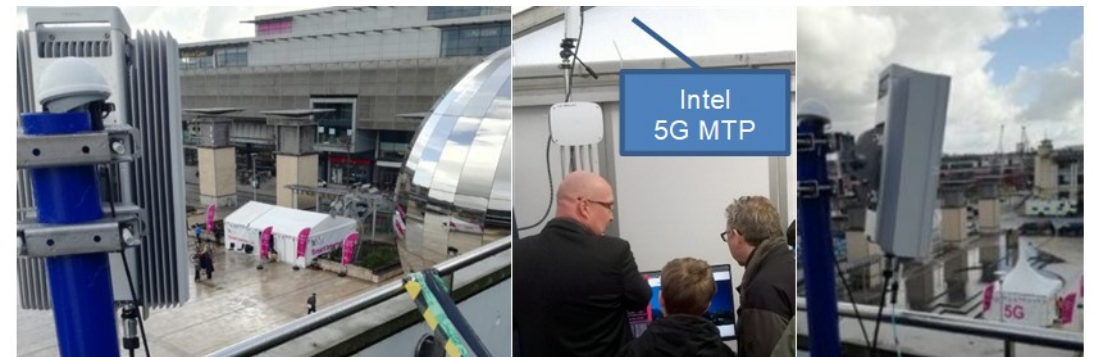
## 5G NR - 3.5GHz

- This system comprises a 128 antenna base station and 12 client devices. Operating in the pioneer band of 3.51GHz TDD, simultaneous transmission to all clients in 20MHz bandwidth yields over 80bits/second/hertz spectral efficiency

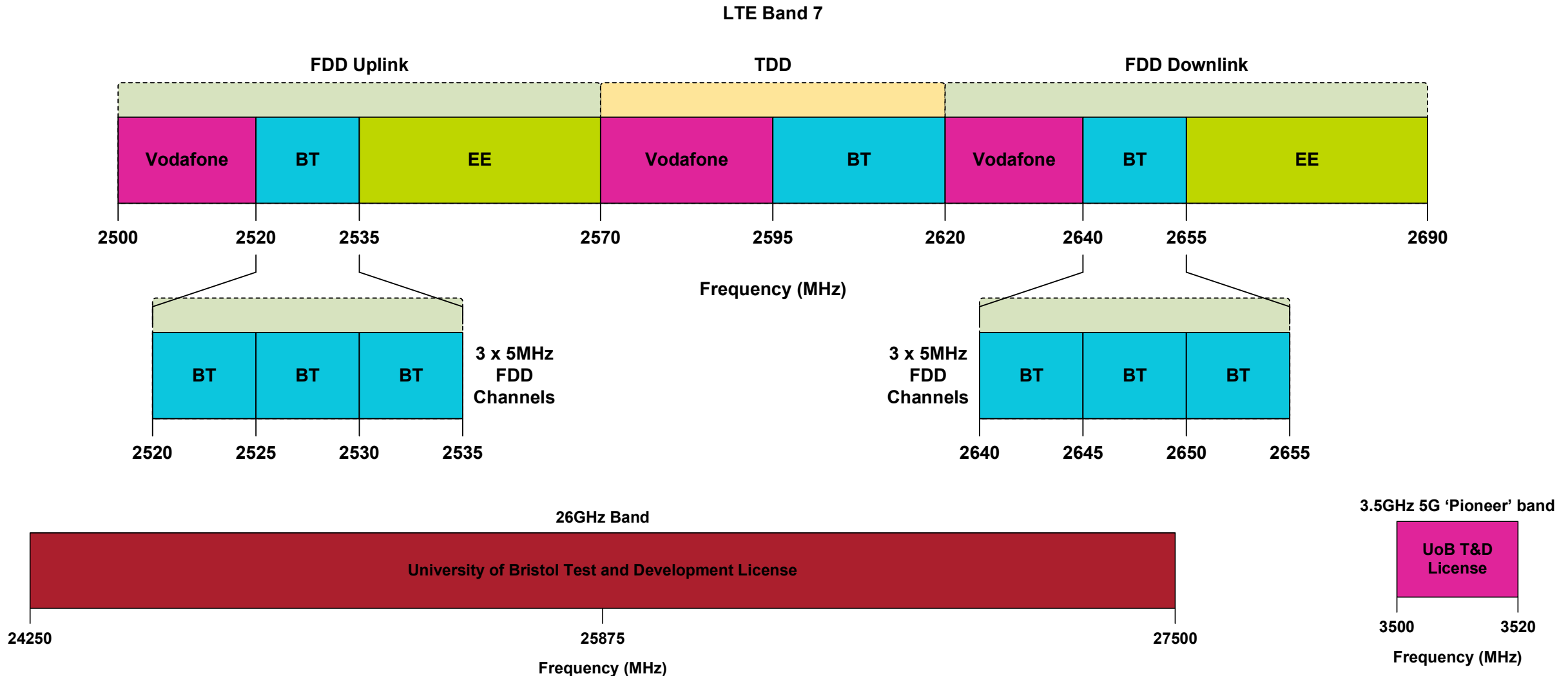


## 5G NR – 28GHz

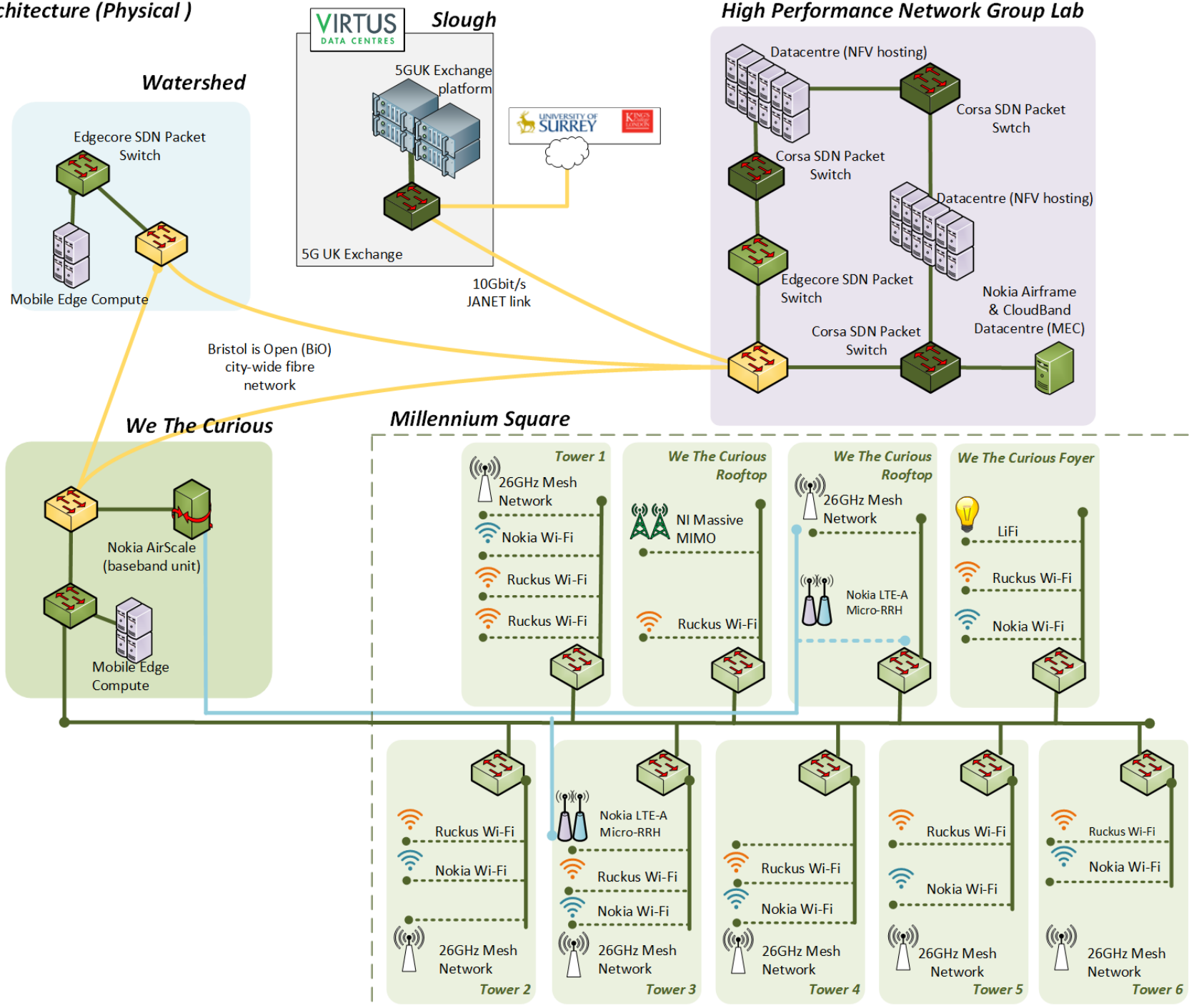
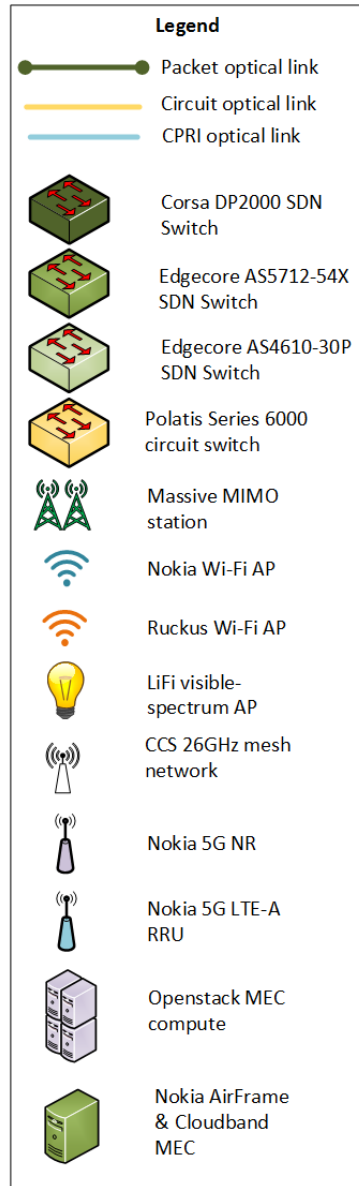
- 5G NR Fixed Wireless Access solution providing high capacity link between the balcony and the marquee in the Millennium square. The system deployed 2 component carrier aggregation based on the available 28GHz license, for a total of 200MHz channel bandwidth. This demonstrated throughput of 680Mbps observed within the marquee.



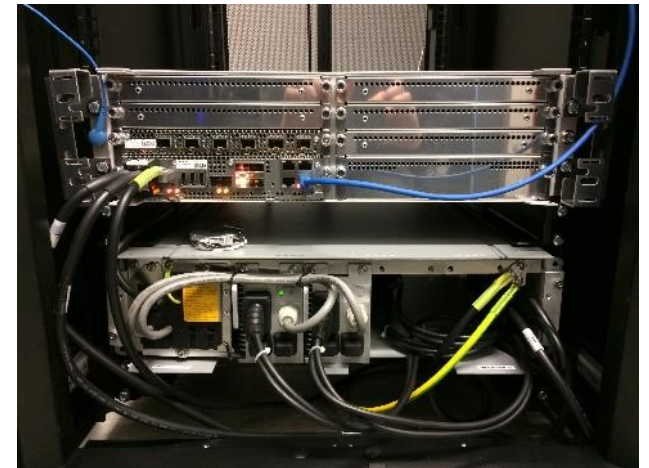
# Spectrum



# Architecture



# Installation

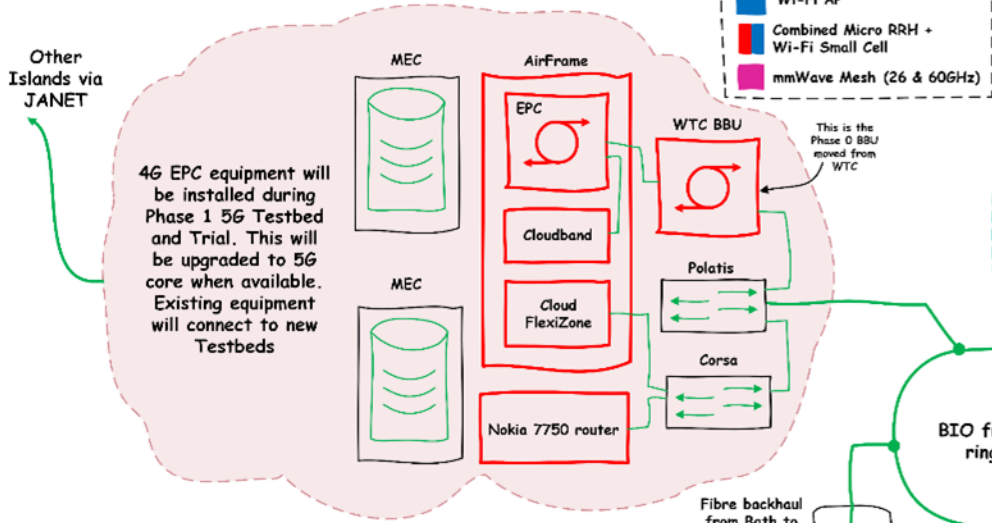


# Showcase

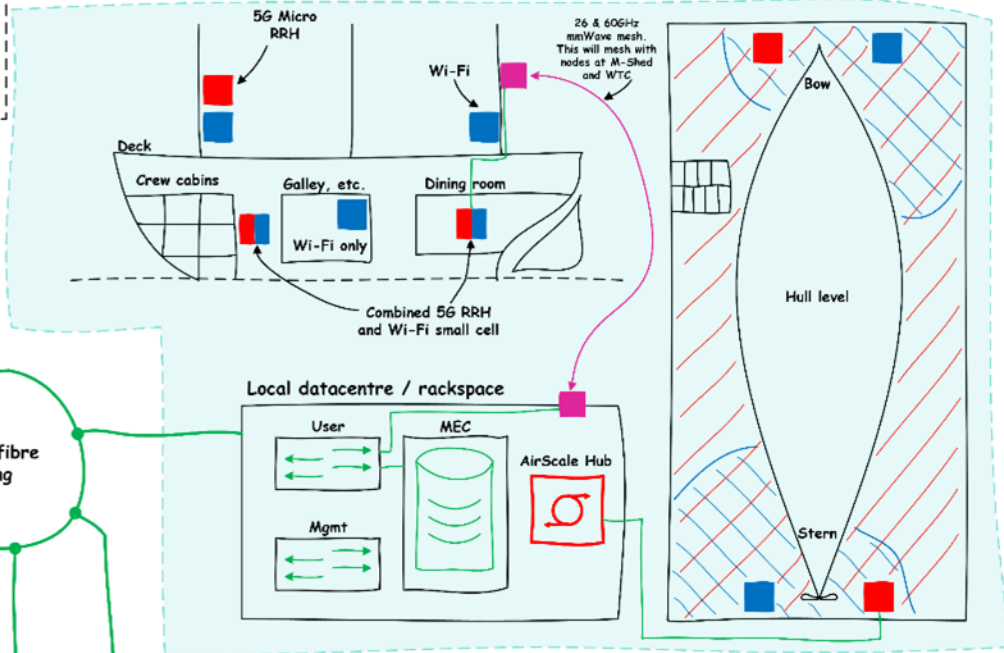


# Future

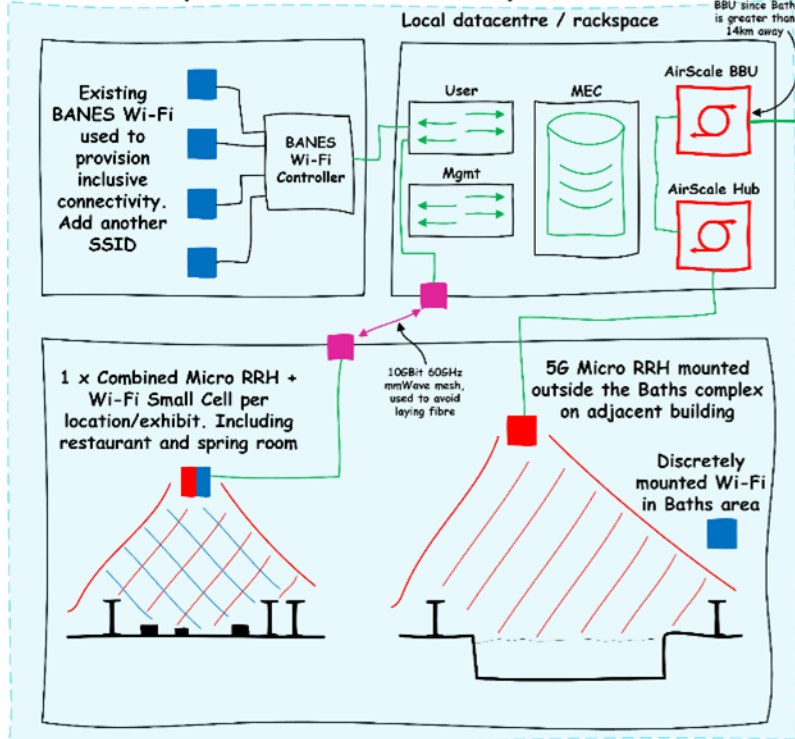
## Smart Internet Lab



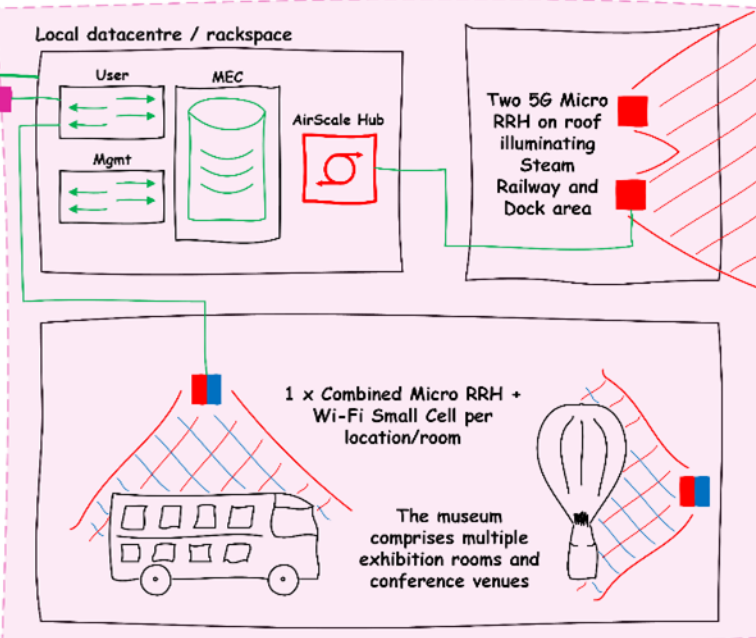
## SS Great Britain



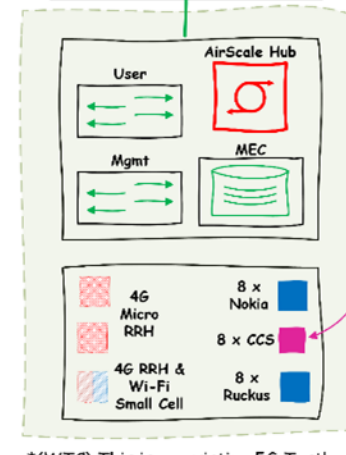
## Bath City Centre & The Pump Rooms



## M-Shed Museum



## We The Curious\*



\*(WTC) This is an existing 5G Testbed

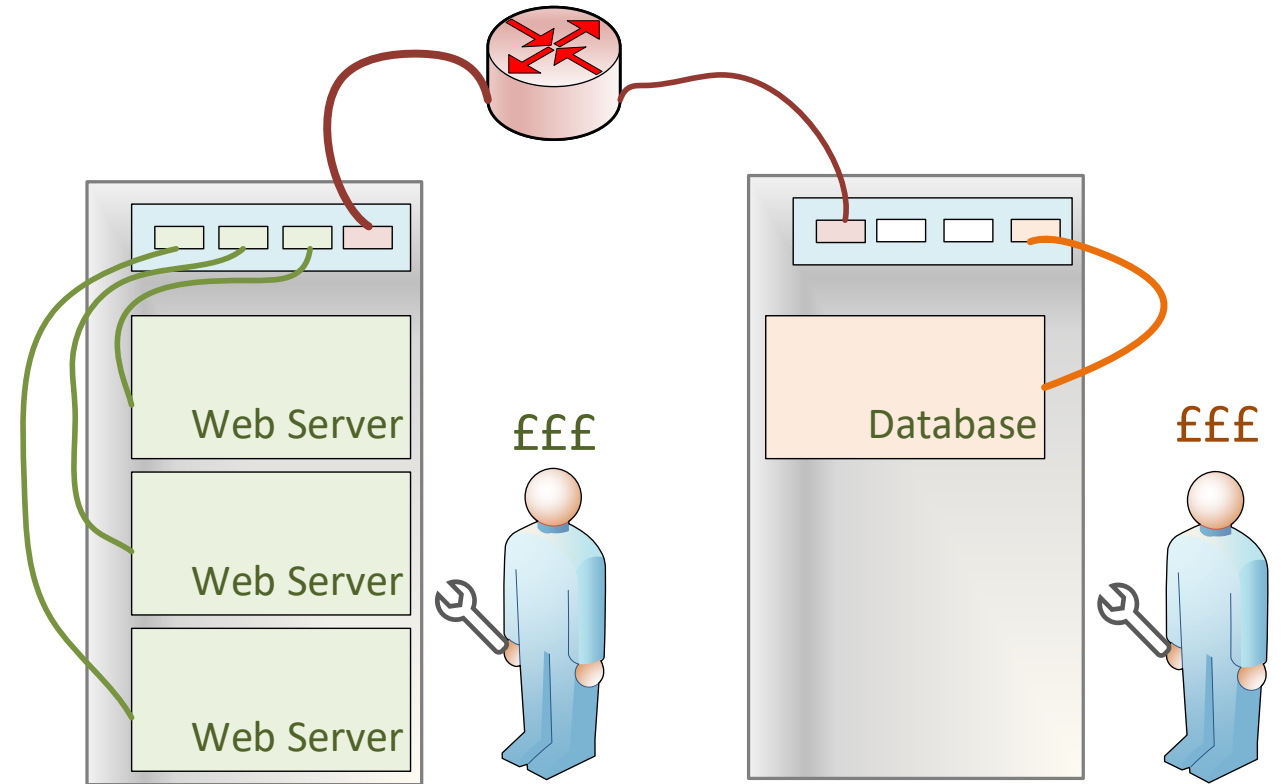


# 5G UK Test Network

## Cloud Network & 5G Exchange

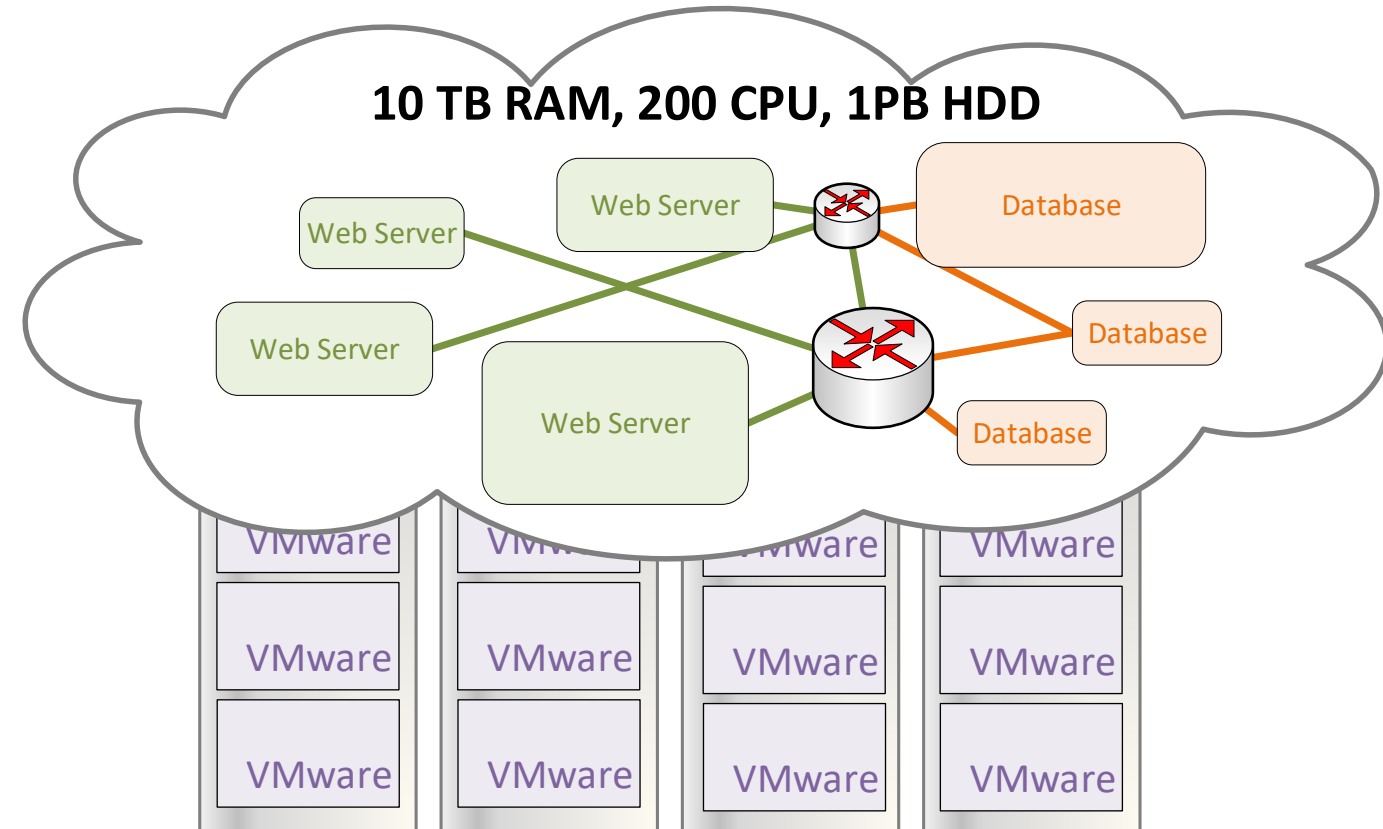
# Legacy Computing in Enterprise IT

- One physical machine; one application
- Services run on bare-metal
- Manual server deployment
- Manual network configuration
- Rigid, expensive and slow



# Cloud Computing in Enterprise IT

- Multiple hypervisors; numerous guests
- Services run virtually
- Automatic on-demand server deployment
- Automatic software-defined network configuration
- Flexible, inexpensive and fast



# Legacy Telecommunications

- One vendor; one network
- Design once, deploy once; repeat every ten years
- Stability is king; change is scary
- “Don’t rock the boat”

## MobileCom Ltd

1,000 minutes  
1,000 SMS  
1GB data

£20/month

- 99.999% uptime
- GSM Release x network
- 99% coverage
- UK PSTN

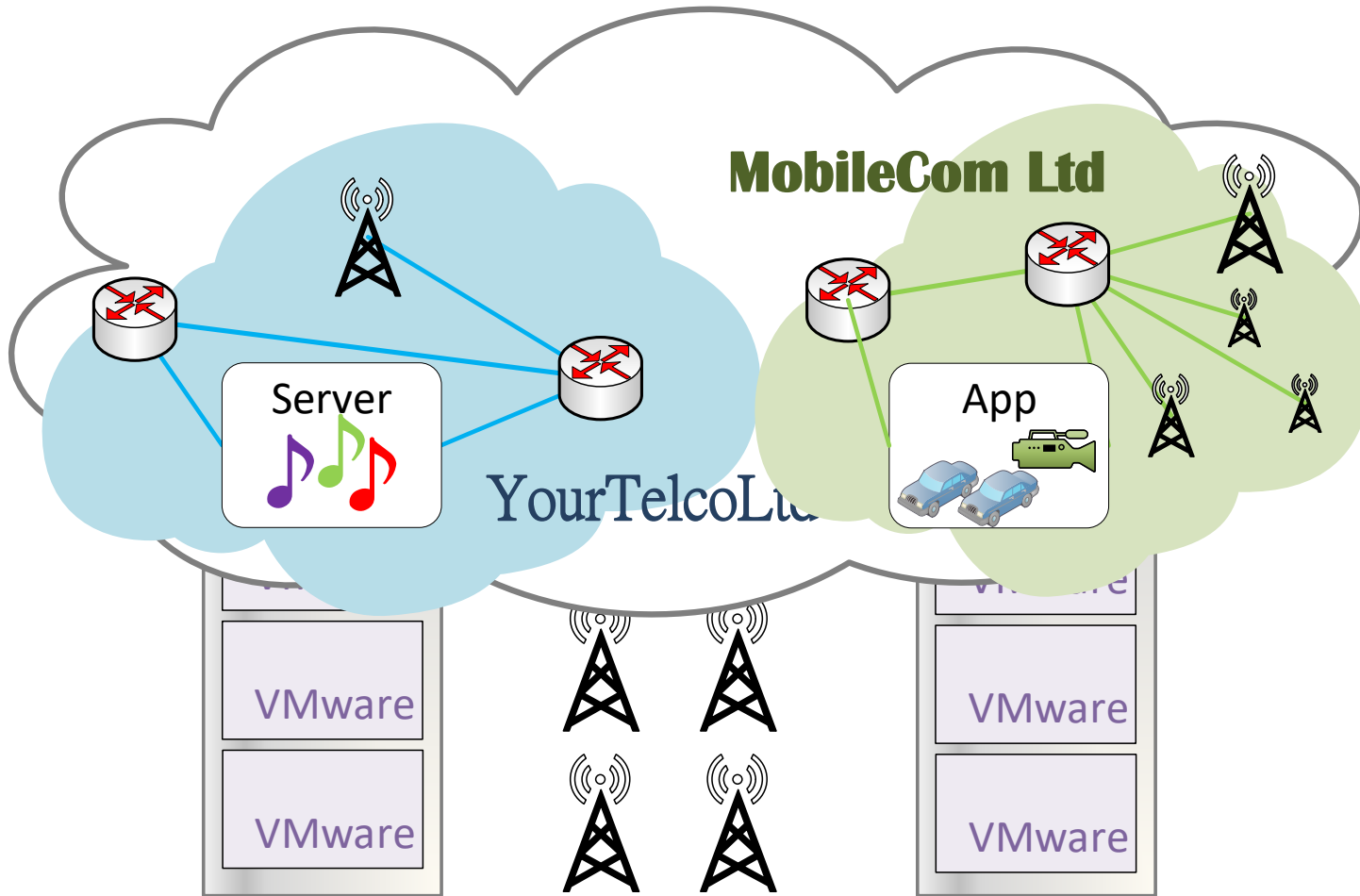
## YourTelco Ltd

500 minutes  
2,000 SMS  
1GB data

£18/month

- 99.999% uptime
- GSM Release x network
- 97% coverage
- UK PSTN

# Future 5G Network Operator



- Network infrastructure is virtualised
- Tailor-made niche 'overlay' networks
- Rapid deployment of network and compute applications

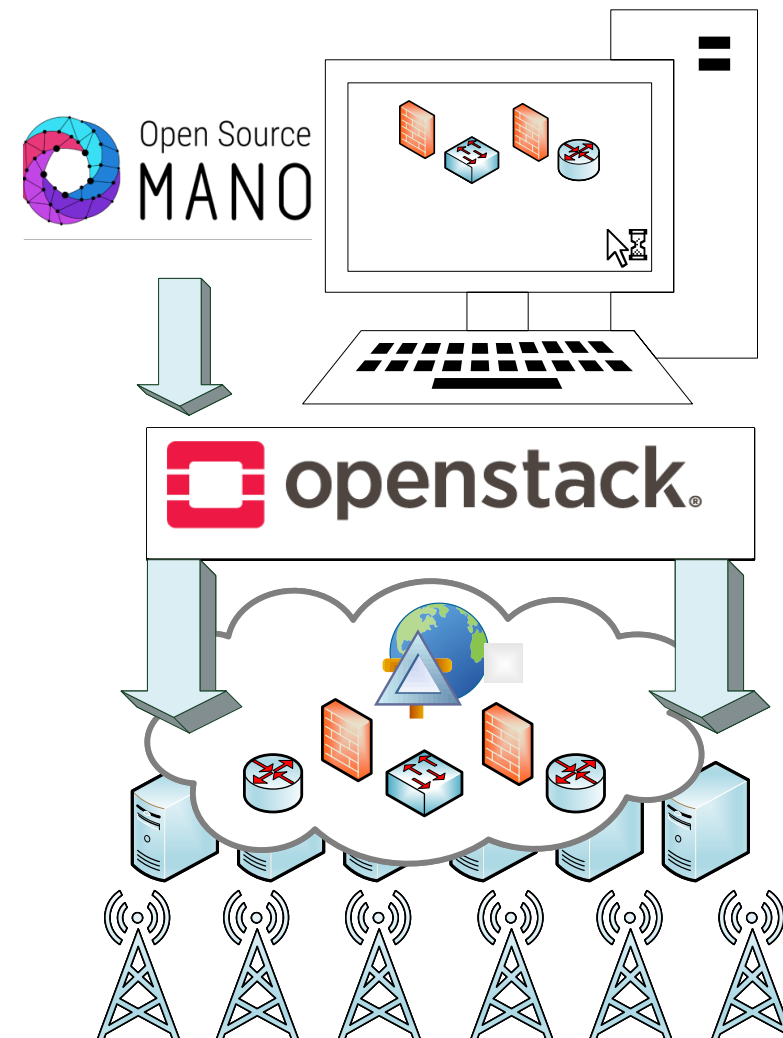
- MANO - **Management and Orchestration**
- Rulebook of descriptors that describe the connections and components of a virtualised environment
- Encompasses: -
  - Overseeing existing cloud orchestrators (Openstack, etc.)
  - **Virtual Network Function** lifecycle (i.e. starting, stopping) management
  - Overseeing existing Software Defined Network management (OpenDaylight, etc.)

# The MANO Vision

MANO orchestrator issues deployment requests of Virtualised Network Functions to VIM

Vendor-neutral Virtual Infrastructure Manager is deployed to control white-box hardware

Generic white-box hardware is deployed at-scale

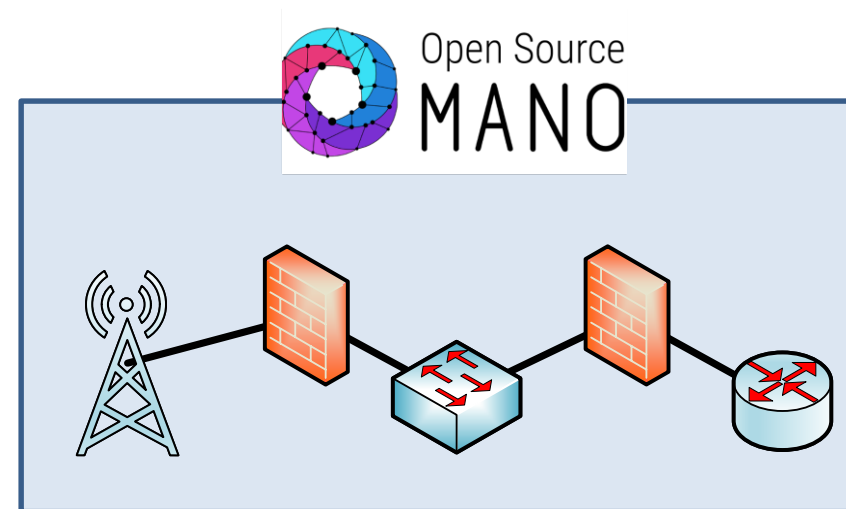
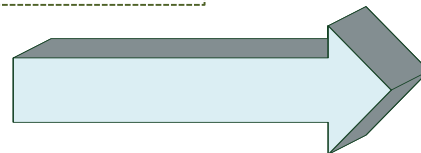


# The MANO Experience

- Network Engineers become programmers (or at least a scripters)
- Each user experiences a unique service according to their subscription
- Network changes are fully automated, frequent and transparent



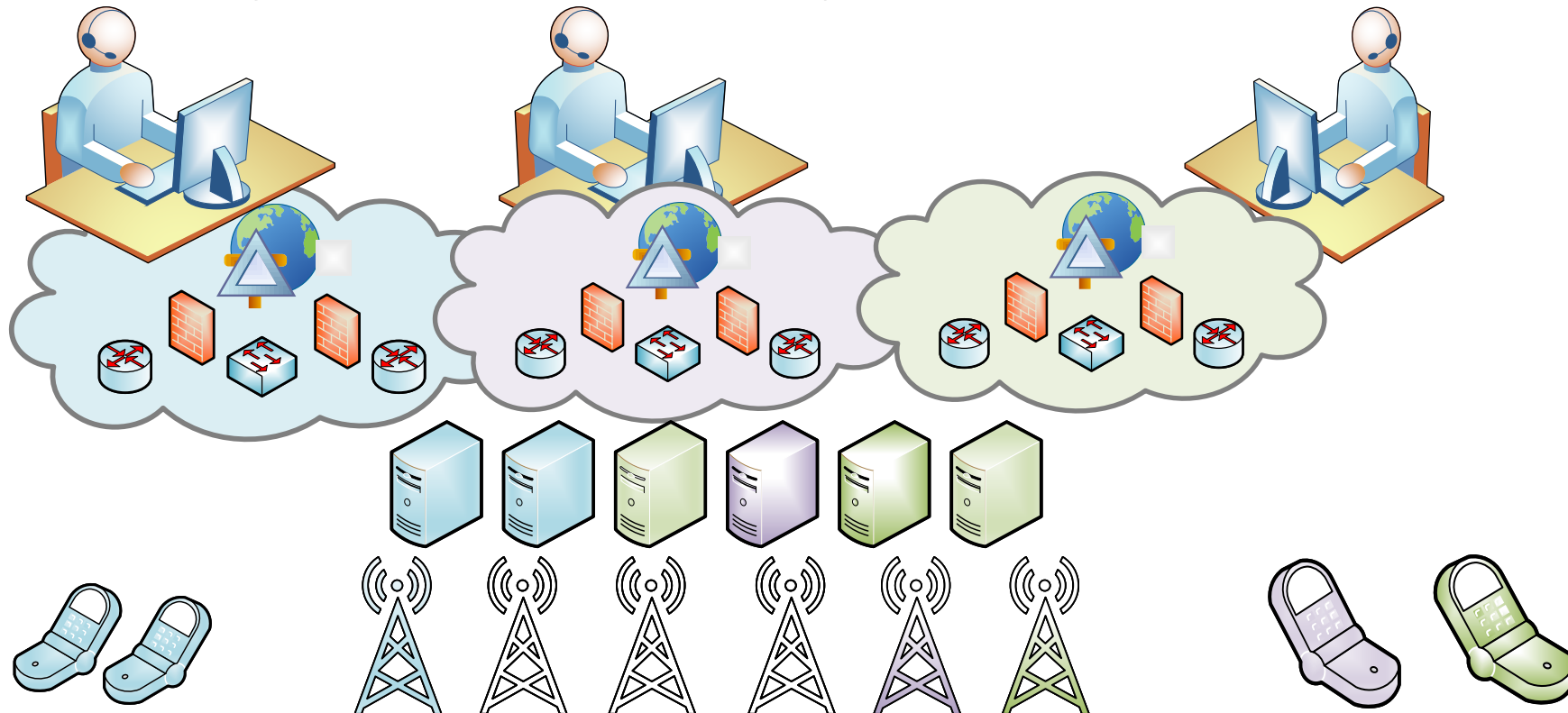
```
}  
list vnf-primitive-group {  
    description "List of service  
primitives grouped by VNF.";  
    key "member-vnf-index-ref"; leaf  
member-vnf-index-ref {  
    description  
"Reference to member-vnf within constituent-  
vnfds";  
    type uint64;  
}  
}
```





# Bristol 5G Testbed

- R&D testbed to experiment and trial new network functions
- Open to industry and academic experimenters



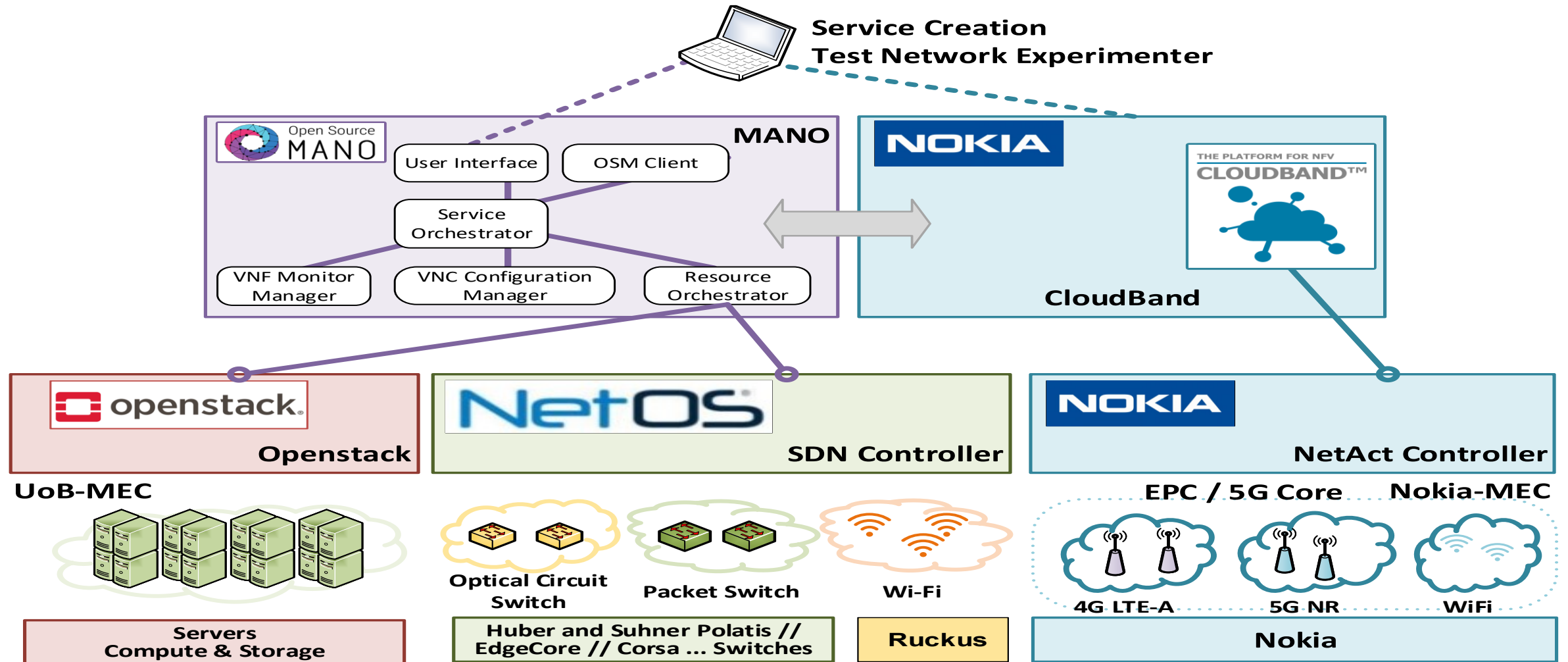
Depending on the service type

- **eMBB** service type aims at supporting "Performance requirements for high data rate and traffic density scenarios".
- **URLLC** service type aims at supporting "Performance requirements for low-latency and high-reliability services."
- **mlIoT** service type aims at supporting "A large number and high density of IoT devices efficiently and cost effectively."

Different service types may include different Network Slice, for example:

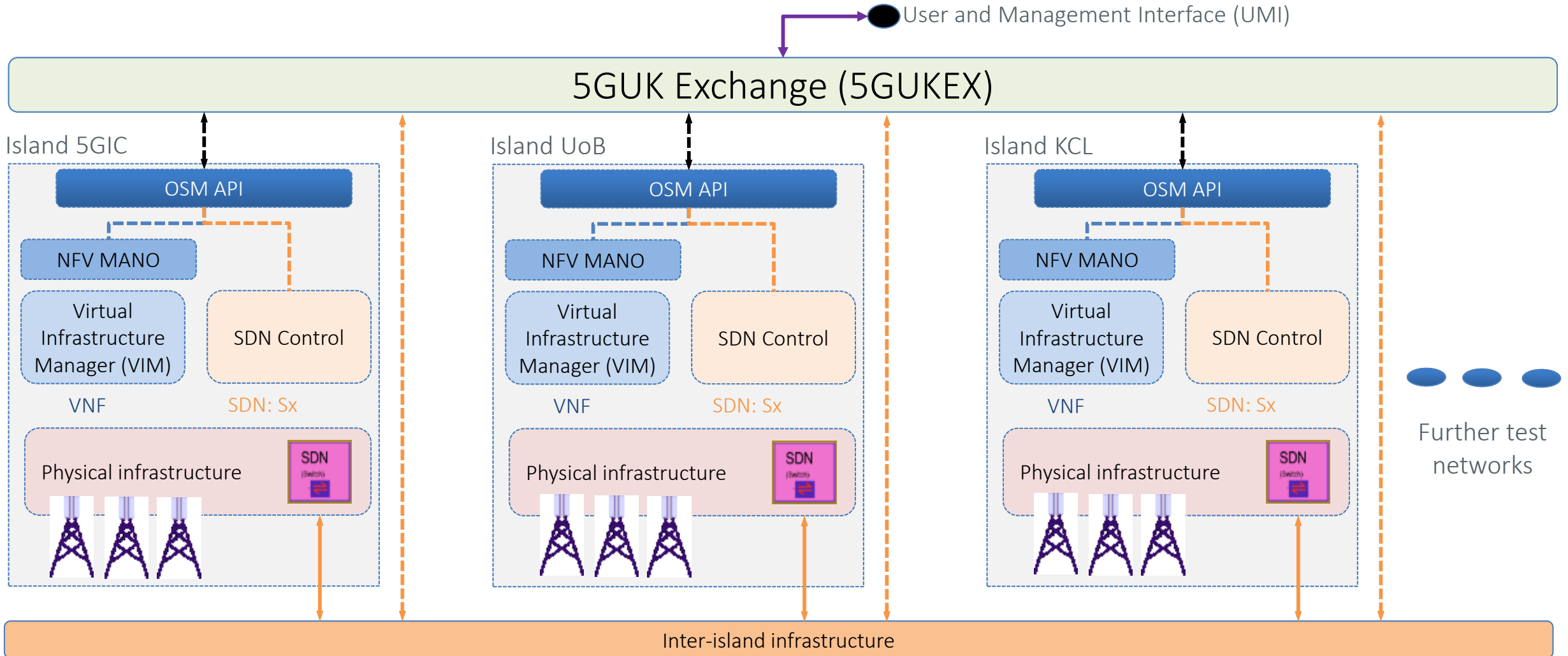
- Area traffic capacity requirement
- Charging requirement
- Coverage area requirement
- Degree of isolation requirement
- End-to-end latency requirement
- Mobility requirement
- Overall user density requirement
- Priority requirement
- Service availability requirement
- Service reliability requirement
- UE speed requirement

# University of Bristol Control Plane Architecture

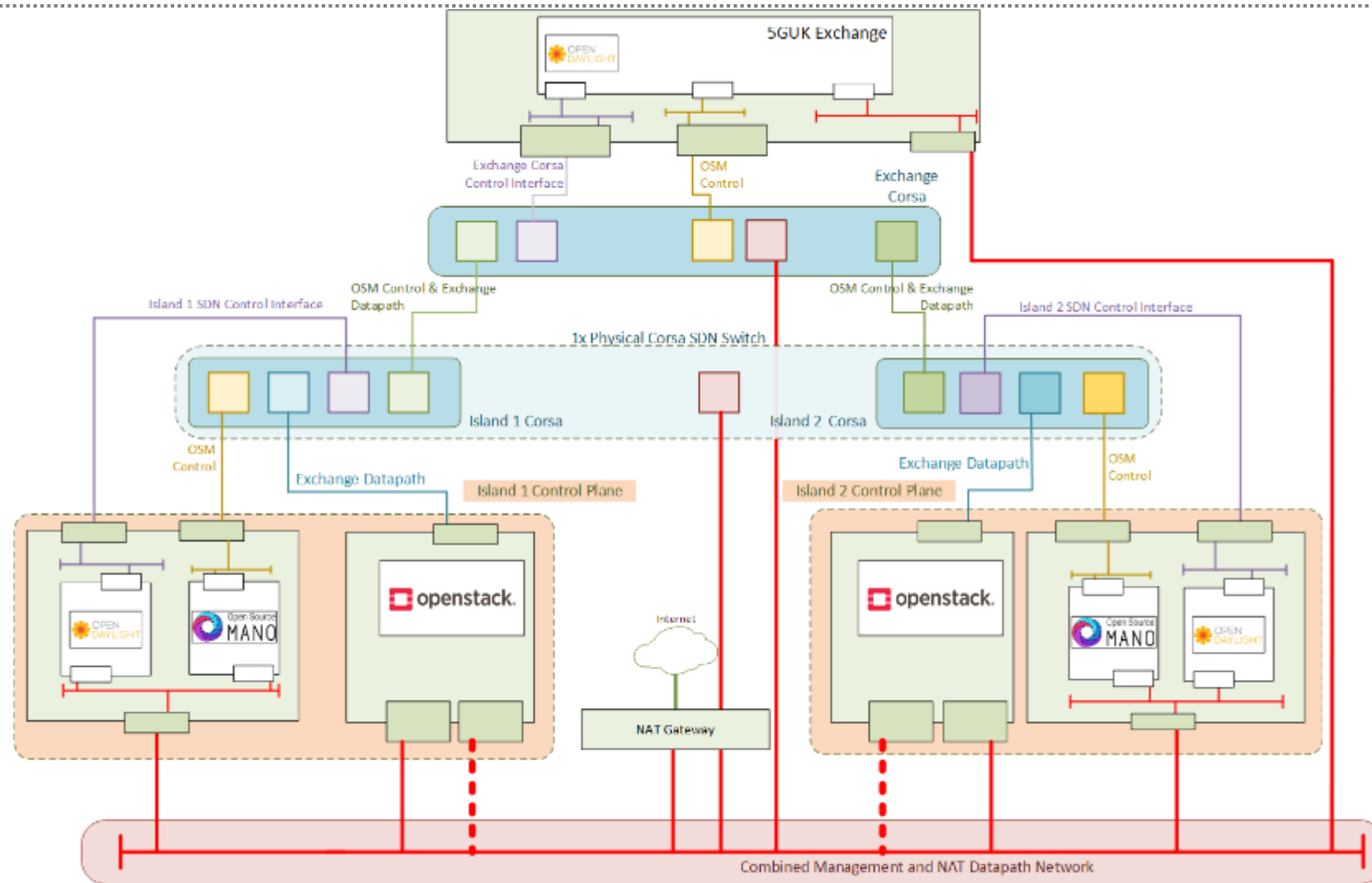


# Connecting Across the 5G UK Test-Networks

## 5G UK Exchange



# Example of Network Slicing (1/2)



5GUKex

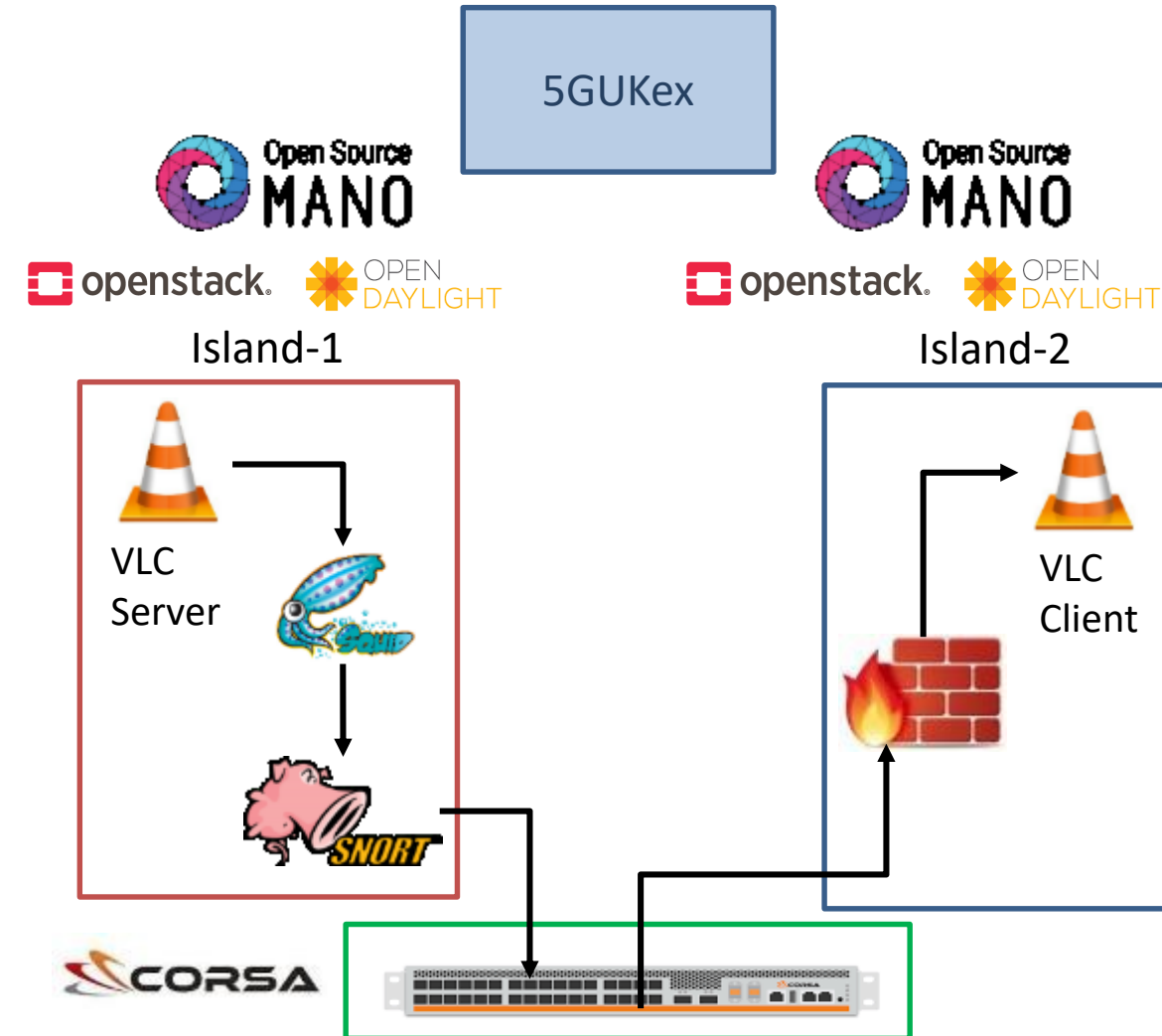
Island 1

Island 2



# Example of Network Slicing (2/2)

- Inter-domain service provisioning through the 5GUKex
  - Brokering inter-domain NS requests through 5GUKex to Islands' OSM
  - VNF (VM) deployment by Island OSM (OpenStack)
  - Inter-island service interconnection through 5GUKex ODL
  - Security use case deployed in two islands
    - Media and Proxy server, IDS, FW, media client as VNFs

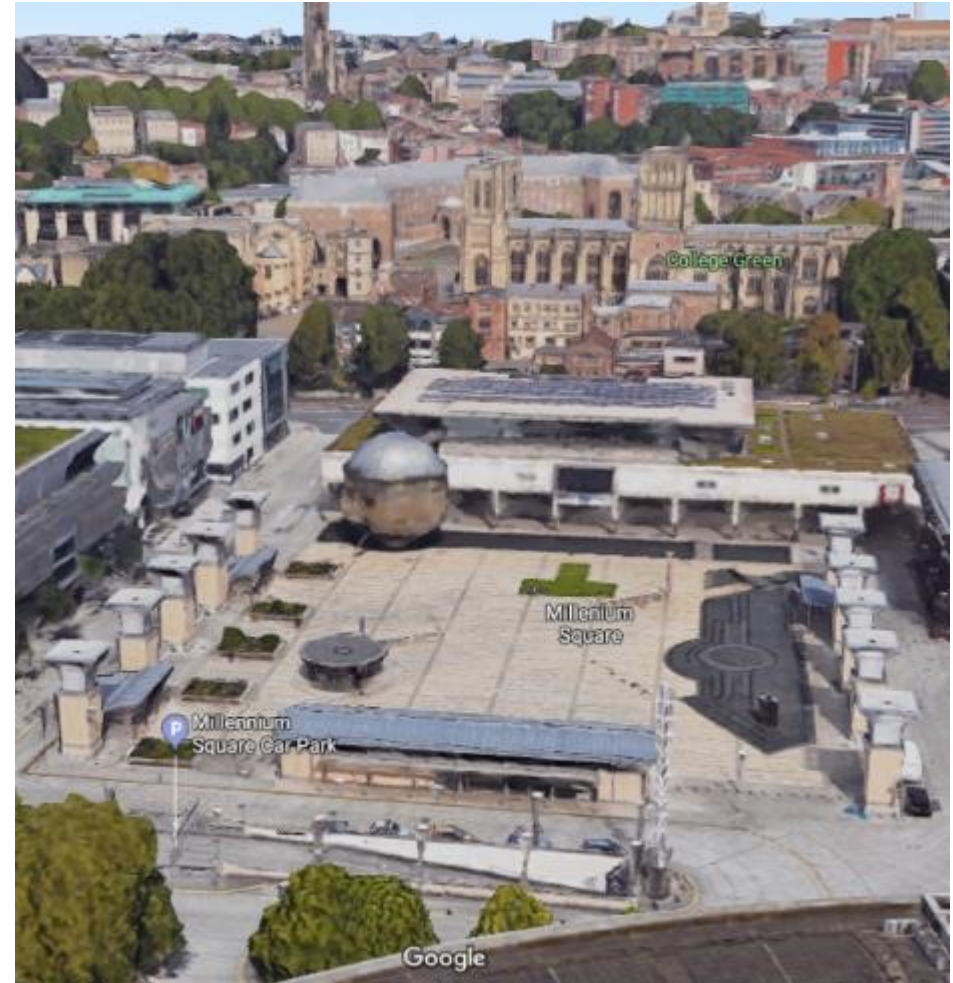


# 5G UK Test Network

## Summary

# 5G Public Showcase at Bristol's Millennium Square: Layered Realities, March 17/18 2018

- Watershed and the [Smart Internet Lab](#) at the University of Bristol examined next generation 5G wireless connectivity through a series of experimental events – we asked artists, researchers and creatives to produce bold new services which explore the capability and potential of 5G
- Technology and culture are inseparable. The experiences created as part of the [Layered Realities](#) project not only explored the beauty of technology but interrogated it to explore how it might fit into the lives of real people
- The Bristol 5G test network was led by the [Smart Internet Lab](#) at the University of Bristol and the [Layered Realities](#) Weekender 17-18 March 2018 was part of these trials.





# Smart Internet Lab 5G Showcase

Extracts from BBC-Click

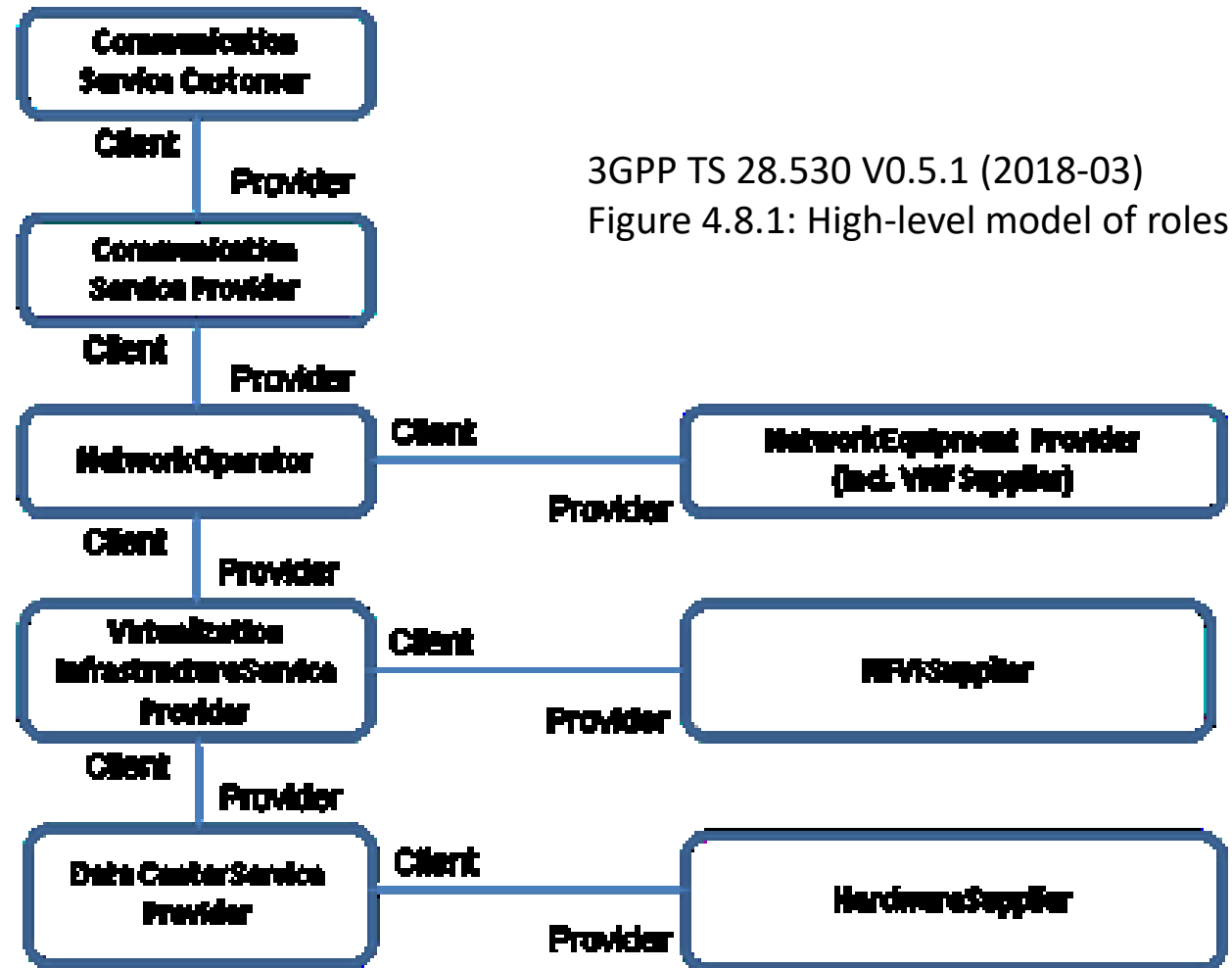
<https://www.youtube.com/watch?v=5hfZxsGcWB4>



# Opportunities

E.g.: End user,  
Small & Medium Enterprise,  
Large enterprise,  
Medical,  
Other CSP, etc.

- Network Services can be rapidly designed and implemented in this ecosystem of clients and providers



# University of Bristol 5GUK Partners & Suppliers

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Thank you

Questions?

