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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Smart Internet Lab

• Provides a holistic approach to design both hardware and software combined so that it solves critical problems in the 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.

Project Funding

5G Testbeds and Trials programme
Universities of Surrey, Bristol & KCL London

2017-18

5G RuralFirst: Rural Coverage and Dynamic Spectrum Access Testbed and Trial
Lead organisation: Cisco Grant: £4.3m

5G Smart Tourism
Lead organisation: West of England Combined Authority Grant: £5.0m
Worcestershire 5G Consortium - Testbed and Trials
Lead organisation: Worcestershire Local Enterprise Partnership Grant: £4.8m

Liverpool 5G Testbed
Lead organisation: Sensor City Grant: £3.5m

AutoAir: 5G Testbed for Connected and Autonomous Vehicles
Lead organisation: Airspan Communications Ltd Grant: £4.1m

5G Rural Integrated Testbed (5GRIT)
Lead organisation: Quickline Communications Grant: £2.1m

2018-19

5G Urban Connected Communities Project
https://www.gov.uk/government/publications/5g-urban-connected-communities-project

2018-21
University of Bristol 5G Test Network

5G room
- 3.5GHz M-MIMO
- C-RAN (Nokia)
- EdgeCore Switches
- Politis Switches

IT room
- 2.6GHz Pico
- WiFi (Nokia) & LiFi
- LTE-A 2.6GHz
- 26GHz Mesh
- WiFi (Nokia)
- WiFi (Ruckus)

5G Performance Area
- Millennium Constellations
- Gazebo-UE MIMO
- Gazebo-UE MIMO

Indoor LTE-A 2.6GHz
- 26GHz Mesh
- WiFi (Nokia)
- WiFi (Ruckus)
- EdgeCore Switch

LTE
- 2.6GHz Mesh
- WiFi (Nokia)
- WiFi (Ruckus)
- EdgeCore Switch

5G NR 3.5GHz (2018/11/01)
- 28GHz 5G NR FWA

EdgeCore Switch

MEC Compute Node

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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

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Smart Internet Lab 5G Showcase

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
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.
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

Ruckus T710

CCS Metnet

Polatis 16x16

SM Fibre

Edgecore AS4610-30P

Massive MIMO

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25/04/2018
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
5G NR

5GNR - 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

5GNR – 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

LTE Band 7

FDD Uplink

Vodafone

BT

EE

2500
2520
2535
2570
2595
2620
2640
2655
2690

FDD Downlink

TDD

Vodafone

BT

EE

2500
2520
2570
2595
2620
2640
2655
2690

Frequency (MHz)

3 x 5MHz FDD Channels

BT
BT
BT

2520
2525
2530
2535

3 x 5MHz FDD Channels

BT
BT
BT

2640
2645
2650
2655

26GHz Band

University of Bristol Test and Development License

24250
25875
27500

Frequency (MHz)

3.5GHz 5G 'Pioneer' band

UoB T&D License

25/04/2018
Installation
Showcase
Smart Internet Lab

Future

4G EPC equipment will be installed during Phase 1 5G Testbed and Trial. This will be upgraded to 5G core when available. Existing equipment will connect to new Testbeds.

Bath City Centre & The Pump Rooms

We The Curious*

1 x Combined Micro RRH + Wi-Fi Small Cell per location/exhibit. Including restaurant and spring room.

Discretely mounted Wi-Fi in Bath area.

* (WTC) This is an existing 5G Testbed

Local datacentre / rackspace

The museum comprises multiple exhibition rooms and conference venues.

Two 5G Micro RRH on roof illuminating Steam Railway and Deck area.

M-Shed Museum

M-Scale

User

Ment

MEC

AirScale Hub

Local datacentre / rackspace

1 x Combined Micro RRH + Wi-Fi Small Cell per location/room.

The museum comprises multiple exhibition rooms and conference venues.

4G Micro RRH
4G RRH + Wi-Fi Small Cell
8 x Nokias
8 x C55
8 x Ruckus

User

AirScale Hub

Ment

MEC

1 x Combined Micro RRH + Wi-Fi Small Cell per location/room.

The museum comprises multiple exhibition rooms and conference venues.

User

AirScale Hub

Ment

MEC

1 x Combined Micro RRH + Wi-Fi Small Cell per location/room.
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”

<table>
<thead>
<tr>
<th>MobileCom Ltd</th>
<th>YourTelco Ltd</th>
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<tbody>
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<td>1,000 minutes</td>
<td>500 minutes</td>
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<tr>
<td>1,000 SMS</td>
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<td>1GB data</td>
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<tr>
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<td>£18/month</td>
</tr>
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</table>

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

- 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
ETSİ MANO

• 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.”

- **mIoT** 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

5GUK Exchange (5GUKEX)

Island 5GIC

OSM API
NFV MANO
Virtual Infrastructure Manager (VIM)
VNF
SDN Control
SDN: Sx
Physical infrastructure

Island UoB

OSM API
NFV MANO
Virtual Infrastructure Manager (VIM)
VNF
SDN Control
SDN: Sx
Physical infrastructure

Island KCL

OSM API
NFV MANO
Virtual Infrastructure Manager (VIM)
VNF
SDN Control
SDN: Sx
Physical infrastructure

User and Management Interface (UMI)

Inter-island infrastructure

Further test networks

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37 25/04/2018
Example of Network Slicing (1/2)
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
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

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

3GPP TS 28.530 V0.5.1 (2018-03)
Figure 4.8.1: High-level model of roles
Thank you

Questions?