University of BRISTOL

World leading in fibre, wireless and 5G convergence research

End-to-end network design and optimisation

Creating the communication networks architecture of the future

Smart Internet Lab

at the University of Bristol

bristol.ac.uk/smart

About us:

The Smart Internet Lab at the University of Bristol is a hub for internet research which addresses grant societal and industrial challenges. We perform cutting edge research on optical and wireless communications and offer a unique holistic approach to hardware and software co-design, solving critical problems in the global internet evolution.

We are witnessing the emergence of a smart world, with 'smart homes', 'smart cities', 'smart stadiums', 'smart security', 'smart energy', and 'smart transport'. Our current internet however is unable to scale enough to support the demand and rapid changes in the way we consume Internet Services. To address this key limitation and support trillions of internet connected machines, we need to increase network capacity, enhance coverage reliability and flexibility, lower end-to-end latency and re-design future networks.

Our 200 experts on 5G radio/ wireless, optical communications and networks research challenge the complexity of tomorrow's world by fusing research expertise and innovation in a range of research areas such as IoT, 5G and beyond, Future Transport Networks, Smart Cities, Autonomous Networks, Machine Learning and Artificial Intelligence, Network Convergence, Mobile Edge Computing, Network Softwarization. Our unique offering across optical, wireless, IoT and cloud technologies enable us to bring together end-to-end network design and optimisation and impact regional, national and global ICT innovations.

As one of the UK's most renowned Information and Communications Technology (ICT) research centres we have an exceptionally strong track record on pioneering concepts of programmable and smart experimental city infrastructures, as well as, developing large-scale applications and service-oriented networks.

Our Labs

Our state-of-the art Smart Internet Lab facilities are uniquely able to support research ranging from devices to applications across multiple technologies, to leverage benefits from hardware/ software co-design and perform experimentation in "the wild", validating our research outputs. Our feature-rich experimental facilities offer 1. Network experimentation, 2. Wireless research, 3. Photonic fabrication and 4. Research test-beds at scale including urban, national and international.

What is 5GUK Test Networks?

5GUK Test Networks is an exciting new 5G Hub partnership linking three leading UK universities' test beds which collectively delivered the world's first end-to-end 5G systems trials. This initiative was funded by the UK Government's Department of Digital, Culture, Media and Sport (DCMS) '5GUK Testbeds and Trials Programme' in an effort to create a world-class 5G technology Test Network that places Britain at the forefront of the next wave of mobile technology, adding up to £173 billion to the economy by 2030.

University of Bristol's 5GUK Test Network

The University of Bristol has deployed 5G capability in Bristol city centre focusing on the convergence of fibre infrastructure and 5G wireless access. The University of Bristol contributes to the key Software Defined Network (SDN) technologies for end-to-end 5G service delivery. Smart Internet Lab researchers have created a multi-technology testbed connected via a city wide fibre ring and several active switching nodes. **Interested in using our testbed? Please contact us.**

The only UK University with an EPSRC funded Centre for Doctoral Training in Communications.

The Bristol Ecosystem and the New Campus

Bristol is at the heart of digital innovation, surrounded by a rich digital SME eco-system, collaborative city leadership, creative industries and engaged citizens. The result is a unique coalition between the University, local government and international and local businesses.

End-to-End Network Research and Experimentation

University of BRISTOL

UK's first urban 5G End-to-End Testbed

Dynamic end-to-end slicing and orchestration over heterogeneous wired and wireless networks

Programmable edge aggregation and mobile edge computing

5GUK Test Networks

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Capabilities

The University of Bristol's '5GUK Test Network' offers multi-vendor capabilities such as:

- SDN enabled L2 packet switched network and L3 service routers
- SDN enabled optical fibre switched network
- SDN enabled multi-vendor Wi-Fi access points
- 4G and 5G Cloud Network Solution operating: EPC, LTE-A, 5GNR, M-MIMO on frequency bands at 2.6GHz, 3.5GHz, 26GHz and 60GHz
- Self-organising multipoint-to-multipoint wireless mesh network in 26GHz mm-wave
- LiFi Access point
- Datacentre, Cloud and Network Function Virtualisation hosting on Openstack and Cloudband using high end compute
- Quantum Key Distribution solution for enhanced security
- Advanced fibre optics FPGA convergence of transmission network integrating Elastic Bandwidth-Variable Transponders and Programmable Optical White-box Wavelength Selective Switches (BV-WSS)

Our 5GUK Test Network is controlled using two different SDN/NFV solutions along with its Orchestration and Management (MANO); one based on Open Source ETSI and the other a commercial solution. Hence providing network slicing and virtualisation with rapid service creation.

Smart Internet Lab

The Smart Internet Lab at the University of Bristol has been recognised as one of three key academic research specialists within the UK as a concentrated 5G hub of estabilised collaborative relationships between national and international institutions, authorities and industry.

DCMS 5GUK Testbeds and Trials Programme

The University of Bristol's Smart Internet Lab, along with 5G expects from the University of Surrey and King's College London, were awarded £16 million by the UK Government's DCMS to develop a cutting-edge 5G test network, namely the '5GUK Test Networks' . The Programme will encourage and fund the creation of a series of Testbeds and Trials in a range of geographic and vertical market segments. It will explore the benefits and challenges of deploying 5G technologies. Phase 0 included a £16m investment in creating the 5GUK Test Network. In March 2018, the six winners of the first Phase of the 5GUK Testbeds and Trials competition were announced which includes the Smart Internet Lab's 5G Smart Tourism project.

Interested in using our Testbed?
Please visit bristol.ac.uk/smart/5GUK or contact Professor Dimitra Simeonidou

A Cutting-Edge Large Scale Urban 5G Test Network for Digital Innovation

University of BRISTOL

New wireless technology for 5G

Reduces network congestion by providing more channels in the same spectrum

Offers enhanced quality and additional services, such as localisation

5G
at the University of Bristol

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5G

5G is expected to deliver ultrafast connectivity, carrying huge amounts of data in support of complex applications, such as mobile VR or holographic TV. The revolutionary potential of 5G could greatly impact the governance of our society and innovate autonomous transportation, robotics, augmented reality, remote surgery and smart agriculture, homes and cities. Government funded 5G platforms will substantially benefit industry and consumers alike, enabling the UK to stay at the forefront of digital technology.

Smart Internet Lab

The Smart Internet Lab is an international leader of 5G research with specific focus on fibre and 5G convergence. It is one of the UK's most renowned Information and Communications Technology (ICT) research centres. With 200 experts specialising in 5G radio/wireless, optical communications and networks research, the Smart Internet Lab directly impacts regional and national ICT innovations. We have an outstanding track-record in pioneering programmable and Smart city infrastructures, developing large-scale applications and service-oriented networks. Our leading international telecommunications research has attracted significant funding from UK Research and Innovation, the EU, industry partners and central and local government.

Smart City, Smart Region, Smart Campus

Smart infrastructures rely extensively on data collected from citizens, the environment and vehicles alike. Our technologies deliver creative solutions to real-world problems in Smart cities/regions/campuses. Network infrastructure requires citywide data retrieval and vast quantities of sensor data. This needs to be collected, aggregated and transferred to data centres for storage and processing. Current digital infrastructure can be a major bottleneck for such Smart city operations, as it lacks the capacity, flexibility and scalability required for emerging urban applications.

Our research on programmable networking technologies can alleviate these issues, offering unique enhancement of Smart city performance. These technologies can reshape current trends in city service provisioning, as they exploit open software and hardware platforms, which can be programmed and tailored to diverse application requirements. By opening the city infrastructure to 5G innovation, we enable citizen participation in the service delivery chain.

Bristol is at the heart of digital innovation, surrounded by a rich digital SME eco-system, collaborative city leadership, creative industries and engaged citizens.

The University's new £300 million Smart campus at Temple Quarter includes broad deployment of fibre and 5G connectivity and advanced cloud services for the businesses, researchers and students in residence. We are in the process of creating the largest 5G urban test-bed facility in the UK, embedded in a real-life Smart city and Smart campus environment.

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Wide deployment of fibre and 5G connectivity at the new £300 million Smart Campus

University of BRISTOL

Showcasing the use of the 5G technology for transforming Visitor Economy in the West of England

Creating 5G regional testbed connecting Bristol and Bath

Showcasing significant research on 5G from

5G Smart Tourism Project

5GUK Testbeds and Trials Programme Phase 1

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About

The Tourism Industry in the West of England is worth £1.75 billion to the region's annual economy. The 5G Smart Tourism project is funded by the UK Government's Department for Digital, Culture, Media and Sport (DCMS) will connect leading West of England tourist destinations such as The Roman Baths, M-Shed and We The Curious to new 5G technology via the University of Bristol's 5GUK Test Networks, a UK national asset. This project focuses on the intersection between infrastructure, mobile services, tourism and digital applications. To expedite the roll-out of 5G services in the UK, this project will enhance the value chain through 5G enabled tourism applications and diversify the revenue stream for popular tourist destinations. Through this unique and representative multi-technology 5G platform, the project will promote the creative digital industries in the UK and thus will generate benefits across the entire visitor economy value chain.

The project consortium

Lead by the West of England Combined Authority (WECA) (our geographical regional governing body), this £8 million project brings together a total of 25 partners. These are: West of England Combined Authority, University of Bristol Smart Internet Lab, CCS Ltd, BT, Grand Appeal, Mo-Sys, Mativision, Smartify, BBC, Zeeta Networks, Destination Bristol, Digital Catapult, VR Lab, Interdigital, Bristol is Open, Bristol Futures Global, Roman Baths, 3Sixty, Landmark, IBI, Mshed, Bristol City Council, Aardman, Bath & North East Somerset Council and Business West.

Our project contribution

The University of Bristol Smart Internet Lab contributes extensive knowledge and expertise in 5G network design. The 5G Smart Tourism project will utilise the University of Bristol's 5GUK Test Networks, which includes 3GPP 4G, 5G New Radio, non-3GPP mmWave and Wi-Fi radio access technologies, as well as, key 5G core network elements such as Mobile Edge Computing, Network Function Virtualisation and Network Slicing. This important UK National asset provides access to radio spectrum at 2.6GHz, 3.5GHz, 26GHz and 60GHz.

Use-cases

The project delivers five unique use-cases showcasing two primary 5G KPIs; Enhanced Mobile Broadband (eMBB) and Ultra-Reliable Low Latency Communication (URLLC) through innovative augmented, virtual and mixed reality applications.

For example; to showcase the capabilities of 5G technology, the 5G Smart Tourism project has partnered with the BBC and the historic Roman Baths to enhance visitor experience via a next generation augmented reality application. This unique demonstration will test eMBB and URLLC 5G metrics through high bandwidth and low latency network requirements inside a national heritage location.

This use-case will be delivered in two parts: (1) Location dependent pre-rendered 360-degree video will be streamed to 20 handsets simultaneously from a local compute platform. (2) Video will be remotely rendered in the local MEC platform from a 3D animated model using orientation/interaction data from the user.

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Leverage key regional expertise on communications and networks research and Bristol's digital creativity

University of BRISTOL

Enabling collaboration across 5G networks to create innovative smart services

Automated and scalable cross-domain 5G service provisioning

Dynamic end-to-end network slicing

5GUK Exchange

Intelligent 5G Platform for End-to-End Smart Services

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About

The 5GUK Exchange (5GUKEx) is an innovative centralised 5G software platform led by the University of Bristol. The platform hierarchically interconnects softwarised 5G networks, to produce a global 5G ecosystem. 5G has been advertised as a network revolution, designed to support higher bandwidth, lower latency and ultra-reliable communications. It excels in transformative industrial vertical applications with unpreceded use cases. These include immersive applications, VR, AR, Smart City management, public safety, autonomous connected cars and Smart factories. Although 5G is being extensively investigated worldwide, the current trend focuses on traditional network solutions that restrain customised vertical network provisioning. Instead, the 5GUKEx demonstrates a unique global 5G system which brings together heterogeneous 5G networks enabling end-to-end management, programmability and control through a single centralised entry-point. Third parties such as network users, experimenters and entrepreneurs can access 5GUKEx to combine the capabilities of several 5G networks. This allows rapid creation, deployment and validation of dynamic and innovative vertical industrial 5G applications.

Let's Get Technical

A network connects to the 5GUKEx and publishes its capabilities (i.e. virtual network services). The participant 5G networks can either be located at the same or at different locations and may support heterogeneous network domains (e.g. packet, optical, wireless, IoT). Based on the principles of 5G, each domain virtualises its services using software allowing a unified platform within each 5G network and hence the 5GUKEx to control them. The 5GUKEx manages the lifecycle of user requests, performing service brokering to the relevant 5G networks. This dynamically combines, creates, deploys and validates cross-domain network services, also performing service interconnection setup and termination to support the cross-domain connectivity.

Why is 5GUKEx important?

The 5GUKEx brings multiple benefits to several stakeholders (users, experimenters, entrepreneurs, application developers, network function developers and vendors, infrastructure providers and service providers). It provides:

- Control plane scalability: thin orchestration and an interconnection layer that performs dynamic service brokering and dynamic cross-connections
- Common standardised API: facilitates 5G network introduction
- Network privacy preservation: service catalogue disclosure, enabling collaboration for creating feature-rich services
- Manageability: single entry-point for service requests
- Sustainability: different network technology domains, "seamless" introduction of new networks
- User-friendly abstractions: composable or pre-composed network services

Technologies

The 5GUKEx leverages state-of-the-art key 5G technologies such as Network Function Virtualisation (NFV), Software Defined Networking (SDN) and Management and Orchestration (MANO). It employs and extends relevant standards, e.g., ETSI NFV MANO, and is built upon open-source solutions.

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5G Research

We are world leaders in fibre, wireless, and 5G convergence research. We have created a unique 5G Trial Test-Bed for a Smart City, Campus, Region and the Telecom Industry.

This project is funded by the UK Government's Department of Culture Media and Sport (DCMS) to develop a cutting edge 5G test network.

Department for Digital, Culture Media & Sport

EPSRC Engineering and Physical Sciences Research Council

INITIATE

TOUCAN ULTIMATE NETWORK CONVERGENCE

Showcasing key 5G technologies:

- Network Functions Virtualisation
- Software Defined Networking
- Management and Orchestration

University of BRISTOL

An intelligent box for convergence of all network technologies and connected devices

Virtualising high-performance network functions at the edge

Re-purposing the network at the edge for delay sensitive and computing intensive applications

5G in a Box

Smart Connectivity for 5G

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About

Key technology sectors, such as Smart City, automotive and entertainment industries, are rapidly being transformed by capabilities offered by 5G. For 5G to support these sectors (also known as verticals), a high degree of technological convergence and programmability is required, empowering the verticals with enhanced technical capacity to trigger the development of new, innovative products, applications and services.

A "5G in a Box" utilises advanced hardware programmable platforms and high-performance commodity computing servers to offer a generic and programmable platform for deployment at the edges of a 5G network. It enables different verticals to deploy and execute on-demand, application specific and customised low latency network functions at the edge of the network. It also provides a point of convergence for various wireless and wired 5G technologies and computing platforms that can be customised for specific services and technologies.

Let's Get Technical

An end-to-end 5G network comprises heterogeneous types of technologies from new radio such as Massive MIMO and millimetre wave, to high speed optical network and advanced computing platforms such as mobile edge computing (MEC). Furthermore, most of the 5G network functions are virtualised as a software entity that requires a low latency computing platform often at the edge of the network.

Availability of high-performance programmable and flexible hardware enables offloading network functions to the hardware and accelerates them. FPGAs (programmable hardware devices) are receiving increasing attention as preferred programmable platforms because of low cost and high performance. Unlike the software that executes in sequential order, FPGAs execute concurrently and hence support high data rate and lower latency. A 5G in a Box node utilises FPGA platforms and high performance commodity computing servers to offer a generic and programmable platform for deployment at the edges of a 5G network. It accelerates execution of 5G network functions and also provides a point of convergence for heterogeneous wireless and optical transports as well as computing platforms.

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TOUCAN
ULTIMATE NETWORK CONVERGENCE

5G-XHaul

5G-PICTURE

Metro Haul

Plug-able advanced computing capability at the edge of the network

Deep learning about network lose to users and applications

University of BRISTOL

Developing technologies for the Internet of CAVs

Smart mobility for smart societies

Quicker, safer, more reliable transportation services

Connected and Autonomous Vehicles (CAVs)

Smart Mobility for Smart

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About

Connected and Autonomous Vehicles (CAVs) will play a significant role in future transportation systems and will unlock enormous societal benefits. Wireless connectivity is one of the underpinning technologies allowing CAVs to transform from autonomous systems to cooperative entities. Not only is the information exchange between all components of the system fundamental to improving road safety and efficiency, but it also paves the way to a wide spectrum of advanced ITS (Intelligent transportation systems) applications, enhancing efficiency, mobility and accessibility. Cooperation amongst autonomous vehicles is enabled by exchanging sensory data and manoeuvring intentions.

Let's Get Technical

Smart Internet Lab researchers at the University of Bristol have a 30-year track record of conducting academically renowned and industrially impactful research in wireless communications and Artificial Intelligence (AI). Research has been carried out on dependable V2X connectivity for over 10 years, most recently leading the development of V2X for Innovate UK funded VENTURER and FLOURISH projects. Reseach is being conducted in: 5G systems and Cellular V2X (C-V2X, LTE-R14); Millimetre Wave 5G for V2X, ITS-G5 (DSRC, 802.11p); Security Privacy and Trust for V2X; Fog computing and in Network AI.

The successful deployment of CAVs is contingent on the ability to devise robust and effective security solutions to resist cyber-attacks and patch up critical vulnerabilities. Researchers have developed novel Fog compute framework - a heirarchical network where the cloud layer is augmented by compute resources that are located in the proximity of CAVs. Such setup vastly reduces latency and facilities additional safety critical services. Fog compute framework allows for scalability of trust provision, increasing the security horizon. The Fog resources are also used to enable sophisticated certificate compression, network coding and CAV data off-loading technologies, all of which pave a way to future secure networks of CAVs.

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flourish
EMPOWERMENT THROUGH TRUSTED SECURE MOBILITY

We work with Innovate UK

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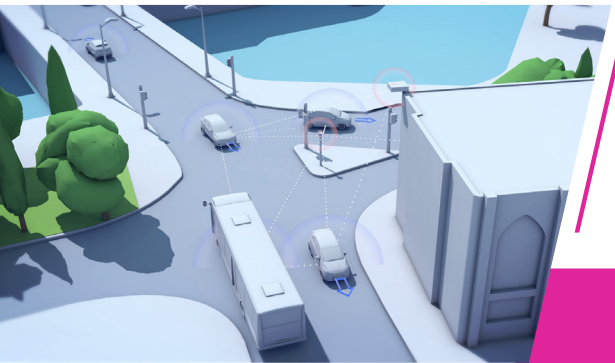

Smart Mobility for Smart Societies

@bristol_smart

University of BRISTOL

New wireless technology for 5G

Reduces network congestion by providing more channels in the same spectrum

Offers enhanced quality and additional services, such as localisation

Massive MIMO

More efficient sharing of wireless channels

bristol.ac.uk/smart

About

Virtually all of us have experienced poor performance whilst using our wireless devices at major cultural or sporting events, although we have five bars of signal. The problem is often not signal strength, but insufficient network resources to support your request. This frustrating experience is becoming all too familiar for today's wireless users. If predictions are correct, we will require 1000 times more capacity by 2020 to accommodate new applications such as Virtual Reality (VR), autonomous driving and the Internet of Things (IoT).

Massive MIMO is a game changing technology which allows us to pack more information into a limited bandwidth by exploiting spatial signal processing. An easy way to consider the Massive MIMO concept is to compare it with human hearing. Having two ears allows us to discern not only the intensity of sounds, but also the direction and approximate location of the sources. A Massive MIMO base station could be regarded as having in excess of 100 ears, or antennas, which give it the ability to identify its spatial relationship to multiple devices with unprecedented accuracy.

Let's Get Technical

Massive Multiple-Input Multiple-Output (MIMO) is an evolution of the Multi-User (MU) MIMO technique which exploits multipath scattering to increase system capacity.

Here in Bristol, we are demonstrating a system with >100 individual digital signal processing chains to separate 12 simultaneous devices using the same radio channel at the same time. The algorithm is more complex than beamforming, as we jointly pre-code the amplitude and phase weighting of each chain so we can unravel the spatial signatures of each user, even when they are in close proximity.

The theory was first introduced in 2010, and through a collaboration with Lund University and National Instruments, we have taken this concept from the chalkboard to the radio mast. Using this hardware, we have demonstrated unsurpassed rates in Spectrum Efficiency as well as addressing the use of this technology under real operational conditions.

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NATIONAL INSTRUMENTS™

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EPSRC Centre for Doctoral Training in Communications

A key enabling technology for 5G, unleashing hidden capacity for sub-6GHz wireless connectivity

University of BRISTOL

Quantum Cryptography for ultimate 5G security

Quantum security for ultra low latency and high bandwith 5G services

Securing multi operator virtualised network services

Quantum Secured 5G Network

Addressing 5G Security with Quantum Cryptography

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About

There are widely reported concerns on security vulnerability of 5G networks which are predicted to transform the telecommunications industry in the next ten years.
New research by the High Performance Network Research Group at the Smart Internet Lab has demonstrated a ground-breaking solution for securing future critical communications infrastructures, including emerging 5G networks.
The proposed solution will enable 5G network operators to offer ultimately secure 5G services while guaranteeing ultra-low-latency and high-bandwidth communications. This is due to the novel combination of quantum and infrastructure virtualisation technologies.
The proposed quantum secured 5G virtualisation platform is capable of working across multiple 5G operators' networks (i.e. EE, O2, Vodafone etc.). It uses advanced and standard compliant virtualisation technology for creating on-demand complex and collaborative 5G network services across operators' domains, while utilising quantum cryptography and optical interconnection infrastructure to secure services and guarantee 5G Key Performance Indicators (3GPP KPIs).

Let's Get Technical

Recent advances in software engineering and commodity computing technologies have revolutionised the telecommunications industry in the past ten years. Entire classes of network communication services that have traditionally been carried out by proprietary, dedicated hardware, are now virtualised and hosted in commodity computing servers. This is commonly referred to as "Network Softwareisation".
The move of critical network communication functions into software, distributed across the internet however, imposes significant security risk for telecommunications networks and specifically for 5G networks that rely entirely on such software architecture. Any malicious attempt to tamper with these virtualised network functions can potentially put the whole internet and its users at risk.
The new research addresses this problem with a new, fully programmable network virtualisation platform leveraging on quantum technologies for securing function virtualisation and service orchestration.
The proposed solution leverage on state-of-the-art key 5G technologies such as:

- Network Function Virtualisation (NFV)
- Software Defined Network (SDN)
- Quantum Mesh Networking
- Quantum Key Distribution (QKD)

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European Commission | Horizon 2020 European Union funding for Research & Innovation

QUANTUM COMMUNICATIONS HUB

UNIQORN

Ultimately secure and programable 5G network

University of BRISTOL

Smart technologies for public security

Smart City is a place where people should feel safe

Intellegent security system and surveillance

Smart City Safety

Intelligent Technology for Improving Citizen Safety in Smart Cities

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About

Given the critical importance of security in cities, innovative advances in wireless communication systems are increasingly improving the safety of city inhabitants. New services such as audio and video monitoring of public areas and automated municipality rule infraction detection allow a quicker response to threats. Based on this context, the Smart Internet Lab at the University of Bristol has been deploying a Smart city safety use case as a proof of concept. This is designed to identify suspicious activities in the city.

A bike rider helmet, a Raspberry Pi and a 360-degree camera with audio are the basic components required. These items are all joined to the internet via a WiFi Interface.

How do we demonstrate this?

The bike rider carries his helmet, which has a Raspberry Pi attached and 360-degree camera. Here the video and audio are capturing and sending data via WiFi to the Mobile Edge Computing (MEC) or Cloud for processing. Once the audio and video has been processed and any suspicious activity has been detected, a notification is generated and sent to the different security agents.

Many of today's municipalities are becoming test beds for Smart city experimentation where technological capabilities are addressing daily needs. This services can include parking, water treatment and city security. The University of Bristol is working to provide the 5GinFIRE platform, a Smart city safety use case, through utilising open-source frameworks (i.e. OpenStack, OpenDayLight, etc).

We are using two key technologies for the video processing:

1. Network Function Virtualisation: a Virtual Network Function (VNF) video transcoder. This is designed, specified and deployed at Bristol's Network Function Virtualisation Infrastructure (NFVI) via OSM MANO orchestrator.
2. Machine Learning: a face detection programme that has been trained and deployed at the NFVI.

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Department for Digital, Culture Media & Sport

European Commission

Horizon 2020 European Union funding for Research & Innovation

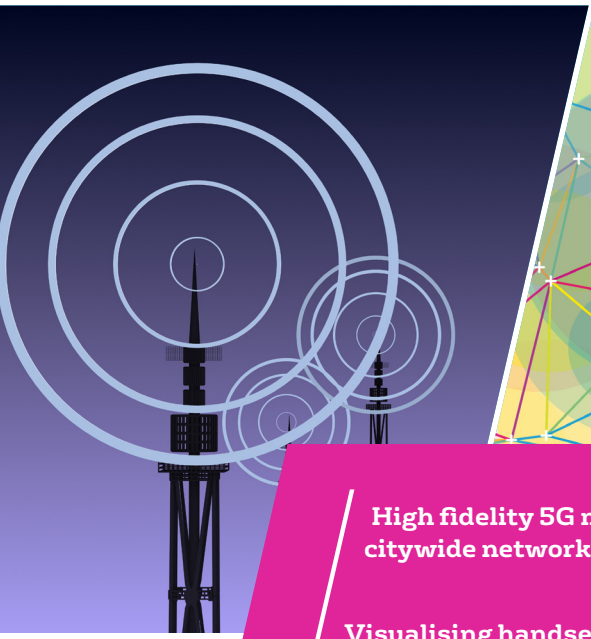
5GUK Testbeds and Trials Programme

5GINFIRE

5G for improving people's safety

Immersive and 360-degree video monitoring

University of BRISTOL



High fidelity 5G mapping for ultra-reliable citywide networks

Visualising handset connections to the 5G network

Understanding radio wave interactions with the environment

Visualisation of RF Spectral Waves

Visualisation of Radio Transmissions

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About

Software tools developed at the University of Bristol can estimate how radio signals travel from 5G basestations to your mobile device. By using ultra-high resolution 3D city maps, generated using airborne laser scanners, these new tools will ensure 5G coverage is optimised throughout the city.

Let's Get Technical

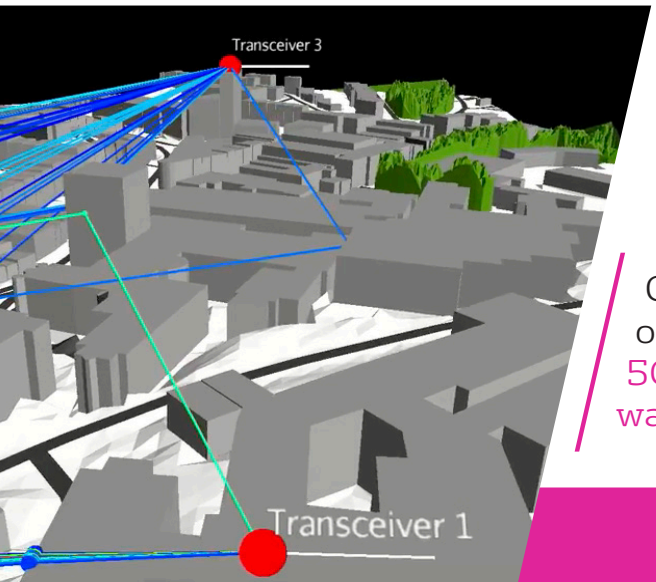
Radio waves scatter off buildings and bend around corners and over rooftops depending on their carrier frequency. The University of Bristol is a world leader in the measurement and modelling of radio waves propagation. Today all cellular and Wi-Fi services operate at frequencies below 6GHz. One of the innovations in 5G is the introduction of new 'millimetre wave' bands at 26GHz and 60GHz. These introduce significant new challenges in terms of electromagnetic modelling. As such, high frequencies, the surfaces of buildings become 'electrically rough' and this scatters the radio signals in all directions. Using ultra-high resolution 3D city models, it is possible to predict how these radio waves travel from 5G basestations to your mobile device. Furthermore, based on the location of a set of basestations, as well as the type of antennas deployed, the software is able to predict radio signal levels at street level throughout the city. These maps can then be used to ensure high-quality and reliable service provision, including for new services such as Smart Cities and Connected and Autonomous Vehicles. The tools in development in the labs at Bristol will be used to support the 5G network planning process. The Smart Internet Lab has also developed a state-of-the-art radio channel emulator, which links to our radio predictions and enables 5G hardware to be fully evaluated in the lab. These facilities are currently being used to develop and deliver Gigabits per second communications as part of a new 5G network for cars and trains.

Smart Internet Lab

The Smart Internet Lab at the University of Bristol has been recognised as the top Higher Education Institution within the UK as a concentrated 5G hub of estabilised collaborative relationships between national and international institutions, authorities and industry.

5G Research

We are world leaders in fibre, wireless, and 5G convergence research. We have created a unique 5G Trial Test-Bed for a Smart City, Campus, Region and the Telecom Industry.



Challenges of exploiting 5G millimetre wave spectrum