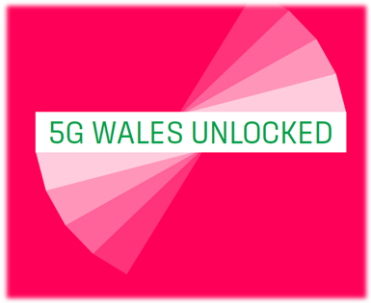
5G Wales Unlocked

Final Report

31 March 2022



Contents

1. Executive summary

a. Key findings including any benefits or impact supported by the evidence

Background

5G Wales Unlocked set out to identify the supply and demand side levers to influence the scale up of the services which can strengthen the business case for accelerated investment in next generation rural mobile access technologies. The project sought to evaluate demand and supply from multiple perspectives.

5G Wales Unlocked have deployed stackable demand-side use cases that centre around their scalable investment value.

The project aimed to provide a sustainable 5G environment for the areas by using a commercial 5G network thus reducing requirements to build bespoke networks to support the delivery of the use cases. The project also aimed to develop an innovative engagement of an MNO partner with risk share for a commercial network as well as to build sustainability into the approach via a combination of partner assets, potential long term delivery structure and commercial focus.

5G Wales Unlocked is comprised of four use cases covering diverse sectors – farming, tourism, transport and education. The technologies deployed at the farming, tourism and transport testbed sites were similar in nature comprising of IoT sensors and cameras encompassing AI capabilities. The education use case was a unique deployment linking the two geographical regions of Raglan and Ebbw Vale over the 5G network.

Outcomes

As a direct result of the project, a commercial 5G network is now in place in Ebbw Vale and Raglan. This activity has stimulated further upgrades to adjacent local areas benefiting directly from investment at Ebbw Vale and Raglan.

These upgrades are permanent, meaning that the benefits will be available to the population and businesses of the affected areas after the project has finished. For testbed sites like the farm and the castle it offers the opportunity to base further innovation projects that utilise 5G technology.

Use cases have generated a range of outcomes at differing levels from ‘interesting research findings’ which merit further exploration, through to strong commercial potential which will result in business cases being developed in parallel with an extended trial. A detailed analysis produced by the project’s Observatory reports on the use case business cases in detail.

A number of use cases clearly demonstrate the ‘additionality’ benefits of 5G over and above 4G, with data demonstrating that the 5G network delivers superior performance compared with the 4G infrastructure it replaced.

A key outcome of the project is the emergence of a distinctive and creative 5G ecosystem in Wales. The project has accelerated the development of a structured community bringing together interested organisations from the public and private sectors alongside academia to explore the benefits and opportunities presented by enhancing and improving connectivity in rural and semi-rural areas (and other areas too!). By bringing these players together, for the first time, a number of potential collaboration opportunities have already started to be identified and are being explored in a more strategic, joined-up approach, drawing from learning from this project as well as the broader 5G Testbed and Trials Programme.

Learning

Partners have derived significant learning from the programme. Beyond the operational lessons, key learnings have included that the deployment of multiple or 'stackable' use cases provides a significantly higher chance of longer term commercial adoption. Regarding the network, it is clear that it is difficult to have a firm timeline for deployment in a rural location which, by definition, has a number of unknowns at the outset of a project. It is also clear that supporting an extended 'run' period would be hugely beneficial for generating programme outcomes.

Sustainability

5G Wales Unlocked has developed a programme of activity focussed on the longer term sustainability of the use cases towards commercial operation or further research where use cases / assets are not being 'retired'.

2. Introduction

a. Key Objectives of the Testbed and Trials

5G Wales Unlocked, part of the 5G Testbed and Trials Programme, set out to identify the supply and demand side levers to influence the scale up of the services which can strengthen the business case for accelerated investment in next generation rural mobile access technologies.

As set out in the project's Grant Framework Agreement the aims and objectives of the project were to:

- Increase provision of 5G in rural and semi-rural locations in Wales;
- Identify the supply and demand side levers to influence the scale up of services to strengthen the business case for accelerated investment in next generation rural mobile access technologies;
- Build a commercially sustainable 5G environment; maximising use of commercial 5G services and reduce requirements to build bespoke networks to support the delivery of the use case demonstrators; and
- Demonstrate the socio-economic impact of increased 5G connectivity for rural communities and stakeholders

To address these objectives the demand-side use cases were selected to have a cross cutting sector appeal to aid transferability of infrastructure provision and to demonstrate a scalable investment value through deploying a stackable use case model; they cover the Diverse Rural Economy (farming), Tourism, Transport and Education sectors.

The project set out to explore and evaluate the supply and demand side levers and barriers to accelerating the deployment of rural 5G in Wales.

Supply side: From the network supply side, the project used a public Non-Stand Alone 5G network provided by BT/EE. Apart from being functionally required to enable the 5G use cases, this relationship explored the technical, commercial and organisational supply side issues involved in getting an MNO to upgrade and develop rural sites that were not on their roadmap.

The project also worked with technology SME's to provide the services and applications required for the use cases. Aside from the provision of the technology the project wanted to explore evidence of a scalable business case from the perspective of these suppliers in the context of the business case developed with the benefit owners.

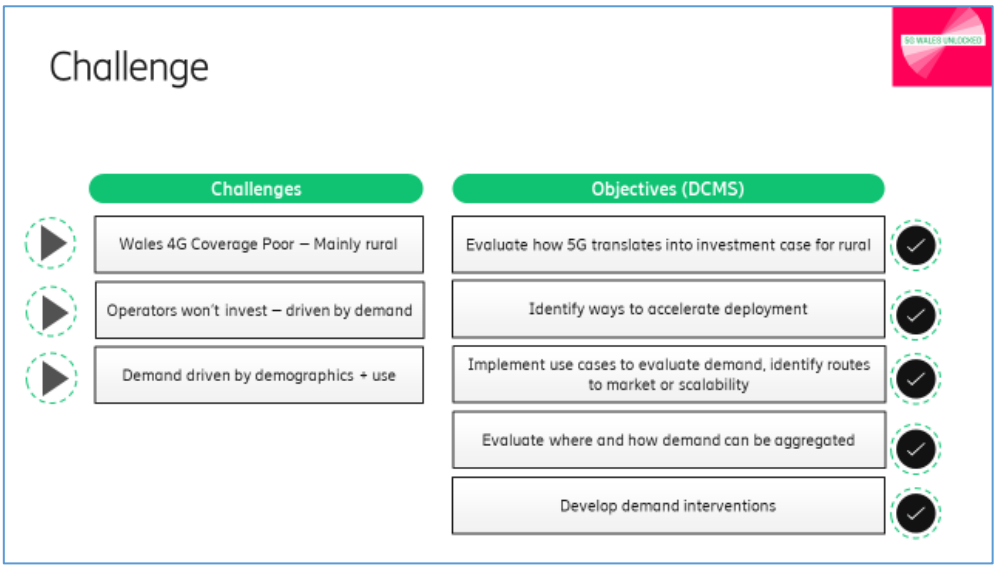
Demand side: The project set out to quantify the demand side of the equation through the development and aggregation of individual 5G enabled business cases. These business cases inform and frame the use cases. Each one contributes individually towards the understanding of aggregate value and demand for 5G enabled services when scaled.

A key outcome of the project is a business case model developed by The Observatory[1] which begins to build a framework for scaling this demand initially through the lens of county-based delivery[2].

The use cases are operational in two distinct areas: Raglan, a rural village based in the heart of Monmouthshire (Farming & Tourism); and Ebbw Vale, a semi-rural town in Blaenau Gwent, one of the South Wales Valleys (Transport & Education). The diversity of the locations provides key findings around the costs, challenges and lessons learned in deploying in such areas.

The project aimed to provide a sustainable 5G environment for the areas, by using a commercial 5G network thus reducing requirements to build bespoke networks to support the delivery of the use cases. This approach was designed to create an experimental environment that is as realistic as possible and which can enable use case projects to be designed around 'standard' notions of network functionality and quality of service. 5G Wales Unlocked used a commercial 5G network in both areas, deployed for this project by the MNO partner, BT.

The local challenges and objectives are summarised below:



The use cases were chosen to demonstrate how enhanced and improved connectivity can assist in addressing a number of issues across various sectors in rural and semi rural areas to:

- Improve productivity
- Create demand for new services
- Improve social and economic wellbeing of targeted communities
- Enhance customer and user experience
- Improve security, preservation and conservation for rural industries

[1] Led by Cardiff University's Business School, the Observatory is the independent monitoring function of the project reviewing the impact of the investment.

[2] A pan Wales sector scale out model is being considered

- Improve generation and dissemination of management information to improve business operations

The different sectors and the different locations have resulted in a number of key findings around costs, challenges, lessons and impact of 5G that will be of interest to DCMS, Project Partners and the broader 5G Ecosystem.

Project Partners

The project partners were selected to provide a blend of demand and supply, scale and agility and willingness to engage on the identified use case areas. Led by Welsh Government, partners included local authorities, private sector technology and creative industry businesses (large and small) as well as a university.

Other key long term aspects of the project were to:

- Develop an innovative engagement of an MNO partner with risk share for a commercial network
- Build sustainability into the approach via combination of: partner assets, potential long term delivery structure, and commercial focus

The partners and their roles are summarised below:

Project Partner	Role
Welsh Government	Lead – accountability and governance. General programme and project support to Partners and Use Case.
BT Networks	Provision of 5G network coverage. 5G service provision and Support. BT Lab access for early development activities.
Cisco	Technology partner providing specialist equipment, materials, and global support network in relation to 5G video analytics, HD motion capture and virtual communications platforms. Participating principally across Diverse Rural Economy, Transport & Education Use Cases.
UtterBerry	Technology partner providing specialist equipment, materials, development and support in relation to IoT sensors, Edge computeing AI, Analytics, Security and 5G sensor gateways. Participating principally across Diverse Rural Economy, Transport and Tourism Use Cases.
Appyway	Technology partner providing specialist equipment, materials, development, and support in relation IoT sensor co-ordinations, AI, Analytics, 5G sensor gateways and App SI. Participating principally in Transport Use Cases.

Cardiff University	Cross-disciplinary partner providing specialist support, development, and research in relation to IoT device application, design, video analytics, edge compute, 5G planning, programme evaluation/measurement. Participating principally across Diverse Rural Economy, Tourism and Transport Use Cases.
Jam Creative Studios	Creative Content partner providing production and deployment of an AR experience that delivers a 5G enabled AR visitor attraction for the Tourism Use Case and development work for the Education Use Case such as immersive classroom interactive content and 5G enrichment programme for schools. Participating principally across Tourism and Education Use Cases.
Blaenau Gwent County Council	Beneficiary, Use Case resource support and 5G testbed host, focussed principally on Education & Transport Use Cases.
Monmouthshire County Council	Beneficiary, Use Case resource support and 5G testbed host, focussed principally on Diverse Rural Economy & Tourism Use Cases.

b. Context of Project

5G Wales Unlocked is a key enabler of the digitalisation strategic aims of the public sector partners involved in the project, notably the Welsh Government's Digital Strategy for Wales[3].The project focusses on 4 key sectors in Wales – farming, tourism, transport and education - which together play a significant role in the rural economy of Wales.

As with the rest of the UK, 5G deployment in Wales has been focussed on adding capacity in urban areas. Latest research from Ofcom reports that in Wales the cities of Cardiff, Newport and Swansea are benefitting from enhanced mobile connectivity, with 5G coverage available outside from at least one operator covering between 23% and 34% of premises. This deployment does not, however, reach the rural areas of Wales where, more broadly, mobile connectivity remains poor especially in some of the very hard to reach where an estimated 7,850 premises in Wales cannot access a decent fixed broadband service or get good 4G coverage indoors; almost all these properties are in rural Wales[4]. 5G Wales Unlocked aim is to demonstrate the demand for 5G in rural areas in an attempt to encourage further investment by Mobile Network Operators (MNOs). MNOs have a significant role to play in ensuring that Wales is fairly covered. As Ofcom's Connected Nations 2021 report highlights although there has been a doubling over the last year of mobile base stations across the UK to over 6,000 sites – only 3% of these were in Wales (which is home to 5% of the UK population).

[3] Digital strategy for Wales | GOV.WALES
[4] Connected Nations 2021: Wales, Ofcom, 16 December 2021

Diverse Rural Economy (Farming)

Although agriculture makes a relatively small contribution to GDP[5] , around half of the food consumed in the UK is sourced from UK agriculture, with the rest imported into the UK from abroad[6]. Agriculture has important impacts on the natural environment especially in Wales where over 80% of land is used for agricultural purposes[7] .

Farming and agriculture are a significant sector in the rural economy in Wales; agriculture in Wales generated an estimated Gross Value Added (GVA) of £457 million in 2017. This represented 0.8% of the total GVA for Wales for that year and 4% of the total UK GVA for agriculture. Agriculture represents a higher percentage of the Wales economy than it does for the UK as a whole (0.6%).[8] In September 2018, agriculture, forestry and fishing represented 3.2% of workforce jobs in Wales. This was higher than the UK average of 1.1%.

Recognising that digital transformation in the agriculture sector is generally expected, on average, to create more value, from time savings and increased output, compared to more traditional agriculture methods, and given the prominence of the sector in rural communities in Wales it is therefore imperative that rural businesses in Wales have the connectivity to be able to compete effectively and opportunities are not limited simply due to poor connectivity.

To assist in demonstrating the commercial case for deploying 5G in rural areas, the Diverse Rural Economy use case comprised two key components of importance to address for the farming community.

- Rural crime and security
- Safety, wellbeing and social isolation

Rural crime and security

Rural crime on farms is increasingly sophisticated and costly; in Wales alone rural crime cost £1.6m in 2020 (see table below for a breakdown by region[9]). Smart technology systems, powered by 5G could offer effective and scalable solutions to decrease the amount of crime and its broader impact, with the added benefit of providing law enforcement with information and evidence they normally lack.

[5] Agriculture, forestry and fishing together account for around 0.6% of UK GDP (source: Office for National Statistics)
[6] Food statistics pocketbook, Defra. Food statistics pocketbook - GOV.UK (www.gov.uk)
[7] June 2021 agricultural survey, Welsh Government Survey of agriculture and horticulture | GOV.WALES
[8] Securing Wales' Future Summary (gov.wales)
[9] https://www.nfumutual.co.uk/globalassets/farming/rural-crime/2021/rural-crime-report-2021.pdf

The cost of rural theft around the UK

Region or country	Cost in 2019	Cost in 2020	% Change from 2019
East	£8.1m	£6.4m	-20.5%
Midlands	£10.6m	£7.9m	-25.3%
North East	£8.6m	£7.8m	-9.7%
North West	£3.5m	£3.7m	3.3%
Northern Ireland	£3.3m	£2.1m	-36.9%
Scotland	£2.3m	£1.7m	-25.0%
South East	£8.7m	£7.1m	-18.6%
South West	£6.6m	£5.1m	-23.7%
Wales	£2.6m	£1.6m	-39.4%
Grand Total	**£54.3m**	**£43.3m**	**-20.3%**

More locally, in our target area of Monmouthshire the following figures[10] are thefts of equipment from rural / farm locations between 01/04/2020-30/04/2021.

Equipment type	Number of Thefts
Quad thefts	15
Outbuilding/shed/garage breaks	55
Horsebox/trailer thefts	15
Fuel (heat oil, diesel) thefts	5
Livestock and working animal thefts	9
Plant/vehicle/caravan thefts	19
House breaks	3
Other (gates/unhoused tools/attempted) thefts	49

Safety, well-being and social isolation

Mental wellbeing and lone worker safety is a significant issue within the farming community. Research by the Health & Safety Executive reported that despite the fact that farming accounts for 1.5% of the economy in the UK, it accounts for 24% of workplace deaths. Agriculture has the worst rate of worker fatal injury (per 100,000) of all the main industry sectors, with the annual average rate over the last five years around 20 times as high as the all-industry rate[11].

This is compounded by findings from the Farm Safety Foundation[12] which reported that that 88% of farmers under 40 believe that mental health is the biggest hidden problem facing

[10] Gwent Police
[11] Fatal injuries in agriculture, forestry and fishing in Great Britain 2021, Health and Safety Executive
[12] Farm Safety Foundation / Yellow Wellies - YellowWellies.org

farmers today, with concerns that the ongoing impact of the coronavirus pandemic will have increased mental health issues for farmers.

The DRE use case aimed to demonstrate the social impact that deploying technology solutions, enabled by 5G, can have on improving safe working practices using the latest monitoring and safety technologies.

The delivery of 5G solutions which decrease the sense of isolation amongst farmers has the double benefit of tackling challenges through increasing social contact whilst also driving use of technologies which can also aid productivity

Tourism

Tourism is a key contributor to the Welsh economy, worth over £6.2Billion GDP and supporting 172,000 jobs[13].

CADW are the organisation responsible for looking after over 130 historic sites across Wales, with over 43,000 visitors per year. 22 of the sites are staffed either all year or seasonally. Although all sites have broadband connectivity (to run local networks) only 11 have publically available WiFi (accessed by passwords). A significant number of CADW sites are in rural or remote locations.

Over 1 million trips are usually taken by international visitors in Wales annually but spend per tourist is also typically far lower than in other UK destinations.

As part of the stackable use case model adopted by 5G Wales Unlocked there are two key components to the Tourism use case

- an enhanced immersive visitor experience through Augmented Reality;
- improving the security, preservation and conservation of tourism sites.

Augmented Reality

Augmented Reality has the potential to be a key differentiator in tourism and attraction management. The delivery of an augmented, immersive, rich media experience can provide an attraction or destination with an edge in a competitive tourist market.

The global augmented reality (AR), virtual reality (VR), and mixed reality (MR) market is forecast to reach US$30.7 billion in 2021, rising to close to US$300 by 2024.[14] This is a solid opportunity for the creative sector in the region to draw in AR/VR content, software and other specialist providers who can add value to the programme and grow their businesses in Wales.

[13] www.wta.org.uk
[14] VR/AR market size 2024 | Statista

As consumer uptake of 5G enabled handsets increases (now c10% of devices) more traffic is being carried over 5G, rising from 1% of total traffic in 2020 to 3% in 2021[15]; this provides potential for deployment of AR at more remote and rural tourist sites.

Given the nature and location of their sites CADW have a strategic interest in the development of scalable AR solutions which can operate across Wales. This project represents a significant proof of concept for them and a step towards the development of a smart attraction network.

Security, Preservation and Conservation

The ancient nature of CADW sites and the decay process makes surveying highly challenging and costly, repair and restoration work budgets need to be supported by compelling evidence of need and priority. It is usually far more economical to make pre-emptive repairs - the domino-like consequence of falling masonry at some of these structures can be dangerous and costly,

Cadw currently relies on quinquennial engineering reviews, ad-hoc visits by regional inspectors, and feedback from local castle management to detect problems, resulting in far from optimised interventions. Ancient monuments, especially those that are un-manned and in remote locations, are, by their nature and location more vulnerable to antisocial behaviour and vandalism.

Transport

There are significant disparities between rural transport services in Wales and what is on offer in more urban areas but there is significant potential offered by improved digital connectivity.

The transport use case, deployed in Blaenau Gwent local authority, is a demonstrator for an integrated multi-modal transport solution covering two key areas of transport infrastructure for the area:

- Bus Services
- Car Parking

Bus Services

Blaenau Gwent, host local authority to the transport use case, operates a Fflecsi-Bus[16] service offering an on-demand bus service. In keeping with the broader Welsh Government transport strategy[17] improved connectivity can open up more multi-modal integrated mobility services

[15] Connected Nations 2021, Ofcom, December 2021
[16] Fflecsi.wales
[17] Llwybr Newydd: the Wales Transport Strategy 2021 | GOV.WALES

(including via rail, bus, and pedestrian services) for residents living in rural and semi-rural locations such as Blaenau Gwent.

In addition to improving the connectivity for citizens the solutions deployed by improved connectivity can assist in revenue generation for often unprofitable rural routes. Planners, highways departments, environmental agencies, parking enforcement and emergency service providers all have interests in acquiring more accurate and time-sensitive BI data.

Car parking

As the numbers of cars have increased on the roads so has congestion. It is estimated that 30% of congestion on roads is from vehicles looking for parking; that £7bn is lost from UK economy due to road congestion; and on average £1.2bn parking fines issued per year[18].

Those who manage parking facilities in local authorities currently don't have access to data all in one place, in a standard and integrated format. The use case aims to use the high speed, low latency of 5G to generate a more integrated and informed transport service to Blaenau Gwent that can help provide the data required to inform policies and interventions to assist in the regeneration of the town centre of Ebbw Vale encouraging people to return to the town to shop, socialise and work.

The Welsh Government's Programme for Government sets out a commitment to ensuring Wales becomes a Net Zero nation by 2050; local authorities across Wales are therefore committed to delivering solutions in their areas to contribute to this target. Blaenau Gwent's Decarbonisation Plan 2020-30[19] sets out its commitment to becoming a Carbon Neutral local authority by 2030; the project set out to explore how improved connectivity could assist in supporting this ambition.

Education

Innovation through technology in the classroom has a long history, the immersive classroom is another step along this path. Education is a foundation of many economic drivers and as a devolved policy area for the Welsh Government is underpinned by the new *Curriculum for Wales.* The *Curriculum for Wales* provides a framework for schools in Wales to create their own curricula to support children and young people in Wales to be

- Ambitious, capable learners, ready to learn throughout their lives
- Enterprising, creative contributors, ready to play a full part in life and work
- Ethical, informed citizens of Wales and the world
- Healthy confident individuals, ready to lead fulfilling lives as valued members of society

[18] Appyway, March 2022

[19] Decarbonisation Plan 2020 to 2030, Blaenau Gwent

The focus of the *Curriculum for Wales* is not simply what is taught but how and why it is taught.

5G Wales Unlocked therefore recognised the opportunity that 5G connectivity could support the delivery of this curriculum for schools in Blaenau Gwent (and the wider community). Solutions delivered through 5G could provide a resource for teachers, as well as learners to develop, deliver and experience lessons in a creative and immersive environment to develop the integral skills that underpin the four purposes of the *Curriculum for Wales*

- Creativity and Innovation: Learners be given space to be curious and inquisitive, and to generate many ideas
- Critical thinking and problem solving
- Personal effectiveness: Learners should develop emotional intelligence and awareness, becoming confident and independent
- Planning and organising: learners should be able to set goals, make decisions and monitor interim results

Recognising the importance of developing digital competency and skills, the project decided that a physical structure, connected to 5G will provide a focal point for the community to explore the direct opportunity to teach about digital media and technology.

Additionally, working with the local authority, a number of local businesses and community organisations were identified who highlighted a need for a community owned high tech showcase facility for engaging community-based organisations, business to business and business to community events.

3. Use Cases

Each of the use cases has an associated Operational Framework document providing the detail behind the technologies used and deployment approaches for each use case. For simplicity of reporting, this document summarises the key methods of deployment, and provides an overview of the use cases themselves.

5G Wales Unlocked is comprised of four use cases covering four diverse sectors – farming, tourism, transport and education. The technologies deployed at the farming, tourism and transport testbed sites were similar in nature comprising of IoT sensors and cameras encompassing AI capabilities; and as outlined below the education use case was a unique deployment linking the two geographical regions of Raglan and Ebbw Vale over the 5G network.

a. Methods including technologies used and deployment approaches

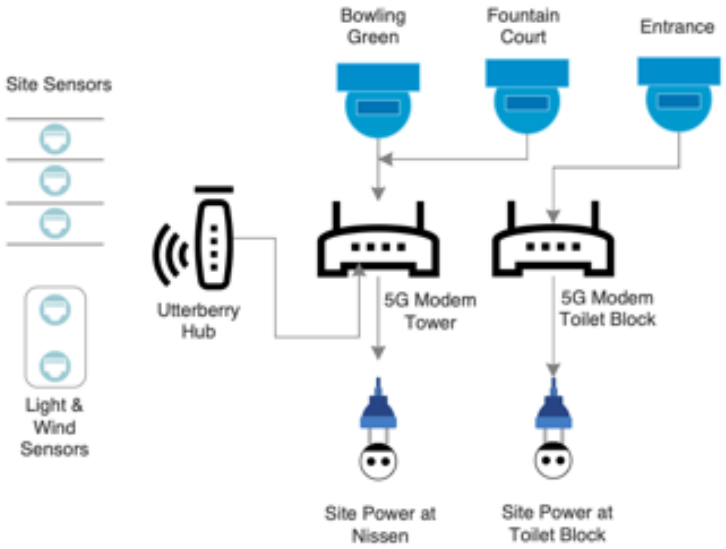
DRE, Tourism & Transport

The key infrastructure deployed for the Farming, Tourism and Transport Use Cases are summarised in the table below:

Infrastructure	**DRE (Farming)**	**Tourism**	**Transport**
5G network	X	X	X
IoT Sensors	X	X	X
Cameras	X	X	X
Augmented Reality		X	

The common thread for all these use cases is the deployment of IoT Sensors and cameras for video analytics. Both data sources are integrated onto a 'Digital Twin' dashboard to supply stakeholders with an interface for data interpretation.

A typical system architecture is shown below, (this is for Raglan castle, but all follow the same pattern).



An overview of each of the technologies deployed across these three use cases follows in the section below

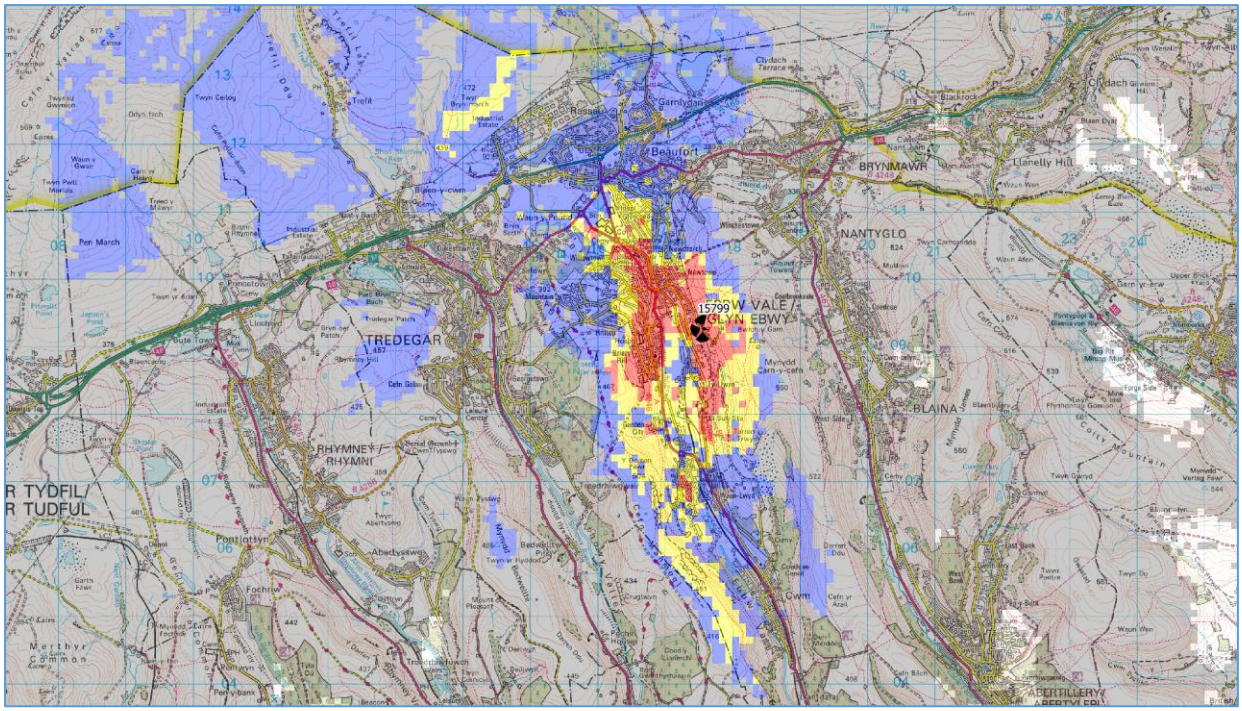
These use cases use the high speed, bandwidth and reliability afforded by the 5G network for downloading and interacting with high quality video and data to dynamically create alerts and trigger events that significantly increases the information available to the various stakeholders.

5G Network

BT as the Mobile Network Operator partner for the project were responsible for the deployment of 5G in 700Mhz in both Ebbw Vale and Raglan. This 5G network enabled the deployment of all 4 use cases, providing the project with stackable use cases that can demonstrate the commercial opportunities for MNOs to exploit by deploying in rural and semi-rural areas.

Ebbw Vale *(and south Wales valleys)*

Two sites in Ebbw Vale were upgraded to provide the 5G coverage as detailed in the map below:



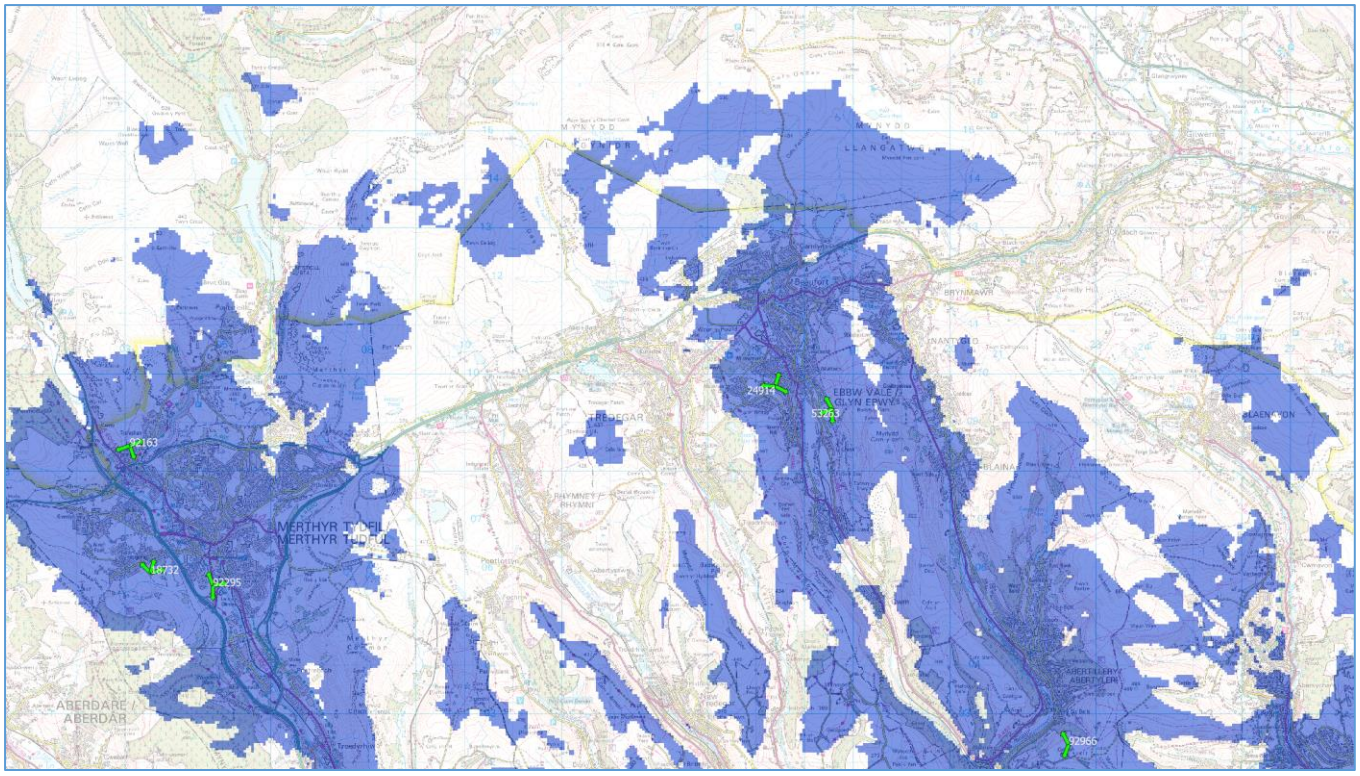
Ebbw Vale, Blaenau Gwent - coverage

Ranges

Minimum	Maximum	Label	Colour
-130	-117	No coverage	
-117	-97	Outdoor only	
-97	-87	Urb / Suburb / R	
-87	20	Urban commerci	

BT have confirmed that as a result of the investment made through the 5G Wales Unlocked project they have accelerated the upgrade of 5 **additional** masts in the south Wales area to cover Abertillery, and areas of Merthyr Tydfil. These upgrades have all taken place as a direct result of the 5G Wales Unlocked Project since October 2021.

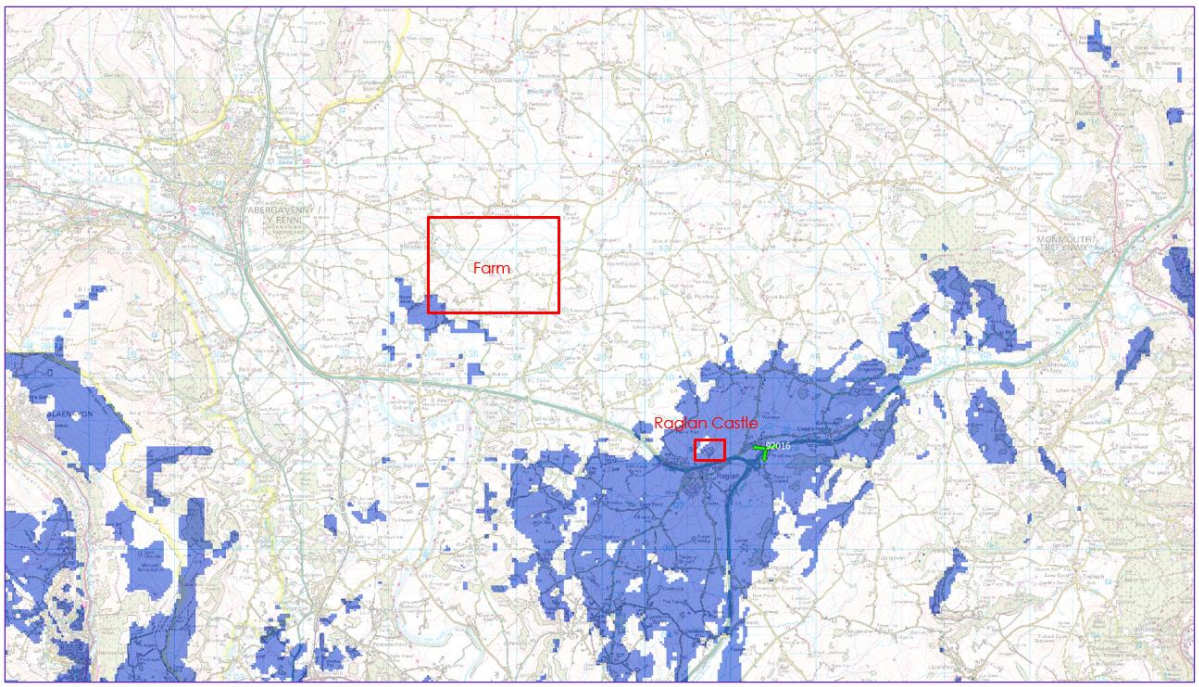
Below is a coverage map demonstrating EE 5G coverage across this extension area of the south Wales valleys.



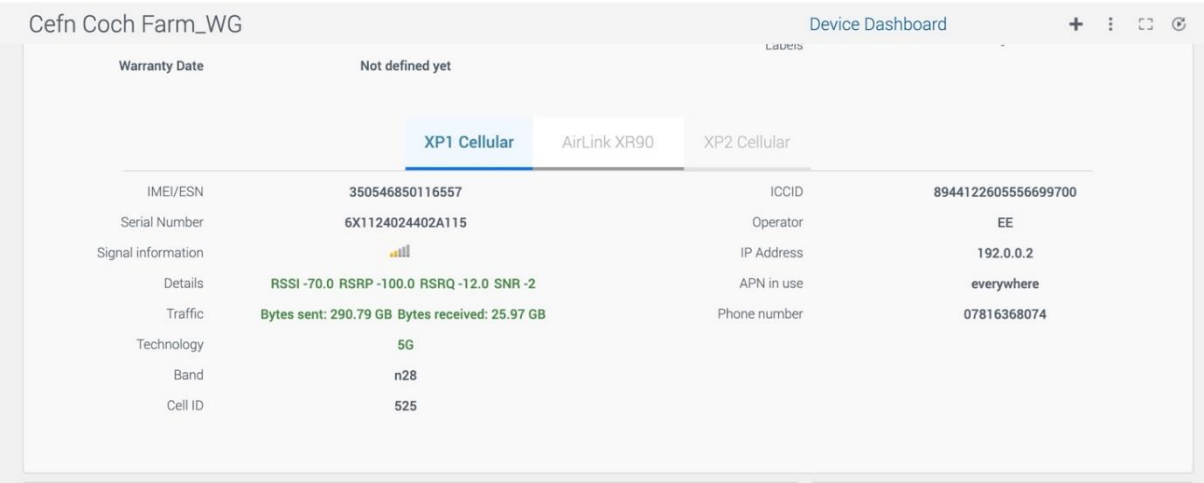
BT/EE 5G coverage across south Wales valleys, January 2022

Raglan Deployment

The Raglan area is covered by a site to the West of the village; chosen to give coverage to Raglan Castle and the Farm. The 5G service in Raglan is on band n28 (700MHz) and therefore gives wide geographical coverage. Speeds are of the order of 150Mbs down and 60Mbs up – fully adequate for the use cases at the farm and the castle.



BT/EE 5G coverage Raglan, Monmouthshire, January 2022



Screenshot of 5G Modem Dashboard, Cefn Coch Farm, Raglan - 5G connection

The investment by DCMS, through 5G Wales Unlocked has ensured that both Ebbw Vale and Raglan now have access to a 5G network; as outlined above BT have also confirmed that this investment has accelerated deployment of 5G in to other areas within the region to demonstrate a joined up network coverage to the area. These are long term, tangible and sustainable outcomes generated from this project for areas that have historically faced challenges of deploying connectivity and making use of associated technologies.

In legacy terms, the approach the project has taken has secured permanent 5G access to the use cases, but also to the businesses and citizens in the area.

Network – Deployment

The decision to use a commercial network reduced requirements to build bespoke networks to support the delivery of the use cases. This approach provided an experimental environment that is as realistic as possible and has enabled use case projects to be designed around standard notions of network functionality and quality of service. There have, however, been a series of challenges associated with deploying a commercial network. This has principally been around the lack of control the project has had over supply-chain work schedules. Although the Ebbw Vale network was deployed quickly over a 6 week period, (March 2021), 5G in Raglan was only deployed on 31 January 2022. This has had a significant impact on the data that can be generated and subsequent benefits realisation reporting.

However, by engaging an MNO to upgrade sites as part of the project has ensured an expedited provision of 5G to areas that would not have benefitted from the improved connectivity for some time and the connectivity is now part of the digital fabric of the identified and surrounding communities.

The upgrade of the Raglan site was initially considered as straight forward and would follow the Ebbw Vale upgrade which took around 6 weeks to complete. Unfortunately, the upgrade took far longer, only becoming live in January 2022. The reasons for this are extensive and revealed some real complexities for rural upgrades. The primary issues that had to be overcome are listed below:

- The site was not owned by BT/EE; changes to the site was owned and managed by a third party;
- The site was not identified as needing significant improvement until the design work was completed;
- Once revealed, the site issues were significant and included obtaining landowner permissions;
- Another party was also upgrading their equipment at the site, compounding the issues;
- Issues seemed to reveal themselves in a serial manner, meaning each issue had to be resolved before the next one could be tackled;
- Power became an issue and a power upgrade was required;
- Physical strengthening of the tower was necessary for all the changes being made by the various operators using the tower;
- Ground condition testing was required before strengthening could take place;
- In all, it took more than six months to resolve all the issues with the site and then plan and deploy the 5G upgrade;
- The upgrade itself took less than two weeks.

To compound the problems, the 4G service at Raglan failed in October and took 8 weeks to restore, meaning both the farming and tourism use cases were unable to operate during this time. The issue was a single sector problem at the same site which took significantly longer to diagnose and repair than normal for 4G sites. It is not known if the 5G upgrade work was the underlying cause of the 4G failure.

IoT Sensors *(deployed in Farming, Tourism and Transport)*

IoT sensors are used to monitor different variables and areas at the farm and the castle in Raglan and on the Fflecsi bus service operational in Ebbw Vale.

Using the UtterBerry base station and IoT devices, the following variables are monitored, analysed and reported on:

- *vibration (PPV)*
- *tilt (vehicle sensors for safety alerts)*
- *displacement*
- *temperature*
- *humidity*
- *geo-fence breach (also tracking)*

The data collected from all sensors is aggregated and shown on use case specific dashboards that are a digital model of the use case. The dashboard is cloud based so that it can be viewed at any time through the internet[20] by the end user.

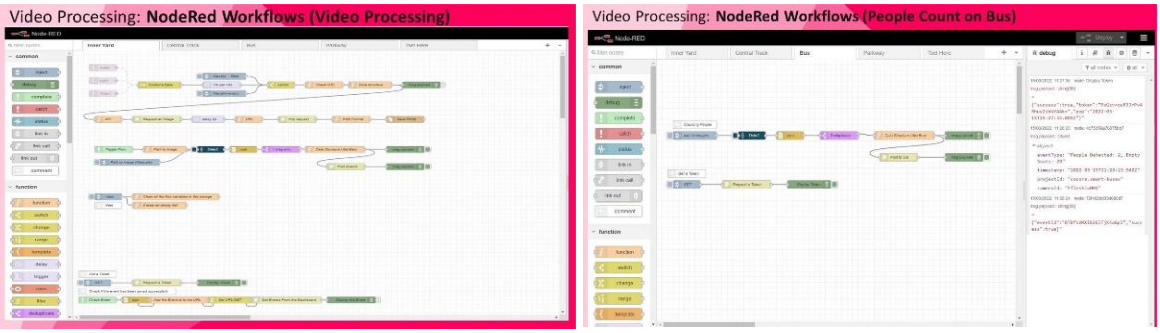
Cameras (deployed in Farming, Tourism, Education and Transport)

There are several cameras deployed across the use cases

- DRE – 4 Cameras, one connected on WiFi
- Tourism – 3 cameras
- Transport - (Bus) 3 cameras
- Transport - (Car Parks) 3 cameras, one connected on WiFi

Cardiff University analysed the real-time video feeds from these cameras utilising the open-source NodeRed.js framework to develop their analytics capability; the outcome of this work can therefore be added to and expanded in the future further enhancing the outcomes generated by the project.

[20] Secure password protection is invoked for all users.



Example NodeRed workflows

Cardiff University also utilised machine learning to identify safety and security issues (at the farm and castle); and monitor seat availability to identify empty seats, the availability of the accessible space (on the bus) and car parking spaces, as they arise in real-time. The Meraki cameras used can, within themselves, generate an MQTT feed identifying when people or vehicles are in the field of view to trigger deeper analysis. Analytics detected any relevant alerts on the activities of vehicles, individuals, livestock with triggers generated to the UtterBerry Dashboard around:

- *movement hot-spots*
- *people movement/ counting*
- *livestock movement/ counting*
- *vehicle movement*
- *video capture from IoT event trigger*
- *out-of-hours movement*

The video streams are integrated and embedded within the dashboard for users to be able to select and view the cameras in real-time within a cloud application from any location[21].

On the bus, the GPS signal from the video system also allows the location of the vehicle to be determined in real time.

Augmented Reality

AR has been developed specifically for the Tourism use case. The challenges with AR are the need to download large files in real time and to provide localisation. For the tourism use case there was some optimisation done to limit the demand to allow the AR to run on 4G initially. iPads were used as the 5G device to make best use of their on-board processing and their graphics capability. Localisation was performed at three points in the castle using Cloud Anchors. The AR was specifically developed to enable multi-user activity within the gamification segments which placed a significant demand on the 5G network.

[21] Provided they have access rights

Operational Documents

A full description of the technology deployed and the operation of the use cases can be found in the relevant operational documents.

b. Description of the use cases

Diverse Rural Economy & Tourism, Raglan, Monmouthshire

The Diverse Rural Economy and the Tourism use cases formed part of the stackable use cases deployed in the rural village of Raglan in Monmouthshire. The two use cases tested solutions to inform the commercial viability of deploying 5G in rural areas.

Diverse Rural Economy *(Farming)*

This use case utilised the 5G network, 5G Sensors and 4 Meraki cameras to address areas relevant to the farming community:

- Rural Crime & Security
- Safety, wellbeing and social isolation

The sensors, deployed by project partners UtterBerry, monitored a range of indicators:

- *Vibration (PPV) and Tilt (vehicle sensors for safety alerts):*

  A tractor and a mule[22] have 5G sensors fitted that provide a full set of data. For the use case the orientation of the sensor is used to detect a safety alert when the vehicle is at an angle (suggesting an anomaly and potential danger to the farmer), either front to back or to the side. The threshold for the trigger is set to 20^0

- *Displacement:*

  The gate sensor data is recorded over time with two states: open or closed to alert the farmer to any possible intruders

- *Geo-fence breach (also tracking):*

  An event can be interrogated at any time to show the actual location of the tractor when the event occurred. As the sensors work on 5G and 4G, the vehicle can be tracked anywhere in the UK and not just in the confines of the geofence area.

- *Temperature and humidity*

[22] A utility vehicle

These functionalities were not required to address the rural crime and mental wellbeing aspects of this use case but the functionality can be activated if required by the farmer at a later date.

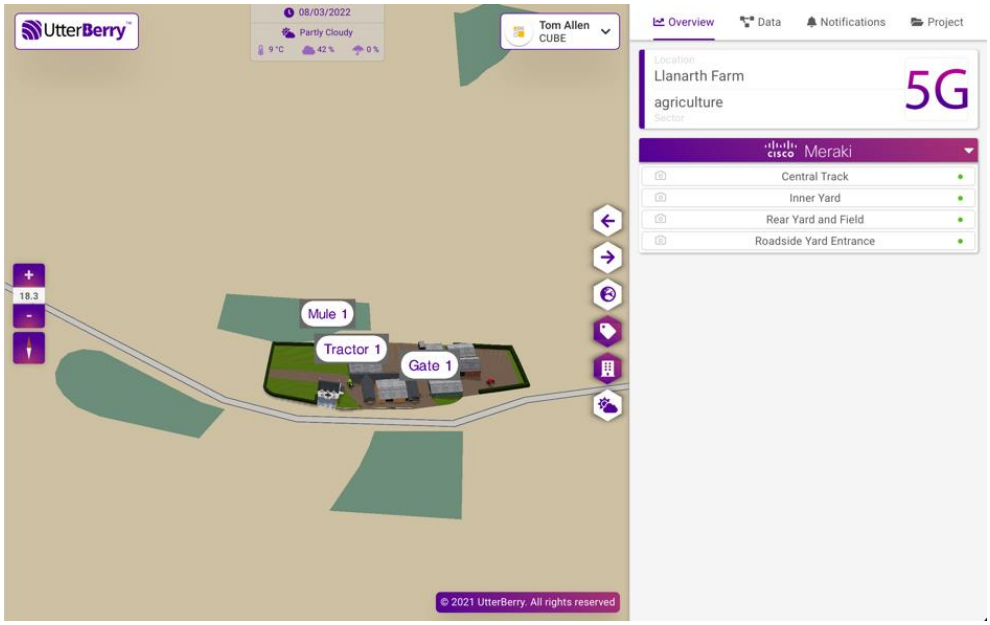
The four cameras at the site relay video for analytics using machine learning and alert status direct from the camera. The video feeds from these cameras are streamed to AI based video analytics to monitor the activities of individuals and also support the monitoring of the sensors. The video analytics detect:

- Unauthorised access (trespass) including time-stamped and time filtered[23] alerts;
- Captured video if the IoT sensors identify any sudden condition changes in areas where video is available; and
- Monitoring movements and hot-spots over time

The cameras have in built analytics whereby they can identify people, and livestock[24], who are within safe areas and people who may stray from this.

The video streams are embedded within the dashboard for users to be able to select and view the cameras within a cloud application from any location[25].

The DRE use case dashboard, developed by UtterBerry, aggregates the data collected from the sensors for two farm vehicles and the gate and embeds the video streams; the dashboard generates alerts when safety or security breaches have been identified either by the sensor and/ or video analytics.



Farm Dashboard

[23] Certain times of day filters are applied, such as gate opening out of hours and people/vehicle movement out of hours

[24] As an extension to the use case the farmer requested that a camera was installed to detect and count sheep. Optimisation work is ongoing to ensure high confidence rate in accurately counting animals using video analytics rather than tags.

[25] Provided they have access rights

Additionally, the farmer was supplied with access to the StaySafe lone worker app to enhance the farmer's sense of security and safety. Mental Well being data was collected in the form of the WEMWEBS based interviews. In reality the limited duration of the project and sample size did not lend itself to establishing credible insights around the effect of technology on mental well being. There is a possibility that this work could be widen its focus to incorporate activity at the livestock market and a re-thought experiment design.

The 5G network enables the solutions to operate with 4 AI cameras simultaneously streaming HD video to cloud based analytics operating alongside IoT data for multiple parameters.

Having a 5G installed network at the farm has enabled Cardiff University to use it as a development platform and explore different perspectives in terms of video analytics using alternative cameras and edge compute architectures. During the lifetime of the project the farm use case was extended to incorporate livestock management technology and the farmer has expressed an interest in developing the solutions to provide a base for soil analysis and farm automation and is comfortable with the farm to be further developed as a testbed site.

Tourism

The tourism use case used the 5G network, an Augmented Reality solution, 5G sensors, and three Meraki cameras to demonstrate the commercial advantageous solutions that 5G connectivity can enable:

- Enhanced immersive visitor experience
- Structural, preservation and security monitoring

Enhanced Immersive Visitor experience

The aim of implementing the augmented reality at Raglan Castle was to:

- Demonstrate how the use of 5G networks can deliver immersive digital experiences at Raglan Castle
- Determine the appetite for such experiences at rural heritage locations and the impact they have on the visitor experience
- Determine whether immersive experiences enabled by 5G connectivity can drive increased tourism to rural heritage sites

The AR experience runs on iPads directly connected to the 5G network, which are loaned from the visitor centre at the site. The device choice of iPads was driven by the fact that they are

held rather than worn which is arguably safer[26] for outdoor, public space use, but other devices[27] could be used in different settings.

Visitors register and the iPads are locked to only the AR experience, so any alternative internet or other use will be prohibited. They are also geo-fenced so they can be tracked and an alarm raised if they are taken off-site.

The AR App uses cloud anchors to locate the visitor at one of three locations:

- At the front of the castle with the cannon game
- At the bowling green for the bowling game
- At the fountain courtyard for a simple quest to uncover information about the castle

Project Partners, Jam Creative, created CGI reconstructions of different parts of the castle allowing visitors to experience and explore the castle as it would have looked in the 17th century, through Augmented Reality. The AR experience incorporated interactive games so visitors could place and fire virtual cannons, play bowls virtually with King Charles 1 and compete in a quest around the Fountain Court area of the castle.

Virtual Cannons

Bowling with King Charles 1

Fountain Court Quest

[26] The site at Raglan Castle runs over many levels, is uneven and presents many hazards including a moat.
[27] With the growth of 5G devices it is anticipated that future rollout will be based on a 'Bring your own' device model. However, the range of devices is limited to ones that can utilise 5G and the proportion of visitors currently attending with 5G devices is low.

The 5G network has unlocked the ability to run multiple visitors concurrently and further development options such as centralised rendering of graphics as well as interaction between users in virtual spaces.

The responses of users have been very positive, especially amongst the younger visitors. Although the experience has been only fully available since March 2022, the responses show:

- Very strong outcomes for enhancing the visit
- Very strong outcomes for enhancing the information about the castle
- Strong recommendations to other visitors

Preservation and security monitoring

IoT sensors are being used to monitor both short and longer term issues already under surveillance for the castle, plus some additional monitoring points to aid in the management of the site. It is the nature of ancient monuments that degrading of structure can be a slow process; CADW seek to strike a careful balance between leaving the original structure intact and careful intervention when necessary. Sometimes this is difficult to predict and the sensors are aimed at creating an alert should unsafe conditions occur sooner than predicted for the structure and to identify unsafe activity from visitors to the site.

Condition monitoring - uses the UtterBerry base station and IoT devices to monitor for several indicators:

  - *vibration (PPV)*
  - *tilt*
  - *displacement*
  - *temperature*
  - *humidity*
  - *ground condition (near effluent tanks)*
  - *effluent tank capacity*
  - *wind-speed*
  - *ambient lighting*

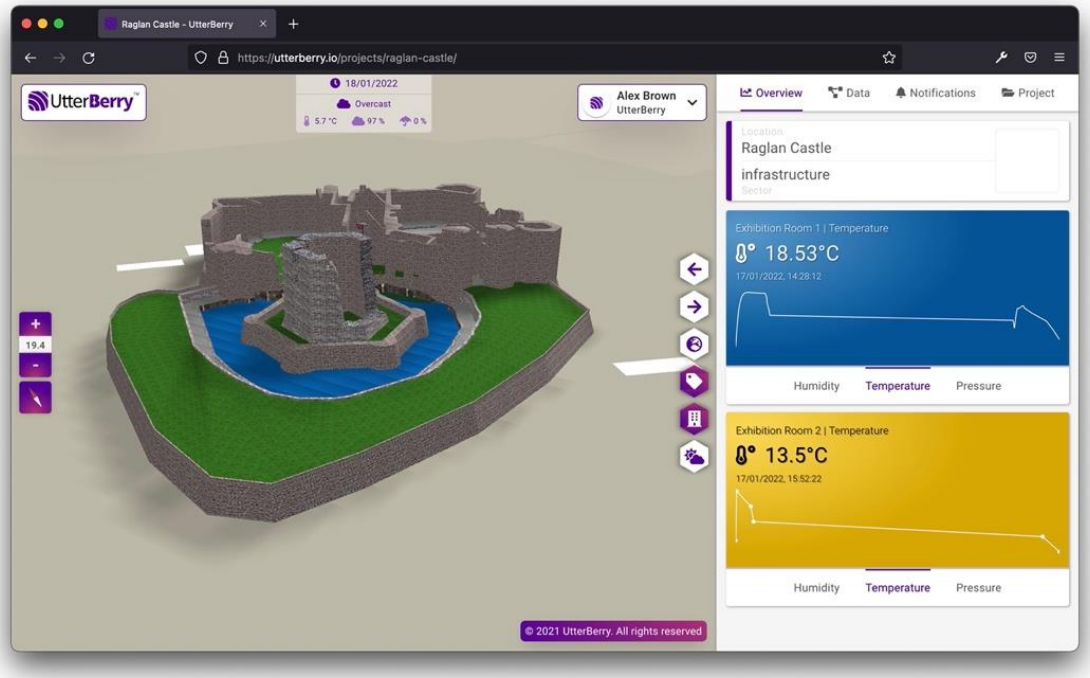
The data collected will be charted over time for use to support any deterioration and to inform any immediate actions and planned maintenance[28]. In addition to the fabric being monitored, other sensors provide data on:

- Ambient light– some parts of the castle need to be closed to the public should the ambient light drop below a certain level; this is due to safety issues arising from low visibility. At Raglan Castle this can now be constantly monitored at various locations in order to build a model of when the ambient light is insufficient and the castle should be closed. The data will be logged over time and be available as graphed outputs over durations up to months. Alerts can be generated onto the dashboard available at the site for monitoring.

[28] No planned maintenance or intervention at this location in the site currently

- Windspeed - some parts of site need to be closed to the public should the wind direction and speed be at a dangerous level. At Raglan Castle this can now be constantly monitored at the top of the great tower. The data will be logged over time and be available as graphed outputs over durations up to months. Alerts can be generated onto the dashboard available at the site for monitoring.
- Sewage tank– there are 3 tanks and by continually measuring the levels a more timely emptying service can be managed, meaning that the toilet block will be better served and contributing to the overall visitor experience. The data will be logged over time and be available as graphed outputs over durations up to months. Alert thresholds can be set and monitored for display on the dashboard.
- Ground Condition – the effluent tanks on the South side of the castle are positioned on a bank that represents some concern over ground movement. To monitor this steel pins have been sunk to 2m depth on which sensors are placed to detect any movement. Trending over time and alerts can be generated and displayed on the dashboard.

The data collected from all sensors is aggregated and shown on a Castle dashboard that is a digital model of the castle itself. The dashboard is cloud based so that it can be observed at any time through the internet[29].



Raglan Castle Dashboard

In addition to the IoT sensors, 3 cameras are installed around the castle. The video feeds from these cameras are streamed to AI based video analytics to monitor the activities of individuals and also support the condition monitoring sensors. The video analytics can detect:

- Challenge climbing, including trespass in areas out of bounds to visitors

[29] Secure password protected

- Captured video if the IoT sensors identify any sudden condition changes[30] in areas where video is available
- Monitoring visitor movements and hot-spots against time and potentially against the AR being utilised by visitors at that moment

The cameras have inbuilt analytics whereby they can identify people who are within specified areas of the picture frame such as the effluent tank location and track. Multiple areas have been set up and these can be added to remotely, or refined in terms of area covered. The cameras themselves have been successfully tested to see whether they can operate in a stand-alone format rather than cloud-based analytics to identify alert conditions, once detected sending an MQTT alert to trigger more detailed video analytics and making available to video of the event.

The video streams are embedded within the dashboard for users to be able to select and view the cameras within a cloud application from any location[31].

In conjunction with the Immersive Classroom in Ebbw Vale, the castle was used to demonstrate the ability to 'Live Stream' 360 camera video directly from the castle to the immersive classroom and linking this to 2D WebEx boards in other schools.

The configuration included a 6 lens 360 camera using 4K resolution. This required a link that was capable of delivering at least a 30Mbs upload speed which was only available using the 5G network. Attempts to use the 4G links gave much lower resolution and break-up of the video stream. Using a lesser camera with 3 cameras running at HD, (1080p), was possible using the 4G links, but again the video and audio broke up at different points around the castle.

The live-streaming demonstrated a good use of the 5G as it was both a high demand for the upload at Raglan and a high demand for the download at Ebbw Vale and demonstrated a 5G end-to-end linkage. To further load the network, simultaneous WebEx meetings were added, where the in room WebEx cameras linked to devices at the castle for real-time questions and answers and also to other schools WebEx boards. The response from the children we extremely positive, especially the real-time Q & A with experts at the castle who were giving the real-time virtual tour. Further information is contained in the Education Operational Framework document.

The 5G connectivity has enabled the AR solution, alongside the three 4K camera feeds and IoT sensors to be deployed and operational concurrently providing enhanced visitor experience as well as valuable data for the CADW management team to inform the operation of the castle.

[30] This level of integration was not completed in time. The positioning of cameras to monitor the min risk of the Tower was not possible. Additional cameras on the visitor centre would make this viable as an extension

[31] Provided they have access rights

Transport & Education, Ebbw Vale, Blaenau Gwent

The Transport & Education use cases formed part of the stackable uses cases deployed in the south Wales town of Ebbw Vale, Blaenau Gwent. Along with DRE and Tourism use cases; these tested alternative solutions to inform the commercial viability of deploying 5G in rural and semi-rural areas.

Transport

Bus

A number of IoT sensors and 3 Bosch cameras are deployed on a Fflecsi bus service in Ebbw Vale and are used to monitor and report on seat availability and journey mapping. The video feeds from the cameras utilise machine learning to identify empty seats in real-time, including the availability of the accessibility space. The video feeds coordinate with the IoT sensors to provide data on

- Available seating
- People Entry/Exit counting
- Identifying journey maps per individual

The video streams are not available for viewing however the analytic outputs are available to inform the bus dashboard and the Information Totem (see below).

The operation of the analytics identifies the number of individuals on the bus and gives a confidence level of it being a person. Where confidence levels are low, an error is flagged to aid in the machine learning. The disabled/pushchair space consists of three fold-back chairs; they have IoT sensors to indicate if they are in use or not, as well as the video analytics being able to identify if an object or a person is occupying this area. The availability status of this area can be alerted directly as well as the seat availability. The use of video analytics demands the highest resolution images possible. However, the comparison of the video analytics accuracy across 4G and 5G areas has not been possible within the time available for the project.

By correlating the information from the cameras, the sensors and the GPS location (accessible from the base station) a database of information can be created to show occupancy against time and against GPS location. This information can be used for further analysis of demand and transport management purposes.

The data generated feeds to a dashboard to provide statistical information and analysis for predictive purposes on journey mapping and demand. Access to the information dashboard is via a cloud based application and hosts statistical analytics available for the management of bus and transport policy within the area.

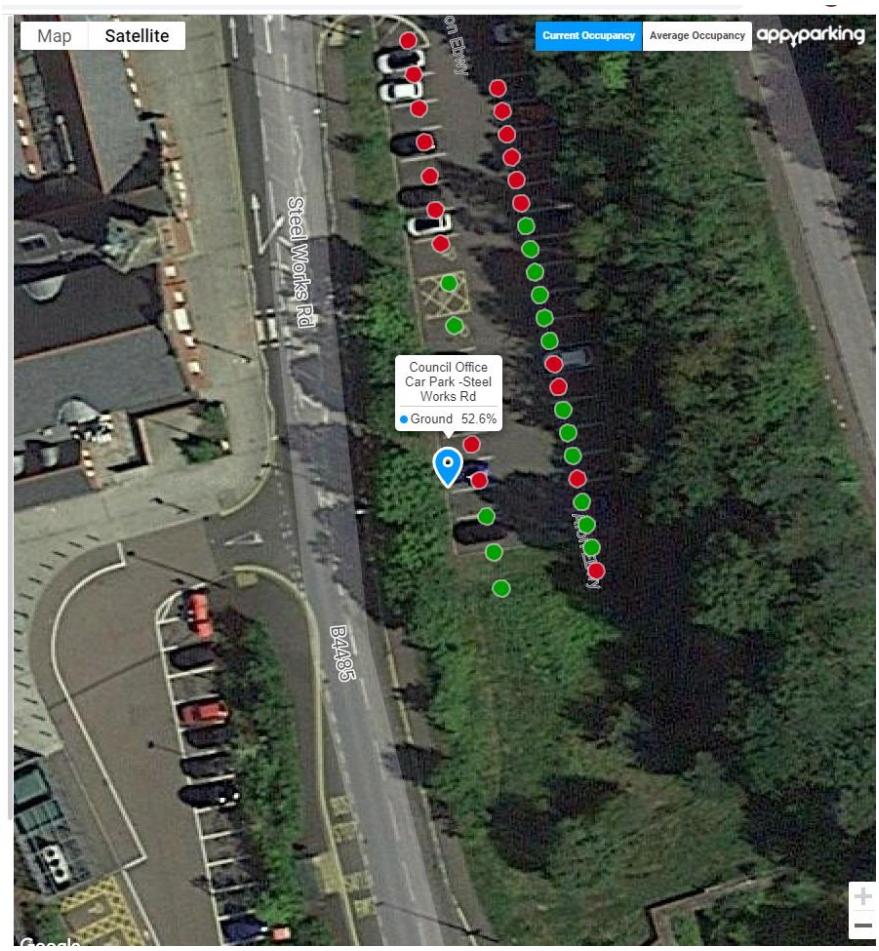
Car parks

This component of the transport use case created 5G-enabled smart car parks which communicate live, and historical, car park space status and data to car park users and local authority transport coordinators.

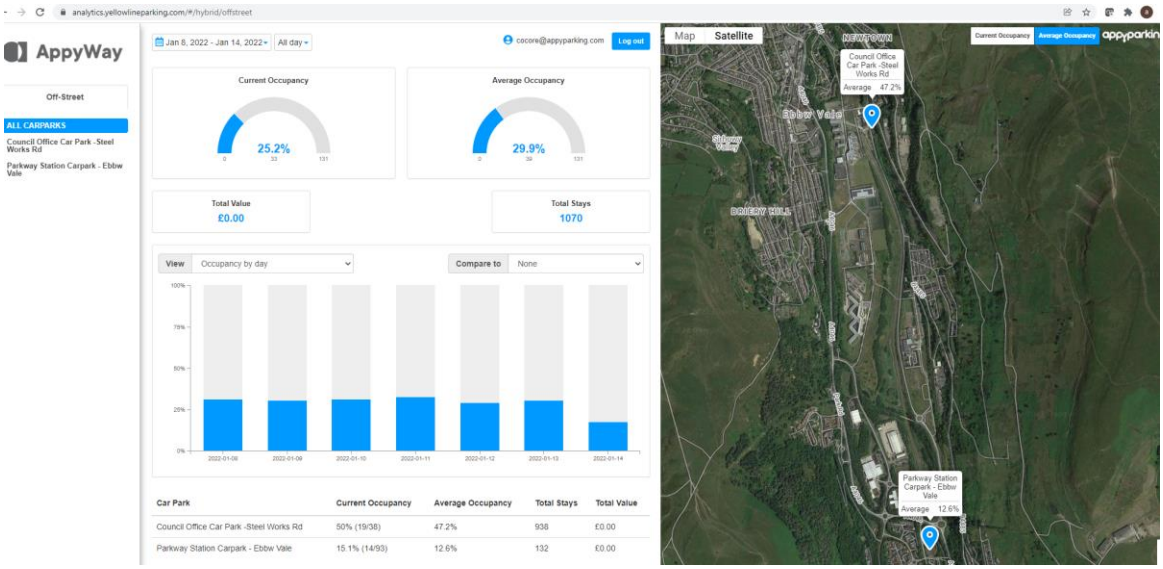
IoT sensors were deployed in three car parks by Appyway; alongside Meraki cameras which are being used to monitor three car parks.

The data collected from all the Appyway sensors is aggregated and shown on the Appyway cloud dashboard as a digital model of the car park itself. The dashboard provides:

- Real-time parking information for car park users
- Statistical historical information generated for analytical purposes



General Office car park



Appyway car park dashboard

The data generated from the video utilises machine-learning to identify parking space availability in real-time to correlate with the information generated on the parking app.

The machine learning reviews and reports on

- Vehicle entry and exit counting
- Space availability

An information dashboard is available to car park managers via a cloud-based application. The access to the dashboard will be by password, with users nominated by Blaenau Gwent Council owner. This dashboard will also have statistical analytics available for the management of the car parks.

The use case also explored how the improved connectivity could open up new solutions to complement and enhance the local authority commitments to reduce carbon emissions and develop an integrated transport strategy. The use case enabled the development of Appyway's App to integrate with the Liftshare app; using the network to develop their product to provide more comprehensive data to the local authority to create multi modal integrated transport solutions to help support a decarbonisation agenda. This work is ongoing with Coleg Gwent in Blaenau Gwent.

Totem Information Point

To integrate the real-time, live data available for the citizens of Ebbw Vale, a 5G enabled Information Totem has been deployed outside of the FE campus serving the region, Coleg Gwent (the campus also includes the town's leisure centre, several businesses and the Immersive Classroom).

The totem is connected directly to the 5G network to allow high speed connectivity and the display of real time information, including video. The totem is highly configurable and acts as its own information broker therefore it can display almost any data source that becomes available in the future[32].

Information Totem, Ebbw Vale

[32] The intention is to integrate data from the Fflecsi Bus Service on to the Totem which will then show information such as current location of the bus on a map of the local area; seat availability; Time to destination, Parking availability and other transport timetables

Education

The Education use case is supported by the 5G network and consists of a 360º Immersive Classroom, 4 Cisco WebEx boards and a handheld 360º camera.

The main focal point of delivery is the Immersive Classroom. It is housed in a stand-alone container and located in the grounds of the leisure centre in Ebbw Vale, Blaenau Gwent.

Video shot in 360º format and computer-generated content can be projected to wrap around all 4 walls of the 6mx6m projection room giving a highly immersive experience. (Appendix B of Operational Framework provides a full specification of the facility).

The content is controlled via the room's iPad over WiFi to the server room and from a modem to the wider 5G network. In this way content can be dynamically searched for and downloaded or livestreamed into the room.

To extend the reach of the use case and test the 5G network across both Ebbw Vale and Raglan, WebEx 85 boards were installed in 4 different schools. Two in the 5G coverage area of Ebbw Vale, Blaenau Gwent, one in the 5G coverage area of Raglan, Monmouthshire and one in a good 4G coverage area in Abertillery, Blaenau Gwent. They are connected by modem to ensure a good base from which to test how connectivity performs across the network and provide a picture of how the use case could work across blended networks. A PTZ camera installed in the Immersive Classroom, with a 120º view at the 'back' of the classroom provides the video feed out to the WebEx boards.

The 360º camera can be used with its app on a smart phone which then becomes a remote control for the camera. By selecting the livestream function in the app the camera will stream video through the phone on 4G/5G to a destination server, either private or public domain such as YouTube.

The use of 5G to support the Full360 classroom has been evaluated by the project, both in isolation and in conjunction with a combination of "learning settings" incorporating the WebEx boards and a remote 360 camera livestream. The objective was to identify the optimum use of the 5G network to support blended learning approaches. Detail of the different learning approaches[33] can be viewed in the Education Operational Framework documentation.

The Immersive Classroom uses the 5G connectivity to download content which is important to support a dynamic access approach rather than needing to download prior to lesson. Whilst content can be downloaded in advance of the session the 5G supported fast and reliable dynamic access which allows the teacher to let the class determine what content they might use during the session.

5G also supported the 360 Livestream interaction which is fundamental to the livestream, virtual day trip, scenarios tested.

[33] Standalone Lesson, Split lesson, Collaborative, Livestream

When the students in the Full360 immersive classroom were linked to students elsewhere this was predominantly done using 5G either within the same coverage area or across the cloud to a remote 5G area and comparisons were also made by linking to a 4G site to the Immersive Classroom.

In addition to the use case operating within the Immersive Classroom itself, this use case spread to Raglan where a number of livestream sessions were conducted from Raglan Castle to the Immersive Classroom – enabling testing of the network in both locations, as well as technical testing of the facility itself.

Immersive Classroom - 360 Livestream from Raglan Castle

In the development of the use case it became apparent that a dedicated resource would be required to manage the facility and the project created a full-time resource, Digital Champion. Six pilot schools were recruited to take part in the training and subsequent evaluation sessions. The Digital Champion works with the local Stem Facilitators to support the users, in particular hosting sessions and identifying content packages that can be used to evaluate the learning settings and then go on to host sessions in the immersive classroom. Full3sixty and Cisco provided training to the team and users so they can use the system and create their own content. Digital champions will cascade the training out as the group widens. This has significantly increased the skills of the local education workforce as well as engagement and knowledge of 5G capabilities within the area.

The Education use case was designed for both the teaching of the curriculum and offering a centre for community organisations and local businesses to explore new ways to communicate. Whether it be corporate training, business to business collaboration or community outreach communication. The project has introduced this immersive concept to

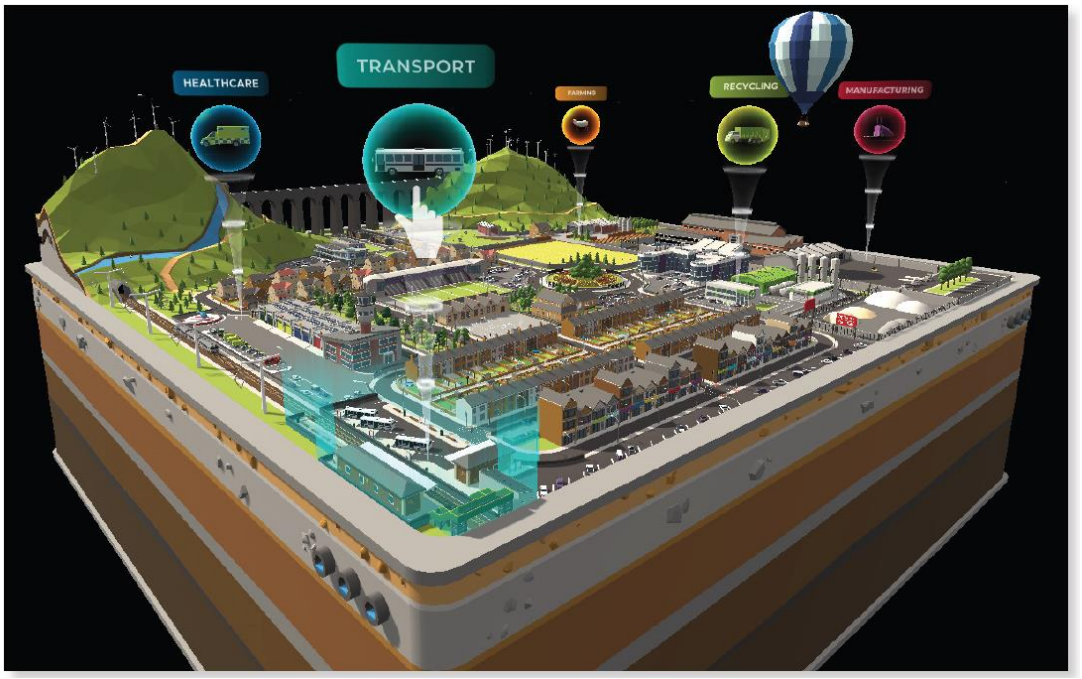
a sample of local organisations who have all shown an appetite to understand how to make the best use of it, whether that means meeting an existing commitment in a more efficient and effective way or transforming the way they connect internally and outside their organisation.

- University: already exploring virtual reality to deliver a course component to a student base that is geographically distributed and economically disadvantaged. The immersive environment represents another tool that could be used in delivering blended high tech learning.
- Local authority: faced with the challenge to both develop services and influence the behaviour of the local public to support the achievement of goals such as inward investment, waste management, uptake of public transport and ultimately net zero carbon emission. The immersive environment offers a new engaging way to communicate, disseminate and gather information.
- Publisher: seeking new sustainable ways to fund their charitable publications that support carers in the community and PSCHE type learning. The immersive environment offers a new high tech platform through which to develop and disseminate highly innovative content and has the potential to open up new markets allowing them to reach others that will appreciate the content and secure funding that will support the creation of new works.
- Cadw: as a contributor to the AR for the Tourism use case and the repurposed AR content for the immersive environment as well as provide subject experts to conduct 360 livestream sessions broadcast with live Q&A sessions in line with a "virtual day trip". The interactive content that has been created for this project offers a new means of learning beyond 360 passive experiences. There is also the potential to further interactive engagement by introducing AR devices within the 360 environment. There is clear potential to reach new and wider audiences, and to meet outreach aspirations in a more cost effective way that traditional model.

The project has also explored, but not implemented, utilising the immersive environment as a means by which virtual access can be offered to spaces that are physically inaccessible due to health and safety or security concerns. Additionally accessible to those with who are restricted physically, and to those with special education needs that benefit from the controlled, virtually nature of the immersive environment.

As an extension to the use case, and a UK5G Collaboration Output to broaden engagement with school communities, raising awareness and developing skills in this area the project created a 5G Enrichment Programme – a 2.5 hour workshop interactive physical session which explores and develops learners' knowledge related to 5G and its impacts. It involves unplugged activities and uses an interactive AR game specifically developed by Project Partner's Jam Creative Studios. The central premise of the AR game is to create a connected community to see how 5G can improve different aspects of life in rural towns and landscapes. An App triggers with AR on a large table or floorspace via iPads depicting a fictional town and surrounding area. The town is made up of various businesses and infrastructure that would benefit from 5G connectivity. Working in groups the children work their way around the town,

carrying out simple STEM activities to unlock 5G for different purposes. Once they have unlocked the 5G at each location, the benefits it affords play out within the virtual landscape.



Interactive 5G Town – AR game representation

c. Approach to security

From the beginning of the use case definitions, 'Security by Design' was adopted. The approach was to consider each element of each Use Case to understand the risks, attack surfaces and the necessary compliance to ensure the data from the use case and access to devices within them was secure.

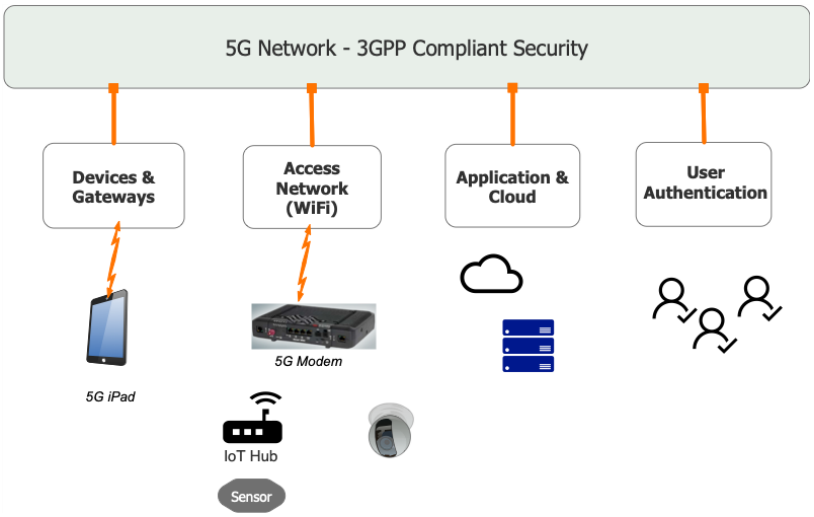
A Security Strategy was developed with Partners to ensure the systems deployed were secure and that the necessary governance was in place. The document has also been made available and copied to DCMS as a deliverable[34].

The security document laid out six areas of interest:

- 5G Network
- 5G Modems & WiFi
- IoT data capture
- Video Capture
- Cloud Storage & Applications
- General Access Control

[34] 5GWU Security Document v1.3

Each of these areas were considered separately to ensure their individual security wrap and finally as end-to-end systems supporting each of the use cases. The elements of the use case end-to-end connectivity can be seen as:



A key benefit of the approach adopted by the project was that the majority of the connectivity, end-to-end, is provided by a commercial 5G network supplied by EE. This has within it full 3GPP compliance to security and can therefore be considered a highly secure black-box wrap on all network traffic.

For all devices and access control, password and two part authentication was implemented where necessary. This is all defined in the security document.

As part of the compliance requirement, it was necessary to undertake a Penetration Test for the Bus use case as this utilised video of the general public. The PEN test found that the network was indeed fully secure with only a recommendation on passwords which is covered in the programme's security document.

GDPR was considered across all use cases. On undertaking a DPIA, it has revealed that all use cases are GDPR compliant, but on a basis that is somewhat new. The basis of the evaluation is that:

- Although video cameras are present in many use cases, there is NO storage of images
- The video streams are processed in real-time by AI engines that determine:
    - An object is in a seat – Bus use case, this can be a person or a bag of shopping, simply an object is detected and the information that the seat is occupied is stored
    - A person is present in an area that is out of bounds to visitors – Tourism, an alert is generated if climbing detected on effluent tanks
    - An unknown vehicle has entered the farmyard – DRE, an alert is generated to the farmer's dashboard

In all cases, the video stream is processed when received and then deleted from the system, in reality it flows through the analytical engine and cannot be used for anything other than what the AI has been trained for. Importantly **no** images are stored or used for identification purposes.

The security for the programme was found to be adequate in all cases and was kept as simple as possible. One area of concern was that third parties who reviewed the security arrangements appeared to be extremely risk averse, to the point where there was no risk assessment by them as part of any decision to look at the security within the project.

4. Description of the results

a. Overall description of the results

Across the use cases the data, as highlighted in the tables below, demonstrates that BT/EE's Non Stand Alone 5G network delivered superior performance compared with the 4G infrastructure it replaced. All the solutions demonstrated a marked improvement in throughput (albeit with little contention) and more tempered improvements in latency. It could be argued that the solutions could be deployed independently with 4G or 4GLTE (with the exception of the Immersive Classroom) however the 5G was required to be able deploy as stackable solutions and at scale especially given that the project worked on a public NSA 5G network – such a network would not be sufficient to enable advanced use cases with a requirement of sub 12ms latency for example. It is a key learning from the project for the broader Testbed and Trials Programme that different approaches are required for different aims.

The individual use cases in this project shows clearly the important role that 5G plays in ensuring a successful delivery as demonstrated in the test results below.

IoT Sensors

The use cases have derived a significant advantage from the connectivity provided by the 5G network; below is an overview of connectivity testing comparing the original 4G available at the use cases and the subsequent 5G, related to the UtterBerry sensors deployed on the DRE, Tourism, and Transport (bus) use cases. The data generated shows the difference in upload speeds and latency across the different use cases within different environments. The data clearly demonstrates the benefits of 5G connectivity.

	4G Upload speed/ Mbps	5G Upload speed/ Mbps	Percentage Improvement
BT Labs	25.9	93.9	262%
Tourism (Raglan Castle)	17.2	34.0	187%
Transport (Bus)	28.64	32.29	13%
DRE (Farm)	11.31	33.60	197%

	4G Latency/ms	5G Latency/ ms	Percentage Improvement
BT Labs	41	28	31%
Tourism (Raglan Castle)	50	35	30%
Transport (Bus)	50	35	30%
DRE (Farm)	43	29	32%

Video Analytics

The primary business case for using the 5G enabled cameras was to prove that video analytics can replace or augment the individual IoT sensors while also deliver safety and security functionality.

The pictures below, taken from the car park use case, demonstrates the video analytics give a high probability of detection. The inbuilt detection in the cameras and its ability to send an MQTT message when triggered proved useful so that video analytics could be called upon when there was an event of interest and proving the worth of the cameras with a level of edge analytics.

The nature of the video analytics is that it can be trained for various occurrences, for this use case this was limited to an object in a parking space. However, this could be expanded to detecting anti-social or threatening behaviour or vandalism.

Video Analytics, Car Park

Multiple Cameras, (DRE, Raglan), & simultaneous Live Streaming

Test data has been collected under set scenarios to both load the 5G network and to assess the performance of the network generally. Availability of the camera feeds and IoT data has been consistently good, both with 4G and 5G. 4G is adequate while only streaming one camera, but when two or more are streaming live, the 4G network shows its limitations and the video quality drops.

5G is able to cope with all cameras streaming at high definition.

Test 1:

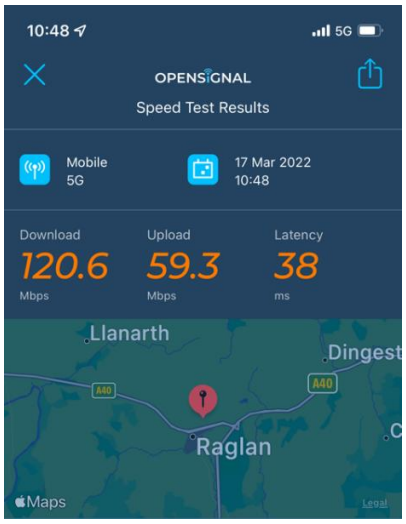
All four cameras set to their highest definition and widest field of view to maximise the data flow using 5G. All four cameras streaming simultaneously a live feed. Comparison to 4G is limited to a single camera stream as the video became unstable at some points using 2 live streams and consistently unstable using 3 cameras.

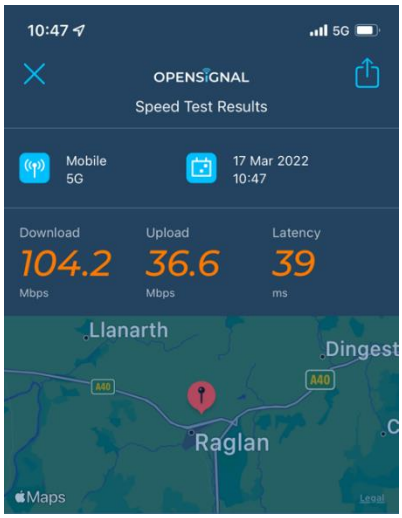
Measure – 5G	Result	Narrative
4 by 8Mbs upload = 32Mbs demand	6GB of data used Speed Required = (6 x 8)Gb divided by 20 x 60 Seconds, Equates to a 40Mbs upload speed.	Test carried out over a 20 minute time slot. The 5G connection showed no degradation in the video streams.
Latency	52ms	Usage of the cameras and the backend AI analytics are not latency sensitive provided this is below 200ms This latency measure included the cloud application the cameras operate within and is not a direct measure.

Measure – 4G	Result	Narrative
1 by 8Mbs upload = 4 Mbs demand	Any single camera streaming successful. Upload speed testing from handset, 18Mbs average	Test carried out over several weeks The 4G connection showed no degradation in the video streams.
Latency	108 - 120ms	Usage of the cameras and the backend AI analytics are not latency sensitive provided this is below 200ms This latency measure included the cloud application the cameras operate within and is not a direct measure.

Test 2:

Tests using a 5G iPhone and the Open Signal app gave the following for 5G[35] at Raglan

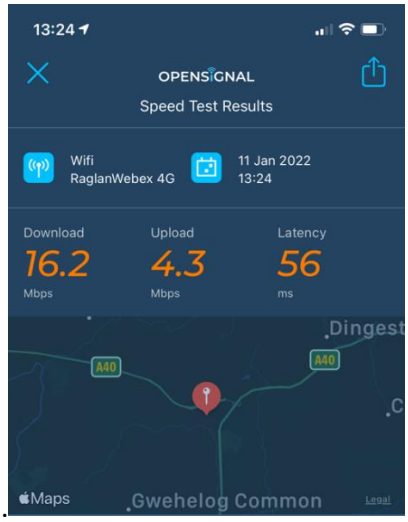




When streaming all three cameras at Raglan at 4K resolution and undertaking 360 live-streaming simultaneously, data throughput was of the order of 6GB in 2 minutes[36], equating to 3Gbs per minute or 50Mbs upload.

Test 3:

Farm testing was problematic as handsets could not pick up the 5G signal due to cell edge coverage at the farm. The 4G itself was poor, meaning that only one camera could be streamed with any reliability at any time. The speeds are shown below.

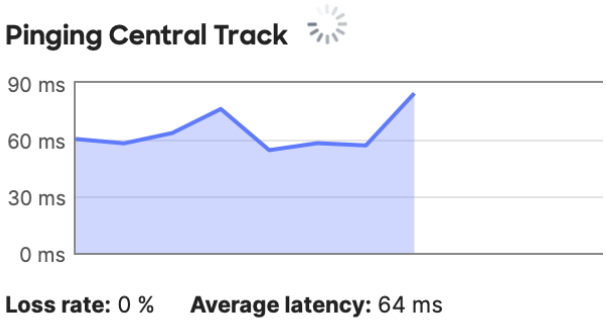


[35] The speeds are to a handset. It should be noted that the devices and cameras at Raglan are connected via 5G modems with external high-gain aerials. Therefore these figures should be taken as a minimum, it is likely that the aerials improve the speeds up and down by at least 30%

[36] There is some interpretation of the duration of the simultaneous links, but this is considered a reasonable estimate

The 5G modem at the site confirmed it was working on 5G by interrogating its cloud based dashboard, but it could not give indicative speeds. It should be noted that the 5G connection was achievable due to the fact that a high-gain external aerial was used to connect the modem. Throughput was tested by streaming all cameras simultaneously at 4K resolutions, which was achieved; this would demand an upload throughput of the order of 50Mbs, (10 times higher than the 4G upload speed recorded).

The ping rates achieved on the Farm cameras is typically shown below:



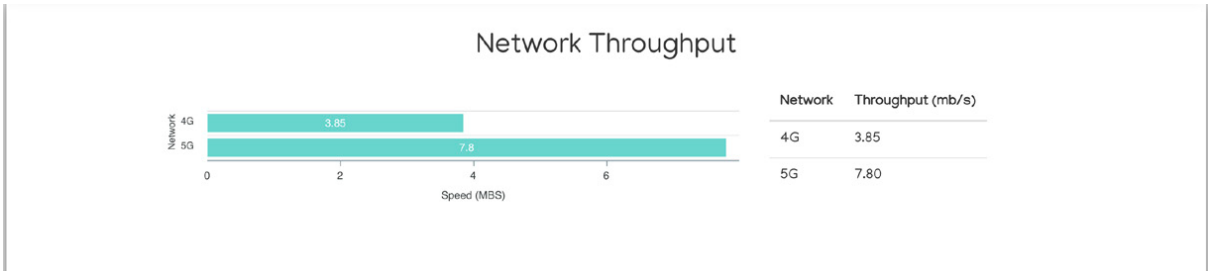
Augmented Reality

The data produced from the testing of the AR for the Tourism use case demonstrates a number of benefits of 5G connectivity including:

- Allows the use of multiple cloud anchors to enable accurate placement of virtual content
- Fast downloading of large quantities of 2D and 3D assets, creating a significant increase to size and detail of virtual assets
- Multiple players to use the experience simultaneously without latency

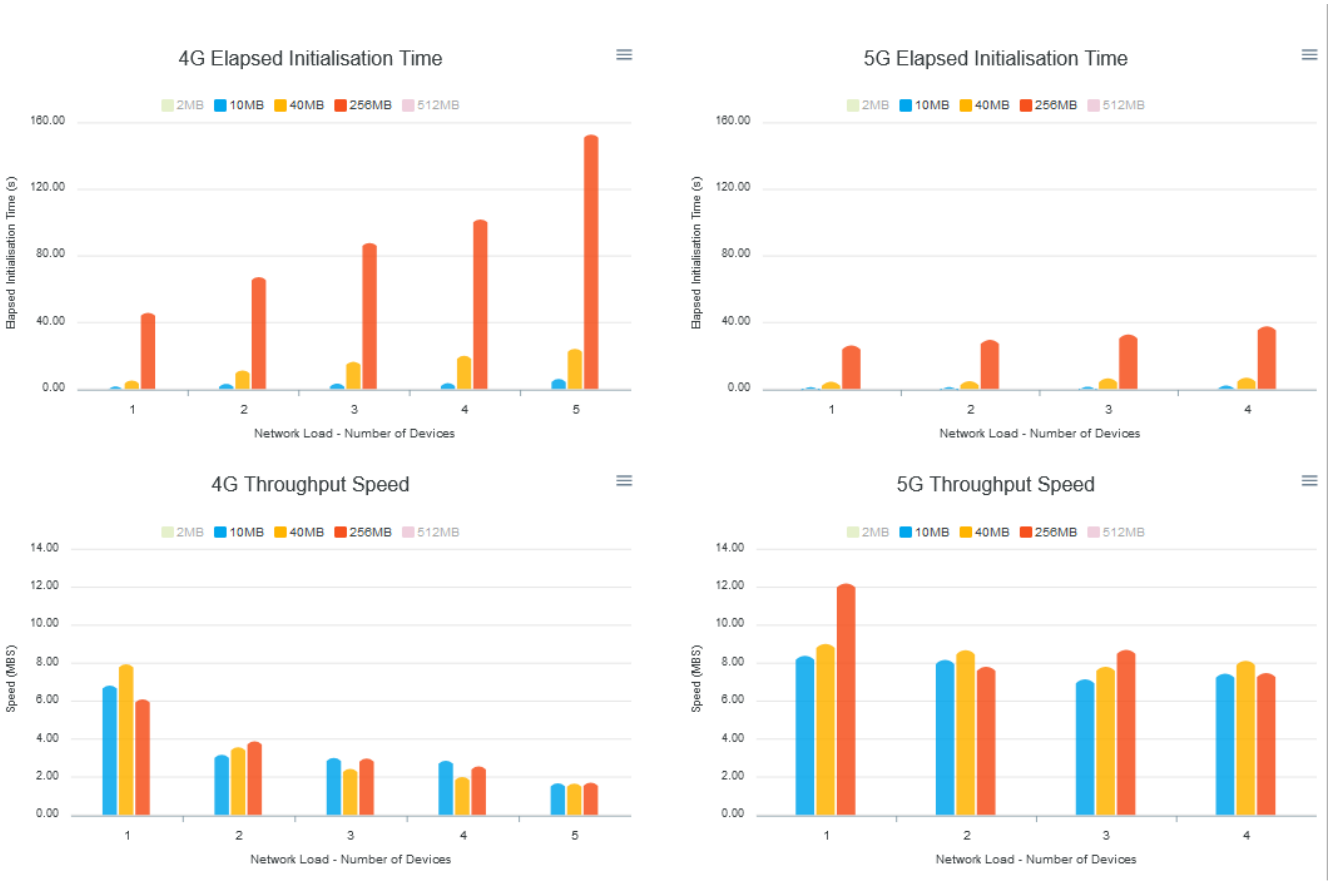
Below is an overview of the data generated throughout the testing period.

Network Throughput - Raglan



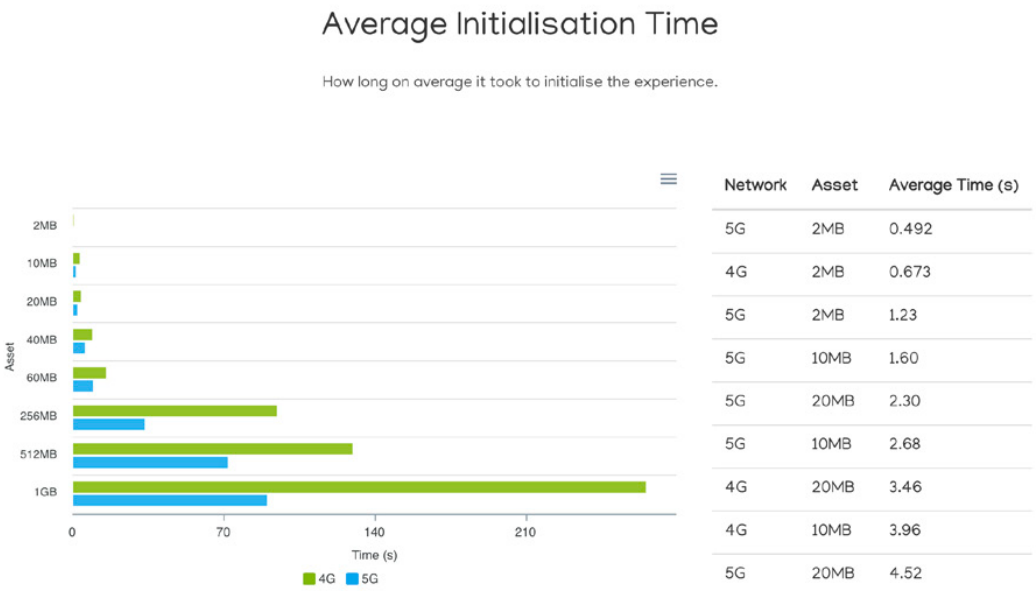
Concurrency testing

- An improvement on the average loading/ initialisation times was recorded between 4G and 5G.
- 5G network also demonstrated to be able to sustain the bandwith across multiple devices whereas on 4G this has noticeable dropped off

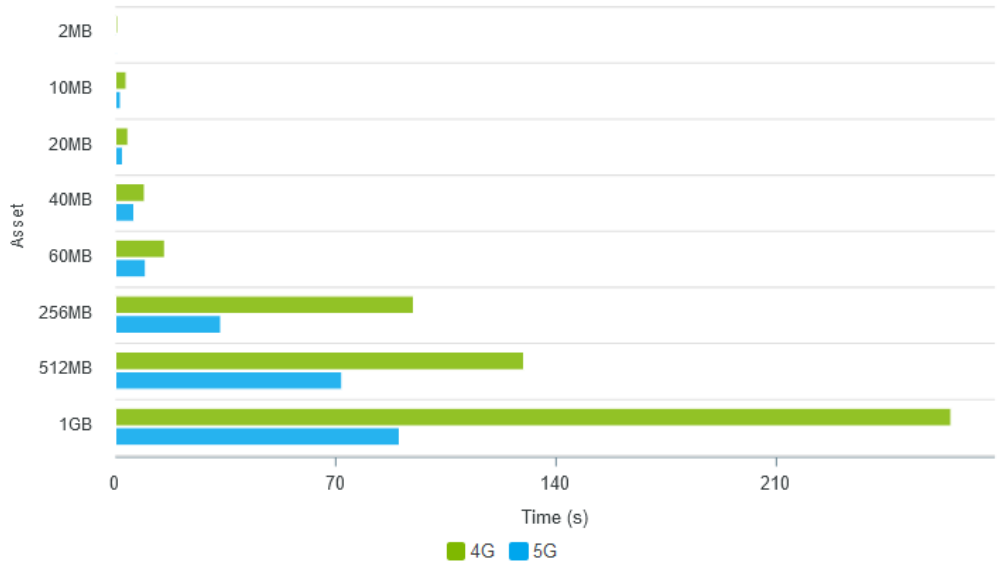


Initialisation speeds of the app.

- In closed testing, network load has been improved and the average initialisation speed between 4G and 5G has almost halved.
- The time it takes to download large game files is reduced dramatically. A 1GB file on 4G tool around 4 minutes but just over a minute on 5G

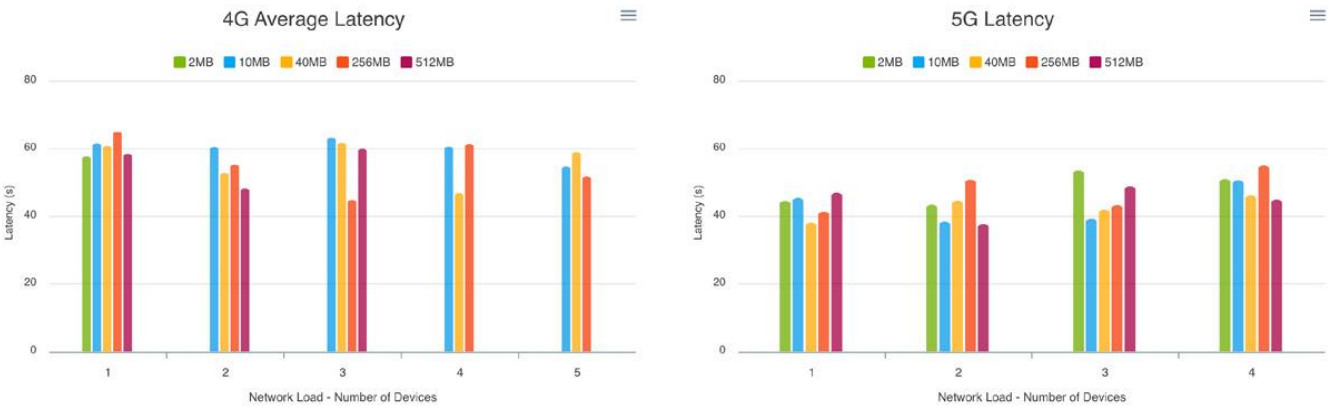


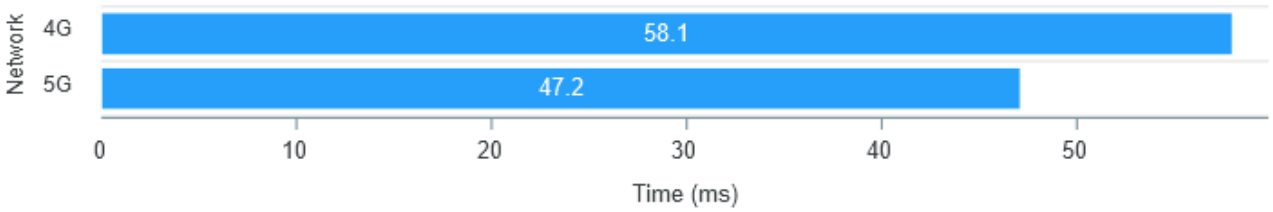
Network	Asset	Average Time (s)
5G	2MB	0.492
4G	2MB	0.673
5G	2MB	1.23
5G	10MB	1.60
5G	20MB	2.30
5G	10MB	2.68
4G	20MB	3.46
4G	10MB	3.96
5G	20MB	4.52
5G	40MB	5.90



Latency

Latency improved from a previous average of 60ms (previous network) to 40ms. The project believes that this could go lower to a range between 16-29, having better latency helps the app in a real sense that communication to cloud services is improved considerably and could be useful for the future in terms of allowing persistent connections between devices which could be used for all kinds of real time applications, eg: multiplayer games

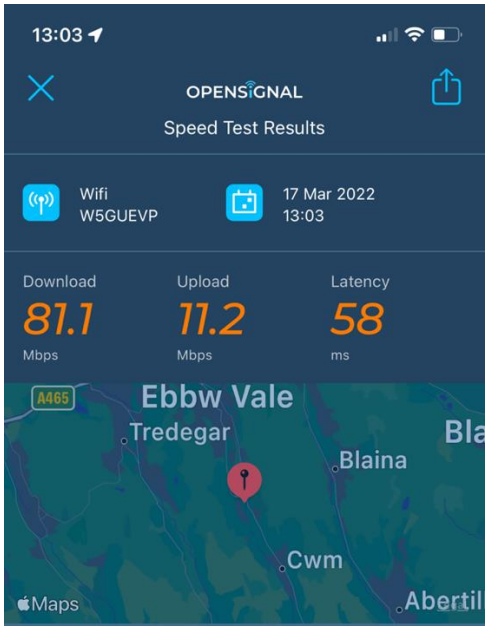


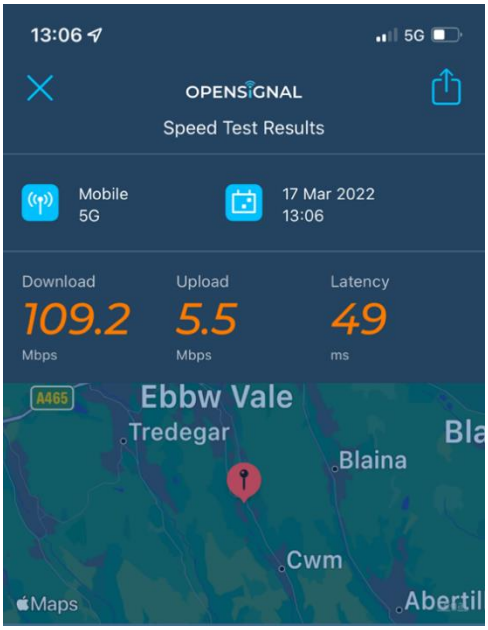


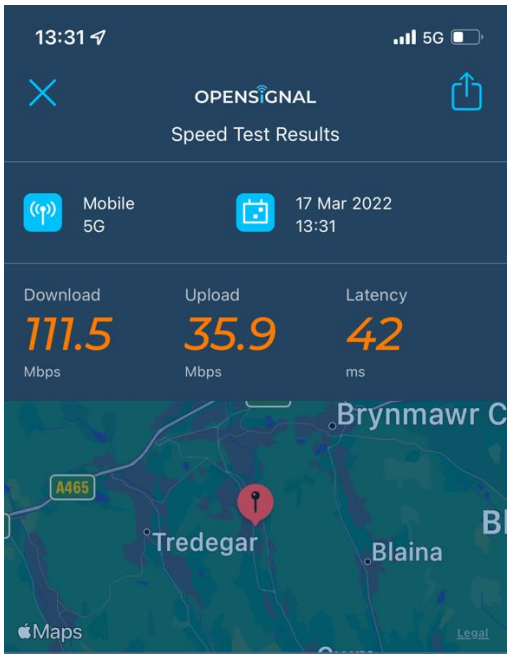
Network, Ebbw Vale

At the Ebbw Vale sites the same 5G service was utilised by the Transport and Education use cases. The immersive classroom can put a high demand on the 5G network when downloading very large 360 video files, also when it is receiving a 360 high definition video stream. The car park cameras and IoT sensors were a lesser demand due to there only being 2 cameras deployed at one car park and one at the other. It was not possible to stream all cameras and do live streaming simultaneously due to logistics of the use of the classroom.

From handset readings using Open-Signal, the following was recorded. The first measurement was at the Parkway car park and measured the WiFi speeds that connected one of the cameras to the 5G modem. The others are 5G speeds.







All the Ebbw Vale use cases utilised high-gain external aerials so the use cases would have received something of the order of 30% better speeds.

Operational Framework Documents

For the full testing information and the outcomes achieved by each use case, these can be found in the Operational Framework Documents. The documents were generated specifically to launch the use cases into their commercialisation phases and define the systems and functionality of the use cases alongside the test and commissioning results.

5. Impact of the results including benefits

Overall the use cases have been successful in demonstrating technologies that support the use of 5G across the four different sectors and have evidenced demand that can be generated for improved connectivity in rural and semi-rural areas. The delays in deployment, notably due to challenges associated with Covid-19, have limited the time and data available to demonstrate all the anticipated benefits of the services deployed for the end users. Despite these limitations, the project has been able to qualify and quantify some early achievements which does suggest that further benefits are likely to emerge in areas. The project will continue to collect data over the coming months which will inform the final report[37] of the Observatory, the independent monitoring function reviewing the impact of the investment.

Below is an outline of the impact of the results by use case; wherever possible a baseline figure or contextual reference has been provided. For example if the benefit is commercial then a reference is made to an appropriate metric such as visitor numbers, or if the benefit is socio-economic then the report references number of children using immersive education from disadvantaged background.

The project use cases cover multiple sectors and within each use case there is a mix of work that ranges from proof of value to proof of concept. A key output is the development of business cases from the different buy side and supply side perspectives. Over the long term the project has the potential to affect the provision of public sector services and leverage the sector based communities of businesses and organisations directly and indirectly involved.

Over the short term there are extension opportunities that aim to provide additional opportunity for existing partners and new opportunity for SME's to become develop and expand their businesses[38].

This project was always intended to be a pilot or pathfinder project for Welsh Government so longer term, indirect influence is hard to quantify, especially as their will be a multiplier effect as it feeds into other departments like digital infrastructure, transport, education and health. Although unquantifiable at this stage, it's likely that the impact of this process will be substantial over the longer term.

5G Network

As a direct result of the project, a commercial 5G network is now in place in Ebbw Vale and Raglan. This activity has stimulated further upgrades to the broader south Wales valleys areas notably in Abertillery and Merthyr Tydfil with other local areas benefiting in directly from investment at Ebbw Vale and Raglan. Under the Mobile Broadband Network Limited joint

[37] Final Observatory report due to be published in June 2022
[38] See chapter 6 for further information on extension opportunities

venture agreement between EE and Three the mast upgrades will also bolster coverage by Three.

These upgrades are permanent, meaning that the benefits will be available to the population and businesses of the affected areas after the project has finished. For testbed sites like the farm and the castle it offers the opportunity to base further innovation projects that utilise 5G technology.

Diverse Rural Economy (Farming)

As with other use cases the Farming use case sought to derive multiple benefits from video analytics by leveraging cameras as multipurpose video sensors. On top of the benefit of CCTV and prevention of theft where object detection was used to detect thieves and vehicles, object detection was also exploited for farm management benefits including livestock monitoring in the form of sheep counting.

Rural crime and security

There are 10,341 farms in Wales [39] (excludes smallholdings) each with an income of circa £26k p.a. subsidies make up another £22k p.a. in income. The cost for 5 network VSaaS Meraki cameras (the type used in the testbed) comes in at around £11,400 with £1,700 recurring costs in license fees. The key takeaways here are that

- The cost of farm theft in Wales averages £153 per farm. Larger, more well equipped farms are likely to sustain more thefts of higher value equipment and therefore sustain far higher costs than the average, closer to £3000. The cost/benefit of video surveillance on its own is not adequate enough to drive a compelling business case for farms, unless an alternative infrastructure procurement model is used and/or more cost effective 'open architecture' cameras are deployed at a subsidised rate. A broader alternative is for the systems to be funded by a third party, for example insurers, who could purchase at scale and would have a material interest in their efficacy.

- For 5G cost/benefit in rural areas to be enhanced, the benefit of technical intervention needs to be scalable and derived from activity that is not directly limited by demographics. Given that there are 9.5 million sheep and 50,500 hectares of cereal grown in Wales[40] and that figure is growing at 5% year on year, productivity driven interventions like automation and robotics are likely to yield more scalable benefits. Video analytics technology around livestock management like that demonstrated in the 5GWU project will contribute, but the net benefit will be far greater if the analytics were part of a broader suite of services such as crop and soil analysis with automation to deliver on precision agriculture.

[39] Stats Wales Agricultural Survey 2019
[40] June 2021 Survey of Agriculture and Horticulture: Results for Wales

Safety, wellbeing and social isolation

The use of an app that tracked location and movement against a working schedule was popular with the Farmer. Once the license expires the Farmer intends to renew his subscription.

Tourism

Enhanced immersive visitor experience

Visitor uplift

Raglan Castle attracted 6% more visitors during the 5G Wales Unlocked operational timeframe[41] than in 2020 (the last set of comparable POS figures before Covid). 3.5% of total visitors experienced the AR installation. Uptake may have been affected by an issue with staff being uncomfortable managing and accounting for the expensive user equipment (iPads) required to view the AR and delays in putting point of sale signage. The limited number of devices available to visitors may also be a factor to consider as although the average daily visitor rate in Feb is 85 it is likely that the distribution of visitors will be heavily weighted around weekend visits.

If this type of uplift were to be directly monetised when extrapolated across the year it could generate approximately £50,000 in additional revenue, and considerably more if the experience is promoted accordingly. A more likely scenario is, that in order to offset costs, when 5G handsets become more widely available then AR delivery via mobile app would be the deployment model of choice with monetisation and strategic benefits materialised via the app. App monetisation could be a blend of paid, in-app advertising subscription or affiliate/ecommerce. National Trust already have a Days Out app, a Cadw app that offers information on days out plus AR capability could be a differentiator.

Cadw have 130 sites across Wales of which only 22 are manned attractions. Many of the unmanned sites are in deep rural areas. If sufficient network coverage could be extended to these areas there is potential to provide a level of digital interpretation that could monetise these unmanned sites. Unlike the highly interactive nature of the deployment at Raglan, a base offering of digital reconstruction and rich media information could enable these unmanned sites to offer value and attract visitors. This could provide extra revenue to Cadw at minimal cost in comparison to and their immediate communities.

Visitor experience

TripAdvisor scores (an independent metric of overall user experience) remained unchanged for Raglan; this is unsurprising given that the size of the operational window was too small to affect this kind of slower moving metric.

[41] The tourism use case became fully operational from 1 February 2022. This data refers to the period 1-28 February 2022

Security, preservation and conservation of tourism sites

Cadw staff were equipped with a dashboard to monitor a range of issues including structural integrity, indoor climate conditions and facilities management operational data.

For each managed site, Cadw conduct a structural review every 5 years, for some buildings a quinquennial review is adequate for many it is not. For example, Tintern Abbey suffers from rapidly crumbling walls, a five year review is not frequent enough to pick up serious problems in time to prevent expensive damage. There are many other sites with less extreme issues that would benefit from continuous monitoring.

Discussions with Cadw reveal that a major source of expenditure is the replacement of artefacts and assets that have been damaged beyond repair by their immediate climate or environment. The solution deployed at Cadw monitors room environment alerting management to changes affecting the room such as humidity which was identified as a major cause of the degradation of artefacts.

The adoption of video monitoring technology and WiFi probe data to analyse and visualise visitor flows throughout the attraction also offers significant insight for preventive maintenance.

Transport

When making investment decisions around transport, local authorities such as Blaenau Gwent have no first hand data of their own. They are reliant on operator data which has proved unreliable and inconsistent. The prospect of a portable suite of operational reporting tools (similar to the 5GWU proof of concept) that are capable of revealing passenger travel patterns and bus and route demand would be extremely useful to the team at Blaenau Gwent. Discussions with Stagecoach Group CTO also revealed a paucity of data around patronage.

The data from the smart car parking platform is useful for end users and car park management, as well as providing a useful data set to Blaenau Gwent with which to understand how, who, when and why people are using Ebbw Vale Town Centre. The work dovetails with initiatives already underway around smart town and place planning and the drive to attract people back to the town for retail, leisure and entertainment.

Education

Augmenting current teaching methods - immersive learning offers enhanced learning for children:

The immersive environment offers a new set of tools for children who have different modes of learning. There are significant benefits for students with additional needs who often learn visually rather than access traditional teaching methods.

Inclusion of socio-economically deprived children in experiential education:

Field trips, school trips and educational visits are costly for parents. For children in socio-economically deprived areas this cost is often prohibitive, for disabled children often the barriers are physical. The immersive classroom offers accessible experiential education to many children who ordinarily would not receive the opportunity.

Extending the reach of educators and educational content:

The use of 5G and Cisco WebEx boards was used to extend the live experience beyond delivery to the immersive classroom to other schools. The low latency enabled by 5G allowed for greater interaction with demonstrations and talks from live educators.

5G enables live, 360 content creation from rural and inaccessible areas:

Broadcasting from the castle in Raglan to classrooms in Ebbw Vale provided benefit to the children and teachers but also opens up opportunities for creators of immersive content (educational or otherwise). A possible use case extension explored by the project was the provision of a live 360 link up with University of South Wales Forensic Room with Coleg Gwent. This would offer Coleg Gwent students the opportunity to experience specialist criminal forensic courses first hand and allow USW to extend their reach and promote their educational content beyond their typical catchment.

Additional markets for an immersive facility:

Include training for NHS staff, Fire Service, technical training, immersive art (immersive galleries are increasingly popular) and immersive entertainment. Blaenau Gwent will take over the management and marketing of the facility after the 5GWU project has finished. The team at Blaenau Gwent intend to market immersive training to local businesses and large organisations like hospitals like Ysbyty Aneurin Bevan.

Supply side benefits

For Video and Video analytics the data costs involved in cloud models of operation are not insignificant, in some cases prohibitive to small businesses and a hybrid model of edge compute/local storage and cloud analytics may make the business case more attractive.

Conversations with Cisco over their Meraki VSaaS suite of tools covered possible changes to the business model and strategy.

CAMERA COSTS & NETWORK DATA

	Value	Assumptions
Data Use Per day per camera	42gb	1440p (4Mp) h.264, 25fps, 4096kbps (constant bit rate)
Data Use Per day per site	252gb	5 cameras per site
Data tariff	£66/100Gb	EE Large business data plan
Data costs per day	£166	excludes cloud egress fees
Camera hardware	£11,360	On a small scale Meraki cameras are less cost efficient; viability kicks in when scalability is an issue and utilise the full Meraki management suite and platform
Recurring costs license fees	£1,760	
		Deployment models varying from all on site, hybrid, cloud. The model makes a huge difference. A model where storage and analytics are handled in the cloud saves money on expensive cameras (less intelligence at the edge) but incurs huge amounts of data fees moving data to the cloud. Onsite storage and analytics massively reduce data fees but use more expensive equipment. Hybrid is somewhere in between. Ultimately ownership of the network dictates where benefits accrue. Public ownership models are only cost efficient at scale.

AUGMENTED REALITY

	Value	Assumptions
Average data consumed per session	60 Mb	Assumes largely on site model
Maximum number of concurrent sessions	10	Limited by the number of handsets/iPads supplied and throughput capacity of a 4G network.
Average number of sessions per month	90	Approximately 3% of visitors - with more time on promotion and marketing this could be increased to 15[42]
AR data consumed per month	5.4Gb	See trade-off between scalability and data consumption below.
		A 5G network would maximise concurrent sessions and support more concurrent user sessions. A hybrid delivery model with more content cached in the cloud would see improvements to scalability and manageability along with data across the network increasing.

[42] It is estimated that this could be increased to 40% with an alternative deployment model

IMMERSIVE CLASSROOM

	Value	Assumptions
Average data consumed per session	36 Gb	Assumes 2 sessions a day
Sessions per day	2	Assumes an operational turnaround time of 2 hours
Average number of sessions per month	12	
AR data consumed per month	432Gb	See trade-off between scalability and data consumption below.
Data costs per month	£285	EE Large business data plan
		A 5G network would maximise concurrent sessions and support more concurrent user sessions. A hybrid delivery model with more content cached in the cloud would see improvements to scalability and manageability along with data across the network increasing.

Supply side benefits can be viewed from a vendors (MNO/Infrastructure provider) perspective as revenue generated from provision either through the lens of data consumed, service provided or combination of both. As other models of network infrastructure deployment emerge where ownership changes these figures could be viewed as cost savings or even return on investment for a public organisation. This alternate model also allows strategic subsidy to be used to improve adoption or uptake.

5G Ecosystem and policy

5G Wales Unlocked has been central to developing a 5G ecosystem in Wales that contributes to the broader UK and international ecosystem; the project has enabled information generation and dissemination on 5G and associated technologies across Wales and worked with a number of other DCMS 5G testbed and trial projects to share knowledge and experience with others[43].

Through the establishment of an online profile, through Twitter, LinkedIn and www.5gwalesunlocked.co.uk, the project has enabled the 5G community in Wales to come together, share information, collaborate and identify opportunities for further engagement. These channels have provided a medium to share project updates, findings and resources to the broader 5G ecosystem.

The project published a number of successful 'Unlocking 5G' podcasts and virtual discussions outlining the potential benefits that 5G offer to the sectors addressed in the use cases through discussions with the users directly; additionally the project engaged with the broader 5G

[43] See 5G Wales Unlocked, Collaboration Report, March 2022 for further details around Collaboration outputs

ecosystem drawing on the expertise and experience of other regions and sectors to highlight the benefits across the broader sectors of manufacturing and health and social care, therefore extending the reach of the 5G ecosystem to beyond the initial scope of the project.

The project enabled Wales' first online 5G forum, bringing together the 5G ecosystem in one place for the first time. The event was attended by over 100 individuals representing a range of interested partners including policy makers and industry experts from local authorities, private sector technology companies and Welsh Altnets. It provided a forum for debate with contributions from major stakeholders Ofcom, Mobile UK, National Infrastructure Commision for Wales, Cellnex and BAI. Post project activity will focus on following up on the interest and engagement seen at these events; with attendees requesting to be part of further discussions in this area

5G Wales Unlocked was led by the Welsh Government providing opportunities for Ministerial engagement to 'launch' the use cases, enabling high profile media engagement to raise the profile of the project but more importantly 5G and the investment made at a UK, as well as Welsh Government, level to ensure that the benefits to rural communities are promoted accordingly. As lead deliver partner, the Welsh Government has also been able to influence 5G and advanced wireless connectivity at a policy level; working cross-governmentally to leverage engagement.

The establishment of an Observatory function, led by Cardiff University, as part the project has also provided an academic resource to draw together 5G activities across Wales, providing independent analysis for the UK 5G ecosystem to learn from the experiences of 5G Wales Unlocked, as well as other 5G Testbed and Trial projects and included a specific focus on challenges and opportunities of Planning Regulation in the deployment of further 5G infrastructure. This was established to provide third party evaluation and develop understanding of how aggregate demand and value could be quantified for modelling purposes.

Cardiff University also provided research around the impact of planning on rural 5G deployment and were also tasked to map out 5G innovation activity across Wales. The project has enabled this disciplined building of an ecosystem in Wales and has already increased engagement with private, public and academic institutions approaching the project to scope out potential development opportunities utilising the 5G infrastructure put in place.

6. Key Learnings

a. Lessons Learnt

Operational Framework Documents and the BR template provide detailed lessons learnt relevant to the specific use cases. This section summarises key lessons learnt across the Project as a whole.

Network

- A key benefit of using a commercial operator to provide network capability is that it requires less input from the customer side in terms of technical and systems integration input and a basic quality of experience should be attainable quickly. This approach also allows difficult engineering issues like security to be addressed by professionals.
- The key drawback is the lack of control over network specification and required QOS when the solution is more demanding on network infrastructure. This is not a major drawback if the required applications can function over 4G or 4G LTE and 5G's role is primarily one of enhancing quality of experience rather than being a key enabler. Deep rural deployment also requires special considerations which is also technically and financially challenging for commercial roll out.
- The timetable for network coverage impacted on the ability to fully test and iterate use cases. The delays were the subject of a range of challenges relating to deployment of network in a very rural location.
- Deploying use cases where 4G already existed assisted in being able to get the use cases up and running on an existing network and theoretically being able to compare and contrast on the 5G network; having a mix of 5G and 4G enables the 5G to do more of the fixed data heavy lifting (such as video) and the 4G for where mobile data is needed
- The 5G and WiFi platform at the farm has proven to be suitable for quick and simple deployment of additional sensors
- The 5G connectivity at the farm was always an issue due to the local topography and has poor 4G coverage. In order to maximise the 5G connectivity to the farm it was decided to fit a high-gain broadband aerial. This device was also fitted high up and in effect gave a much better 4G/5G signal that could be achieved on a handset. This proved successful with an acceptable 5G signal being achieved.
- The project set out to explore supply side levers. The projects use of a big ticket item like the immersive classroom had an accelerative effect on upgrading infrastructure in Ebbw Vale which was completed by March 2021. This financial incentive coupled with the political interest that an educational intervention in a socio economically deprived area generated made this use case a key focus for BT. BT are now actively pursuing the roll out of immersive classrooms throughout Wales. This experience goes some way to proving that if suppliers can be financially incentivised to provide a 5G enabled service then 5G rollout could be accelerated as a by-product of procuring the 'right type of product'. Building in the 5G requirements and necessary service level agreements into procurement and contractual negotiations will enable a price point

to be reached that reflects not only the cost of the classroom and technical equipment but also the necessary network upgrades to facilitate the asset.[44]

Data Collection

- Access to data on a commercial network performance is problematic and in some cases sensitive, so not available
- Obtaining data from the 5G access points proved impossible, despite considerable pressure to BT. This was disappointing as the 5G modems used have a comprehensive dashboard of data that can be extracted whenever need. This severely limited the amount of detailed data available on the performance of the systems and network and the testing that could be carried out. Arranging more supporting data using DPI techniques would also have improved the granularity of the data sets for the 5G service

Collaboration

- The multi-use case / multi-partner approach has been very beneficial in terms of developing projects with real impact and breadth. This requires a structured approach to technical leadership providing a systems integration / solutions architecture function.
- Engaging with stakeholders early ensures understanding of project aims and objectives so they remain engaged and support the delivery of the project. Stakeholders and beneficiaries of the use cases provided input into the project development reflecting change in scope, based on their requirements and them seeing potential development opportunities; their active engagement throughout the life-cycle of the project added to and enhanced certain use cases.
- Partners have demonstrated differing levels of commitment throughout the programme. In some instances this has impacted negatively on a partner where they are dependent on another. More robust development of programme plans and systems integration activity should be deployed.
- The strong role of the public sector partners has been key in getting businesses engaged. Public sector partners should be engaged in all consortium projects.

Technology Deployment

- Global supply chain issues impacted the project in terms of chip manufacture and purchasing components.

[44] This process is at an embryonic stage. There is much work to be done on intelligent procurement to ensure that scope and benefits necessitate network upgrade in the host region. From the supply side there will be a similar learning process whereby they will need to cost in the necessary network upgrade along with those of build, materials and labour.

- Training of the video analytics engines took more time than anticipated, but once a few stakeholders adopted the potential things went much quicker
- Camera locations need to be optimised for best results
- Cameras suffer from raindrop distortion in bad weather – better covers would assist
- Night-time capable cameras or linking in automated lighting systems would improve the services being offered
- The ability to position cameras in a position when and where needed would be a significant gain, fixed cameras are by their nature sometime compromised due to the dynamic use of a farm through seasons. Introduction of site wide WiFi would enable additional cameras and IoT devices to be deployed at will
- Edge of coverage can be enhanced through the use of high gain external aerials and allow 5G services to be used in rural locations, provided that mobility is not critical
- Using WiFi to connect HD cameras over long distances has been problematic. For a full installation, a mesh of WiFi Access Points (AP) should be used

Communication

- Communications activity started relatively late in the programme following some financial challenges experienced by the partner with responsibility. A solution was found but the impact of the communications workstream was reduced.

Project Reporting and Grant Claims

- A significant amount of resources across project partners was allocated to project reporting to DCMS including grant claim documentation, finance and reporting; returns should be a minimum of quarterly so partners can focus on delivering use cases
- Payment processing from DCMS has been consistently slow throughout the programme. This has caused problems in particular for technology SMEs. In this programme, the lead partner has been able to help the cashflow but further consideration should be given to how this can be resolved / accelerated.
- The 'end of March' deadline for programme completion has meant that use cases have not been as thoroughly tested and iterated as possible. Withholding, say, 10% of programme budget for continued testing and refinement would have benefited the programme significantly.
- Not all partners have recognised the resourcing requirement for the project in advance and as resource needs increased during key phases of the programme a few partners struggled to meet the demand, which impacted on the project timetable.

Security

5G Wales Unlocked has provided input into the 5G Testbed and Trials programme review of security activity, *5GTT Security Narrative.* In addition to the findings that will be produced as

part of this programme wide work we have captured the key findings below from the 5G Wales Unlocked project.

- Using a commercial 5G service removes many of the security concerns for the customer around data access and allows concentration on device security
- The use of video analytics is becoming more common, updating GDPR compliance and DPIA checklists to accommodate situations where no images are stored or where AI engines are not trained to identify any personal information would be helpful
- Using a risk based approach when looking at security, or at least making sure this is done at the outset would help. A DPIA is in effect a risk analysis as much as anything else, but not particularly looked at in this way
- Early engagement with security leads in relevant authorities to ensure they have understanding of the project aims, objectives and timescales.
- Creating a centrally coordinated expert panel may be helpful to some local authority stakeholders to help them understand the technology risks and how to interpret the need for compliance to GDPR and data security
- Engaging with the broader Security Network across the programme helped share experiences, disseminate learning and resources to avoid duplication of effort.

b. Suggestions for policy, regulation or other things that may need adjustment arising from the project

The project demonstrated the requirement for a lead delivery agency to bring together key stakeholders, MNOs, technology providers and public sector bodies to capitalise on the resources, opportunities and developments within this area.

As outlined above, key to the success of the project was the strong role of the public sector partners in getting businesses engaged.

Initial findings from the Observatory[45] provide a summary of policy operations to accelerate rural deployment of 5G. These options are set out in the table below and provide a range of risk share models

[45] Draft Observatory Report, Cardiff University, March 2022

Policy option	Models	Actors	Cost
Infrastructure development	Private networks, infrastructure sharing, fibre deployment (e.g. SRN)	Government/ Private Community	High
Use case aggregation	Aggregation of use cases and organisations – particularly data heavy uses, including private 5G solutions (e.g. 5GWU)	Government (national / local) Private	Medium
Strategic enabling	Collaborative support for public and private parties to develop 5G solutions	Government/ Private	Medium
Barrier busting	Support deployment / manage trade-offs between policy agendas	Government (national / local)	Low
Uptake support	Awareness raising of benefits of use (e.g. SFC)	Government/ Private	Low-Medium

This project, confirmed by the Observatory initial findings, has demonstrated the benefits that a Wales-focussed body with responsibility for driving this agenda forward, to encourage collaboration between private, public and academia, to engage different sectors to recognise the opportunities presented by improved mobile connectivity and support them with their ambitions to support and deploy innovative solutions.

c. Future work that would help with the next step

As with a number of the 5G testbed and trials projects, 5G Wales Unlocked did suffer from delays due to the impact of Covid. This resulted in elements of the use cases requiring further work, in terms of honing them to make them into pre-production tests of the use case outcomes. There were also a few issues with gathering network data that could be improved significantly. Taking the topics and use cases separately, the following tables are offered on the basis of the next steps.

Tourism

Not Proven	Future Work
Full commercial proposition All the planned systems have been deployed, but insufficient time to fully prove the commercial case.	The castle has proven a good testing ground and longer term monitoring of the sensors that have been deployed will show trends that can identify issues. However, there are much more immediate concerns at other sites and some specific monitoring at Raglan that could give immediate results and demonstrate real worth in the short term.

	Expansion to another two sites already selected by CADW would enable specific issues to be addressed. The addition more sensors at Raglan will monitor some areas of concern and provide assurances or spark remedial work.
Value engineered solutions The original deployments were by their design hi-spec solutions to maximise functionality. There is a likely position whereby these can be enhanced by the deployment of cheaper camera technology with further integration across IoT and Video Analytics	The use cases proved WiFi connectivity to camera devices. There are several candidate cameras that can be deployed with battery and solar charging systems for under £250 per device. Using such devices allows greater flexibility and simplicity to add to existing deployments. Development of video streaming cloud apps and using edge based analytics on cheap small computers would enhance capability further.
AR increase in footfall There simply has not been time to even promote the experience to the general public in a consistent way. Advertising at the site for the experience is limited and is only seen by people who are visiting anyway. Efforts are needed to make the AR experience widely known.	In some respects time will tell, however, a concerted approach to attract visitors to use the AR over a 6 month period, including the summer holidays to get visitors would be able to provide tangible results and inform the commercial case for scaling up.
High quality 360 live streaming – additional scope The use of personal type 360 cameras has been used to date and it has been found that the video quality from these at anything further than 10m is limited. Some experiment with professional level 360 cameras demonstrated that they should be used, along with professional training to make live streams appear more professional.	Professional level 360 cameras were tested and results were positive. These however, proved to need 5G connectivity to cope. To expand and improve the 360 livestreaming, it will be necessary to invest in better cameras and also to train and develop presenters to use the technology to its full.
Integration of AR into Livestreams – beyond scope The AR content has been overlaid onto recorded content and proved extremely useful to pupils in the classroom as it adds a narrator that is rendered as a floating robot (Luna). This concept could be significantly developed and enhanced.	Develop the narrator concept and overlay this onto the live streams as an additional resource.
Development of 360 Content – beyond scope There is a great deal of 360 content available, but this is not curriculum based for Wales. Cardiff is the second creative centre in the UK outside London and has some of the leading innovators in content creation and production. It was not possible to extend the work by joint commissioning of specific content other than 'The Bee in a Billion'. This proved that there is a market for such material and could lead to growth in this sector.	Work with education and other training functions on a number of commissions for 360 content, including live-streaming.
Further integration of Dashboard – additional scope The dashboard integrated all the details of the cameras and sensors as planned. However, the full integration of trigger alerts and IoT alerts was not tested for accuracy, nor was the processes within CADW for responding to alerts.	The dashboard contains some logical flows, such as an alert when wind speed exceeds safe opening. However, there is more integration necessary to complete a commercial installation. Such as alerts detecting people outside hours and how this information is relayed and actioned. Additional levels of integration within the dashboard and within CADW's operations is needed.

DRE

Not Proven	Future Work
Full commercial proposition All the planned systems have been deployed, but insufficient time to fully prove the commercial case.	The Farm has proven a good testing ground and further development of the sensors and cameras that have been deployed will show increasing automation and functionality. Further integration of alerts to the farmer and the ability to use mobile phones to view alerts and dashboards would enhance the usability in general.
Value engineered solutions The original deployments were by their design hi-spec solutions to maximise functionality. There is a likely position whereby these can be enhanced by the deployment of cheaper camera technology with further integration across IoT and Video Analytics	The use cases proved WiFi connectivity to camera devices. There are several candidate cameras that can be deployed with battery and solar charging systems for under £250 per device. Using such devices allows greater flexibility and simplicity to add to existing deployments. Development of video streaming cloud apps and using edge based analytics on cheap small computers would enhance capability further.
Extended Functionality – additional scope Scope extensions made the first use of the cameras to monitor livestock and in this case to count sheep as they moved about the farm yards. This was different to usual counting methods of channelling the animals through a single pass area. This work demonstrated good promise of achieving high accuracy of counting during normal farm operation, extending to other animals would be simple as well. In addition, the tractor sensors have made them into 5G data collection hubs, where other sensors and cameras can be added to the vehicle. In particular cameras and/ or sensors monitoring crop conditions while fertilising fields and providing feedback on the amount used is a potential function.	Further enhance the 5G hubs on the tractors to provide multiple device interfaces for sensors and cameras. This could be a 'Lego' type development whereby sensors can be simple added as needed and the data fed back to the current dashboards after analytics have determined new data sources.
Further integration of Dashboard – additional scope The dashboard integrated all the details of the cameras and sensors as planned. However, the full integration of trigger alerts and IoT alerts was not fully tested for accuracy, nor was the processes the full integration into the Farmer's day to day operation.	The dashboard contains several logical flows, such as an alert when an unknown vehicle enters the farm. However, there is more integration necessary to complete a commercial installation. It is likely that a 'Menu' of sensor and camera functions could be developed as part of a 'Pick&Mix' solutions approach tailored to a Farmer's concerns, also deploying systems that are simple to expand, both geographically and functionally.

Transport – Bus

Not Proven	Future Work
Full commercial proposition All the planned systems have been deployed, but insufficient time to fully prove the commercial case. In particular, the accuracy of the video analytics and sensors has not been proven over time to a point where commercial decisions could be made around routes and demand profiles.	The Bus has proven a good testing ground and further development of the sensors and cameras that have been deployed will show increasing automation and functionality. The accuracy of the sensors and analytics has been proven for short periods of monitoring. However, there is a need to improve these so they are

	accurate over the longer term. This would entail short and long test scenarios and likely further refinement of the analytics and sensor operation.
Value engineered solutions The original deployments were by their design hi-spec solutions to maximise functionality. There is a likely position whereby these can be enhanced by the deployment of cheaper camera technology with further integration across IoT and Video Analytics	The use cases proved WiFi connectivity to camera devices. There are several candidate cameras that can be deployed with battery and solar charging systems for under £250 per device. Using such devices allows greater flexibility and simplicity to add to existing deployments. Development of video streaming cloud apps and using edge based analytics on cheap small computers would enhance capability further. However, the reliability and repeatability of these systems would need further investigation, particularly if security was an overlay function.
Extended Functionality – additional scope The data sets being generated by the use case have only been explored against the original scope. Further use of the data in terms of security and safety and the use of the forward facing camera has not been fully explored.	The analytics being applied are limited to identifying objects in seats. The AI could be trained for far more in terms of identifying unwanted behaviour, parking infringements, etc. The bus is configured as a data collection platform with camera and IoT hub on board, additional data collection can be supported as needed.
Further integration of Dashboard – additional scope The dashboard integrated all the details of the cameras and sensors as planned. However, the full integration of trigger alerts and IoT alerts was not fully tested for accuracy, nor was the processes the full integration into the Farmer's day to day operation.	The proving of the data sets and developing these for consistent accuracy will require more refinement and deeper longer term testing. The data sets are displayed via a dashboard, but this is a static representation of the information. It would be beneficial to add more data sets as above, but to also integrate more data sets and also provide some predictive elements such as at what time the bus gets busier and the optimum routing for the current bookings and waiting passengers at bus-stops.
Further integration of Totem and external information Systems – additional scope	The Information Totem has extensive information brokering capability. Moving the transport data sets onto the totem has been explored and is perfectly feasible, but has not been attempted. Further work to bring the information to life on the Totem would enable further benefits to be drawn and to offer the opportunity to extend the totem information to other sites including personal devices.

Transport – Car Parks

Not Proven	Future Work
Full commercial proposition All the planned systems have been deployed, but insufficient time to fully prove the commercial case.	The Appyway Apps and data analytics are all functional, but there was not time to promote these to the general population of the area or to use the data to help decision making about changes to parking regimes or the introduction of links between car parks to ease congestion of spaces. Further promotion and development of users and user interfaces would improve the impact and support decisions at local authority levels.
Value engineered solutions The original deployments were by their design hi-spec solutions to maximise functionality. There is a	One of the outcomes was to test whether cameras could reliably replace individual parking sensors. At a technical level, cameras can indeed replace sensors,

likely position whereby these can be enhanced by the deployment of cheaper camera technology with further integration across IoT and Video Analytics	but accuracy has not been proven fully and there is a need to deploy additional cameras to overlap and give 100% accuracy. The current camera deployments would be too expensive for this role, but cheaper cameras would be possible. A series of developments need to be undertaken to deploy cheaper camera solutions and to explore their use as WiFi connected and solar powered to make deployment quick and simple. The analytics would likely benefit from being done at the camera rather than streamed for the task of identifying empty parking spaces.
Counting Occupants This was not completed in the time available. The concept was to be able to count the people exiting a car as part of a liftshare integration. This would have been done at priority parking areas to ensure cars parked did qualify.	The analytics can identify people and this has been used for other purposes. However, the ability to identify that they had emerged from a single car was not developed or tested. It is highly likely that this can be done with cameras correctly positioned at a priority zone. The existing deployment s could be enhanced to provide this functionality, at least to a proof of concept phase.
Extended Functionality – additional scope Scope extensions to use the cameras for safety and security purposes has been identified as an extension of using the existing deployments	Including the safety and security functions on the camera analytics would require deeper analytics for identifying behaviours and incidents through machine learning techniques. There are some early examples of this already. A series of detectable events need to be defined and the Analytics developed to explore each one, such as a person moving between vehicles in a random manner rather than moving generally to a specific location and entering a vehicle.

Education

Not Proven	Future Work
Full commercial proposition All the planned systems have been deployed, but insufficient time to fully prove the commercial case.	The initial sessions using the immersive environment and the WebEx boards have, in the main, been with the pilot schools that we engaged. The feedback has been extremely positive and by Whitsun break all the teachers from the primary schools in Blaenau Gwent will have been trained and had the opportunity to run a session with their class in the facility. In order to fit well in the school day there are 3 bookable sessions each day and an after-school session also available for other users. With approximately 30 schools in the local authority, you can quickly see that 70-90 school day sessions every half-term will not be sufficient to cover even one lesson every half term for every class and will severely limit the access for other non-school users of the facility. There is a need to determine the most effective and efficient use of the classroom and to undertake specific investigations to support this.

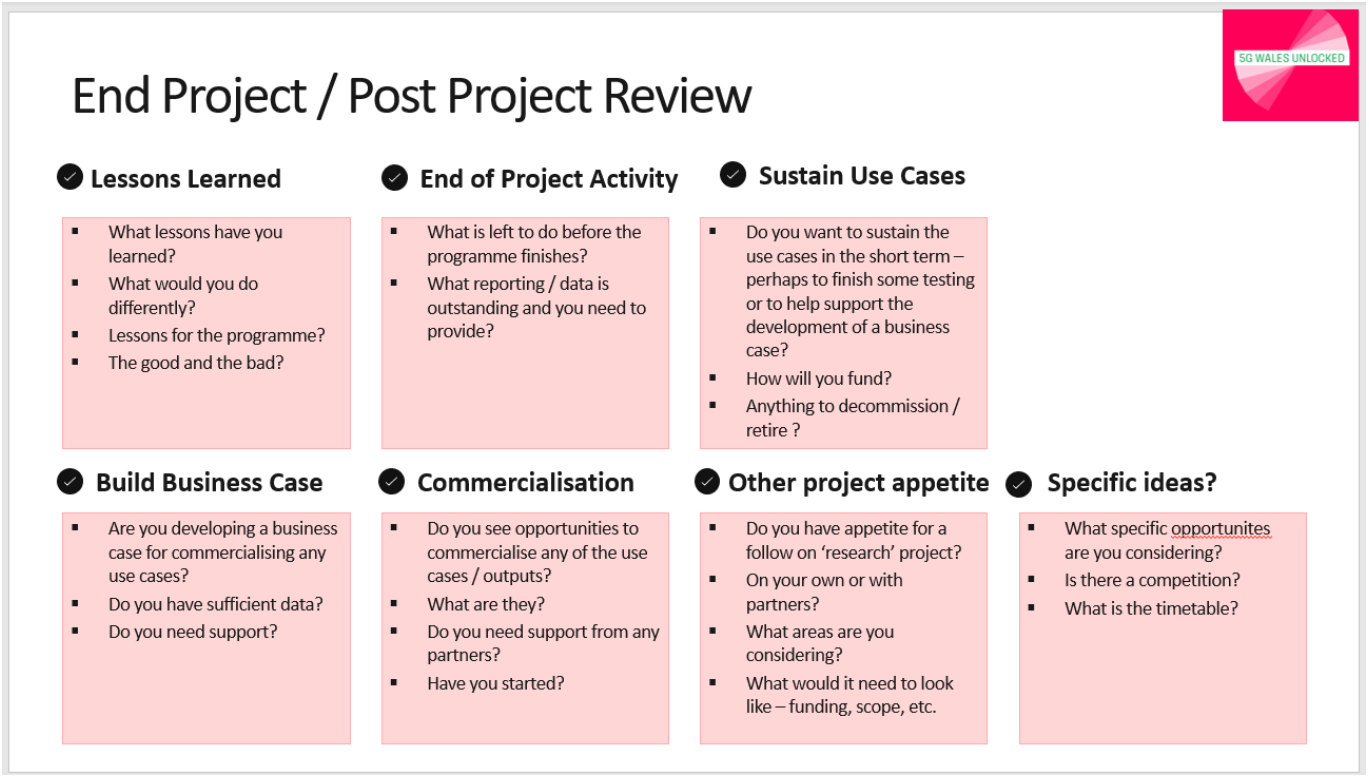
	The use case has demonstrated the benefit of locating it on a site independent of a school. The best way to increase capacity must be evaluated in the light of connectivity, user community and cost/benefit analysis to maximise the business case for further scaling and content development
User evaluation A full evaluation could be made with the cooperation of schools to ascertain the pedagogical benefit derived from using such a facility in terms of retention, creative writing, engagement in topic and performance in exams.	Working with the pilot schools to run the evaluation with a control group and commitment to the desired outcomes would be necessary. A full evaluation programme should be developed with Cardiff University to fully understand the benefits the resource provides. This evaluation should be evidence based and would be a key element for scaling, development and resourcing.
Value engineered solutions The original deployment required a temporary integration between the Full 360 and Cisco kit to support the delivery of all learning settings that we evaluated; Stand-alone, Split/Collaborative and Livestream. It is likely that some elements can be achieved or even enhanced with the deployment of alternative components and further software integration.	The use case ran the split/collaborative sessions using WebEx boards and they were found to deliver a good user experience. Key Cisco functionality was cited as supporting this such as the video tracking the speaker which enhanced the level of engagement across the call. There were issues in running 360 content on the WebEx boards, which could only be controlled from the laptop and not the board itself. Further investigation could be undertaken to see if it would be possible to run the content on the WebEx board from the immersive classroom so that both ends are synchronised. A further extension would be to run Live 360 to the WebEx board via the classroom controller. A fully integrated set up to run a livestream session could incorporate the link to the 360 camera and the WebEx call allowing full control from the classroom. Additionally, now the 5G network is stable it would be good to evaluate different 360 cameras for broadcasting. There may be further opportunity to upgrade the classroom itself, with higher definition projectors being a possibility.
Commercial, community and business use – additional scope Local organisations have shown an interest in using the facility to address their differing communication, training and outreach needs, even supporting business to business collaboration and training.	Promotion within the facility needs to be taken beyond the schools. Individual facilitation with each organisation would assist in reaching the full potential of this and offer scope for further evaluation and input to a commercial business case. Bringing in tertiary education and specialist training functions to exploit the facility is possible and interest has been shown, but further integration and support would be required to deliver a wider function for the classroom, as well as new content.
Different types of 360 camera – additional scope The use of personal type 360 cameras has been evaluated and it has been found that the video quality from these at anything further than 10m is	Professional level 360 cameras were tested and results were positive. These however, proved to need 5G connectivity to cope with the bandwidth. To expand and improve the 360 livestreaming, it will be

limited. Some experiment with professional level 360 cameras demonstrated that they should be used, along with professional training to deliver a more professional livestream experience.	necessary to invest in better cameras and also to train and develop presenters to use the technology to its full.
Integration of AR into Livestreams - beyond scope The AR content from the tourism use case has been overlaid onto video content with a narrator/instructor that is rendered as a floating robot (Luna) and run in the classroom. This concept could be significantly developed and enhanced.	The AR could be incorporated into a livestream session.
Development of 360 Content – beyond scope There is a great deal of 360 content available, but this is not curriculum based for Wales. Cardiff is the second creative centre in the UK outside London and has some of the leading innovators in content creation and production. The programme did not allow commissioning of specific content but the joint development of the 'The Bee in a Billion' content alongside a local charitable publisher demonstrates that there is a market for such material and the immersive environment could lead to growth in this sector.	Work with education and other training functions on a number of commissions for 360 content, including live-streaming. Use this content to take Wales based content out to the wider UK and international market. It also offers opportunity in the Welsh language market.

7. Sustainability

5G Wales Unlocked was committed to delivering a sustainable project that would leave a legacy in the communities we have worked with and through the permanent 5G infrastructure provided by BT, the assets purchased by the local authorities of Monmouthshire and Blaenau Gwent and the solutions tested via Jam Creative Studios, UtterBerry, Appyway and Cisco we believe that this project has demonstrated some of the benefits to businesses and communities to ensure further investment from network operators into Wales. The Observatory, the project's independent monitor, provided by Cardiff University are analysing the impact of the project and will report in summer.

Partners were engaged in dialogue around the themes shown in the diagram below :



This section describes a 'sustainability' statement for each use case within the programme. The document describes the intention at the time of writing and is subject to change / finalisation.

*Diverse Rural Economy (**Farming**)*

The intention of partners is to retain the farm as a 'demonstrator' facility where new farming technology and services can be trialled on a longer term basis. The farmer supports this vision and remains very engaged in testing the services. Monmouthshire CC will provide ongoing engagement support.

The farmer will continue to use the UtterBerry dashboard and alerts system to understand further how they can develop their business. Cardiff University will continue to explore the practical use of video analytics for productivity and security applications utilising the Cisco camera equipment.

Other stakeholders such as the National Farmers Union and the Rural Crime Commissioner will be engaged to share the learning and consider opportunities.

Tourism

The use case based around Raglan Castle creates 2 opportunities.

For the AR experience, Jam Creative are working with Cadw to boost visitor numbers and run the experience through the summer season in order fully assess the impact on the visitor experience through greater use and further survey data. The experience has potential for long-term commercial deployment at Raglan. From this further assessment, Jam Creative and Cadw will explore the potential for use on a wider basis across their heritage estate.

For the security and preservation service, Cadw are committed to further use of the dashboard provided by UtterBerry and analysing the data to better understand its broad potential and deep insight. The use case demonstrates a range of additional potential applications across the Cadw estate and the requirement and business case for further expansion will be explored. Similarly Cardiff University will continue to explore the practical use of video analytics in securing the site with Cadw. The Cisco camera equipment will remain at the site long term for this use.

Transport

Blaenau Gwent are the sponsor of key aspects of the transport use case

There has been a more limited opportunity to fully review the learning from the bus use case to date. Blaenau Gwent CBC are reviewing and considering use of the bus data as part of their approach to transport planning. They will engage Transport for Wales and consider if and how the service has use on a wider basis integrated with the Fleccsi bus service which is commissioned by Transport for Wales and operated by Stagecoach. This use case has been challenging in terms of commercialisation options and partners will explore options.

The information totem will remain a permanent fixture and will be further supplied and integrated with additional data feeds by BT.

Following the trial, the car park use case has now been launched publically and the service will remain operational on a commercial basis provided by Appyway and supported by Blaenau Gwent CBC. The local authority will use the insight provided by the management platform to inform their integrated transport planning. Cardiff University will continue to explore the practical use of video analytics for parking applications utilising the Cisco camera equipment.

Education

The immersive classroom is owned by Welsh Government but will be grant aided to Blaenau Gwent CBC. It will exist as a semi-permanent facility with an expected multi-year lifetime. Blaenau Gwent will be the owner–operator managing the facility against the terms of the grant agreement. The grant agreement will specify use for both education and business. Blaenau Gwent will fund ongoing operating costs.

For business use, the intent will be to monetise the facility over time, seeking sources of income generation. Blaenau Gwent will embark on an engagement exercise with local businesses to support this aim.

For education, a job description has been developed for a full time 'digital champion'. Such a digital champion has been in place since the classroom was launched and will continue to be responsible for engaging schools to use the facility. Welsh Government and Blaenau Gwent are currently considering if / how best to fund the digital champion long term. Blaenau Gwent schools continue to book teaching sessions in the classroom.

The WebEx Boards in the 4 schools will be allocated 1 year licences by Cisco who will develop collateral and engage with the schools on optimising their use. Welsh Government, Blaenau Gwent, Cisco and BT will consider if and how the model might be extended geographically.

Longer term aspirations include engagement with Cardiff Met University and the University of South Wales in HE as well as Coleg Gwent in FE. Work will also be explored on how to establish and ongoing model for content sourcing, curation and development (in particular by using those consumers to also develop content).