Final Report

Date June 2022

Audience Department for Digital, Culture, Media and Sport

Author Tim Robertson 5G RuralDorset Project Manager

History

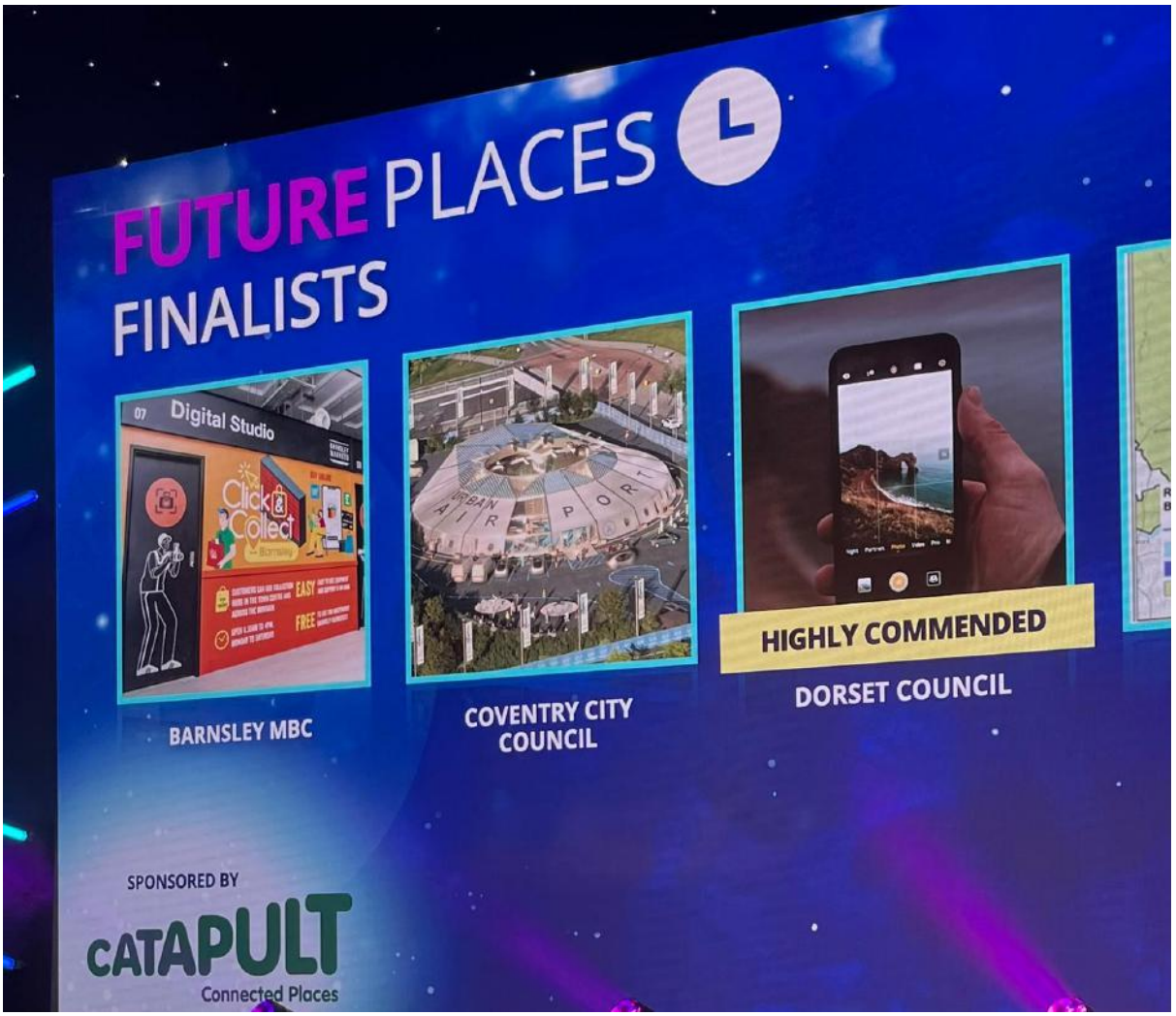
Version	Description	Issuer	Approval	Date
0.1	Document structure	Tim Robertson	Tim Robertson	
0.2	Restructured for brevity and 2 x sample WPs populated	Tim Robertson	Colin Wood	21/06/22
0.3	Remaining work package content added (except WPX as their final report has not been submitted	Tim Robertson	Colin Wood	15/07/22
0.4	Work Package X content added following submission of their report. Report	Tim Robertson	Colin Wood	19/07/22
1.0	Final Report Issued to DCMS	Tim Robertson	June Best	22/07/22
1.1	Review comments actioned	Tim Robertson	June Best	15/08/22

In May 2022 Dorset Council Leader Spencer Flower set out his mission statement for Dorset Council in 2022 - 2024. It included:

Digital Innovation – continue to pioneer new technologies and create the foundations of longer-term economic development. Work to safeguard and encourage job retention and growth through direct action and positive engagement with the private sector.

Table of Contents

Executive Summary



"We were hugely impressed by the innovation, pace and energy of this submission from a new council which has delivered a tangible economic shift. A great and nuanced use of disruptive thinking across a wide range of use cases really impressed us. This feels like the start of a new ecosystem with huge potential."

Judges Comment from Local Government Chronicle Awards 2022 – Highly Commended in Future Places category

5G RuralDorset (5GRD) was a ground-breaking £10m research and development project aimed at understanding how next generation connectivity can help people lead safer and more prosperous lives in rural communities.

The project consortium was led by Dorset Council and included local, national and international partners.

5G RuralDorset was part-funded by DCMS as part of its 5G Testbed & Trials programme (Rural Connected Communities competition).

5G RuralDorset achieved a number of world firsts, resulting in four national awards at the time of writing:

- World's first 5G buoy at sea
- Globe's first 700MHz in-field standalone 5G network
- Only UK integration of satellite backhaul into a 5G standalone network
- Largest ever 5G agri-trials, including plans for world's first 5G connected agricultural robot
- UK first - Neutral Hosting over 5G with unique cores

For Dorset Council the legacy of 5G RuralDorset will include:

- An enhanced reputation for world class digital innovation in sectors key to the success of our region and the UK
- New and valuable partnerships with government, business and academia that demonstrated momentum to deliver positive outcomes on the national stage
- New opportunities for residents in Dorset and rural communities across the UK
- Support for priority corporate goals, including attracting skilled and better paid jobs to the county
- Becoming a county where digital innovation is supported to flourish by a forward-looking local authority and its partners

Key findings including any benefits or impact supported by the evidence

Work Package 1 – Programme Management

- Dorset Council has recently proposed a major capital investment in the Dorset Innovation Park. £14.6 million investment is proposed to support 1,200 jobs, 10 light industrial units, expanding the site by purchasing a further 6 hectares of land, creating an amenity hub and improving the security gate building. 5G RuralDorset has been instrumental in raising the profile of the innovation park in partnership with the development of the Defence Battlelab, which hosts the 5GRD indoor testbed network.
- Dorset Council is now recognised as a proactive digital county, well known to government and national bodies as seeking opportunities to innovate in the rural connectivity space.
- Over two years the programme won multiple awards including
    - Connected Britain 2021 5G Initiative Award
    - Connected Britain 2021 Barrier Removal Award
    - Connected Britain 2021 Sustainability Award
    - UK5G Showcase Awards 2022 Best Collaborative Engagement Across the Programme
    - Local Government Chronicle Awards 2022 Future Places - Highly Commended
- A number of the networks funded during the project have move into commercial operations (see separate sustainability report)

Work Package 2 – Rural Community Accelerator

- Overall both Fixed Wireless Access (FWA) trialists were satisfied with the performance they received as part of the trial, rating the service and overall experience quite positively.

- Longer term, if FWA were to be deployed at scale utilising an external antenna could improve the quality of the connection significantly.

- We know from colleagues in our Tech Enabled Care (TEC) team that the trials we have conducted via the 5G RuralDorset project of NBIoT is likely to lead to further trials and demonstrations and we would anticipate further adoption at the front line of council services over the coming years.

Work Package 3 – Coastal Public Services

- Connected Digital Signage was installed at four key tourist locations along the coast delivering safety, litter and advertisement information to visitors.

- A 5G enabled buoy was launched in Lulworth Cove which monitored sea conditions and the information was used to inform the safety information displayed on the signs.

- Local first responders had equipment fitted to their vehicle which provided connectivity using the 5G networks and satellite back up to alleviate communication blackspots in their area.

- This work package also explored the feasibility of using satellite connectivity for backhaul (achieving very low throughputs of 0.43Mbps) and appropriate architectures for a distributed 5G core to support novel radio deployment.

Work Package 4 – 5G Innovation and Test Centre

Of the Indoor 5G facility Lt Col Andrew Gascoyne writes:

- "The Battlelab facility is significantly enhanced through the inclusion of the 5G Network facility……which adds capability and therefore value to the important Defence and Security work that the Battlelab is engaged with. The presence of the network within this MOD Innovation Facility is helping to catalyse interest and foster wider knowledge of the threats and opportunities of enhanced mobile connectivity within the Defence and Security sphere."

By creating the 5G Outdoor Testbed on the Data Innovation Park, 5G RuralDorset:

- Provided a very low-cost point of entry and instantly available infrastructure for organisations involved in testing, enabling vendors and service providers to make use of the Secure Features of the Dorset Innovation Park, to prove and demonstrate 5G connected devices including the NSTIx BattleLab facility.
- Provided combustible 5G networks for the purposes of training, system engineering and testing of applications and devices
- Provided MEC hosted applications for use with Ericsson Industry Connect hardware to enable vendors to test their 5G aware applications
- Co-worked with other 5G test environments
- Built and integrated with the 5G Defence test environment.

Work Package 5 – 5G Agri and Aqua Applications

- Connectivity can be done differently with 5G.
- So much is still to be done.
- A vision is needed.
- Mid-band 5G in Agriculture
    - More development required
    - Central co-ordinated vision
    - Precise topics of focus
    - Farmers as partners
    - Future kick-start investment
    - A hybrid system
- NBIoT in Agriculture
    - NB-IoT or LoRa
    - Integration of systems and software
    - Suitability of IoT devices
    - Battery life
    - Device procurement
- 5G in Aquaculture
    - Development sites are required
    - 5G fits
    - UK tech required

Work Package 6 – Neutral Host Business Service Design

- The deployment and successful demonstration in Dorset's rural environment is a good starting point towards the commercialisation of the Neutral Host capability in the region and beyond.
- Numerous opportunities arise from the successful demonstration of Neutral Host, which creates a framework for similar deployments around the UK.

Work Package 7 – National Collaboration

- We estimate our collaborations assisted in nearly doubling our project's value.
- We also believe that the additional profile gained from our collaboration has directly contributed to Dorset Council deciding to invest further at Dorset Innovation Park.
  We would advise DCMS, in line with our previous public submissions, of the need for a strong and experienced collaboration lead for any project in the future. The contacts and experience that come from this approach make it possible to progress further and faster than would otherwise be possible.

Work Package 8 – Dissemination of Results

- With well-planned and effective communications, the programme has avoided significant challenge from local community members regarding 5G Health Concerns.
- Press releases and newsletters have generated significant interest resulting in enhanced profile for the council amongst local and national audiences.
- Through the professional and impactful efforts of the WP8 'Dissemination of Results' team, a strong foundation for future projects and programmes like DCIA and Innovation hub has been established.

Work Package X – Coastal Cliff Monitoring

- Due to delays and technical challenges, the project did not achieve all of its planned objectives
- Nevertheless, the limited collected data allowed British Geological Survey to conduct a first analysis and evaluation of the accuracy of the IoT GPS module.
- Other positive outcomes include the development of a better understanding across disciplines (Computer Science, Geology, Earth Science) and stakeholders (Mobile Network Operators, Academia, local authorities) of the use case, and of the potential of 5G/NB-IoT technology in efficiently managing coastal cliffs and the natural environment in general.

Introduction

Objectives of the Testbed and Trials Programme

The 5G Testbeds and Trials Programme (5GTT), overseen by the Department for Digital, Culture, Media & Sport (DCMS), looks to harness areas where the UK has a competitive advantage – such as in scientific research, engineering talent and our rich variety of technology businesses.

The 5G Programme is exploring the benefits and challenges of deploying 5G technologies in line with the following key objectives:

1. Accelerate the deployment of 5G networks and ensure the UK can take early advantage of the applications those networks can enable.

2. Maximise the productivity and efficiency benefits to the UK from 5G.

3. Create new opportunities for UK businesses at home and abroad and encourage inward investment.

For Dorset Council, in line with the Digital Innovation priority outlined by Councillor Spencer Flower at the start of this report, 5G RuralDorset must contribute to the council objective to make Dorset a better place to live, work and visit. It has achieved this through raising the profile of Dorset Council with central government, academia and attracting high tech businesses to the county.

The 5G RuralDorset programme has also raised the profile of rural connectivity issues on a national scale with government, Mobile Network Operators and academia.

Work Package 1 – Programme Management

Description of what the project did

This work package was responsible for the management of the 5G RuralDorset Programme from the perspective of the lead partner Dorset Council. This included co-ordination ensuring effective delivery, risk management and reporting supporting consortium partners, administration and financial mechanisms. It also included establishing governance frameworks and managing stakeholder communities.

This was achieved through the appropriate application of Agile based project management approaches and values, mixed with more standard 'waterfall' type project management approaches and documentation.

Methods including technologies used and deployment approaches

- Daily Delivery Team 'scrums' which reviewed team activity over the prior 24-hour period, the following 24 hours and which shared any blockers to achieving deliverables within the core team.
- Regular drumbeat of focused and fit for purpose project meetings including:
    - Project Management Office calls with partners every fortnight to share what is going well, what is not going well and where the assistance of partners might help achieve deliverables. These calls were loosely minuted and actions captured and tracked. This gave partners a forum in which to share and debate issues away from the immediate gaze of sponsors at DCMS.
    - Weekly check-ins with our first point of contact at DCMS to review the previous 7 days, next 7 days recorded in advance on a standard DCMS template and to share questions. These meetings were collaborative and ensured effective and timely communication between the programme sponsors at DCMS and the lead partner

Dorset Council. 'Transparency' was the intention with the aim of 'no surprises' for either party which was largely achieved.
    - Monthly reviews with our colleagues at DCMS, with discussions based around a standard monthly review DCMS template. These meetings were more formal and attended by more senior DCMS colleagues to review overall progress towards programme deliverables.
    - Quarterly reviews - a formal checkpoint each three months which broadly coincided with the completion of each milestone to review all aspects of the programme, supported through the completion of the standard DCMS template
- A dedicated Teams channel was created to host and securely share all programme documentation, video conferences and online programme related chat, organised by work package. This platform provided one version of the truth and aided effective document sharing.
- Considerable investment of time, energy and funds were made in supporting effective communications across the entire programme with dedicated staff employed to ensure that best results were achieved. As can be seen from the profile achieved for the programme and awards won, these efforts were highly successful. More detail of the channels employed and success achieved can be found in the Work Package 8 'Dissemination of Results' section of this report below.
- Risk and Issue registers were maintained throughout the programme and referenced at each project meeting / report. Action logs were similarly kept and tracked to ensure progress towards delivery of value at all levels of the programme.

Description of the Results

- Multi-award winning programme
- Significant number of world firsts in mobile communication achieved
- Multiple programme extensions granted
- Significantly enhanced profile for Dorset on the national digital connectivity stage
- Testbed networks sustained beyond the closure of the 5G RuralDorset programme itself

'So what?'

'Stackability' of Use Cases: It has been noted through the work on the 5G RuralDorset project that the ability to stack a variety of use cases together underpinned by the same connectivity infrastructure is one of the strengths of the 5G opportunity. The benefits to this approach lie specifically in an increased economic, social and environmental return on initial infrastructure investment.

From an economic perspective, the applications enabled by enhanced connectivity may reduce costs, increase revenues and improve policy compliance. However, the challenge with this approach is that without identifying one single anchor use case that balances the business case, there is less likely to be one single entity willing to bear that initial cost of investment. The requirement for collaboration between sectors poses a challenging question as to how costs are shared, and who is in the best position to lead. The implication of this challenge may point toward the need for more central bodies to make the initial investment in order to unlock the value within different sectors. Such bodies could range from local councils, LEPs, or on a national scale, central government departments.

Roll-out: Whilst national roll-out of connectivity infrastructure could be looked at as one large strategic investment, there is value in exploring a staggered approach to investment to unlock high value areas first, which can then support the case for wider roll-out. This type of regional roll-out

requires identifying locations with similar challenge profiles and ambitions to create economic, social and environmental growth through digital transformation.

Within each area there are likely to be a set of use cases that make the initial case for investment, and multiple subsequent use cases that will create additional value once infrastructure is in place. Taking this approach, it seems likely in the first instance that the use cases that are chosen to support investment follow a 'spend-to-save' approach, exploring areas where there is currently large local and national spend which, over the course of a short period of time, would be reduced by a factor that provides a valuable return on initial investment.

Key Learnings

Strategies for Success: Investment in infrastructure

Sustainability

- Planning for sustainability from outset reduces risk of redundancy
- Gaining multi-stakeholder commitment
- Leveraging national targets such as net zero and levelling up to drive long-term funding

Business Case

- Undertaking a high-level options analysis for co-investment by councils / HMG, industry
- Showing the impact of multiple use cases/verticals in a single area - demonstrating demand to encourage investment
- Align future work with Governmental priorities to access national support and funding
- Identifying applications with comparatively large user groups or "big wins" e.g. areas that currently absorb significant council budget and use these to get "buy-in" on an early use case
- Focusing on immediate benefactors and immediate timelines e.g. 1yr or 3yr
- Kickstarting the ecosystem through government subsidies to put infrastructure in place to enable market growth
- Moving to a 'spend to save' environment to unlock investment
- Wider roll-out leads to more users helping to build business case and improve viability and profitability of infrastructure and application development

Service cost to end users

- Not expecting end users to front service costs that enable infrastructure development. Service costs must be clearly balanced by value created
- Exploring long term financial models that prioritise adoption and long-term sustainability would realise a greater user base sooner. The hypothesis is that volume with smaller margins would be more sustainable and see cashflow sooner, rather than larger margins with a smaller number of customers.

Spectrum regulation

- Creating a more flexible approach where spectrum is assigned where it is needed
- Moving to a 'use it or rent it out' model of infrastructure and spectrum

Strategies for Success: Increasing adoption

Engagement and promotion
• Proactively engaging with the network operator, infrastructure owner, service provider and the customer/end user. This includes understanding each of their needs and feeding these into the design of a mutually beneficial solution
• Creating partnerships with local business who understand the region and are bought into protecting and delivering
• Engaging with communities on issues important to them and aligning on which problem needs to be addressed first
• Utilising organisations who have seen significant benefits through trials as part of the campaign
• Getting buy-in from leadership teams so they can communicate the benefits and promote it
• Being clear that technology is about iterative improvement rather than reinventing the wheel
• Running demonstrations of solutions already trialled and ensuring outcomes are accessible to as wide a group as possible
• Share stories via media and local communities using non-technical language and emphasising both personal and community benefits.

Skills
• LA-wide strategy to build capability and linking to National Skills Fund; HEFE; institutes of technology, etc
• Ensuring accessible training is available
• Showcasing opportunities for students and young people to come to more rural areas, such as Dorset

Building trust
• Paying attention to security
• Seeking legal advice and best practice guidance for putting in place information sharing and data use agreements.
• Inviting expert users to share their experiences

Ease of adoption
• Developing technologies that don't require large amounts of training or completely new methods to adopt
• Ensuring devices are made to last in-situ for long periods of time.
• Leveraging existing and future personal tech devices and wearables
• Working with MNOs to ensure a frictionless experience for the user so that their device can connect to the 5G network automatically

Strategies for success: National rollout

Lessons learned
• Learning from other rollouts
• Sharing case studies from existing programmes overseas, e.g. Japan, Canada, Australia
• Utilising national forums (e.g. UK5G, UKTDTF) to engage nationally
• Promoting the Dorset example nationally. Situating their story within the "rural challenge" so other authorities recognise they could do it too

Partnering for wider rollout

• Consider regions that have similar challenges to 'partner' with e.g. coastal, rural etc. Running joint pilots across several regions for one or more specific use cases will demonstrate scalability and benefits across region
• Working with other councils would enable shared learning as well as allowing for resources to be pooled
• Identifying local authorities who can be part of a fast follower programme
• Identify councils taking active roles in funding digital transformation in aligned priority sectors

Incentivisation
• Supporting incentivisation for organisations and regions that choose to make the leap for the benefit of the wider sector

Work Package 2 – Rural Community Accelerator

The full final report for Work Package 2 can be accessed via the programme's Teams Channel @5G RuralDorset>Files>Technical and Security>MS09 Deliverables>WP2 Vodafone

Description of what the project did

Work Package 2 set out to build 5G networks in two highly protected locations to demonstrate the benefits of enhanced mobile connectivity to the people living, working and visiting those very rural and previously ill-served (by mobile connectivity) places.

A mast was successfully erected and commissioned at Worth Matravers where previous attempts to improve mobile networks had failed. The attempt to build a mast at East Lulworth on the Binfield MOD Range site was unsuccessful, however the process yielded useful lessons learnt for future deployments on MOD land most notably the 5GRD project would highly recommend that certain MoD land is flagged as "no go" from the perspective of telecoms infrastructure build and specifically anywhere that is a "firing point" should be excluded now we understand that a wide range of RF emissions are prohibited in such areas.

Work Package 2 collaborated with the Dorset Council Tech Enabled Care team and East Borough Housing Trust to deploy IOT Services Group sensors in residents' homes, operating on the Vodafone NBIoT network.

Change request 19 provided for the deployment of a further 30 IOTSG "Doris" devices into East Borough Housing Trust (EBHT) in a number of their facilities across Dorset.

Methods including technologies used and deployment approaches

1. **5G Fixed Wireless Access trial at Worth Matravers**

   There is significant interest in the potential for 3.5GHz fixed wireless access (FWA) in rural areas because it has better range capabilities than higher frequency bands but also can potentially

deliver an appropriate amount of throughput to be practically useful to home and business users who struggle to achieve useable speeds using their existing very poor fixed connection.

This was intended to be a fairly limited first step in understanding the real-world experience of FWA users in Worth Matravers selecting two trial users who were sufficiently close to the mast location to be likely to receive a good level of throughput.

Fixed Wireless access of choice was the Nokia FastMile 5G Gateway. Selected due to its feature set, product availability and suitability.

2. Assisted Living Trial using NBIoT technology across the wider Dorset Council area 5G Fixed wireless Access (FWA) trial

This element of the the work package aimed to explore the use of the Vodafone NB-IoT Network as part of the RuralDorset 5G programme primarily with the use case of monitoring vulnerable independent residents where existing mobile phone reception is poor and prevents the use of standard telecare type equipment 5 NB-IoT “DORIS” devices were delivered to chosen residents based at different geographical locations.

The Hardware Sensor Device

The device has factory fitted batteries and simply monitors changes in environmental conditions so that human activity in the kitchen can be detected and reported over a radio link to the Software Dashboard.

To perform device Activation, all that is required before the Hardware Sensor Device is delivered to the Resident, is that the battery isolation tab is removed before sealing the envelope and delivering the unit through the Residents letter box.

Description of the use cases to enable sufficient understanding

Two use cases were identified and developed for WP2 as follows:

1. **5G Fixed Wireless Access trial at Worth Matravers**

   There are a number of remote areas across Dorset where residents experience very poor fixed connectivity. Some of these clusters of properties could be served by a FWA solution at 3.5GHz which may not deliver Gigabit speeds but DOES deliver sufficient throughput to support a wide range of use cases (streaming, email, browsing etc). We wanted to understand the user experience and see how useful individuals found the FWA service by comparison to the fixed alternatives they currently "enjoy".

   Each of the trial users were supplied with a Nokia FastMile 5G Gateway with a pre-installed VF 5G capable sim card and some very basic set-up instructions. The trial gathered information from one business and one family home within the identified range, and this included information around download/upload speeds, as well as narrative feedback around how well it worked, any connection issues and what difference it made to achieving a reasonable level of connectivity.

2. **Assisted Living Trial using NBIoT technology across the wider Dorset Council area**
   5G Fixed Wireless Access (FWA) trial

   IOTSG supply a single sensing device per resident which passively monitors activity within their kitchen and provides granular data on every change in atmospheric conditions e.g., when using an appliance or washing up.

   The devices supplied under CR19 were deployed only for the month of June 2022 in order to ensure data collection and reporting could be completed prior to the end of the 5G RuralDorset project. However, IOTSG have agreed to extend the pilot timeline to 12 months so Dorset Council and EBHT can continue to gather data and explore the usage of the Doris devices longer term.

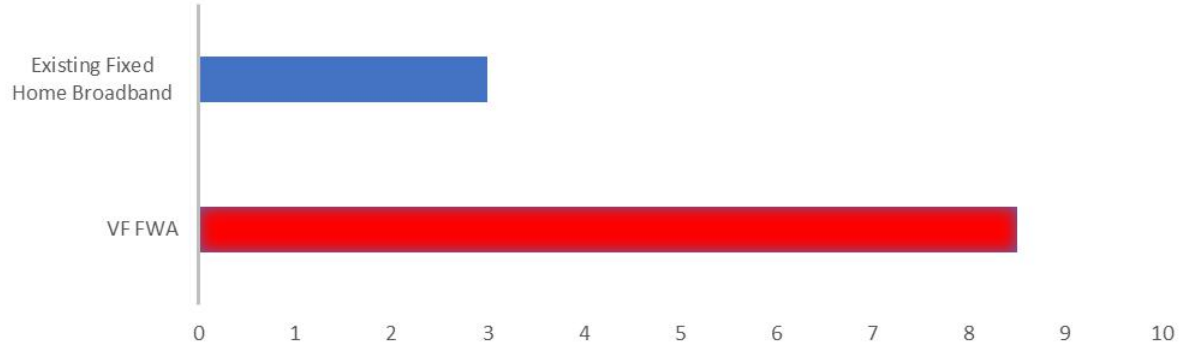
Description of the Results

1. **5G Fixed Wireless Access trial at Worth Matravers**

Work package 2 explored the potential to improve connectivity and the nuances of deployment in rural environments, including useful learnings around effects of location within the building on equipment performance. Deployment times were very short, simply requiring the device to be supplied and plugged in once the network coverage was available (mast build took significant time but was a one off 'cost' whereas fixed connectivity costs would be incurred for every premise install).

When asked "How does Vodafone's service compare to your previous service from your current [fixed broadband] provider? Better/Worse/About the same" both trialists responded with "Better"

When asked “How would you rate your current home [fixed] broadband service for overall speed in contrast to Vodafone’s FWA on a scale of 0 to 10?” the average trialist response rose from 3 to 8.5



Trials were also asked to submit a number of speed tests on the existing fixed connection and then rerun the tests using the VF FWA equipment:

Figure 1- Speedtest (Existing Fixed Connectivity)

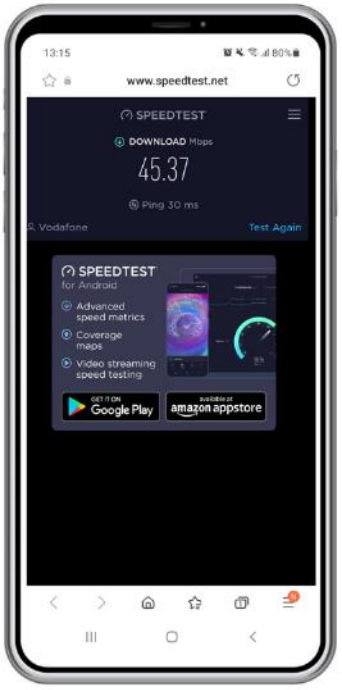


Figure 2- Speedtest (Using VF FWA equipment)

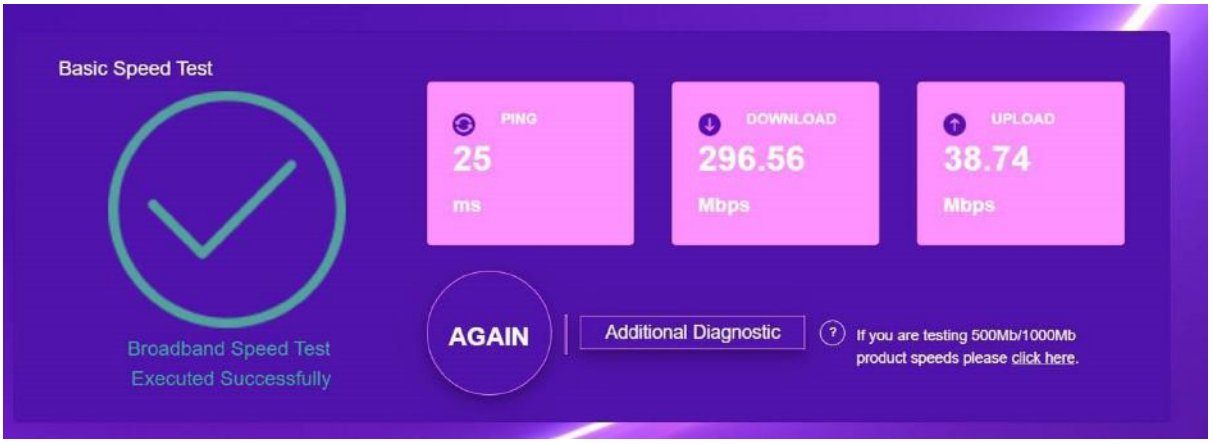


Figure 3 - Speedtests (Using VF FWA equipment)

2. Assisted Living Trial using NBIoT technology across the wider Dorset Council area 5G Fixed Wireless Access (FWA) trial

There was only a very short data collection window for the devices deployed under CR19 during the month of June 2022. During this period data was collected from 29 devices (the 30th device has not been activated as the resident to which it was delivered has been taken into hospital)

Two devices had connection issues. Investigation by IOTSG revealed that the NBIOT coverage in the location at which the two devices were located was extremely poor. However, IOTSG deployed a firmware fix which they believe will improve the performance of the devices during the remainder of the 12-month pilot.

The evidence gathered during the trial has been acknowledged by IOTSG as being extremely useful in assisting them with their product development and feedback we have provided is helping them consider further developing some of their connectivity options (such as having an anchor device with a mains power supply and external antenna that can connect to subordinate devices at the same location) to enable the use of devices where there is poor or no indoor NBIOT coverage.

Initial analysis of before and after survey responses from an East Borough Housing Trust manager indicates that the responses are balanced (i.e. not 100% positive) but with some real-life feedback that will assist IOTSG in the future development of their strategy and product development activities

'So what?'

1. 5G Fixed Wireless Access trial at Worth Matravers

Overall both trialists were satisfied with the performance they received as part of the trial rating the service and overall experience quite positively. A significant issue was identified however with the standard specification for the rural aerial site backhaul capacity as implemented by Vodafone, where the 1Gbps capacity specified would potentially be used up by only two FWA sites and beyond which the contention of users would seriously degrade performance.

Longer term, if FWA were to be deployed at scale utilising an external (to the property) antenna could improve the quality of the connection significantly. Vodafone have also indicated that they are increasing the capacity secured for the backhaul in similar rural areas from 1Gbps to 10Gbps which could partially mitigate the contention issue identified during the trial for a larger number of users on that mast.

Assisted Living Trial using NBIoT technology across the wider Dorset Council area

With regard to NBIoT connectivity and the continuing support of this technology across the Vodafone network, the Dorset Council project team for 5G RuralDorset believes the project has helped to highlight some new opportunities for NBIoT deployment nationally and this will we believe contribute towards the longer-term viability of the NBIoT technology within the Vodafone national network.

We know from colleagues in our Tech Enabled Care (TEC) team that the trials we have conducted via the 5G RuralDorset project of NBIoT is likely to lead to further trials and demonstrations and we would anticipate further adoption at the front line of council services over the coming years. These initial trials may therefore act as a pilot exercise for further work, providing a good basis from which further measures and the methodology can be developed.

Key Learnings

From the perspective of Dorset Council's 5G RuralDorset Project Team, we were able to draw the following conclusions from this trial:

1. Dorset Council may need to review its planning processes to ensure equal weight is given to protecting the county's outstanding built/natural environment and the social/economic benefits of improved mobile connectivity. In the case of the Binfield Range proposal the latter appeared not to have been quantified.
2. NBIOT Coverage in Dorset is better than standard 4G/5G mobile cellular coverage, particularly in very remote areas
3. Mobile Network Operators may not be best placed to manage and deliver use cases
4. There are Implications of State Aid when infrastructure is funded with a life beyond the end of the project
5. MoD are a difficult customer to work with, in particular when trying to build telecoms infrastructure on a live firing range.

Vodafone provided the following summary:

What went well

1. Close collaboration between Council Planning team, Vodafone, Parish Council and build partners at Worth Matravers - *the Worth Matravers site deployment was the fastest acquisition and deployment of a rural site by Vodafone to date.*
2. Fixed Wireless Access and Tech Enabled Care Use cases at Worth Matravers
3. NBIoT coverage across rural Dorset

What did not go well

1. Site planning authorisation for Binfield Range Site which was difficult and led to drawn out delays
2. Site access for Binfield Range site
3. MoD range as mast site (multiple siloed stakeholders)
4. Responsibility for making good damage to other systems on mast site

How might things be improved next time

1. Early clarity on responsibility for use cases is needed to ensure clear definition of use cases, and how those can be usefully tested within the required timescale.
2. 'Single voice' for MOD as mast site hosts to ensure all parties moving towards a common goal.

Work Package 3 – Coastal Public Services

The full final report for Work Package 3 can be accessed via the programme's Teams Channel @[5G RuralDorset>Files>Technical and Security>MS09 Deliverables>WP3 Excelerate]

Description of what the project did

The project deployed 5G wireless capabilities at four new strategically placed sites around the Dorset coastline to maximise coverage and enable a range of use cases.

Connected Digital Signage was installed at four key tourist locations along the coast delivering safety, litter management and advertisement information to visitors. The signs also incorporated footfall counting technology to monitor visitor numbers and inform estate of higher than normal levels of activity.

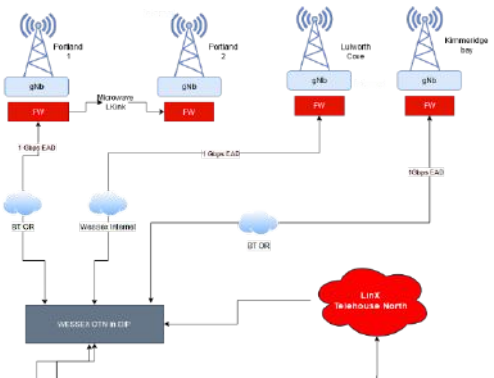
A 5G enabled buoy was launched in Lulworth Cove which monitored sea conditions and the information was used to inform the safety information displayed on the signs.

Local first responders had equipment fitted to their vehicle which provided connectivity using the 5G networks and satellite back up to alleviate communication blackspots in their areas of operation.

This work package also explored the feasibility of using satellite connectivity for backhaul (with very low throughput identified at 0.43Mbps) and appropriate architectures for a distributed 5G core to support novel radio deployment.

Methods including technologies used and deployment approaches

Four radio sites were deployed, see diagram below.



- Kimmeridge Bay:
  - 700MHz 5G radio system
  - Deployed on an existing wooden mast adjacent to the Wild Sea Centre

- Lulworth Cove
  - 3500MHz 5G radio system
  - Deployed on a new building mount antenna on the Boat Shed by the cove.

- Portland 1 (Fancy's Farm)
  - 700MHz 5G radio system pointing back at the Dorset coast.
  - Deployed on an existing old O2 mast (used for the Olympics)

- Portland 2 (Coast Guard Lookout)
  - 700MHz 5G radio system and 3500MHz radio system.
  - Deployed on new building mounts on the Coastguard lookout.

Kimmeridge Bay.

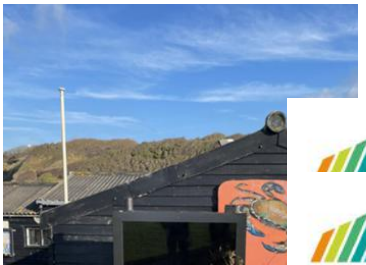
Lulworth Cove

Portland 1

Portland 2

Description of the use cases to enable sufficient understanding

Kimmeridge Bay - Digital sign and footfall counter



A 5G digital sign was installed adjacent to the Wild Sea Centre.

The sign can be seen here in its final position.

The antenna on the top left is the radio antenna and the antenna on the top right is for the footfall counter.

Lulworth Cove - Digital sign, footfall counter and connected buoy

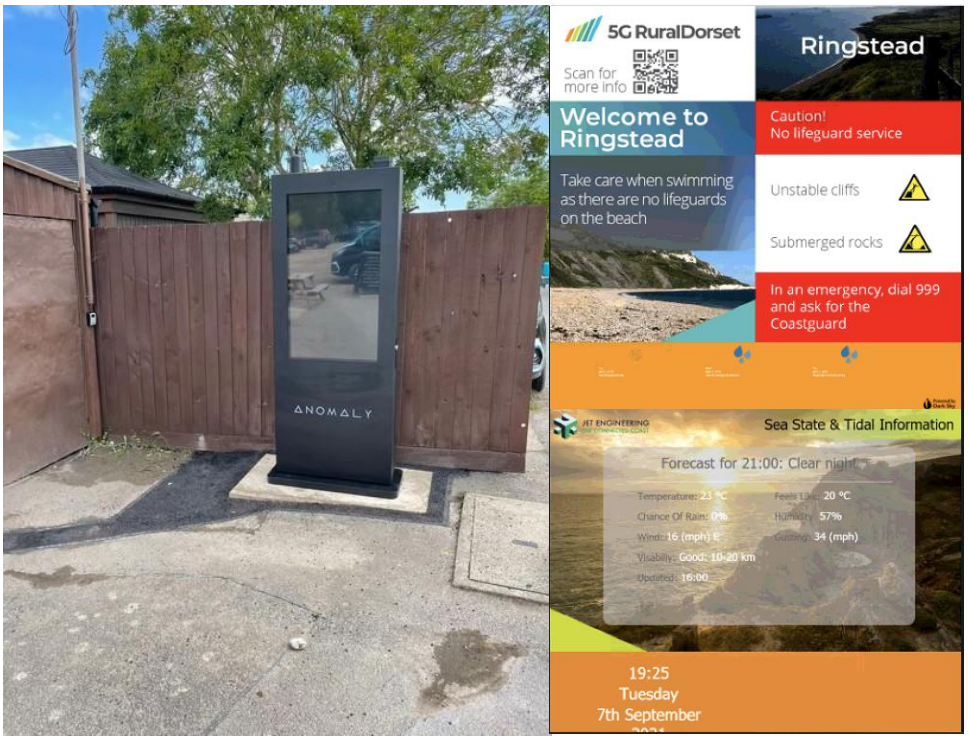
The 5G digital sign was installed on the wall of the gift shop.

Durdle Door - Digital sign and footfall counter

The 5G digital sign was installed at the exit to the car park. The faint land in the background is Portland where the 700MHz system is located which provides the signal for this sign.

Ringstead Bay - Digital sign and footfall counter

The 5G digital sign was installed at the exit to Ringstead car park. The 700MHz RF signal comes from Portland 1.



Description of the Results

Connected Sign

It has been clear from the offset that the public have engaged with the digital signage in a positive way

Content has varied from weather and sea conditions to requests by estates to pick up litter and how to stay safe. As seasons and conditions change these messages can easily be updated to reflect circumstances and the messages that stakeholders want the public to see.

In the context of cost saving the Lulworth Estate has seen a 7.31% reduction in staff members collecting litter with a 63.64% reduction in the cost of litter signage. Whilst this cannot by any means entirely be attributed to digital signage it is a strong indicator of response levels and positive reactivity of the public being delivered at a lesser cost. This level of engagement can likely be attributed in the receipt of the other messages across the screens. Please see WP3 for full details of the trial and findings.

Connected Buoys

To date there has been significant press coverage, ranging from articles in local to national press. This has included BBC coverage, UK5G magazine and online coverage, a number of websites picking up the press releases, in addition to over 8,500 views of the content on JET Engineering System Solutions LinkedIn directly linked to 5G RuralDorset.

Audience analysis of these posts reveals an even split between those actively working in 5G service and product industries and those who would likely benefit from deployment of maritime 5G solutions, such as defence, offshore wind, smart ports, and aquaculture, mostly UK based audience but with some US and European impressions as well.

From the initial engagement a business model has been tested, providing some evidence of the potential benefits of using coastal safety buoys. There has been a significant reduction in RNLI call outs concurrent with the deployment of the buoys and safety signs and there has been a significant number of data views that may have contributed to the reduced number of incidents though the reduction is highly unlikely to be wholly attributable to the buoys and related safety signage.

With the cost of life so high and with the potential cost saving to the RNLI in excess of £50,000, it is possible that the return on investment for the outlay for these safety measures can be recovered. Further to this, knock-on savings would be present for NHS and onward patient care.

It can also be seen that there are further additional 'stackable' use cases for connected buoys that have significant benefits. These range across safety, security and environmental use cases. Please see full details of use cases and trials in the WP3 report.

Community First Responders

Matt Warman MP Minister for Digital Infrastructure with Lulworth Community First Responders

The project provided 5G connectivity to the community first responders vehicle, with satellite failover, which worked to eliminate black spots in mobile phone coverage for local volunteers. Volunteers can now be tasked and supported via a Wi-Fi signal from their vehicle to their mobile phones, in areas where previously they had no connectivity at all. The trial included work to map connection black spots and match these against geographical locations where first responders are most active. Please see WP3 report to see an overlay of connectivity on identified first responder sites.

'So what?'

Maddy Pfaff from the Lulworth Estate team commented:

"The signs display not only visitor management data but also this exciting new wave buoy data live from Lulworth Cove. This allows visitors to be alerted to the sea state in real time so it's a nowcast not a forecast with possible swell or dangerous sea conditions highlighted and that is helping to keep

people safe on the coast. They have reinforced all our visitor management messages about being safe by the coast and are helping visitors to make sensible decisions about where they go and what they do and when they do that. They are on all day so we don't need to have a full visitor centre open 24 hours a day but you can see the signage. That has made a massive difference to how visitors are engaging with our site here."

The Benefit targets attributed to the digital signage were as follows:

Water Safety - to reduce the number of local lifeboat launches and thereby reduce costs for the lifeboat service. It was recognised that only a small proportion of the lifeboat services for the lifeboat stations either side of the testbed location were located along the coastline, with many launches to vessels out in the Channel or to coastal events either side of the test area. Recognising this fact, the target reduction was set at a modest level.

Taking the cost of an operational launch figure (£2,639 per launch) it is possible to suggest a cash value to the charity of a reduction of 24 lifeboat shouts in 2021 from the long-term average figure for both stations. 24 lifeboat shouts at a cost of £2,639 per launch can be hypothecated to a cost saving for the charity of approximately £63,000. This figure considerably exceeds the target of £7,917 (2%) reduction in operational costs identified above and represents a 16% drop in operational costs for the two lifeboat stations over the period when the safety signs were operational.

Litter messaging – Target - Active signage 3 x more effective than static imagery suggesting £30k worth of 'signage effect' for £5k cost.

The baseline metrics (estimated by the Consortium) used for this aspect was that the Lulworth Estate spends £10K on litter signage, with the aim of the trial to determine whether the cost of litter signage could be reduced. This baseline of £10K was calculated for the year 2020, and it was anticipated that costs could be reduced by 50%.

Litter and littering was significantly reduced at Lulworth and Durdle Door when compared to 2020.

Management of Litter in staff hours for litter picking

Staff hours: 2020: 543.75 hours	2021:504 hours	*7.31% reduction*

Cost of Litter signage

C*ost of signage:* 2020: £5505.07	2021: £2001.57	*63.64% reduction*

Between August 2021 and March 2022 (8 months), it was found that there had been a reduction in spend by £3.5K - a 64% reduction in costs. We were able to calculate the costs for installation from costs provided by Lulworth Estate.

Litter Picking Spend

Where we needed three or four beach cleaners each morning in 2020, we only required one or two each morning in 2021, with far less 'emergency' call-outs i.e. extra staff being taken off their jobs to assist.

We also called upon our volunteer network on multiple (perhaps 12+) occasions in 2020, whereas in 2021 they were only called out three times, and of these three it was more of a precaution than a necessity.

Summary of litter messaging: Although these figures are not wholly conclusive, the Lulworth Estate has obviously seen the necessity for many different approaches after the 2020 season. We certainly did not want another repeat of the scenes on the coast post lockdown, which were not just litter orientated, but also general antisocial behaviour on the World Heritage Site. All of this, coupled with the onsite technology provided by the **digital signage** have contributed to somewhat curtailing the problem which will be built upon going forward.

In 2020, Lulworth Estate spent £18k on litter picking, with the aim of achieving a 10% reduction in spend. The key metrics to take away from these trials are:

Bins collected:	2020:1289 Bins	2021:1437 Bins	*11.48% increase**
Staff hours:	2020: 543.75 hours*	2021:504 hours*	*7.31% reduction***
Cost of signage:	2020: £5505.07*	2021: £2001.57	*63.64% reduction*

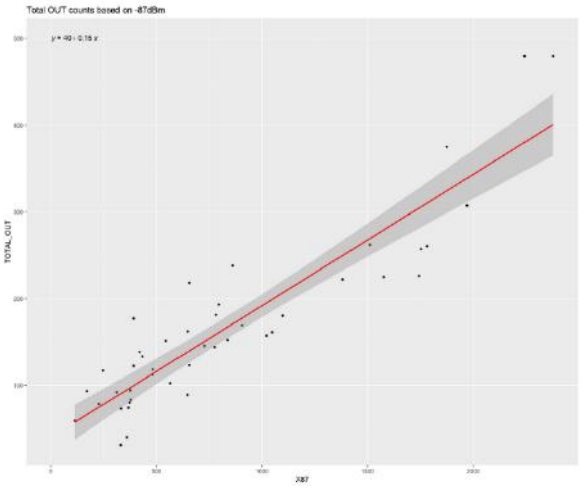
So, more bins collected, using less hours and less cost for litter signage.

Key Learnings

Network resilience: There were some issues with the 5G network we were using, the network was not available 99% of the time as this is required from a commercial 4G/5G network. In our case the network was available approximately 90% of the time. Reasons for that are that the 5G core was one of the first available 5G standalone networks, compliant with 3GPP release 15, which was expected to face such stability issues comparing to major vendors.

Unwanted Devices Detection: Due to the Wi-Fi data collection, some static devices in the surroundings were detected, such as computers and other electronic equipment. Detecting static equipment is not of interest, as the goal of this trial is to be able to count people in the area. It was decided to disable the Wi-Fi detection, leaving only active the Bluetooth detection.

Devices Detected in the Distance: When analysing the Bluetooth data, it was spotted that more devices than the ones present in the digital signs' areas were being detected. A dynamic filter has been implemented on the website so the parties involved in the trial can set different RSSI threshold levels to correlate the numbers shown in the page with the real numbers collected in-site. Lulworth Estate provided daily totals figures of people detected entering/leaving two of their facilities (Heritage Centre and Café), corresponding to the months of December 2021 and January 2022.
An analysis of the data has been conducted between the information provided by Lulworth Estate and the data collected by the Footfall Counter during the same period.
The analysis calculated the correlation between the data from two different data sources, Lulworth Estate and the FFC. It also generated a mathematical model that relates both data sources.
In general, all the correlation values between the TOTAL_IN/TOTAL_OUT (total number of people entering/leaving the Café and Heritage Centre) and the data from the FFC using different RSSI filters are above 0.8. That means that there is a strong relationship between the data collected by Lulworth Estate and the data collected by the FFC.
Using these two datasets, a simple lineal model (red line) was calculated



Kimmeridge Signage: The key issue raised in messages of complaint from a member of the local community was the brightness of the screen and the fact that it was visible when the light faded / went dark.

The lessons learned from these comments fall into the following categories:

Location:

- This is critically important and in these trials three of the four signs were located in the "first choice" location identified by the landowners. However, the Kimmeridge sign was the exception. The building construction was too weak to hold the sign and so it was moved to a more prominent position; this meant it was more visible than originally intended.
- The lesson learned is that much more consideration should go into the location of the screen given how bright it can be as the light fades. This can only be done in consultation with the landowners (albeit that we did this in Kimmeridge too!). With hindsight we probably could have foreseen this at Kimmeridge but would argue that is part of what the trial was about.

Local information:

- One of the complaints from Kimmeridge was that it did not display safety information specific to Kimmeridge. Instead, it used data from the buoy at Lulworth Cove and general public wide data.
- So, in terms of lessons learned, at the very least the water safety messages should indicate these are general messages rather than location specific messages. Alternatively, if the funding is available, then local 5G connected buoys close to the area covered by the sign would be even better. In this case, if we had been able to have a 5G connected buoy in Kimmeridge Bay then that would have resolved one of the complaints.

Brightness

- The signs were meant to turn off after "dark". However, this was based on a timer rather than a light sensor. Additionally, there were some problems with the timer not actually turning the sign off.

- Lessons learned would be to make sure the signs went off based on light sensors rather than a timer.

Work Package 4 – 5G Innovation and Test Centre (Indoor Network)

The full final report for Work Package 4 Indoor can be accessed via the programme's Teams Channel @5G RuralDorset>Files>Technical and Security>MS09 Deliverables>WP4 Indoor (Vodafone)

Description of what the project did

The Indoor testbed enables a customer to trial a solution exclusively indoors, in the BattleLab Workshop managed by the MoD, a facility provisioned with radio head equipment enabling connection from 5G-enabled User Equipment such as handsets, headsets, cameras, wearables etc.

Methods including technologies used and deployment approaches

The radio head(s) is/are connected downstream via an Indoor Radio Unit (IRU) and underground fibre to an Industry Connect Network Controller implementation. This Indoor service is provided by and under the management of Vodafone. The Industry Connect Network Controller implementation itself is however provided by Ericsson and is physically located in Kimcell's data centre, in Unit 20 at D3IP. Ericsson itself has responsibility for monitoring and managing this equipment, with Kimcell providing rack space and power for the dual units and network connectivity for secure access to the equipment by Ericsson engineers.

The Indoor service is designed to be self-contained and does not provide for any external radio network interface nor any Internet connectivity (other than for Ericsson engineer access). Without such external Internet connectivity, any application functionality that a customer's use case may require can only be delivered from local server(s) resident in Kimcell's data centre (servers owned by Dorset Council, but managed by Kimcell).

Description of the use cases to enable sufficient understanding

While the specification and configuration of the indoor network were entirely proposed and driven by Vodafone, with many use cases suggested initially for such networks, Vodafone did not record evidence of any use cases being demonstrated or their value measured on the network provided. Once it became obvious that Vodafone were not going to expend effort on staging and reporting the benefits of any use cases on the network, Dorset Council and Kimcell sought opportunities for the

demonstration of 3 use cases and requested narrative from the MoD on the value of the network provided. These 3 use cases included VR briefing with reduced latency, 5G enabled agri-robot bench testing prior to infield tests and MOD Cyber security exercises attacking and defending the 5G network.

Description of the Results

It has been challenging throughout the 5G RuralDorset testbed and trials programme to assess accurately the value of the 5G Standalone Indoor Private network established within the Battlelab Workshop at Dorset Innovation Park.

The specification and configuration of the network were dictated by 5G RuralDorset partner Vodafone from the outset. At the time the nature of the network was decided there was no building identified to host the network or customer in mind who would benefit from use of the proposed network.

Dorset Council worked to support Vodafone in identifying a suitable venue for the proposed network and was able to secure the support of the MOD in hosting the Vodafone network within the Battlelab Workshop, a collaboration and innovation workspace built on the Innovation Park site during the time that 5G RuralDorset was active as a programme. Whilst the MOD were keen to host and understand the opportunities and threats of enhanced mobile network technology, Vodafone and the MOD were unable to identify specific use cases and test / demonstrate their value over the period of the Rural Connected Communities 5G RuralDorset programme.

It has been suggested that despite the lack of engagement with use case trials and demonstrations of benefit metrics the presence of the 5G standalone private network within the Battlelab Facility has had a positive impact for the MOD in raising interest in and knowledge of the potential benefits of enhanced mobile connectivity for UK defence and security.

‘So what?’

Lt Col Andrew Gascoyne SO1 Business Development Army Innovation Team wrote the following letter in support of the value of the 5G network embedded within the Battlelab Workshop:

Future Force Development Branch
Futures Directorate
Army Headquarters
IDL 26 Zone 3
Blenheim Building
Marlborough Lines
Monxton Road
Andover
Hampshire
SP11 8HJ

Telephone: 0300 157 3340

16 March 2022

Dear Tim,

Vodafone 5G Standalone Private Network Facility at Battlelab Workshop

I am writing to you regarding the Vodafone indoor 5G standalone private network in the Battlelab Workshop at Dorset Innovation Park. This is a facility funded and installed / commissioned as a result of the efforts of the 5G RuralDorset programme within the Department for Digital, Culture, Media and Sport's Rural Connected Communities initiative.

I can confirm that the use of the Battlelab facility is significantly enhanced through the inclusion of the 5G network facility brought to the building by Vodafone as part of the 5GRuralDorset activities, which adds capability (and therefore value) to the important Defence and Security work that the Battlelab is engaged with.

The presence of the network within this MoD Innovation facility is helping to catalyse interest and foster wider knowledge of the threats and opportunities of enhanced mobile connectivity within the Defence and Security sphere. The presence of the 5G Standalone Private Mobile Network provided has given the MoD the ability to understand and develop skills relating to the latest generation of mobile communications.

There has been some concern reported that no specific use cases have been highlighted or exploited through the facility. From my perspective focusing on this as a metric or measure of effect probably misrepresents the true value to the MoD. The 5G testbed at the BattleLab is part of a wider programme of work in Defence looking at use cases across a range of areas with the BattleLab providing the focus for enhanced training and deployed/tactical 5G. Significantly, it has provided a foundation for the more ambitious plan to roll out a 5G network to cover the Lulworth Cove Training Area, which will deliver this year. Other Defence areas of development include smart bases and ports, smart logistics and spectrum management technology; whilst the BattleLab is not the lead location for these work stream it provides a key node within the network.

The 5G network has been aa valuable addition to the BattleLab and the benefits will continue to accrue for the foreseeable future.

Yours sincerely

Lt Col Andrew Gascoyne

SO1 Innovation

Key Learnings

1. **Configuration of network chosen to suit needs of customer**

At the root of the use case issue for the indoor 5G standalone private network delivered by Work Package 4 appears to be the choice of network and configuration offered at the outset. End user devices are extremely limited which work with 5G Standalone networks, and those which are available are manufactured and supplied by high-risk vendors which cannot be funded through DCMS programme grant claims.

The decision to make the network private and not allow access to the wider internet also severely restricted potential applications of the network, requiring any application to be hosted locally.

The customer for the enhanced mobile network coverage provided by Vodafone at the Battlelab Workshop is the MoD, and their understanding of and ability to utilise enhanced mobile connectivity as provided by an indoor 5G standalone instance is not yet well enough developed to exploit such a network.

It is the author's opinion that the configuration of the network provided at the Battlelab was not based on an understanding of user needs and the challenges that the customer wished to be addressed. It was therefore not possible to engage the MoD in practical trials and demonstrations utilising the enhanced mobile connectivity provided during the timeframe of the 5G RuralDorset programme.

The Vodafone Defence Team are now liaising with Andrew Gascoyne at the Battlelab and are putting together a proposal to enhance the current capability of the 5G indoor network and provide a more encompassing facility to support the wide range of use cases that they would like to see. With the right engagement, this could have been done much earlier in the project.

Vodafone now have good engagement with Ben Parish, Head of Defence Digital to share different perspectives on the use of 5G for the military. Specific activities will come out of this workshop which could then drive further utilisation of the indoor 5G network.

Vodafone also wish to highlight that they have received Industry engagement from existing defence primes that are aware of the Battlelab and want to see if Vodafone will open the door to allow them to use the 5G indoor network for testing and proving their portfolio of capabilities.

2. Early clarity on responsibility for use cases

There is a need for justification of the investment in testbed and trials networks through clear Use Cases with benefits that can be measured against targets, including who is responsible both financially and in management terms for the identification and practical demonstration of those use cases. These key details of the trial should be clearly stated and attributed up front at the initiation of the project.

The lack of meaningful and demonstrable use case justification for the indoor network proposed and built by Vodafone in work package 4 has yet to be ameliorated through the efforts of Dorset Council and other partners in picking up the requirement once it became clear on 14 January 2022 that Vodafone had not trialled or demonstrated use cases and were not to invest further time and resources beyond the provision of the network infrastructure itself.

Once Vodafone decided to provide an indoor standalone 5G private network at Dorset Innovation Park the network was always facing the challenge of being a solution looking for a problem, and during the initial stages an 'indoor' solution looking for a building.

A more clearly stated responsibility for these use case demonstrations at the outset would have highlighted to all concerned the difficulty of utilising the particular network and configuration being proposed and may have led to different decisions based on understanding of the customer and configuring a network to address real world challenges.

Work Package 4 – 5G Innovation and Test Centre (Outdoor Network)

The full final report for Work Package 4 Outdoor can be accessed via the programme's Teams Channel @5G RuralDorset>Files>Technical and Security>MS09 Deliverables>WP4 Outdoor (Kimcell)

Description of what the project did

WP4 is set up to deploy 5G Mobile Private Network(s) with a Mobile Edge Cloud computing element at Digital | Data | Defence Innovation park (D3Ip), to deliver a commercial and bespoke managed mobile service. It envisages the deployment of infrastructure to provide a testbed facility for organisations to experiment, exercise and exercise with 5G infrastructure. A focal point is to work with next generation systems which rely on communications and sensors.

Methods including technologies used and deployment approaches

WP4 comprises two discrete testbed environments, to cater for differences in the kind(s) of experiment/trial(s) that a given Customer wishes to pursue.

One variant addresses use cases revolving around activities conducted in an Indoor environment (e.g. office, factory) as covered in the preceding report, and the other supports use cases of an essentially outdoors nature, such as might involve ground-based vehicles or drones. The Outdoor testbed service, managed and operated by Kimcell, enables a customer to carry out experiments/trials in an outdoor setting, thereby enabling use cases that involve vehicles, cameras, drones etc.

The User Equipment connects to radio heads mounted on masts and on the roof of buildings et al (See Fig 1 below), which again are connected via fibre to Kimcell's data centre. The Outdoor environment, unlike the Indoor, does provide for onward connection to the Internet and thus caters for use cases that require remote connectivity.

Description of the use cases to enable sufficient understanding

The Live and Online Demonstrations usually followed the following format:

Objectives: Demonstrate the 5G core and physical capabilities of the network, answer questions and present a case for involvement in further defence/intelligence related events.

Demonstrations Given: Demonstrations of the 5G infrastructure were provided to our guests, largely based on the System Test Plan. We demonstrated the following:

•5G core emulated environment

•Live usage of User Equipment:

•Inspection of real-time log data

•Visibility of information in the 5G core

Description of the Results

Reception

All the 28 groups drawn from defence, security and policing organisations attending either live or online demonstrations were engaged and interested, responding positively to the presentations. Many had questions which Kimcell were able to answer in most cases, and provide supporting context when not. Details of dates and objectives and outcomes are available in a table in the Work Package 4 Outdoor final report on pages 12 to 14.

Conclusion

Overall, feedback from the events was positive, suggesting that customer objectives in attending the events were met and there is potential for further events of this nature down the line.

Narrative of key impacts and benefits of the trial

By creating the 5G Outdoor Testbed on the Data Innovation Park, Kimcell:

•Provides a very low-cost point of entry and instantly available infrastructure for organisations involved in testing, enabling vendors and service providers to make use of the Secure Features of the Dorset Innovation Park, to prove and demonstrate 5G connected devices including the NSTIx BattleLab facility.

•Provides combustible 5G networks for the purposes of training, system engineering and testing of applications and devices

•Provides MEC hosted applications for use with Ericsson Industry Connect hardware to enable vendors to test their 5G aware applications

•Co-work with Local Authority Smart Places 5G test environments

•Build and Integrate with the 5G Defence test environment.

The Business Model is the marketing of the services mentioned above to gain funding from external organisations and Industry, that wish to get instant access to skilled individuals and capabilities for the delivery of an oven ready solution.

The purpose of the use case is to determine how does WP4 support product/ service development with the aim of improving RCC and wealth generation. As such a further question emerges:

Can a facility at DIP support local service and product development and create employment in Dorset?

In order to answer this question we started from the premise that cost savings will be made if a 5G facility is already set up when conducting experiments as opposed to the Government setting up their own 5G network each time they wanted to start a new experiment. The cost of setting up and maintaining the 5G infrastructure at D3IP was £300K.

In September 2021 a 5G security event took place at D3IP. The objective of the event was to explore the emerging threats and opportunities around communication, surveillance, and 5G. The total cost of organising the event was £30k, thus making savings of 90%. The event included introduction to the Innovation Park for all in attendance, highlighting the facilities available and clearly outlining the benefits of working at D3IP.

The main events included 5G connectivity exercises with data analysis using the 5G testbed, an aerial surveillance demonstration using cutting edge drone technology, and talks on understanding 5G data and future opportunities.

'So what?'

As a result of the 5G efforts, five businesses have opened on the Innovation Park. The military are building their own 5G facility, using the Park as the hub for training and collaboration. We have had enquiries and expressions of interest to operate and develop facilities at the park. The projected investment for services being delivered from the Park is currently £30m per annum which equates to 1,000 new local jobs in the science and technology sector, specifically focused on Security, Communications and Sensors.

Key Learnings

Over the course of the two year project, Kimcell has faced several challenges which are summarised below:

Lesson Summary	Challenge	Resolution	Further Detail
Due Diligence on Partners	Financial due diligence is undertaken to a basic level on partners at the start of the programme. However wider background checks are not completed.	Broaden due diligence on partners as the programme is being established to include high level checking for published information that might embarrass the programme such as convictions and ask for disclosure of relevant history	This could include a simple Google of key officers within partner organisations and / or a request for disclosure of relevant convictions? Need to be informed by rehabilitation of offenders regulations and understanding of risk appetite of funders and what is considered relevant / admissible
Import Customs / VAT confusion	BREXIT customs implications mean there remains delay	If possible, allow extra time - expect	Arrival of AW2S radios significantly delayed by customs confusion

	and confusion over tax and duties at borders importing equipment to UK – Suppliers / Shipping Companies and Customers remain confused over arrangements and process that causes delay and confusion	confusion and delay at borders	
Working with the MOD	Frequent turnover of personnel, meaning military contacts are always changing and succession is not always well planned or executed	Ensure role rather than individual responsible for liaison is understood and clear succession / handover / briefing is in place prior to departure of previous incumbent	
Reliance on 3rd parties	Reliance on 3rd parties for patches / fixes when bugs emerge may impact timelines – especially as issues tend to cascade, resolving one uncovers another, low confidence until entire system is up and running.	Mitigation using a hardware solution has mean timing source can still be provided, however we remain dependent upon the 3rd party for the software	
RAN diversification problems for MNOs	Paying SMEs not on supplier rostas is very difficult for large organisations	Recognise problem and instigate new ways of working that encourage diversity in suppliers and agility in purchasing orgs	Kimcell are providing hosting and technical support services for Vodafone. It has proved impossible to date for Vodafone to pay Kimcell
MNOs working with third party hosting equipment	MNOs can work with 3rd parties to host and support their equipment despite concerns	SLAs negotiated to ensure quality of service	Difficult for MNO to pay supplier not on roster however!

Work Package 5 – 5G Agri and Aqua Applications

The full final report for Work Package 5 can be accessed via the programme's Teams Channel @5G RuralDorset>Files>Technical and Security>MS09 Deliverables>WP5 Wessex Internet

Description of what the project did

Wessex Internet led the 5G RuralDorset agriculture and aquaculture work package (Future of Food) with around £1.2m of funding from DCMS and partners. The two-year project has as its objective to identify what value NB-IoT and mid-band 5G could bring to farming, and better understanding of how that will be delivered into the future.

Description of the use cases to enable sufficient understanding

Over 80 different organisations were engaged in developing the use cases to be trialled. All the different ideas were eventually broken down to six principal use cases to be tested on the 5G network. For each use case, Wessex Internet worked closely with an agri/aqua-tech organisation to deliver the trial . This is indicated here:

Use case	Description	Partner
Farm Operations	Deploying a range of around 40 sensors across the farm trial sites. Feeding live data from multiple sensors into a single, simple to use farm platform.	FMEC Group (software solutions provider for agriculture)
Connected Drone	Enabling images to be sent from the drone, in the field (in flight) automatically for processing to enable the farmer to reduce input usage.	Hummingbird Technology (AI software provider for agricultural drone images)
Connected Cow	Enabling images to be sent wirelessly from a CCTV camera for automatic processing to get quicker information of cow lameness for the farmer.	CattleEye (AI software provider for cow imagery)
Water Monitor	Deploying range of underwater sensors, feeding back data over 5G to the farmer for stock management purposes.	RS Aqua (sensor and software provider for aquaculture)
Underwater Camera	Deploying an underwater camera to monitor biofouling on seaweed remotely.	JET Engineering (buoy engineering company)
Automated Farm Vehicles	Enabling images to be sent live from an automated vehicle in the field through to farmer to demonstrate possibilities with automation of machinery.	Small Robot Company (farm robot provider) Intrepid Minds (automated vehicle provider)

Description of the Results

Mid-Band

•Enormous amounts of data will soon be collected and used by machines and devices across farms which will require upload and download speeds of up to 200mbps.

•N77 is likely the frequency band to be used on farms to deploy private 5G networks as this spectrum is accessible by smaller operators. Public

5G networks will not provide sufficient coverage over farms due to the nature of the frequency.

•Mid-band 5G will not provide more than 40% coverage of farms in the short to medium term due to the nature of the frequency and the cost of equipment.

•5G hotspots are likely to provide data offload spots on the farm. This is more convenient than Wi-Fi but requires a new generation of farm machinery to be worth the investment.

•Regulation and licensing needs to be developed centrally alongside a national vision of automation and telecommunications in agriculture to accelerate farm vehicle development and adoption of new-era technologies.

•Fibre currently only reaches c. 27% of farms and therefore fibre roll out must be prioritised to be able to provide the backhaul infrastructure that will be required for any 5G networks on farms.

NBIoT

•NB-IoT and LoRa can add hundreds of millions of pounds of value in marginal gains to the UK agriculture sector.

•Deployment of these IoT networks is most suited to large MNOs who can deploy very quickly at scale and provide a low-cost service.

•NB-IoT cost model is significantly simpler than LoRa as no gateway is required and scale is much easier for hardware providers.

•Significant initial funding is required for companies to specialise in developing fit-for-agriculture IoT sensors in the UK.

•Vodafone's UK-wide NB-IoT coverage now opens opportunities for companies to begin developing NB-IoT hardware solutions.

5G in Aquaculture

•Aquaculture is a young industry with many small operators. The South West of England has a strong community and is seen to have high potential.

•Technological development is accelerating in aquaculture with 5G trials happening in different locations across the globe.

•Site location is particularly sensitive in aquaculture which will dictate whether 5G infrastructure is worthwhile.

•Main opportunities lie where 5G networks can support multiple industries in a hub location such as ports, with neutral host technology also helping to reduce cost.

•A centre of aquaculture could help stimulate technological and connectivity development in aquaculture in the UK.

•Mid-band 5G is especially promising as it provides suitable coverage and bandwidth for long-term technological change in the industry.

Narrative of key impacts and benefits of the trial,

Mid-band 5G benefits

Initial hotspot deployment: Roll out of 5G networks (or alternative connectivity methods) on farms could be encouraged initially through farm hotspots. The ultimate reason for this is that these hotspots can reduce the cost of deployment to match the value that could be delivered in the short to mid-term by agri-tech.

Local processing: The other major design feature of a private 5G network which would bring value to the use cases trialled is processing space on the farm. Whether that is processing power specifically on the user equipment or at a central site on the farm, this could enable operation where coverage is patchy, reduce load on a fibre network back to the internet and deliver 'data devolution'.

Automating vehicle movements: This new era of farm vehicles will be automated. The agri-tech companies that are emerging (as well as the major existing machinery providers) are all developing fully automated systems. This removes the requirement for people to operate machinery allowing vehicles to run continuously throughout the day and avoiding human error.

Sending data between vehicles: The other major use of connectivity in the automation of farm operations is communication between vehicles and systems. It is commonly believed in the agri-tech sphere that future farm machinery will operate as a fleet system.

Requesting / making decisions: Another use of connectivity is sending data between the vehicle in the field and the farmer themselves. This is a way of providing information to the farmer about the development of their crops, the health of their soils or the status of vehicles.

Remote servicing of vehicles: Being able to access vehicles remotely is also seen as a major requirement of automation. Although the trials have not focused on remote maintenance/servicing, this was something discussed at length with a local machinery manufacturer at the beginning of the project. Being able to access machinery meant that software updates can be done without an engineer being sent out and vehicle faults could be fixed remotely.

Providing locational accuracy: What has been out of scope but should be highlighted is the potential of connectivity to provide greater accuracy and precision by being able to locate to the millimetre. By having this level of accuracy, machines can send data between themselves and understand locations to a greater accuracy so that every seed or weed could be located in the field and understood by every machine.

Providing data offload stations: Finally, as highlighted previously, automation will still require some form of data offload point with very high upload speeds. Mid-band 5G will not be able to provide sufficiently strong upload speeds in the field to upload some of the very heaviest data loads. Small Robot Company's robots can collect up to 6 terabytes of data each day. This would theoretically require upload speeds of 200mbps which has not been achieved by the 5G network at the trial farm sites. Mm-wave 5G could be the answer here, providing super quick speeds at a hub location on the farm which means that the vehicle would not require being 'plugged in' to fibre.

Virtual farming: Another concept which has not been explored in this project is that of farm virtualisation. This is the concept of having a virtual image of the farm in one place, with all information shared between all vehicles and people on the farm in real time. Such a system would enable farmers to monitor progress of tasks and react to issues as they arise with decisions being made remotely. Connectivity will be the beating pulse of this information and compatibility of devices would be required.

NBIoT benefits:

Reducing wastage: Ultimately, the main benefit most IoT sensors bring to agriculture is the reduction of waste across the farm. This can be reducing waste of grain in the grain store, fertiliser on crops and water or electricity used. By measuring data continuously (as the sensor is fixed in place) and more accurately (providing 'cold, hard data' as one of the agricultural stakeholders put it), systems can be optimised. Additionally, alerts can be used to tackle any arising issues straight away.

Enabling automation: Completing the benefits realisation exercise has underlined the ultimate opportunity of IoT sensors–automation. Although each of the farmers on the trials has shown genuine curiosity in the data that the IoT sensors deliver, the real financial benefit brought is the action which is made based on that data. Automating this process in many cases is the end goal.

Saving time: Farmers are busy –it's not just a stereotype. By feeding in data which the farmer would otherwise have had to collect , IoT devices can save farmers' time. Not only this, but the data can be collected a lot more frequently and more accurately too.

Environmental reporting: Providing evidence of environmental good practice and high welfare conditions for cattle will become more and more important. Both in terms of public-sector funding and private sector supply chains, reporting data can increase existing revenue streams for farmers. Not only should this be seen as a revenue stream but also a compliance measure.

'So what?'

Connectivity can be done differently with 5G.

NB-IoT will deliver coverage to connect anything and everything to the internet. It will provide the information gathering to drive the efficiencies required for feeding the world while rebalancing the natural ecosystem. Large telecoms providers will be able to quickly upgrade existing infrastructure to provide coverage to almost every corner of every field across the UK. This will negate the need for complicated private IoT networks.

Mid-band 5G will support the intimate connections suitable for individual farms. This will drive automation and reimagine how farm equipment works. This allows the much-dubbed precision agriculture to become a reality, providing enormous financial value for the industry. 4G will retain its necessary role providing coverage for mobile phones and devices. Satellite will become more and more prominent as Low Earth Orbit satellites decrease the cost and improve the capacity of ubiquitous connectivity for roaming autonomous vehicles.

So much is still to be done.

Despite these great pictures, much more development is required for these to become reality. The current state of technology in agriculture and aquaculture could not bring value from investment in private 5G networks. This report has shown that network operators must therefore work hand-in-hand with the agri and aqua innovators and influencers to make sure that full value of technological advancements can be appreciated.

To do this, the use of existing and new forums (such as Satellite Application Catapult's Agri Living Lab) will be required to accelerate technology and develop sustainable business models. These spaces bring different industries together around funding opportunities to stimulate ideas in a safe environment to test, fail and progress. It is so important however that such spaces belong to the grassroots and do not disengage the very people they are there to serve.

A vision is needed.

Some form of central co-ordination of this agreed future is required. Organisations such as DEFRA, NFU and CEFAS must build a practical vision of the new era agriculture and aquaculture landscape. Through engagement with grassroots farmers and external stakeholders, the UK can begin to work together towards this new state.

This future must learn from the mistakes of the past. In a computerised era, this lesson is principally of openness and interoperability. Regulation must be updated speedily across government departments to ensure it can provoke rather than prohibit this positive change. What's more, organisations must not be afraid to share data or gain value from it. As a fundamental utility, fibre and 5G can be one force behind this change.

Key Learnings

Mid-band 5G in Agriculture

More development required: The ultimate learning from 5G RuralDorset is that agriculture is not yet ready for 5G roll out. The cost of the equipment and the coverage/bandwidth capabilities are not yet at a point which make 5G beneficial to current state agriculture.

Central co-ordinated vision: One suggestion is that a central vision of how connectivity will work in agriculture is needed and should be adopted within a vision of agri-tech by the farming industry.

Precise topics of focus: Future funded projects must focus on very specific areas of interest to agriculture. One of the learnings from the 5G RuralDorset trials is that too many use cases were explored and not in enough depth.

Farmers as partners: A clear requirement of future projects is for farmers to be included in any consortium and to be accountable within the project.

Future kick-start investment: As agri-tech solutions develop and a tipping point is reached as to when automated vehicles can replace existing farm machinery, large capital investment will be required by farms into telecommunications equipment.

A hybrid system: The final learning from 5G RuralDorset is that mid-band 5G will only be part of any connectivity solution. N77 and n78 5G does not achieve the coverage needs for some types of data which require immediate upload and download in the field.

NBIoT in Agriculture:

NB-IoT or LoRa: The trials have found that LoRa devices currently outperform NB-IoT devices in terms of reliability and simplicity to connect. This is simply down to the greater maturity of LoRa as a solution in the market. More devices are available, more devices are designed specifically for agriculture and a proven supply chain exists.

Integration of systems and software: The most prominent challenge faced in the trial was the integration of differing hardware and software systems. Wessex Internet worked with FMEC Group to

develop an NB-IoT platform which could interpret and visualise data from sensors. This was an addition to their existing platform for LoRa devices in agriculture.

More attention needs to be focused on:

a) Integration data from NB-IoT hardware providers is accurate, simple and inclusive of all information.

b) NB-IoT hardware providers are forced to provide all relevant information for integration.

c) Systems managed by NB-IoT hardware providers are designed to be integrated rather than siloed.

Suitability of IoT devices: Another key finding of the trials is that most of the existing IoT hardware on the market is not suitable for use in agriculture (especially in the case of NB-IoT devices). Primarily this is due to devices not being rugged enough.

More attention needs to be focused on:

a) Investment in NB-IoT devices which are designed specifically for agricultural purposes.

b) Testing of devices before they are deployed to ensure they can last.

Battery life: It is too early to make any definite conclusions on battery life of NB-IoT sensors. It is known that some of the devices deployed have run out of battery and that advertised figures should be taken with a pinch of salt.

More attention needs to be focussed on:

a) Testing and improving hardware for improved battery life.

b) A mechanism for holding manufacturers to account on battery life of their devices.

Device procurement: The final main barrier that was faced in the 5G RuralDorset trials was the purchasing and procurement of NB-IoT devices. For the Efento devices and the Digital Matter devices (among others) lead times on devices were over two months. Generally this was blamed on two main factors: 1) the global chip shortage, and 2) devices still being in development.

5G in Aquaculture

Development sites are required: Currently choosing sites to start aquaculture developments is tricky. There are many regulatory boundaries with lengthy processes to gain permissions to set up an operation. This is slowing down industry growth. Therefore, oven-ready sites need to be developed for aquaculture operations to choose.

5G fits: 5G offers a perfect balance of coverage and bandwidth for aquaculture. Unlike in agriculture, aquaculture sites are not as large and do not face many obstacles blocking coverage.

UK tech required: As an island nation, the UK has a wealth of opportunity in regard to aquaculture. Looking over the North Sea, Norway provides a good example of how progressive aquaculture operations have attracted high-tech innovations with investment from the likes of Alphabet. Indeed, Indonesia has also produced some advanced aquaculture technologies. The UK requires more investment into aqua-tech which could be facilitated through local regeneration of coastal areas.

Work Package 6 – Neutral Host Business Service Design

The full final reports for Work Package 6 can be accessed via the programme's Teams Channel @5G RuralDorset>WP6 Neutral Host Bus Service Design>Deliverable Documents

Description of what the project did

Work Package 6 'Neutral Host Service Design' completed tasks grouped under the following 8 broad headings:

1. Neutral Host Architectures – report can be found here
2. Security and Privacy – report can be found here
3. ORAN and Neutral Host – report can be found here
4. Spectrum – report can be found here
5. Business Study – report can be found here
6. OpenRAN for Neutral Host Product & Market research – report can be found here
7. Demonstration – report can be found here
8. Dynamic Spectrum Sharing Demonstration – report can be found here

Methods including technologies used and deployment approaches

1. **Neutral Host** - The 5G CN architecture and its respective network functions and interfaces are described. Thereafter, the different NH roaming architectures are presented ranging from home routed roaming for 3GPP access, to local breakout roaming for non-3GPP access. Next, different RAN sharing architectures are discussed, focusing on MORAN and MOCN architectures. Furthermore, different NH deployment aspects are discussed, through the concept of network slicing. In addition, a reference architecture for backhauling to multiple cores using satellite networks at Ka and Ku band is presented.
2. **Security and Privacy** - A rural Neutral Hosting network architecture is similar to a suitably protected 'zero trust architecture' of a national operator. JOTS has been designed with an in-building solution in mind, rather than a rural environment, but the underlaying architecture could be applied.
   This demonstrates, from a security perspective, that it would be possible to provide rural NH coverage, assuming that MNOs are suitably incentivised to look for enabling solutions, rather than find commercial barriers. One way through which this could be done would be coverage obligations.
3. **ORAN and Neutral Host** - an introduction to O-RAN alliance, the OpenRAN architecture and the corresponding standardized interfaces are demonstrated in detail. RT and non-RIC components are described together with the service management and orchestration functional block. The functional splitting points are discussed for the fronthaul, midhaul and transport data layers. An architecture for combining the OpenRAN framework within the NH concept is provided, emphasizing on the capabilities and benefits of deploying OpenRAN-based platforms for the NH use case.
4. **Spectrum** - This paper begins by introducing the term "neutral host" and its many guises, then looks in detail at the complex interrelationships involved between them, and on key relevant additional factors so as to deliver a complete and comprehensive picture.
5. **Business Study -** This paper studies the business and commercial aspects of a NH operator, the practicalities of creating a commercially viable rural NH operator at-scale, and some of the key enabling steps which would be required to support this, as an alternative

connectivity solution at potentially lower cost. It also provides some practical recommendations for action, in particular, positive regulatory discrimination for rural areas to reduce the digital divide in line with Ofcom's existing statutory duty

6. **OpenRAN for Neutral Host Product & Market research** - the analysis undertaken provides an overview of the most advanced commercially available ORAN compatible platforms, offered by UK and non-UK vendors. Furthermore, the comparison among these solutions and their suitability for NH deployments are discussed. More specifically the OpenRAN solutions provided by the following vendors are presented: Mavenir, AirSpan, Parallel Wireless and Acceleran.
7. **Demonstration -** This sets out the implications and the interworking of the successful NH trials that took place in September 2021, using the 5G Standalone (5G SA) trial network along the Dorset coastline. In the 5G RuralDorset Network, 5G Connectivity is provided by Satellite Applications Catapult's (SAC) 5G Centre in Westcott and includes the UK's first integration of satellite backhaul within a 5G Stand Alone (5GSA) network, as well as the world's first 700MHz standalone network. Furthermore, Wessex Internet (WI) has deployed their on-premises 5G network.
8. **Dynamic Spectrum Sharing Demonstration** - 5G & LTE Dynamic Spectrum Sharing (DSS) is a technology that allows 4G LTE and 5G NR (New Radio) user equipment to connect on a common, single, base station hardware on the same frequency band. This provides a dynamic allocation of spectrum resources between LTE & 5G based on user demand. The licensed frequency band is shared by "4G LTE" and "5G NR" radio access technologies (RAT), avoiding a split into dedicated spectrum for each RAT with separate base stations.

   DSS enables a single antenna (or antenna array) and radio base station to operate functionally as both a 4G eNodeB and a 5G NR gNodeB. This is most useful for operators without new 5G spectrum who need to re-farm existing bands to 5G. DSS uses new intelligent scheduler algorithms to set an optimal split in resources for the mix of 4G and 5G devices in the network as it changes in time.

Description of the use cases to enable sufficient understanding

1. **Neutral Host** - The following use cases can be exploited using neutral host deployments:

   a. Rural / remote areas such as the areas investigates by 5G RuralDorset
   b. Urban centres needing 4G/5G RAN densification
   c. In-building / on-premises coverage for large sites such as shared office-space, entertainment venues and resorts
   d. Road and rail-side coverage
   e. Industrial sites and transport hubs
   f. Temporary sites and events, such as cultural events and major civil-engineering projects

2. **Security and Privacy**
   a. MNO to be able to securely interconnect with NH operators
3. **ORAN and Neutral Host**
   a. Caters for any future production, test and integration efficiently
   b. Allows for the customised services which can be rapidly scaled up/down as required.
   c. Service velocity is improved by remote provisioning and the enablement of a wide variety of multivendor/multi-tenant systems bringing new services and new revenue streams at a lower risk.
   d. Allows for network configuration optimisation on a near real time basis.

4. **Spectrum -** New approaches to bust barriers and to the greater uses of fallow spectrum in rural areas are essential as what we have is clearly not delivering fast enough. The Communications Act has at the time of writing, been in place for 18 years. In that time the digital divide has worsened but the underlying economic and social need, especially "post Covid," has sharply increased.
5. **Business Study** - One way to reduce the cost of deploying connectivity in rural areas is to avoid inefficient allocation of capital, commonly manifested as "over-build", where multiple operators each incur their full costs of site build-outs.
6. **OpenRAN for Neutral Host Product & Market research -** Empowered by the principles of intelligence and openness, the OpenRAN ecosystem is the foundation for building the virtualized RAN on open hardware and software, with embedded AI-powered radio control. Inspired by the O-RAN alliance, the OpenRAN infrastructure combined with increasing RAN virtualization and data-driven intelligence, will allow complexity reduction, faster innovation and significant reduction on deployment and operational cost.
7. **Demonstration -** a network solution enabling NH can benefit both operators and end users. It was demonstrated that NH over 5G is relatively easy to deploy and maintain without the support of large MNOs and specialist cellular companies. What is more, in addition to terrestrial connectivity, it is possible to extend the NH functionality and integrate with satellite communications (5G over satellite was already deployed in 5G RuralDorset Network) for added redundancy and higher link availability.
8. **Dynamic Spectrum Sharing Demonstration** - A big advantage of DSS is that it allows operators to smoothly migrate from 4G LTE to 5G NR as well as hosting both technologies under the same existing antenna infrastructure. This clearly speeds up 5G NR deployments, since no new equipment nor new spectrum re-farming is needed.

Description of the Results

1. **Neutral Host** - a range of implementation architectures have been proposed for the successful deployment of NH platforms.
2. **Security and Privacy** - To deliver a secure NH solution, it is necessary for the NH provider to be security-aware, and able to architect and implement a secure network of distributed endpoint devices. The provider should also keep these updated, maintained and available, while simultaneously carrying out appropriate proactive monitoring to detect attempts to compromise those endpoint devices. To deliver this viably at scale, a zero-trust architecture would be required, using suitably locked-down endpoint equipment to act as COTS hosts for the virtualised workloads that are likely to be required to enable a NH operator to provide independent and suitably isolated interfaces to each operator.
3. **ORAN and Neutral Host** - In RAN deployments until now, the software, the interfaces and the underlying hardware are proprietary of one vendor and are all tied together. On the other hand, the key concept of Open RAN is based on openness of interfaces and infrastructure between the various building blocks in the RAN. Open RAN targets to achieve open, interoperable interfaces non-proprietary of a closed vendor environment but a standardized, multi-vendor one which maximizes the use of common-off-the-shelf hardware.
4. **Spectrum** - The issues faced are principally regulatory, not technical – and the Finnish example discussed in this paper makes this clear. In rural areas, the problem should be re-framed towards how to ensure use of the spectrum to provide a service, rather than how to prevent use of the spectrum which could prevent a theoretical other user from also using it, since at present this contended demand remains a distant dream.

5. **Business Study -** A move to a model of rural "shared infrastructure", which could be manifested as a rural NH service, would allow for the costs of infrastructure to be shared by all operators benefiting from coverage provided by a NH operator. Another way of reducing the effective cost is sharing the costs over a larger number of users. Therefore, the paper also analyses potential revenue streams through taking conservative estimates for consumers such as smart agriculture, local authorities, social care and in-fill coverage, and comparing these against the potential costs of providing such as a service: spectrum, equipment and backhaul.
6. **OpenRAN for Neutral Host Product & Market research -** This report details the OpenRAN platforms available on the market from various vendors, highlighting their advantageous features alongside with their missing elements and weaknesses. Furthermore, the association to the Neutral Host paradigm is also presented in terms of the platform ability to provide NH deployments in a flexible and efficient manner.
7. **Demonstration –** To demonstrate the NH deployment, Neutral Networks (NN) have deployed a 5G RAN (gNB) in Dorset, Portland 2 site, acting as the NH provider. Engineers from SAC, WI and NN, have successfully managed to demonstrate the NH concept. This was achieved by managing to attach different 5G UEs, to the two different 5G networks using the same NH gNB. Each User Equipment (UE) was whitelisted in one of the two 5G networks. Through the single gNB, each UE was able to see and register to a 5G network and have access to network's resources and services. This was the first demonstration of 5G network sharing in the UK 5G network sharing.
8. Dynamic Spectrum Sharing Demonstration - A preliminary DSS demonstration has been carried out in the Satellite Applications Catapult's (SAC) Future Networks Development Centre lab in Westcott. We were able to demonstrate the basic capability to share a band between 4G LTE and 5G NR.

Narrative of key impacts and benefits of the trial

1. **Neutral Host** - an NH operator builds a network (with or without its own local spectrum), and the other Telcos either 'roam onto it' or use its shared facilities for their own radios
2. **Security and Privacy** - an operator that was ready and willing to enable NH interconnections with suitable NH operators would have confidence in the robustness and security of their RAN infrastructure's peering connections over X2/Xn interfaces, the correctness of those implementations, and appropriateness of monitoring in place.
3. **ORAN and Neutral Host** - An open, vendor-neutral hardware and software-defined technology with open interfaces between all the components, environment like this, aims to expand the ecosystem and increase the competition. It is also expected to stimulate innovation and service optimisation since more vendors are involved and provide the building blocks of a RAN.
4. **Spectrum** - New approaches to bust barriers and to the greater uses of fallow spectrum in rural areas are essential as what we have is clearly not delivering fast enough. The Communications Act has at the time of writing, been in place for 18 years.
5. **Business Study -** This paper demonstrates through reference to three case studies that active NH business models have considerable potential if applied to rural areas *if* there were sufficient regulatory and consumer protections in place. Rural NH *can* be a viable business proposition, with the right regulatory and political incentives in place, and provided that some work is carried out to streamline IP voice support on existing user handsets where users have moved between operators. As financial data from other infrastructure projects shows, rural NH *can* provide improved connectivity that is likely to be available to operators

more cheaply than MNOs can deploy themselves, making this a viable proposition for them as potential customers of the wholesale NH service provision.

6. **OpenRAN for Neutral Host Product & Market research -** The report begins by emphasizing the importance of OpenRAN platforms aligned to ORAN alliance features, especially when it comes to end to end NH deployments. Thereafter, OpenRAN platforms from companies such as AirSpan, Mavenir, Parallel Wireless and Acceleran are described in detail. More specifically the focus relates to the disaggregation, AI and RIC, service management orchestration and multi-PLMN NH capabilities of each platform.
   Next, additional vendors related to radio virtualization and intelligence are presented such as Intel, Nokia, Samsung, Radisys and Altiostar.
7. **Demonstration** - NH architecture allows MNOs to share a common Radio Access Network (RAN) infrastructure, reducing capital investment and releasing capital for deployment acceleration and service optimization. This is particularly important for rural areas, where the cost of deploying cellular connectivity outweighs the financial Return on Investment for the MNOs. By sharing the infrastructure supplied by the NH providers, network operators can now provide a seamless and robust service in previously unserved areas, bridging the digital divide.
8. **Dynamic Spectrum Sharing Demonstration** - 4G and 5G NR will co-exist for many years and DSS can be used to lower the cost of 5G entry for existing 4G operators. DSS could be an ideal technology for rural areas, with a lower density of users, if a lower frequency band is used. There are still areas with poor 4G coverage so a DSS deployment may help to fill in the gaps.

'So what?'

1. **Neutral Host** - increased coverage and high QoS in underserved rural areas.
2. **Security and Privacy** - a suitably hardened zero-trust MNO RAN should be designed such that a compromised node does not have management access to any other node, and that it is not in a position to allow for lateral or vertical movement in the network, thus containing the attack until the node can be removed from service and the issue remediated.
3. **ORAN and Neutral Host** - reduced costs for MNOs and MVNOs via Network Sharing in terms of capital investment in physical infrastructure, operational costs, and maintenance of equipment as well as deployment of new technologies much faster, maximisation of use of available resources, with minimal environmental impact.
4. **Spectrum** - recommendations to assist 5G deployment in rural areas, and open the door to the potential for neutral hosting to improve rural connectivity for businesses and citizens
5. **Business Study -** rural NH in-and-of itself cannot provide enough of a cost saving to make traditional operators keen to deploy in rural areas, even with the improvements in costs of deployment. This is due to the generally perceived poorer investment case for deployments in rural areas due to lower population densities. This is further exacerbated by the higher frequencies required for high-capacity 5G networks, which travel shorter distances, and therefore require more infrastructure to be deployed to deliver coverage across the same area.
   Nevertheless, there is now evidence that based on the potential use-cases which can be "stacked" (including NB-IoT-based public services, smart agriculture, aquaculture, etc.) that *there is a viable commercial model for delivery of rural NH in the UK*. The concept of use-case stacking to aggregate cross-sectoral and cross-vertical demand has been introduced by the 5G RuralDorset testbed. In spite of this, our analysis has identified that there are a number of areas where careful consideration must be given to the regulatory and legislative position around NH operators, to ensure that, if we are to rely on them to deliver rural coverage to

areas left behind after SRN roll-out is complete, they present a viable investment opportunity for private investors to fund and see a return on their investment.

6. **OpenRAN for Neutral Host Product & Market research -** The ultimate scope of this analysis is the selection of the most suitable platform that will be utilized in the current project as well as at a possible continuation of the existing project, targeting integration of OpenRAN and NH and moving towards 5G and beyond as well as 6G technologies.

7. **Demonstration -** Neutral hosting (NH) is a relatively simple concept but has a huge potential to address connectivity challenges. The term NH architecture is used to describe a network where resources are shared by multiple Mobile Network Operators (MNOs). Different methods exist to manage this multi-operator environment. Examples are:
    - a single operator owns the resources and provides access to these resources to others
    - two or more operators own resources and mutually provide each other with access to their resources
    - an independent network provider owns the resources and provides a service to any operator customer

8. **Dynamic Spectrum Sharing Demonstration** - the technology is evolving and there are options for DSS in rural areas that require further study and trial deployments.

Key Learnings

1. **Neutral Host -** a range of implementation architectures have been proposed for the successful deployment of NH platforms.
2. **Security and Privacy** - This approach would put an MNO in a strong position to be able to securely interconnect with NH operators.
3. **ORAN and Neutral Host** - Empowered by principles of intelligence and openness, the OpenRAN architecture is the foundation for building the virtualized RAN on open hardware and software, with embedded AI-powered radio control. Inspired by the O-RAN alliance, the OpenRAN infrastructure combined with increasing RAN virtualization and data-driven intelligence, will allow complexity reduction, faster innovation and significant reduction on deployment and operational cost.
4. **Spectrum** - Neutral hosting in and of itself is not principally a technology problem, rather a policy and regulatory choice.
    a. Government should direct Ofcom to stimulate investments in rural infrastructure
    b. The Communications Act itself needs a refresh.
    c. There is an urgent need for a new an updated Statement of Strategic Priorities (SSP)
    d. Ensure any changes reflect commitments already made relating to the (4G only) SRN
    e. Automated licensing could be trialled for rural areas
    f. It is time to review Spectrum pricing
5. **Business Study**
    a. Rural NH operators would, based on current spectrum policy, realistically prefer to use MNO spectrum through a local access licence arrangement in order to gain the coverage required to be financially viable. MNOs are, by their own admission, reluctant to facilitate and support the large numbers of local access licences which would be required to do this.
    b. New players would also require regulatory and financial incentives to drive improved rural coverage, beyond that which will be delivered through SRN, which effectively acts as a subsidy to incumbent operators

c. Separating spectrum access mechanisms between rural and urban areas, as Ofcom has recently done with the introduction of shared access licences, generally only made available in rural areas, could present another opportunity to drive innovation in rural NH providers, by making available longer-term access to spectrum that is unutilised or under-utilised under the current national licensing framework used for mobile spectrum.
d. To deliver a viable and usable rural NH solution, there needs to be further enabling work carried out as a matter of priority to ensure that mobile handsets sold in the UK support standardised IMS profiles.
e. There are unnecessary technical barriers, such as carrier-specific configuration bundles, which would serve to hinder use of IMS in the UK, and which act as barriers to switching a device which does support IMS between operators.

6. **OpenRAN for Neutral Host Product & Market research**

From the analysis undertaken in the previous sections and the features highlighted in the table above, the following conclusions can be derived:

- Acceleran is the only vendor that holds a 5G enabled platform, ready to be deployed on premises
- Acceleran provides a documented API for third party xApps deployment and a complete and easy to function RIC platform
- Parallel wireless provides the most sophisticated system in terms on multi-RAT integration. This is based on their aggregator software and HetNet gateway. Acceleran and Mavenir clam that they provide this functionality, however, a statement of work would be critical on understanding better the level of the platform capability in terms of multi-RAT aggregation
- In terms of SMO, Acceleran and Vilicom provides the most suitable platforms offering both CLI and GUI interfaces to configure the various radio parameters (i.e. PLMN, bearer selection, RIC, DU,CU, Power levels)
- Acceleran does not provide its own DU, but they are closely engaged with third party solutions, which can be adapted easily as a plug-n-play software module

Based, on the above analysis, and considering cost is not a major barrier, we propose the procurement of the solution offered by Acceleran, as long as they map the platform features sufficiently, in the SoW that will be shortly circulated. This platform can directly target the requirements of this project and can be easily scaled based on the needs of future projects related to the use of OpenRAN in 5G and beyond.

7. **Demonstration -** The deployment and successful demonstration in Dorset rural environment is a good starting point towards the commercialisation of the NH capability in the region and beyond. Numerous opportunities arise from the successful demonstration of NH, which creates a framework for similar deployments around the UK. The ideal next steps would be a continuation of this project and the deployment of RAN enabled NH platforms as follows:
    a. Deploy and demonstrate various NH configuration over different RAN platforms as well as over an Open RAN platform at SAC's premises and test the platform with different core network available at SAC's premises
    b. Engage with a MNO (such as Vodafone), extend their network as part of the NH network in Dorset and explore further real use case opportunities as well as risks
    c. Deploy at Dorset and test NH over satellite backhaul
    d. Create a hybrid satellite-terrestrial backhaul network which supports NH over 5G and over satellite, for added redundancy and higher link availability with smart handover capabilities (satellite, fibre) to extend backhaul intelligence in the transport network

e. Investigate the security aspects and challenges of NH through a study resulting in recommendations for MNOs and service providers
f. Explore the capability of NH and network slicing, specifically on the NH concept that can be used to support radio slicing. Radio slicing is the use of different frequencies, radio access types, as well as network slicing, so that certain Network Functions of the 5G core can be shared among different core operators
g. Investigate Dynamic Sharing Spectrum (DSS) technology and deploy in 5GRD. This technology investigates the capabilities of Neutral Hosting over both LTE and 5G while at the same time enables the parallel use the two technologies in the same frequency band.

8. **Dynamic Spectrum Sharing Demonstration** - The following areas are suggestions for further investigation:
    a. Deploy 2 or 3 base stations for DSS lab-based experiments and investigate high load tests and cell selection
    b. Combine DSS with OpenRAN platform at SAC's premises and investigate full potential
    c. Deploy and demonstrate DSS technology in a rural area such as Dorset
    d. The DSS technology could be combined with the Neutral Host solution already deployed in Dorset
    e. Integrate DSS network with satellite communications (5G over satellite was already deployed in the 5G RuralDorset Network) for added redundancy and higher link availability.

Work Package 7 – National Collaboration

The full final report for Work Package 7 can be accessed via the programme's Teams Channel @5G RuralDorset>Files>Technical and Security>MS09 Deliverables>WP7

Description of what the project did

Our collaboration endeavours far exceeded committed deliverables. We quite literally "wrote the collaboration rulebook," since it was one of our documents on how to organise collaboration that was adopted by DCMS as its own policy document for all projects.

The depth, breadth and impact of 5GRD's collaboration were formally recognised with the award of best individual collaboration accolade at the UK5G Showcase event earlier this year. We also secured the runners up award from Exeter University for best Alumni support activity.

Throughout the project we have provided 6-weekly updates of Collaboration activities to DCMS via the project Board. These can be reviewed here (work package 7 highlight reports).

Description of the Results

Some key achievements of undoubted benefit included:

- Founding the UK Telecoms Data Taskforce (Scottish & Welsh governments, Cabinet Office NIC, BEIS, Treasury represented and BT, Virgin, BIS and other testbeds), which continues after project ends, and is the biggest collaboration known of any test bed.
- Ground-breaking Exeter University Postgrad student collaboration. Secured employment for postgrad plus recommendations to DCMS to improve collaboration with universities… supported by multiple papers

- Collaboration with MoD for Army Battlelab – drawing to building in 56 days & 90 jobs created. On-going activity with planned expansion to Navy
- Supported to UK5G/KTN at several collaboration events including multiple speaking slots (3 with the British Ports Association alone)
- Multiple papers and conference speeches supporting at request of DCMS to promote collaboration. Worked with them to secure Finnish interest (Oulu Port), South of Scotland and NHS events and Qualcomm Inc's collaboration in the programme and beyond.
- Multiple DCMS led topic-based collaborations including skills, spectrum, 5G health issues, MEC, etc
- Helped secure and then organise a Ministerial visit to Dorset

- Significant support to DCMS spectrum activities and direct dialogue with Ofcom to open up the 26GHz band for rural use on sensible terms
- Collaboration with Spirent Plc. Led to Customer Contact centre opening
- Speaker at multiple events, including the UK5G Showcase and Connected Britain

‘So what?’

We estimate our collaborations assisted in nearly doubling our project’s value. We also believe that the additional profile gained from our collaboration has directly contributed to Dorset Council deciding to invest circa £14m in the Dorset Innovation Park.

Key Learnings

We would advise DCMS, in line with our previous public submissions, of the need for a strong and experienced collaboration lead for any project in the future. The contacts and experience that come from this approach make it possible to progress further and faster than would otherwise be possible. This benefits the whole programme, the department, and even the Minister.

Work Package 8 – Dissemination of Results

The full final report for Work Package 8 can be accessed via the programme's Teams Channel @5G RuralDorset>Files>Technical and Security>MS09 Deliverables>WP8

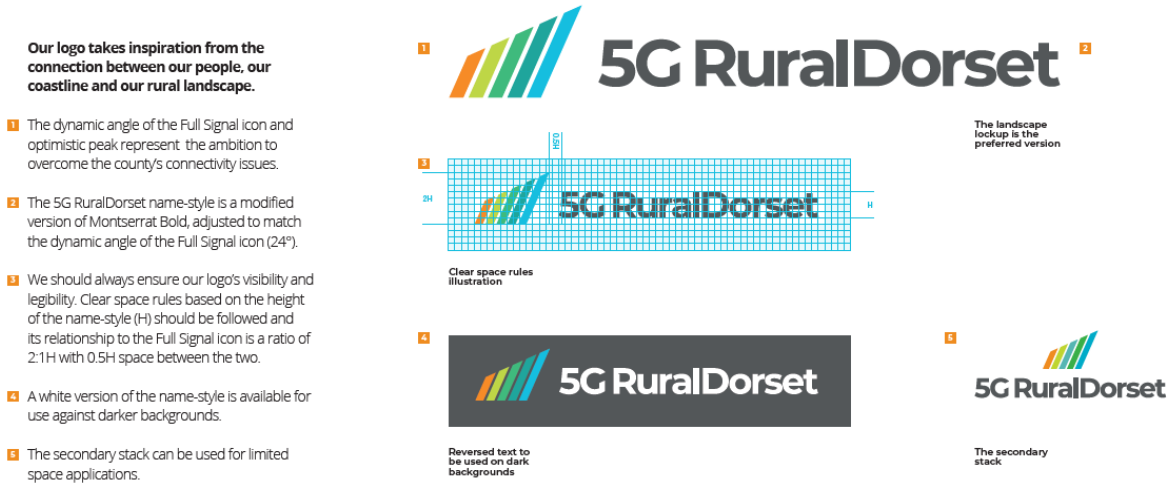
Description of what the project did

WP8 aimed to effectively communicate how 5G could make Dorset a better place to live, work and visit.

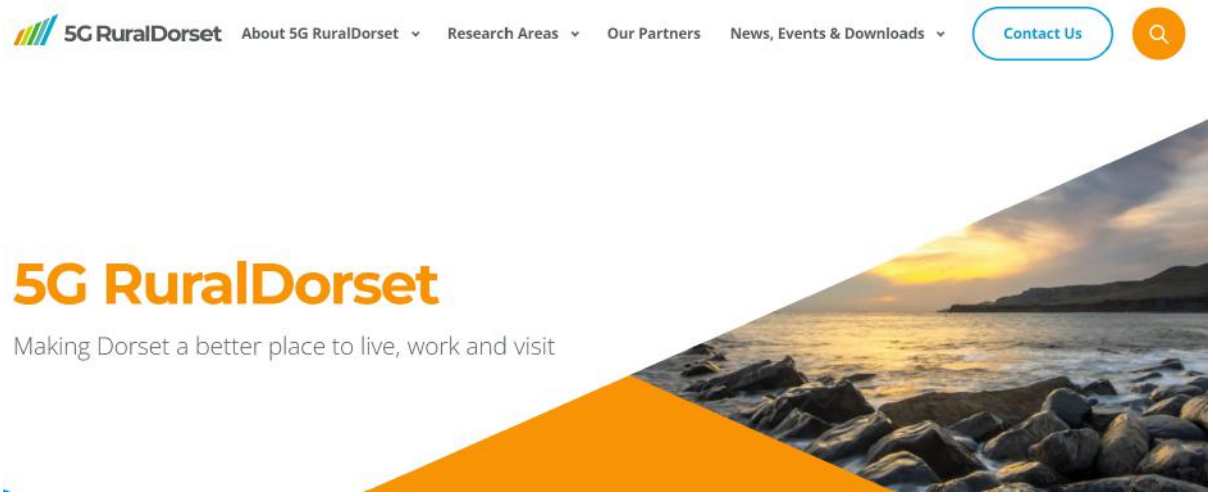
The research and development project contributed to the understanding of how 5G can be used to address some specific challenges – public safety, economic growth, food production and environmental – as well as create new opportunities in Dorset and rural communities across the UK. Work Package 8 sought to ensure this success story was told in the most engaging way to the right people

Methods including technologies used and deployment approaches

5G RuralDorset developed a bespoke brand and website as its primary publication platform.



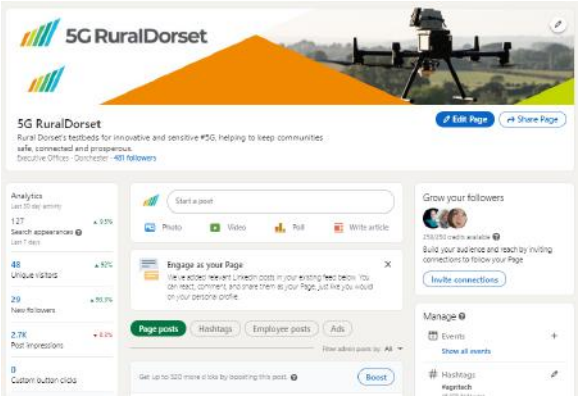
Extract from the 5G Rural Dorset Brand Application Guide



The 5G Rural Dorset website home page

Supporting this was a Twitter account and LinkedIn profile for dissemination of news and press releases.

The 5G Rural Dorset Twitter Account



The 5G RuralDorset LinkedIn page


5G RuralDorset

Summer 2022

Hi there,

Despite the project officially wrapping at the end of June, we have had a couple of project extensions which has kept the whole team busy and will see this innovative work continue through the Summer.

We have also been involved in panel sessions recently and in talks with Government about further agri-tech work, proving the good work that has already been done and making our partners an indispensible resource for other projects.

As ever, please feel free to get in touch if you want more information.

The 5G RuralDorset team.

The Summer 2022 5GRD Newsletter

Press releases were developed with partners and DCMS to mark milestones and technical achievements. We also published a regular newsletter to an audience of around 450, collating press releases and latest updates.

The whole comms eco-system was connected through Google Analytics and Google Alerts to produce reports and track metrics as noted in the results section.

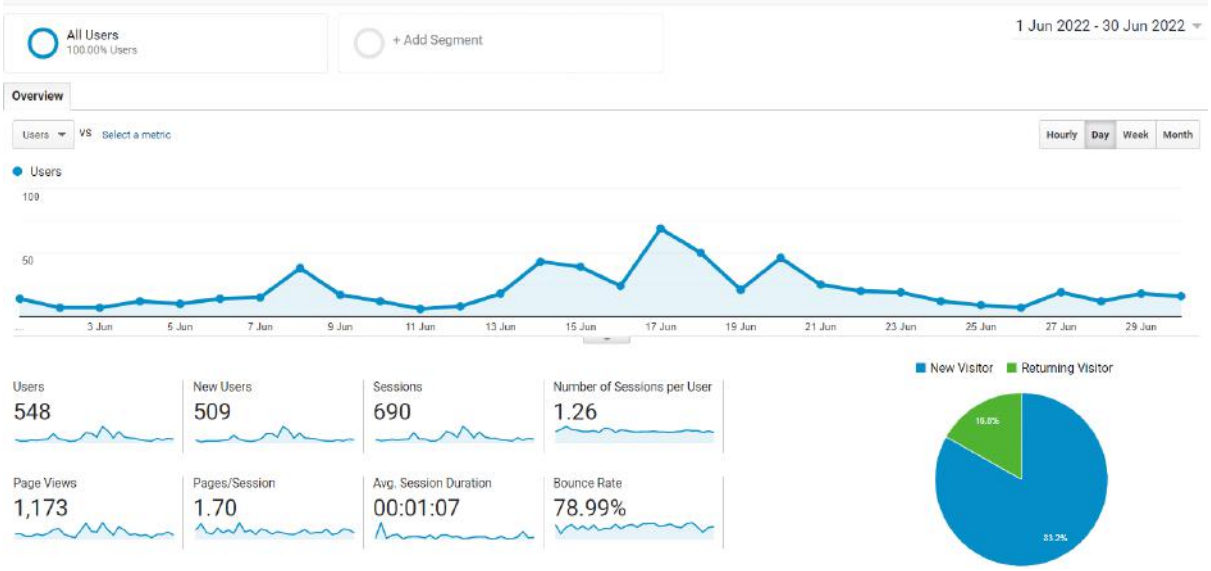
Description of the Results

WP8 supported the progress of the work packages use cases through press releases and social media, as comms itself didn't have any use cases of its own.

Metrics and coverage were tracked in the following documents on Teams.

Platform growth and engagement. Press release coverage

A Power BI dashboard was also employed to visualise progress but is inaccessible externally. Instead, an example Google Analytics dashboard for the previous month is provided below.



Google Analytics Dashboard of 5G RuralDorset website activity June 2022

Narrative of key impacts and benefits of the trial

A successful communications campaign around the 5G RuralDorset has significantly increased the awareness of the benefits of 5G in the local community as evidenced by our steady growth in followers and subscribers.

The campaign has also attracted interest from tech and trade bodies as well as international enquiries for speaking opportunities and collaboration requests.

Connected Britain seem to be particular fans, having given the project 3 awards at last year's event and inviting the project to fill four speaking slots this year.

The engagement we've seen with tech and trade publications, as well as national media attention and BBC Click, has played a part in forging important relationships with the likes of Qualcomm, the resulting work having wide reaching importance beyond DCMS and the UK borders.

Furthermore, we have seen no adversity incidents over the life of the project on social media thanks to a positive and sensitive local message.

‘So what?’

The dedicated communications resource at Dorset Council in support of the 5G RuralDorset programme has achieved an excellent profile for the activities undertaken and resulted in the winning of multiple national awards.

With well-planned and effective communications the programme has avoided significant challenge from local community members regarding 5G Health Concerns. Press releases and newsletters have generated significant interest resulting in an enhanced profile for the council amongst local and national audiences.

Through the professional and impactful efforts of the WP8 ‘Dissemination of Results’ team, a strong foundation for future projects and programmes like DCIA, Innovation hub, and work with other government departments has been established.

Key Learnings

The following lessons learned have been captured during the life of the project, many of which have been resolved:

- Need to engage Dorset Council central comms team in high level activities and get sign-off for major outputs.
- Need to engage with project partners to align efforts on stakeholder communications and make sure message and approach is understood and consistent ahead of planning applications.
- Need to tighten up content sharing process so we don’t miss opportunities.
- Need to improve signoff process when dealing with large organisations e.g. BGS
- Need to push partners for timely responses were press release are concerned
- Need to impress upon partners the need to feed us information and opportunities for dissemination
- Longer lead times needed when dealing with large organisations e.g. Vodafone and DCMS private office


5G RuralDorset: a showcase film
Watch Later
Share
Watch on YouTube

Work Package X – Coastal Cliff Monitoring

The full final report for Work Package X can be accessed via the programme's Teams Channel @5G RuralDorset>Files>Technical and Security>WPx Deliverables>MS09

Description of what the project did

The overarching aim of the Coastal Cliff Monitoring workstream has been to develop and trial a novel monitoring system for coastal cliffs using 5G/NB-IoT technologies. To this end, Bournemouth University (BU), the British Geological Survey (BGS), Vodafone (VF), Dorset Council (DC) and Neutral Networks (NN) combined their complementary expertise to develop a trialling system at an intermediate to high technological readiness level. The system comprises a set of small, fully autonomous, highly integrated and power efficient sensing devices that are able to collect geological sensory data. This data can then be wirelessly transmitted using 5G/NB-IoT to a cloud-based Data Management Platform, where they are presented to the end user over a web interface and are curated for processing by Machine Learning algorithms

Methods including technologies used and deployment approaches

In September 2021 a first batch of devices were deployed at Lyme Regis and Burton Bradstock. While the sensing devices were not fully functional due to technical issues faced by Vodafone in registering the NB-IoT boards on their 5G network and achieving the desired energy efficiency (the devices demonstrated a very short battery life), this first deployment provided valuable insights with regard to modes of deployment and the physical design of the devices.

By February 2022, the second batch of devices was developed. These devices featured an updated design based on the insights gained from the first deployment (an expanded sensor suite, and a smaller, more robust physical design). Vodafone had made progress with the NB-IoT boards however, the devices were still not fully functional. Development continued in the hope that any issues would be resolved in the following months via over-the-air software updates. The Data Management Platform (DMP) is a Big Data Analytics and Machine Learning platform that supports storage, curation, and visualisation of collected sensory data in a scalable and cost-efficient way.

Phase 3 of the use case provisioned the commission of the fully functional system. Due to the aforementioned delays and technical challenges, the use case did not reach this phase.

The first version of the DMP was implemented on Amazon Web Services (AWS) using a leased EC2 instance, which functions as a virtual server. This virtual server was then configured to host the Elastic Stack[1]; a cross-platform search, index, and visualisation platform for unstructured Big Data. The deployment also comprised complementary tools for managing data streams, such as Apache Kafka and NiFi.

Due to the nature of the costal cliff monitoring use case, the geolocation of the deployed sensing devices is an important piece of information. Therefore, the deployment locations of the devices are presented as pins on an interactive map. It is noted that the geolocalisation of the devices is dynamic and based on the latest GPS coordinates transmitted by each device.

Description of the use cases to enable sufficient understanding

Although, the primary driving force of landslides is gravity, the stability of a slope is influenced by a variety of other factors. Knowledge of these conditions can help to predict the location, types, and volumes of potential failures. Currently, available landslide monitoring techniques can coarsely be taxonomized in methods requiring physical access and methods of remote monitoring. Topographic surveys and on-site visual inspection by experts are probably the most commonly employed method; however, this method is subject to ease of access and does not scale well with respect to area coverage. More accurate methods include the use of sophisticated equipment, such as terrestrial laser scanners, extensometers, tensiometers and inclinometers. However, these methods require specific expertise and introduce high operating costs. Furthermore, these methods are also not easily scaled to cover large areas.

Remote monitoring methods include the use of satellites, either in the form of GPS systems or interferometry techniques via synthetic aperture radar (SAR) satellite images. It is worth mentioning that apart from the issues already discussed, few of the aforementioned methods are able to provide data in real or near-real time. Also, some of these methods are not accessible to local authorities either due to them requiring high expertise or due to introduced deployment and operation costs.

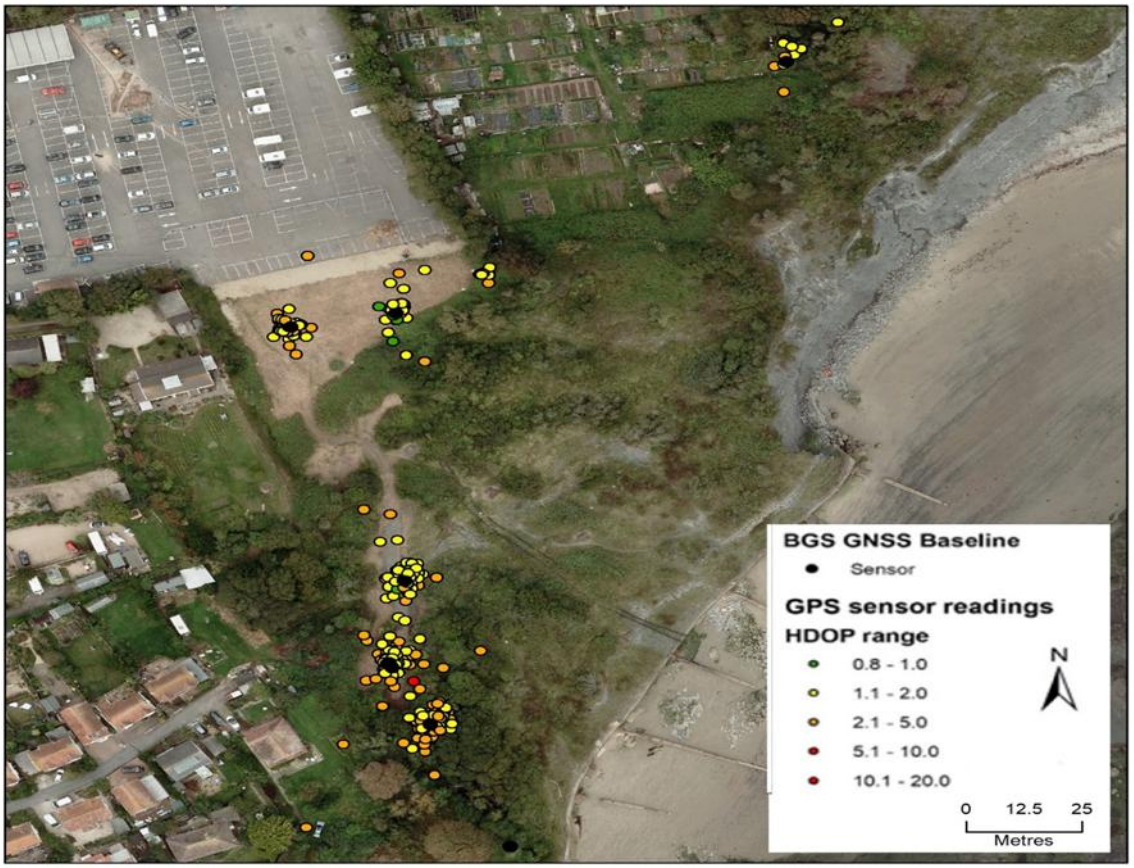
At Lyme Regis, Dorset Council currently has a number of inclinometers and piezometers in the East Cliff area, which are surveyed and reported twice yearly by external contractors. This forms part of a larger monitoring programme in Lyme Regis but pro-rata the estimated cost for the East Cliff area is about £1.5k per survey. There are also a number of co-ordinated ground markers in the study area but these are not surveyed on a regular basis. At Burton Bradstock currently there is no regular monitoring taking place other than visual inspection by Council's coastal rangers with no significant use of technology involved.

1

For both the Lyme Regis and Burton Bradstock study areas, Dorset Council has access to aerial photography and LiDAR information at the Plymouth Coastal Observatory, as part of the South West Regional Coastal Monitoring Programme which can be used for monitoring purposes.

Description of the Results

23 sensing devices were deployed within the initially provisioned timeframe, i.e. by the end of February 2022, which was specified as the final date for device deployment in order to avoid any disruptions during the bird nesting period. Due to the technical challenges faced by Vodafone in rendering the NB-IoT boards fully operational, most of the devices either were not able to connect to Vodafone NB-IoT service or depleted their devices in very short time. In July 2022, three devices were still operational and able to transmit data from their onboard GPS modules at multiple irregular intervals throughout the day. This data was used by BGS in order to conduct a first, basic evaluation of the GPS accuracy.



Narrative of key impacts and benefits of the trial

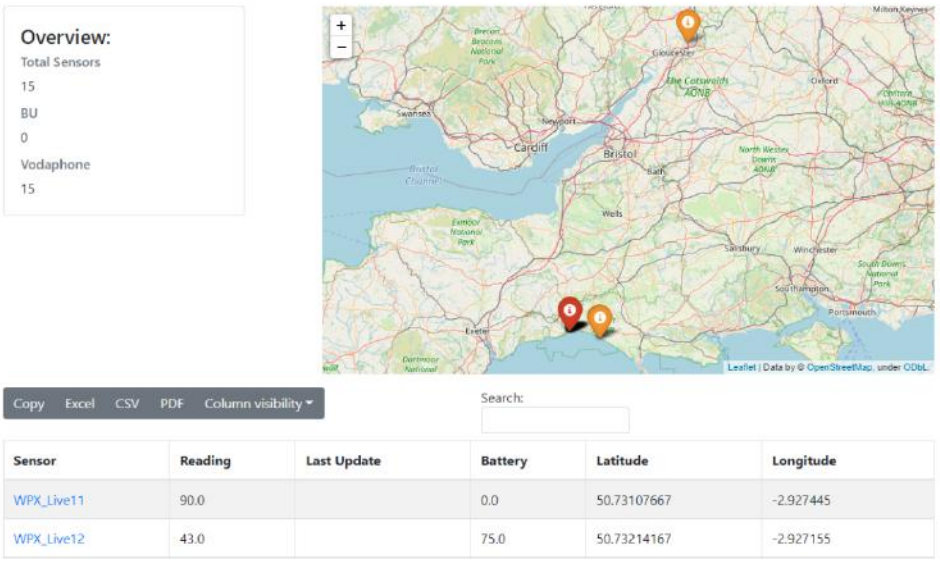
The usefulness of a fully functional remote tracking system at both locations is undoubted. The principle of being able to remotely track the position of sensors at either location would be beneficial particularly given the tricky issues around access and health and safety at both sites.

In terms of benefit realisation for each stakeholder, these cannot be measured rigorously for each partner due to the aforementioned technical challenges. However, each involved partner benefited from the use case. In particular, Bournemouth University and the British Geological Survey made significant progress in developing a common interdisciplinary understanding of the use case. This will facilitate future research in the same topical area. BGS were also given the opportunity to develop their understanding and know-how in developing and working with IoT technologies, thus helping

them expand the arsenal of monitoring methods at their disposal. Dorset Council has become aware and holds concrete understanding of 5G and IoT technologies, how these can be onboarded on its current coastal management plans, and how they will benefit from their use (cost reduction, augmented capabilities to collect monitoring data remotely and in near-real time). It is worth noting that Bournemouth University, BGS, and Dorset Council will continue their collaboration on this use case in the context of a PhD studentship, match-funded by Bournemouth University and Dorset Council. Finally, Vodafone has made significant progress in developing their NB-IoT hardware solution and has become aware of the technical challenges that they need to overcome towards making their solution commercially available.

'So what?'

Although the exact costs of deploying, operating and maintaining a 5G/IoT-enabled system were not possible to be estimated due to the technical challenges faced in the use case that hindered the full commissioning of the system, it has already become apparent that these would be comparable, if not significantly lower, compared to existing methods. Indicative costs would be in the order of £100 development costs per sensing device, £150 per month for Cloud Services supporting the Data Management Platform, and few pounds per month per device for 5G/NB-IoT service charges.



Sensor	Reading	Last Update	Battery	Latitude	Longitude
WPX_Live11	90.0		0.0	50.73107667	-2.927445
WPX_Live12	43.0		75.0	50.73214167	-2.927155

Key Learnings

When reflecting on the work and activities carried out in the context of this coastal cliff monitoring use case, the following lessons were learnt:

- It is of paramount importance when designing a new use case to carefully consider and identify the actual starting point. For instance, with regard to the technologies to be employed, a key question to be asked is what is their current Technology Readiness Level (TRL)? For technologies with TRL smaller than 6 careful consideration is needed of the amount of effort needed, provisioned dependencies, and cost and time limitations in order to evaluate if it is feasible to deliver the envisioned use case within the abovementioned constraints.
- The IoT technology landscape is currently fragmented and difficult to navigate, even for experienced professionals and academics. Example issues include lack of interoperability among components (even of the same manufacturer), both hardware and software. This

often results in using “trial and error” approaches that have a negative impact on time of delivery and development costs. Furthermore, often the developed solutions heavily rely on ad-hoc custom solutions that are rather complex and not-easily replicable or transferable.

- Hardware R&D activities have been found to pose significant challenges. This is because the procurement of hardware components depends on global supply chains that were proven to be fragile and vulnerable to disturbances (e.g. the semiconductors global shortage following the covid-19 pandemic). To mitigate this risk there should be a focus on building resilient hardware supply chains by limiting dependencies on externalities and/or incentivising domestic hardware production (or even developing national hardware supply chains). Similarly, currently there exists a shortage of available talent and skills on embedded systems (e.g. hardware OS development) in the labour market, which negatively affects hardware R&D capabilities. In this context, if a use case identifies the need for significant hardware R&D activities, this should be identified as an important risk.

- Include partners covering the entire set of stakeholders; namely a national Mobile Network Operator, a local authority, subject matter experts covering multiple disciplines, industry, and academia. This enabled the use case to assume a holistic approach covering multiple facets such as technical, governance and legal (e.g., in securing the needed consents and approvals), environmental (e.g. the environmental impact of certain technologies, like batteries), health & safety (working on coastal cliffs), and logistical (e.g. organising fieldtrips) aspects. Therefore, it is suggested that a stakeholder analysis is performed at the very initial stages of developing a use case.

From this proof-of-concept project, we make the following recommendations for future work:

- At the point of deploying sensors in the field, it is important to be able to ascertain whether the intended location has good network connectivity to be able to transmit data.
- More research is needed on the physical installation of the sensors and how external factors may influence the sensor outputs such as temperature, rainfall, ground saturation, aspect, surrounding vegetation and people/animals.
- Some work around improving the precision of the GPS data is required. Using only the GPS data obtained over four months, with precision of around 2-3 m, it is not possible to set movement thresholds beyond which IoT actions could be taken. This would require more precise sensors and big data analysis.
- The geological processes we hoped to observe in WPX occur over annual, decadal and longer time periods. A much longer and continuous data collection period is required to capture landslide drivers to help understand landslide processes and develop early warning systems
- For this pilot, GPS sensors only were installed. Additional sensors are required to capture external variables (e.g., temperature) which may help explain the data. Additional sensors are also required for capturing information about landslide drivers (e.g., moisture at depth, borehole data and a weather station).
- The main reason for failure of these devices was battery life and connectivity. More work is needed to resolve these issues.
- It is important to continually review health and safety while installing sensors in the field in these dynamic environments.

- Consideration needs to be given to public engagement with this kind of research. Sensors placed visibly in public spaces could encourage positive engagement with the work but could also raise the risk of vandalism or theft.