WEST MERCIA RURAL 5G PROJECT

A partnership testing how 5G transforms rural services

A project of the Department of Digital, Culture, Media, and Sports - 5G Testbeds and Trials - Rural Connected Communities programme

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i. Foreword: Mark Stansfeld, Chair West Mercia Rural 5G

The Department for Digital, Culture, Media, and Sport (DCMS) 5G Testbed and Trials Programme is the cornerstone to the government's ambition for the UK to be a leader in the next generation of mobile technology, 5G.

'West Mercia Rural 5G' (WMR5G) commenced in April 2020, as part of the Rural Connected Communities (RCC) funding round and is located in Malvern and around Tenbury Wells, where the counties of Shropshire and Worcestershire meet; both areas providing a superb location where many of the challenges of rural life and rural connectivity are present.

The WMR5G project highlights the huge ambitions of the innovative public and private sector partners, as we strive to find ways to improve connectivity and provide access to key services in rural areas.

WMR5G set out to explore infrastructure challenges when planning, building, and operating a 5G network in a rural setting and how 5G can enhance services for the benefit of residents; particularly researching 5G-enabled health and social care applications.

We recognise that rural communities require the same, if not greater levels of connectivity as their urban counterparts, yet it is often sadly lacking. Largely due to the financial challenges the operators face in making a return of investment in sparsely populated areas. The project has therefore sought to understand how, by deploying 5G infrastructure in a new way, by re-purposing existing 'fixed wireless' infrastructure, we might be able to identify a more cost and time effective route to connectivity.

At the same time Local Authorities (LAs) and Clinical Commissioning Groups (CCGs) in rural areas are facing increasing demands for their services from an ageing population at a time when their funding has been under increasing pressure. Maintaining current approaches to service delivery is not sustainable and alternative models are required.

At a time of increasing demand for public services, improvements in connected technologies offer new ways of working that can help maintain and improve service delivery and quality of life for residents and businesses alike. As examples, the cost, added time and inconvenience of delivering and accessing public services across a wide rural geography, including how the distance travelled by both the resident and professionals can be avoided.

Compounding our challenge – our project commenced shortly after the global Covid-19 pandemic had begun and completely changed how we live, do business, and run services. Our project and both use cases were severely affected by the

pandemic, as access to care homes, hospitals, GP surgeries and staff were completely revoked for months at a time.

Despite the experiences through Covid-19 and other situations, for example flooding and severe weather where there is a restriction on movement, the project has opened eyes, changed attitudes, and emphatically proven the worth of digital connectivity, particularly in the face of challenges such as on-going infection risk, continued high or increased demand on services.

I would like to invite you to continue reading to see what the project has managed to achieve in the two years it has been running.

I would like to thank all the consortium members for their ongoing support, but also DCMS for facilitating this opportunity to allow the project to explore and investigate the positive impacts that emerging 5G technologies could have on rural communities, around how 5G networks can be built, and their use in supporting health and social care services.

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1 Executive Summary

The West Mercia Rural 5G (WMR5G) commenced in April 2020, after being funded as one of seven 'Rural Connected Communities' 5G R&D projects within the Department for Digital, Culture, Media, and Sport's 5G Testbeds and Trials programme, with an aim to investigate two very distinct challenges.

- To explore a new model to deliver 5G in rural areas; and
- How can 5G help provide new ways to deliver health and social care in and to rural communities?

The WMR5G project area included geographies in and around Malvern and around Tenbury Wells, where the counties of Shropshire and Worcestershire meet; both areas providing a superb location where many of the challenges of rural life and rural connectivity are present.

1.1 The consortium partners included the following organisations:

- Airband Community Internet
- BT (from November 2020)
- Herefordshire and Worcestershire CCG (NHS)
- Shropshire Council
- University of Chester
- University of Worcester
- VR Simulation Systems Ltd (VRSS)
- Worcestershire County Council (WCC) – Lead Partner
- West Midlands Academic Health Science Network (WMAHSN)
- Three UK (April 2020 to August 2020)

1.2 The technology:

The final network used within the use cases was a mixture of:

- private 5G network (NSA) – at Tenbury Community Hospital, Tenbury Wells GP Surgery, Old Rectory care home (Tenbury Wells) and Hastings Residential care home (Malvern),
- commercial 5G network (EE - NSA) – Malvern Community Hospital, Malvern Health Clinic (2 x GPs) and Howbury House care home,
- and utilising commercial 4G (EE) network at all sites initially to aid onboarding and familiarisation but Haresbrook Park care home (Tenbury Wells) for the whole project.

This approach provided the project an opportunity for qualitative comparisons between existing commercial 4G and 5G coverages and the private 5G network option through subjective feedback from those involved in the use cases and the project delivery.

1.3 The challenge of rural delivery

Rural areas, largely due to their low population density, often fall towards the end of, or do not fall within, the commercial mobile deployments of the Mobile Network Operators (MNOs). This is largely understandable but not acceptable, particularly to

those living or working in these communities. There are 2G, 3G and 4G black spots across all four operators within the focus area of the project and at the outset of the project there was no 5G coverage even within operator delivery plans.

At the same time providers of public services in rural areas are facing increasing demands from an ageing population, at a time when their funding has been under increasing pressure. Maintaining current approaches to service delivery is not sustainable and alternative models are required. Smart connected technology solutions are often seen as an alternative way to deliver these services, to enable efficiencies to deal with increased demand and focus resources on those with highest need. However, for health and social care services to be delivered in this way a more reliable and more widely available level of connectivity is required.

1.4 A new model for 5G rural delivery

The project set out to explore a proposed new business model and test how the UK mobile industry could deploy 5G in rural areas at pace, but also at a reasonable cost. Due to the partners involved in the project the research focussed on the potential for the utilisation of existing 'fixed wireless' assets and whether this does or does not have an impact on the deployment timeline and costs.

WMR5G explored the infrastructure challenges around planning, building, and operating a rural 5G network. Working with a mobile network operator (MNO) and a wireless broadband asset owner, the project set out to test the technical and commercial viability of a new business model. Elements considered included:

- using existing infrastructure,
- commercial arrangements,
- and technological solutions.

To establish a baseline, the capital / operational costs and deployment time was taken of a known 2018/19 rural deployment of 4G mobile infrastructure. This deployment formed part of a mobile network operator's (MNO) solution. 'Target' figures were established based upon initial expected benefits of circa 10% of the baseline data.

Five sites were originally identified and progressed through acquisition and planning phases to the point at which infrastructure build activity could commence. Two additional sites were considered but not progressed. The five sites ranged from a 'greenfield plot of land' and 'wooden telecommunications poles' through to 'monopoles' and 'lattice masts'. However, due to a descope within the project, only one of these progressed through site build.

A case-study was also completed reviewing the fixed wireless infrastructure in the area between Ludlow and Tenbury Wells to understand if a theoretical deployment of 5G across the area by an MNO using infrastructure currently available to them, could be improved through the use of existing fixed-wireless assets, that otherwise would not be considered.

1.4.1 A new model for rural delivery conclusions

Notwithstanding the acknowledged limitations of our cost comparison exercise and case-study in terms of statistical validity, the project found that through the reuse of fixed-wireless assets:

- The CAPEX costs associated with site agreement and planning applications could be reduced by over two thirds, whilst the time taken to complete this phase could reduce by over half,
- The deployment time taken to install radio equipment and commission the site could also be almost halved.

The full report, Appendix E: West Mercia Network Deployment Desktop Survey - Ludlow and Tenbury Wells Area, identifies the ways in which the efficiencies highlighted above were found. The case-study also established that by utilising a shared infrastructure model, 5G coverage could be increased to 85% in the rural area between the towns of Ludlow and Tenbury Wells. This represented a 2% performance improvement when compared to a single MNO deployment. The case-study in the chosen area only identified a small improvement and as such would unlikely be economically viable in terms of coverage improvements in the use case area. However, it was recognised that against a wider area footprint of known fixed-wireless assets, their reuse was expected to be more beneficial and therefore more research into this area could be explored for commercial benefit.

In conclusion, the reuse of fixed-wireless assets may be part of the solution in improving 5G and wider mobile connectivity in rural areas across the UK. But shared asset utilisation should not only be limited to third party fixed-wireless or mobile operators. There is huge potential to be realised through agreements with a variety of land and facility owners to allow cellular coverage to be distributed through existing infrastructure. Examples of such being railways, local authorities, and other public sector locations. Furthermore, the exploration of wider ‘neutral host’ models, private networks, alternative technologies, more mature business cases, and additional public funding beyond the current Shared Rural Network (SRN) proposals are required to support the levels of connectivity truly required in rural areas.

1.5 How 5G can help provide health and social care in and to rural communities?

To address the challenge of how 5G can help provide health and social care in and to rural communities when faced with increasing demands, critical care service providers could find new models for delivery. These service providers included councils, clinical commissioning groups, and other care providers. The project considered whether service providers could utilise enhanced digital solutions instead of in-person visits or being reliant on solely telephone conversations. Could they redesign their services to:

- save transport costs
- reduce carbon footprint
- undertake more visits (albeit virtual) per day
- respond quicker and understand the issues of the patient before attending site

- prioritise staff resource more effectively by only physically attending those with highest need, and
- reduce unnecessary hospital admissions and assist with diagnosis
- reduce stress and negative impact on patients who would normally be transferred to appointments.

In addition to the wider infrastructure challenges identified in Section 2.4, the healthcare industry is having to digitally transform at scale and rapid pace. Subsequently health and care professionals are looking for ways to:

- increase their patients' access to care,
- enabling individuals to become self-activated,
- to adopt healthy behaviours and action.

With a context of increased demand and magnified by the impact of the Covid-19 pandemic, approaches are required that reduce the overall cost of health and care.

The thought is that mobile telemedicine can make the NHS more efficient and can enhance preventative solutions. WMR5G project investigated whether 5G-enabled technology could improve health and social care delivery through 5G-enabled telemedicine and domiciliary care scenarios for wearable video via the two use cases run in a rural context.

We are seeing that innovations in digital technology are making it easier for health and care professionals to communicate with their patients. Digital technology and improved connectivity is breaking down the traditional barriers that can hinder a patient's access to medical care, allowing them to receive relevant information, advice, and guidance remotely. With the help of live video, audio and remote monitoring, patients can now interface with healthcare providers from the comfort of their own home, care home or any other convenient location. This is especially beneficial for those who live in rural communities, who would otherwise need to drive long distances to their local doctor's surgery or to see a specialist and brings the patient's service experience in line with those in urban areas.

Section 6 of the report outlines the use case context, key drivers, the use case selection process and onboarding and delivery of WMR5G Health and Social Care Testbed.

1.5.1 Summary of the health and social care use cases

Whilst several potential use cases across health and social care were identified, after a rigorous selection process WMR5G focused on two specific use cases:

- **Health XR** – supporting the development and evaluating the impact of an extended reality (XR) solution to track improvements in gait and movement for people using hospital Musculoskeletal (MSK) services.
- **Connected Worker** – giving GPs and community nurses access to support workers in care homes equipped with wearable connected cameras and examining how effective the increased connectivity is in providing rapid access and information to assist the resident's welfare.

1.5.1.1 Health XR app – Extended Reality (XR)

The Health XR app is designed to provide an extended reality view of the patient's body outline and present this to the clinician as a 3D avatar. The product went through some iterations in build with the support of the project team. The key points of note are:

- supporting the product from a Technology Readiness Level (TRL) 3 through to TRL 5 that could be trialled on Critical Friends,
- and the progression from IoT suit being worn by the patient, to IoT sensers attached in specific places to the finally agreed LiDAR camera that modern high end mobile phones have.

1.5.1.2 Connected Worker – remote warding

Using live video conferencing clinical staff can see their patients from a remote distance. Through the use of the RealWear HMT-1 device this was further enhanced by moving to a hands-free video conferencing device. This still allowed real-time video and audio capability but meant that the clinical staff member, wearing the head mounted device, could use both hands for things such as turning the patient safely over. The use of connected worker was also seen to:

- benefit patients as they can stay in the familiar setting of their care home especially important with dementia patients
- saving the patient having to travel to and from clinical settings which might expose them to additional health risks
- reduce the carbon footprint of those involved in the remote consultations
- reduce the time a GP or nurse would take to travel to visit the patient, freeing up more time to see more patients.

1.6 Technical design

1.6.1 Use case network and CPE deployment design

Due to the use case sites identified during the project and the final broadcast direction and strength of the private 5G network both at Tenbury Wells and Malvern, the final networks used within the use cases was a mixture of:

- **private 5G network** – at Tenbury Community Hospital, Tenbury Wells GP Surgery, Old Rectory care home (Tenbury Wells) and Hastings Residential care home (Malvern),
- **commercial 5G network** – Malvern Community Hospital, Malvern Health Clinic (2 x GPs) and Howbury House care home,
- and utilising **commercial 4G network** due to the coverage limitations of the private 5G network – all sites initially to aid onboarding and familiarisation but Haresbrook Park care home (Tenbury Wells) for the whole project.

This approach provided the project an opportunity for qualitative comparisons between existing commercial 4G and 5G coverages and the private 5G network option through subjective feedback from those involved in the use cases and the project delivery.

The full report provides further details behind the findings highlighted in this executive summary and aims to provide a further catalyst to support improved mobile coverage in rural areas and begin to identify the art of the possible for mobile solutions to assist in the levelling up agenda to support the delivery of health, social care and a range of other public and private services in rural areas.

2 Introduction

2.1 The 5G Testbeds and Trials Programme and UK5G

The 5G Testbeds and Trials Programme (5GTT), part of the Department for Digital, Culture, Media, and Sport (DCMS), looks to explore the benefits and challenges of deploying 5G technologies in line with the following objectives:

- Accelerate the deployment of 5G networks and ensure the UK can take early advantage of the applications those networks can enable.
- Maximise the productivity and efficiency benefits to the UK from 5G.
- Create new opportunities for UK businesses at home and abroad and encourage inward investment.

Additionally, UK5G is the national innovation network dedicated to the promotion of research, collaboration, and the commercial application of 5G in the UK. UK5G aims to facilitate and encourage the engagement and coordination of organisations working on 5G activities across the UK. Over the years, UK5G has enhanced links between ongoing research and development and other activities undertaken by organisations across telecoms and other sectors, as well as the testbeds and trials that have been funded through the UK Government's 5G Testbeds and Trials Programme.

On 27 August 2019 DCMS announced a '5G Rural Connected Communities' funding round across the UK. Having identified 'Health and Social Care' as one of the key 5G verticals in late 2016 and having several partners interested in this opportunity, Worcestershire County Council applied to DCMS as the lead partner of a 'West Mercia Rural 5G' bid, to include other public and private partners on a 2-year project to commence on 1 April 2020.

The application focused on innovative ways to deploy 5G networks in rural areas on the borders of where Herefordshire, Shropshire, and Worcestershire meet. The 'use cases' in the bid were expected to primarily focus on 'health and social care' applications.

2.2 What is 5G?

5G, the fifth generation of mobile technology, promises to offer truly transformational opportunities for a wide range of verticals, including healthcare and associated businesses.

5G is not a replacement for 4G, it works alongside 4G networks and devices such as phones will continue to use both for the considerable future. Whilst Private Networks, sometimes referred to as non-public networks (NPN), have existed previously and

continue to encompass other technologies, 5G is expected to be a catalyst for a surge in new private networks. It is important to note that Public 5G and Private 5G networks will co-exist, alongside other networks and in some cases are expected to converge, creating a network of networks.

5G is undoubtedly faster than its predecessor – typically around 200Mbps and up to 1Gbps, compared to download speeds of up to 60Mbps for 4G. 5G also brings with it greater capacity and lower latency, allowing for the simultaneous connection of thousands of 5G-enabled devices, and the rapid, secure transfer of huge amounts of data.

Table 2.1: Initial claims of capabilities of 5G technology

Availability	99.999%
Security	Advanced cyphering and integrity protection
Capacity	1 Million device connections per Square Kilometre
Performance	1mS latency and fibre equivalent Gbps speeds
Efficiency	Up to 90% reduction in network energy use
Virtualised	Utilises standard IT servers and hardware. Specialist hardware is only needed for radio transmission units
Network Slicing	Share secure isolated network slices based on common hardware
Agile	Dynamically create services on demand according to your business needs

N.B. At the time of writing the report it is widely recognised that a number of these capabilities are yet to be achieved e.g. 1mS latency. It is also important to acknowledge that whilst release 16 has been signed off, vendors have not yet incorporated these into their current technologies and release 17 has not yet been adopted.

With a wide variety of connected devices gathering and sharing information in real-time, 5G can provide a variety of possibilities. From reducing road and traffic travel through remote monitoring, early warning monitoring of patient conditions reducing more critical medical issues, remote delivery of medicines, tackling mental health and loneliness.

2.3 West Mercia Rural 5G (WMR5G) Project

The proposed West Mercia Rural 5G (WMR5G) Project aimed to bring together two very distinct challenges.

- The first was a proposed new business model to test how the mobile industry in the UK could deploy 5G in rural areas at pace, but also at a reasonable cost.
- The second was how providers when faced with increasing demands for critical care services could find new models for delivery. The service providers included councils, clinical commissioning groups, and other care providers.

2.3.1 A new deployment business model

The first test looked to overcome key digital infrastructure challenges facing rural 5G deployments, as well as addressing the need for new models of service delivery by local authorities and health organisations.

Operating in the rural area where the counties of Shropshire and Worcestershire meet, WMR5G explored the infrastructure challenges around planning, building, and operating a rural 5G network. Working with a mobile network operator (MNO) and a wireless broadband asset owner, the project set out to test the technical and commercial viability of a new rural 5G business model to accelerate deployment. Elements considered included:

- using existing infrastructure,
- commercial arrangements,
- and technological solutions.

The project aimed to provide an assessment of a new business model for how 5G can be deployed efficiently in rural areas, further details of which can be found in Section 4: Deploying 5G in Rural Areas: A Case-study.

2.4 Why 5G and wider mobile connectivity is important to rural areas

Accepting that rural areas, largely due to their low population density, often fall towards the end of, or do not fall within, the commercial mobile deployments is largely understandable but not acceptable. It is also acknowledged that in addition to the Shared Rural Network (SRN) delivery to support rural 4G coverage, the mobile industry within the UK has other current challenges it needs to address across its existing infrastructure, such as the removal of Huawei equipment from the MNO's estates and growing demand for public and private 5G network deployments.

There are short-, medium- and longer-term justifications for improved mobile connectivity in rural areas across a range of user needs from basic voice conversation and wide area networks (WANs) to support sensors, to fixed-mobile broadband and high bandwidth ultra-reliable low-level latency 5G based applications we can see linked to agri-tech, rural businesses, transport and health and social care as well as other verticals.

In the short-term the immediate need is for voice and basic data infill across the rural geographies. In the medium-term demand in rural communities is changing, there is a need to meet the growing need for enhanced mobile capability to support many of the 5G use-cases we have seen generated by a range of DCMS projects and the wider Research and Design 5G ecosystem. Longer-term the planned sunsetting of 2G and 3G networks by 2030 will place a growing importance on 4G and 5G deployments to deliver mobile in rural areas. The ongoing switch off of ISDN / PSTN services and planned retirement of copper networks, places a requirement on the mobile networks to provide resilience in the event of a local 'power-cut', based on current mobile coverage this already presents an immediate issue to many rural communities.

Both public and private sector services increasingly look to ‘digital-first’ to both offer new products and services but also address environmental issues such as carbon reduction. In our area specifically, the counties of Herefordshire, Shropshire and Worcestershire, environmental issues such as flooding and severe winters mean ‘digital’ can be the only way to communicate and potentially reach, via drones, vulnerable communities cut-off from their usual services. This choice is limited by the scope of spectrum licences, e.g., N77 spectrum licence does not permit the operations of drones. This position is being explored further outside of this project with Ofcom.

It is acknowledged the transfer to 4G VoLTE and 5G low-band spectrum, will mean many residents will also need to upgrade their packages and handsets. Work is already taking place locally to ensure residents are aware of the things they could do to make the most of the signal or other types of connectivity they may have; from opening windows and choosing the right network / handset properties to enabling Wi-Fi calling and VoLTE options.

2.4.1 How can 5G help provide health and social care in and to rural communities?

Technology already has a significant role in health and social care as services being provided are moving closer to the community or indeed within patient’s homes. There is also more emphasis on people taking a greater interest and management of their own health and wellbeing. Meanwhile globally, social care, health care and preventative approaches are being integrated to focus resources where they are most needed and to personalise services.

Innovations such as telemedicine (remote consultations), wearable (physiological data transmission and analytics) and personalised services are all under development.

Potentially, this technology can have a transformational impact in healthcare and beyond, and it is essential that innovation meets patient and provider needs, ensuring access whether the area is urban, suburban, or rural.

The secondary challenge was for the project to look at how 5G can enhance services for the benefit of residents, particularly researching 5G-enabled health and social care applications. This was done through testing to what extent 5G-enabled capabilities can improve health and social care outcomes.

The testbed looked to address the issue of end-to-end connectivity from a sector demand perspective and evaluate the benefits of 5G-enabled services for patients.

Benefits, outcomes, and lessons learnt for both challenges can be found in subsequent sections of this report.

2.5 Some facts and figures

2.5.1 Shropshire

Shropshire Council area (excluding Telford & Wrekin area within the

county of Shropshire) covers 1,235 square miles and borders Wales, the West Midlands, and the Northwest. It is one of the most sparsely populated counties in the country, with 1.01 persons per hectare. The total population for this area is 325,400, where 25% of this population is aged 65+ and the projected population for 2043 will be 381,514. 57.2% of the population live in rural areas which makes up 97.5% of the land mass. Conversely 42.8% of the population live in urban areas which makes up only 2.5% of the land mass. These facts highlight the issues that Shropshire Council has in relation to its demographics both in the age of the population, potentially requiring Health and Social Care services, as well as the remoteness of this population spread over the rural areas who may have limited-service delivery compared to urban areas.

2.5.2 Worcestershire

Worcestershire covers 670 square miles and borders the Cotswolds and outskirts of Birmingham, within the county of Worcestershire there are six district councils. The total population for this area is 592,158. 74% of the population live in urban areas which makes up only 16% of the land mass. Conversely 26% of the population live in rural areas which make up 84% of the county's land mass. While Worcestershire has a smaller overall area with less rural areas, it still faces the significant challenges of providing Health and Social Care services to those communities that live in the rural areas.

*Figure SEQ Figure * ARABIC2.2: Map showing Worcestershire County area and main towns*

2.6 Consortium partners and project governance

Worcestershire County Council (WCC) was the lead partner for WMR5G.

WMR5G was one of a small number of projects within DCMS's Rural Connected Communities Programme. The grant funding covered the period of 1 April 2020 to 30 June 2022, and as the lead partner WCC was the recipient of the grant funding and responsible for managing the grant between the consortium partners / participants.

2.6.1 The consortium partners were:

- Airband Community Internet
- BT
- Herefordshire and Worcestershire CCG (NHS)

- Shropshire Council
- University of Chester
- University of Worcester
- VR Simulation Systems Ltd (VRSS)
- Worcestershire County Council (WCC)
- West Midlands Academic Health Science Network (WMAHSN)

A brief description of each partner can be found in Appendix B.

Airband and BT were the network key partners who supported the planning, building, and operating of the private 5G network with further support provided through the Worcestershire 5G testbed. This group looked to explore the challenge previously mentioned around deploying a 5G network to rural areas more cost effectively and at increased pace. In addition to extending the 'nexGworx' private 5G Non-Standalone network for the project, public 4G and 5G networks were also utilised so that a comparison could be made within the use cases to understand the performance each network provided.

The local NHS organisations alongside Shropshire Council, Worcestershire County Council, and private sector partners led on the testing of the health and social care applications.

University of Worcester, University Centre Shrewsbury and West Midlands Academic Health Science Network provided their expert support to help deliver the new health and social care technology enabled pilots that worked with residents, care homes, community hospitals and doctors' surgeries.

2.6.2 Project governance

A formal project structure was implemented, project management principles were applied to the project and formal documentation completed at the relevant milestones that had been agreed.

A project board was set up, chaired by Mark Stansfeld, which met on a bi-monthly basis who reported high level management information to DCMS. Reporting to the board was the project team (run by the Project Management Office (PMO)) that met on a fortnightly / weekly basis. Two working groups were set up:

- **Technical Group** – this group consisted of BT, Airband and WCC and was responsible for the build of the network as well as testing the new deployment model for 5G in a rural environment.
- **Health and Social Care Group** – this group consisted of local NHS, the two councils, AMAHSN, private organisations (BT and VRSS) and the universities, and was responsible for driving the two use cases forward – Connected Worker and Health XR app.

There were six change requests (CRs) within the period of 1 April 2020 to 30 June 2022 including one for the three-month extension. Additional CRs of note were:

- **CR001** – Request to detail the required changes to the project as a result of 3UKs withdrawal and their replacement in the consortium by BT.
- **CR004** – Request to change the milestones, milestone deliverables and claim schedule, following urgent review meeting and changes to the project plan and High-Level Design.
- **CR005** – Request change to milestones, milestone deliverables and claim schedule following recent resource review.

The project milestones have been reviewed and updated through the change requests and the final full listing can be seen in Appendix C within this document.

2.7 Key outcomes

The two challenges (outlined in Section 2.3) intertwine as whilst the new business model promises to reduce initial build costs, mobile operators must also find new revenue streams, beyond traditional 'mobile phone users' to justify the ongoing operational costs of delivering a network. Whilst 5G can provide improved home broadband services, it also has the capacity to support critical services such as those within the Health and Social Care sector.

Our hypothesis considered, if a local authority, health organisation, or their care providers could utilise digital solutions instead of some face-to-face visits or being reliant on solely telephone conversations, could they redesign their services to:

- save transport costs
- reduce carbon footprint
- undertake more visits (albeit virtual) per day
- respond quicker and understand the issues of the patient before attending site
- prioritise staff resource more effectively by only physically attending those with highest need, and
- reduce unnecessary hospital admissions and assist with diagnosis

It is envisaged that this service transformation could generate efficiencies through reduced transport costs - individuals 'down' time, maintenance, and fuel. These 'savings' could then be utilised to support financing the use of a 5G network and reutilised to address increasing demands on the service providers.

The impact of limited existing digital connectivity has an effect not only on rural public services and businesses but also on general quality of life. This covers such diverse concepts as:

- lone workers
- lonely and vulnerable individuals lacking the reassurance that they can reach emergency services or family members if needed
- gamers wishing to access the latest augmented reality (AR) gaming services.

The project aimed to address the challenges highlighted with the aim of supporting both the growth in the type and quality of services available in rural areas as well as bringing improvements in quality of life to rural residents.

2.8 Our challenge – the rural locality

Located in the heart of the United Kingdom, Herefordshire, Shropshire, and Worcestershire is a contiguous region within the midlands often referred to as West Mercia. It has a variety of different geographies both in terms of topography ranging from rolling hills and valleys to open plains. West Mercia has many significant features including Areas of Outstanding Natural Beauty (AONBs), Sites of Special Scientific Interest (SSSI) and major rivers in the Severn, Avon, and Wye.

All three counties include communities that meet the definitions of rural ‘sparse’ and ‘not sparse’ and all ‘settlement types’. The region covers two Health Sustainability and Transformation Plans (STP) areas and two Local Enterprise Partnerships (LEP) areas; it is also represented by one police force - West Mercia Police.

The characteristics of both the selected areas for the trial and the wider three counties mean it is an ideal geography to demonstrate the capabilities of the proposed new 5G deployment model, in a way that could be scaled across large parts of the UK’s rural areas.

Rural areas of England and Wales are often the poor relations of their urban neighbours when it comes to the roll out of digital infrastructure. Both superfast broadband and mobile services in rural areas still lack the coverage and quality that residents have come to expect across the majority of the population. Deployment to rural areas is often expensive, technically difficult, and so commercially unattractive for network operators.

The following data shows the state of 4G mobile coverage from Ofcom 2020 Connected Nations Report published 12 May 2021, showing coverage data as of Jan 2021, and also the predicted coverage based on the Shared Rural Network (SRN). The SRN is a project supported by the four UK MNOs and Government and looks to upgrade existing sites, work together on shared infrastructure and building new sites, but also utilise government funded masts being built to target areas with no mobile coverage from any operator.

Figure 2.3: Shared Rural Network Coverage Forecast Improvements in England

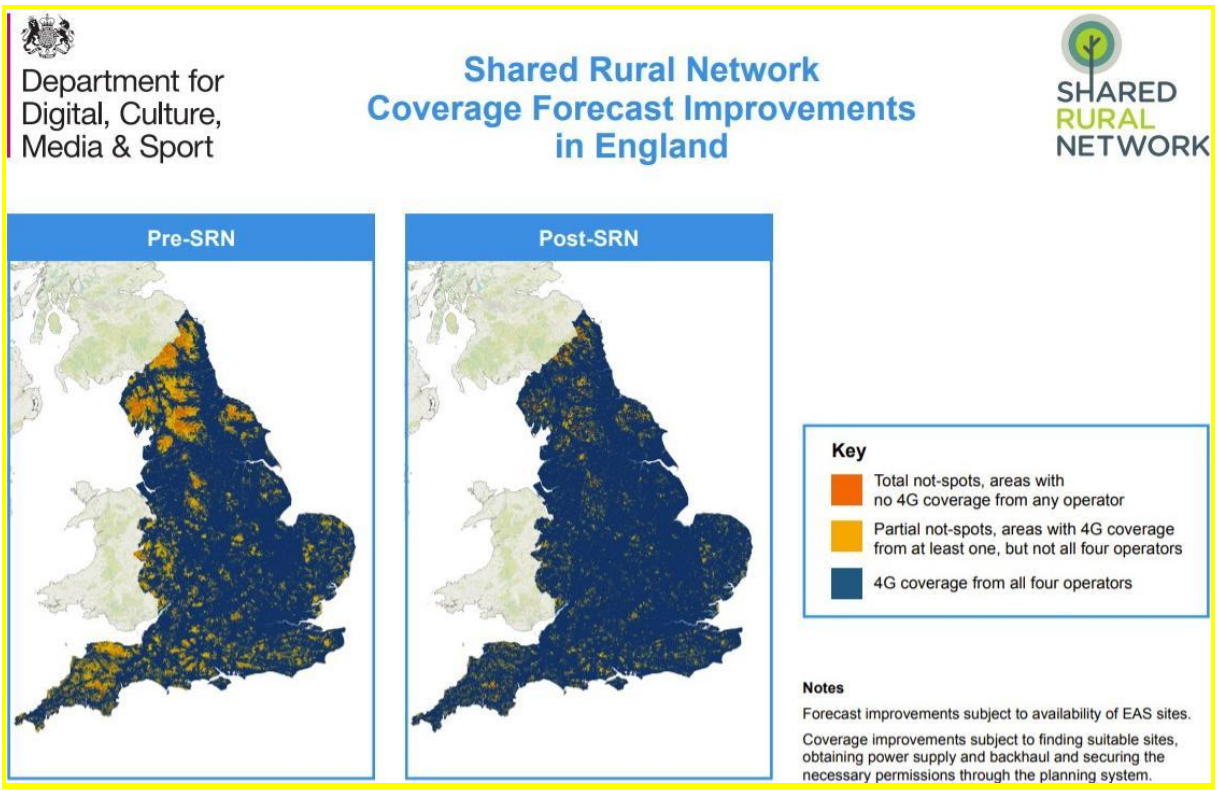


Table 2.2: 4G Coverage

	4G Coverage from all MNOs		4G Coverage from at least one MNO	
	Pre-SRN	Forecast post-SRN	Pre-SRN	Forecast post-SRN
Overall UK	69%	84%	91%	95%
England	84%	90%	97%	98%
West Midlands	78%	92%	99%	99%

A recent All-Party Parliamentary Group (APPG) report '*Levelling up the Rural Economy: an inquiry into rural productivity*' published that rural broadband connectivity was slow and there was a need to urgently improve 4G and 5G mobile infrastructure. The cost to network operators is significantly higher in rural areas due the costs such as civil-engineering works (up to 68% of the total cost), cabling (24%) and then the associated costs for delivering connectivity to the small number of users / properties.

2.9 Introduction to health use cases

WMR5G focused on two specific use cases:

- **Health XR** – supporting the development and evaluating the impact of an extended reality (XR) solution to track improvements in gait and movement for people using hospital Musculoskeletal (MSK) services.
- **Connected Worker** – giving General Practitioners (GPs) and community nurses access to support workers in care homes equipped with wearable connected cameras and examining how effective the increased connectivity is in providing rapid access and information to assist the resident's welfare.

2.9.1 Health XR app – Extended Reality (XR)

The project partner, VRSS, looked at how an extended reality view of a patient, utilising biometric data, can be used in any place where human motion is desired to be studied. Within the Health XR application, WMR5G partners supported the development of the app from a Technology Readiness Level (TRL) 3, through to healthy patient testing in a controlled environment (TRL 5) within the area of physical therapy.

The LiDAR technology within a mobile phone was used to capture image and depth data, which then translated into body model (an avatar) on the phone using GPU-based deep neural networks. The advantage of using an avatar is that this minimises the security implications as it anonymises the data into a generic body model. Transmission of the data from the mobile device through the cloud to the physio does not therefore require costly data security protocols to be adhered to, and this is increased by anonymising the patients name so that only the physio knows this within their secure work networks.

The data was then displayed to the patient in real-time, to the physio in real-time through a live session or the patient could send a recording to their physio to be reviewed at a later date.

2.9.2 Connected Worker – remote warding

The Connected Worker use case looked at how emerging technology could be used to improve the real-time face to face online meetings by using a hands-free option to replace a mobile device that a clinical staff member has to hold. By moving to a hands-free device, still allowing real-time video and audio capability, meant that the clinical staff member wearing the head mounted device could use both hands for things such as turning the patient safely over. The use of connected worker was also seen to:

- benefit patients as they can stay in the familiar setting of their care home especially important with dementia patients
- saving the patient having to travel to and from clinical settings which might expose them to additional health risks
- reduce the carbon footprint of those involved in the remote consultations.

The Care Home Manager at Haresbrook Park stated that taking a dementia patient out of their familiar surroundings within a care home to attend a routine consultation with a clinician at a hospital or other location would often have a negative effect on the dementia patient for days after their appointment. By using the connected worker solution for routine check-ups not requiring the patient to be present in the hospital, she could imagine that the negative impact on the patient could be minimised providing a better outcome for patient and care home staff.

2.10 Use case support

It was agreed within the PMO that the initial point of contact for both Use Case End Users would be the Use Case Product Expert within the PMO. A process diagram was written up clearly showing the responsibilities of parties within the Connected Worker process, see Section 6.5.12 . A similar process was envisaged for Health XR

when the trial entered Phase 3 but with the primary point of contact being the physio who would then contact the Use Case Product Expert so as to not pass on patient details.

For each type of device used within the use cases there was a backup device that could have been supplemented for a faulty device if required.

2.11 Data protection

As this was a trial in the use of 5G networks and devices that can utilise the benefits of 5G, the project was focussed on not storing identifiable user data.

2.11.1 Connected Worker

With Connected Worker, a Data Protection Impact Assessment (DPIA) / Privacy Impact Assessment (PIA) was created initially by the Health and Social Care Use Case Subgroup and agreed by the Senior Information Risk Owner (SIRO) for the Herefordshire and Worcestershire Clinical Commissioning Group (CCG). This was then used as the base document for BT to complete their PIA. Appendix D has a copy of the final BT PIA.

2.11.2 Health XR

The Health XR app did not make it to Phase 3 - trialling with Healthy Public Volunteers. The app has been designed so that an avatar is created from the body shape of the patient, and this is sent through the system from A-End (patient) to B-End (physio) with no personal data or distinguishing features ensuring the anonymity of the patient. A full DPIA / PIA would have been completed before starting Phase 3 to ensure data protection aspects had been considered and challenged, and that the DPIA position was recorded appropriately.

3 Network Design Including Security

3.1 Background and context

This project reflects how an original scope to deliver a given network to support two use case can organically change when new partners, challenges and circumstances affect the expected outcome. When BT joined the project as the new network provider the result was a change of equipment vendor and a re-evaluation with the rest of the collaboration team as to scope of the project and the network topology.

Following various network reviews and designs, BT determined that a holistic approach was necessary to deploy this solution and support the use case trialists. The network design was a mixture of private 5G network, commercial 5G network and also utilising the commercial 4G network due to the coverage limitations of the private 5G network. The network design process was very much an organic one, with amendments required where the coverage options were formulated through the deployment process. This approach provided the project an opportunity for comparisons between existing commercial 4G and 5G coverages and the private 5G network option.

It’s important to note that the private 5G designed and deployed during this use case, reflects a ‘vanilla’ solution. For clarity a vanilla network is one where neither

the network, nor the on-prem receiving equipment were designed as a bespoke offering for health specific use cases. Rather, the vanilla network would provide a glimpse into a more generic service that would serve multiple use case types, thus ensuring commercial viability of the network operation.

As outlined in the project background, with BT inheriting this delivery mid-flight various changes needed to be made to the design and the site locations in conjunction with the appropriate stakeholders. Originally there were five sites which were identified to support the trial. A key decision which was made through the new BT design was to reduce this down to a single deployment at the farm in Tenbury Well.

The decision to adopt the existing Non-Standalone (NSA) 5G Private Network Core at Malvern Hills Science Park (MHSP) in Worcestershire to support the trial led to the decision to add a macro site at MHSP. This would provide the benefit of additional coverage through the Malvern Site as well as providing the core architecture for the Tenbury Wells RAN at its Monopole Farm location.

For the provision of the connection from the core network at MHSP to the macro site at Tenbury Wells there was familiarity in the supporting infrastructure at MHSP from previous deployments to other satellite locations across the West Midlands.

3.2 Network design and solution

3.2.1 Background

The solution was constrained in Tenbury Wells as it needed to be delivered by Airband's infrastructure as part of the use case looking at how to deploy effectively and efficiently into a rural area and help towards the understanding of the 'Rural Model' model.

The network design was never optimised to deliver specific use cases as the project wanted to understand how a typical 5G network, likely to be deployed in rural areas by MNOs, might be utilised by public services. However, it was important that considerations were made to ensure the network had a reasonable chance of being able to serve the two-project health and social care use cases - Health XR and Connected Worker.

Before the final solution was designed and deployed there were two previous designs:

- First, the original project with the MNO partner 3UK planned to deploy across a much wider geography and build out to five sites, with an NSA solution supported by the commercial network.
- Second, when BT were initially onboarded to the project the design was for a 5G Standalone private network solution, as covered in Section 3.2.2.1.

However, due to issues encountered, the final design agreed upon and eventually deployed, was a 5G Non-Standalone solution. With hindsight, this also allowed the project to test and trial a solution most likely to be the predominant deployment method in rural areas via public mobile networks for health and social care. The 5G

Non-Standalone solution also assisted in a value for money perspective as the project was able to reuse and build upon previously deployed assets at MHSP.

3.2.2 The Non-Standalone (NSA) solution

A 5G NSA network consists of the following elements:

- Core network
- RAN – Radio Access Network
- Mobile Backhaul and connectivity
- Operational Support System

The following diagram describes how the radio sites are connected to the core network and also the how the core network connects to the internet. Each boxed section of the connection highlights which team or teams are responsible for managing and maintaining that section.

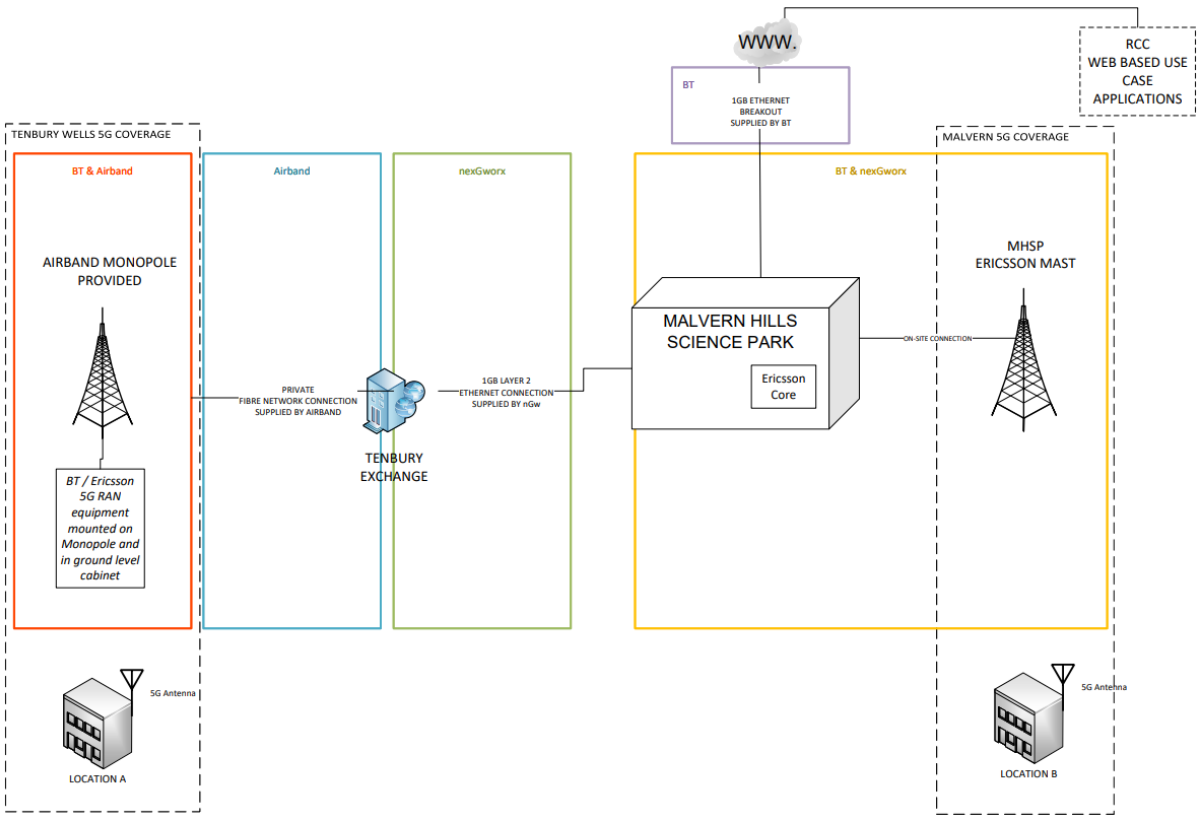


Figure 3.1: Describes the High Level view of the 5G NSA solution

3.2.2.1 Core network

The original requirement was to deliver a 5G Standalone network with a Nokia Digital Automation Cloud (NDAC) solution to be deployed utilising the N77 frequency band. Due to delays in deploying a validation solution in the BT Lab environment to allow additional testing, it was deemed that this solution could not deliver the network functionality within the timescales required.

As a result, it was then decided by the project on the recommendation of BT to utilize the existing core at MHSP and replace the N77 band with a higher power

Commercial N78 Frequency on the BT Owned Spectrum Licence. This would reduce licence application delay and also provide greater coverage range.

The core network (based at MHSP) serves the RAN and provides a bridge to connectivity to the Internet which hosts Application Servers.

The design of the core is not specific to this project as it hosts other Ericsson solutions on sites across the West Midlands.

When creating the core network there are no specific design considerations made to for a rural or private network.

3.2.2.2 RAN - Radio Access Network

The RAN solution adopted was for 5G NSA using two macro-sites to provide outdoor coverage. These were located at MHSP in Malvern and a farm in Tenbury Wells.

The macro-site at MHSP utilised the existing infrastructure with a new radio unit provisioned with additional power to provide coverage to the Malvern area in the N78 band described below:

LTE Frequency Division Duplex:

- Downlink (DL) 2640.1 – 2655.1 (Channel 3026, central 2647.60 MHz)
- Uplink (UL) 2520.1 – 2535.1 (Channel 21026, central 2527.60 MHz)

New Radio (NR) Time Division Duplex (TDD):

- Frequency 3540 – 3580 MHz

  TDD uses the same frequency for each duplex direction, with a frame that includes different time periods and slots for uplink or downlink communications.

The site in Tenbury Wells also utilises the same N78 frequency band for 5G and the same 4G frequency as used in MHSP which has also been temporarily loaned from the BT commercial frequency range.

The deployment of the above hardware is BT / Ericsson's standard for providing coverage in a rural area.

3.2.2.3 Mobile backhaul / other connectivity

The mobile backhaul connection to the core was delivered by two services:

- The first connection ran from the Airband infrastructure located at the Tenbury Wells Farm macro site to the Tenbury Wells exchange and from there it connected with the nexGworx's Layer 2 connection back to MHSP.
- The second connection was a local connection from the macro site at MHSP to the core network located in the communications room at MHSP.

Connection from the core network to the internet was via a 1 GB Ethernet breakout which was provided by BT.

L2 Ethernet connection between Malvern Hills Science Park (MHSP) and Tenbury Wells Exchange (TWE) – nexGworx

When formulating how the newly proposed 5G Private Network (PN) Non-Standalone (NSA) solution for the Tenbury Wells deployment would function, nexGworx were able to draw on existing architecture that was operating within its current estate.

Hosted in Malvern Hills Science Park (MHSP), nexGworx has a fully operational Ericsson Core.

The core connects out to sites in Worcester and Birmingham among others, where the radio units deliver 5G connectivity in a manufacturing setting generally. In addition, there is indoor 5G and onsite outdoor 5G provided at MHSP from the same core.

The Estates Team at MHSP and the nexGworx technical team have become proficient at extending the existing core functionality to satellite locations with the support of its network partner BT and Ericsson.

There were a number of key challenges for this project:

- Working with health partners to understand and facilitate the chosen use cases.
- Due to differences in network capacity; ensure bandwidth performance remains consistent with the potential user number and use case requirements.
- This would be the first time that nexGworx had provided connections to a macro (Outdoor) broadcast tower that was not onsite from the MHSP Core.
- Coverage considerations for longer range broadcasting than undertook previously in Malvern and new broadcasting in Tenbury Wells.

Tenbury Wells Exchange (TWE) and Tenbury Wells Farm (TWF) – Airband

Originally five sites were looked at as part of the initial bid to DCMS RCC. However, due to delays within the project and the change of network partner, a single site was chosen by the project. Tenbury Wells Farm was selected as it was based within the proximity to an existing Airband fibre deployment area (plan name SF037), the site's availability and proximity to the Tenbury Wells Exchange.

Table 3.1: 5G potential sites to gain coverage from Ludlow to Tenbury

5G Potential sites to gain coverage from Ludlow to Tenbury					
Site Number / Name	**Position**	**Area**	**Coverage**	**Current status**	**5G spec'd - status - site - power**
S#1 - H004	52.381679, -2.621815	Bitterly	Upper Ludlow, Bypass, Business Parks	Live - Mast 15m	**Site 1:** Replace Mast, Power DNO ready
S#2 - SH299	52.348290, -2.736746	South Ludlow	Bypass, A49 to Brimfield, South Ludlow	Live - Pole 12m	**Site 2:** Replace pole with mono pole, transformer power option available across field (~150m)

S#4 - SH346	52.361616, -2.590452	Clee Hill	Bypass, A49 to Brimfield, South Ludlow	Live - Pole 12m	**Site 3:** Replace pole with mono pole, Power DNO ready
S#4 - Old Manor Farm	52.267542, -2.604692	Tenbury	Tenbury and over Clee Hill	Live - Pole on barn	**Site 4:** New site at back of farm, DNO right next to site
S#4 - Ms - Tenbury	52.321035, -2.591037	Tenbury	Most of Tenbury	Airband Decommission	**Site 5:** Massive mimo, build new monopole site at back of farm, No wayleave req. No planning Reg. Adjacent to existing fibre build SF037

1GB Ethernet breakout connections - BT

With the potential traffic operating at speeds above 800Mbps on the private 5G network and the expected users of the network on both this project and others linked to the Ericsson Core at Malvern being 30+, it made sense to order a data connection with 20% additional bandwidth to prevent a choke point.

This decision was taken when considering all connectivity beyond the 5G radio equipment.

3.2.2.4 OSS – Operation Support System

An Enterprise OSS system was provided as part of the existing core network at MHSP. No upgrade to capacity was required to support the increased traffic presented to the core network.

Enterprise OSS (E-OSS) provided a user interface to manage and monitor the private network system. This was running on Enterprise OSS (OSS Navigator) 2.7 software.

E-OSS provided the following functions and features:

- Network and Systems Monitoring and Control
- A set of Enterprise network monitoring and control functionality
- Services Monitoring
- A set of Enterprise services monitoring functionalities
- Service User Management

3.3 Description of what the project did

3.3.1 Core / RAN network

The core network located at Malvern Hills Science Park (MHSP) was deployed as NSA mode whereby the 5G radio was dependent on the control plane of the 4G LTE network.

Acquiring Ericsson N78 radio units proved challenging as these were in short supply due to high demand. These units had to be taken from other projects otherwise delays to this project would have been counted in weeks. The increased delivery lead times for sundry radio items pushed back the initial planned installation date.

Prior to deployment of equipment, site surveys were performed. In addition to this radio predictions were formulated by Ericsson which provided foresight as to how the radio network would perform. The radio predictions can be viewed in Appendix M.

3.3.1.1 RAN – MHSP, Malvern

The radio coverage provided by the macro site at MHSP encountered issues with the terrain and sector direction whereby coverage was not achieved for Howbury House care home and Malvern Community Hospital.

The following measurements were taken outside of the premises. While outside the Malvern Health Centre the measurements were adequate for the private 5G, it was decided that the commercial EE 5G should be used instead.

Table 3.2: External network performance measurements for Malvern sites

Malvern Sites	Measurements			
	5G Downlink throughput TCP (Mbps)	5G Uplink throughput TCP (Mbps)	5G Latency (mS)	5G RTT (mS)
Howbury House care home	No coverage			
Malvern Health Centre	146	5.44	28.12	56.24
Malvern Community Hospital	No coverage			
Hastings Residential care home	147	46	33.5	67
Court House care home	257	50	28.5	57

Table 3.3 below identities the minimum requirements needed to support the service that was captured in the WMR5G Use Case LLD V2.2 document.

Table 3.3: Minimum network requirements to support the use case

Device	DL Bandwidth minimum (Mbps)	DL Bandwidth maximum (Mbps)	UL Bandwidth minimum (Mbps)	UL Bandwidth maximum (Mbps)	Max latency	Number of units
Head mounted camera	2	5	1.5	6	40mS	5

In order to overcome the coverage issues the following investigations were made by BT:

- Increase the height of the mast at MHSP
- Provide a portable radio solution in Malvern
- Provide a rooftop antenna on Malvern Community Hospital
- Changing the orientation of the antenna

The outcome of the investigations was that the options listed above could not be completed with any certainty within the remaining project timescales (6 months) and therefore the Project Board agreed to rule out the options. With regards to changing

the direction of the antenna investigations performed indicated that this would provide no improvement to coverage.

At this point, the project team identified that commercial EE 5G coverage was now available in Malvern covering some of the original sites identified in the LLD. This service was utilised to enable the use cases to be run at Malvern Heath Centre GP surgeries, Howbury House care home and Malvern Community Hospital.

The Health and Social Care Use Case subgroup also approached and successfully onboarded a care home that was covered by the final direction of the private 5G network, Hastings Residential care home, as well as the GP surgery (at Malvern Heath Centre) that serviced it.

3.3.1.2 RAN – farm, Tenbury Wells

The radio coverage provided by the Tenbury Wells site was unable to adequately provide service to Haresbrook Park care home to support the Connected Worker use case. The following measurements were taken outside of the trial sites identified for the Tenbury Wells area.

Table 3.4: External network performance measurements for Tenbury Wells sites

Tenbury Sites	Measurements			
	5G Downlink Throughput TCP (Mbps)	5G Uplink Throughput TCP (Mbps)	5G Latency (mS)	5G Round Trip Time (mS)
Haresbrook Park care home	**18.2**	**0.04**	**180.5**	**361**
Old Rectory care home	98.2	2.53	22.055	44.11
Tenbury Wells GP	201	2.39	20.75	41.5
Tenbury Community Hospital	318	41	11.72	23.44

Unlike Malvern there is no commercial 5G coverage available in Tenbury Wells. To enable the Connected Worker use case to progress at Haresbrook Park, the project continued to utilise the routers connected to the commercial 4G network which provided a baseline to the overall Connected Worker trial.

3.3.2 Mobile backhaul

3.3.2.1 L2 Ethernet connection between MHSP and Tenbury Wells Exchange – nexGworx

Layer 2 provides the procedural and functional means for data transfer between network nodes and provides the means to detect and correct errors that may occur at the physical layer (Layer 1). Ethernet, which is used for multi-node local area networks (LAN), is the best example of the data link layer protocol.

In designing and implementing the data connection between MHSP and Tenbury Wells, the first consideration was that of use case performance requirements.

With the primary data flow being out to the internet for access to web-based application servers for both Connected Worker and Health XR, an uncontended 1GB Link to the core (which has a 1GB internet breakout) was the choice made.

The next step was to identify the key differences in the connectivity flow to previous core extensions. This meant understanding the entire infrastructure plan to prevent gaps forming.

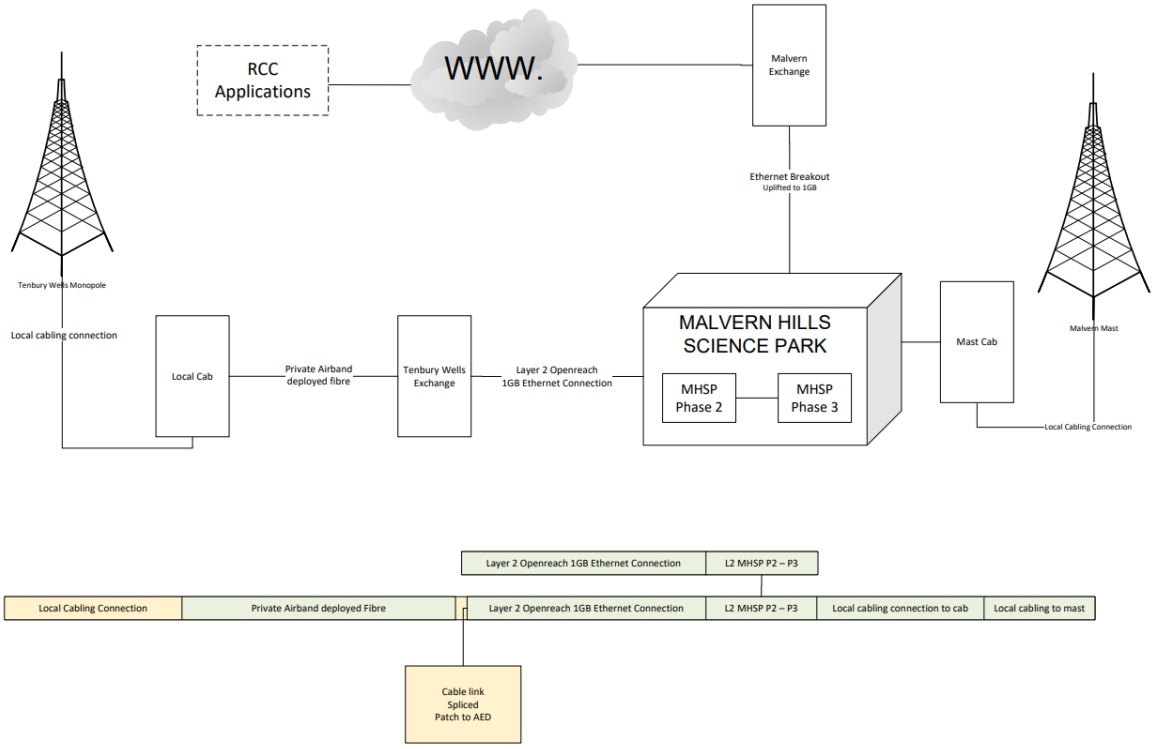


Figure 3.2: Layer 2 Openreach 1GB Ethernet Connection

Shown in the Data Connectivity map excerpt above is the link between MHSP and the Tenbury Wells Exchange.

This differs to a typical procurement, provisioning, and deployment of the connection in that it would terminate at the site where the network was planned to be operational (A-End).

Presenting as a traditional lease-line order, the Openreach engineering team patched the connection through the site / building to the exact location specified in the order. This would be the communications / frame room and rack where the RAN equipment was planned for installation.

However as demonstrated, the L2 Ethernet connection terminates at the Tenbury Wells Exchange, being picked up there by Airband before being connected into Airband's Private Fibre Network.

The B-End at MHSP would pass through an undefined Exchange (probably Malvern Hills, this would not show on the plan as it sits within the network planning order with Openreach) and terminate at the Phase 2 communications room where all other connections routed into the site.

At the Tenbury Wells Exchange, the A-End would terminate at a defined Openreach rack, to a specific port. Airband would then splice cabling going into its owned

in-Exchange racking and patch the connection across to the Openreach rack / port specified in the order completion documentation.

This required thorough communication between the Openreach engineers at the exchange and the Airband Team.

The B-End connection was then patched by the MHSP Estates Team using pre-existing local fibre across to the nexGworx Communications Room within the Phase building, where the 5G core is located. Connected up by the Ericsson engineers as part of their commissioning activities.

The flow of data across the network is secured firstly by the design of the private solution; firewall to the core, limited configured devices, network specific SIMs, and privately held Access Point Names (APNs).

Given the fact that the use case carried patient data, and to align it with NHS expected best practice, the project decided to create a PIA. This PIA, which initially was supported by an interim DPIA underwritten by (Herefordshire and Worcestershire CCG) and then moved to a full PIA supplied by BT. The PIA and associated interim DPIA can be seen in Appendix D.

The key private network features listed above, as well as the PIA were not in place for the data traffic that flows over the commercial EE network.

Layer 2 data link encryption is a high-performance security option that offers some advantages over Layer 3 networking layer encryption in some scenarios, particularly in unified communications environments that require low-latency, high-volume data transmission. The increased availability and popularity of high-speed carrier Ethernet services provide fast, relatively cheap transmission, particularly for voice, video, and other latency sensitive traffic.

> *"If you are looking to aggregate a whole bunch of traffic across a metro Ethernet network on a very high-speed link, that's where Layer 2 really shines,"*
> Scott Fanning, Senior Engineering Manager for iOS security at Cisco Systems.

Because it operates below the network layer, Layer 2 encryption is protocol agnostic and is very attractive for high-speed data transmission between data centres and encrypts everything.

3.3.2.2 On-site connection between MHSP radio and MHSP core – nexGworx

Local fibre cabling was installed as part of the initial design and deployment of the 5G macro at MHSP. This cabling ran directly from the mast to the 1st Floor Communications Room within the Phase 3 building, where it was connected to the 5G core.

Capable of speeds in excess to 1GB, it was deemed suitable for the transmission of any data from the planned enhanced cell capabilities of the macro. Mainly because the planned enhancements were to increase the range of coverage, not upper level bandwidth or latency performance.

The connection demonstrates no standalone exposure to remote security risk. The network is closed with no remote entry points, this is possible as both ends of the network (internet breakout and user devices) are secure:

- Mast secured as private 5G network with private SIM / APN security
- 5G core protected by Enterprise Firewall at Internet Breakout

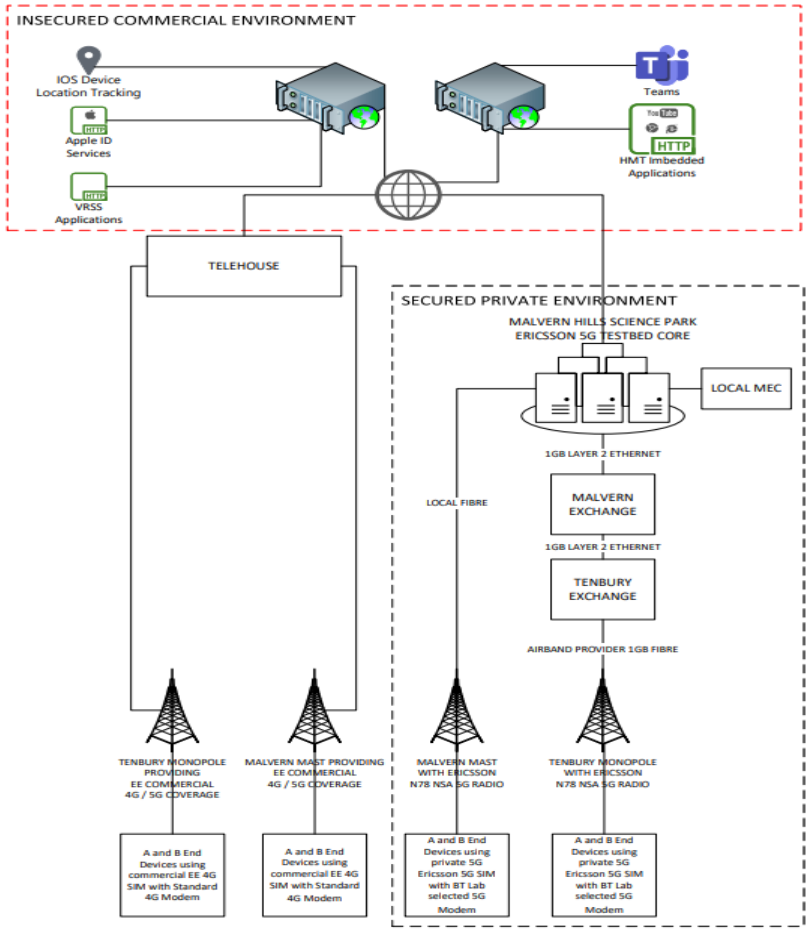


Figure 3.3: 5G Network Estate as a multi-level Secure Environment

3.3.2.3 Tenbury Wells exchange to Tenbury Wells farm – Airband

There had been some concerns from alternate existing landowners about what Airband might need to do with the site and how this might affect power consumption and require more frequent access. Some landowners also wanted to renegotiate their current agreements with a much larger compensation fee which would not have been feasible.

The selected site already had a wayleave agreement thus narrowing down the acquisition time. As the monopole was 15m or below then planning permission was not required, thus narrowing down the timeframe to build. Airband had to procure a 15m monopole from Swann Technology. Swann provided an end-to-end solution compiling of site survey, groundworks, mast installation and mast safety test and sign off. Airband provided the cabinet with a 12-way DC 48v fused PDU and 2 Polarium 50Ah Lithium batteries and racking ready. Airband applied to Western

Power Distribution (WPD) for a single phase 230v power connection to the site connected to the cabinet via a new underground low voltage cable.

Airband connected this site by running an underground fibre cable from the monopole to the Tenbury Wells Exchange. Within the exchange the fibre was patched from the light source into our cassette within Airband racking within the exchange. The fibre was terminated at the monopole into our cassette within the onsite cabinet. A duplex patch cord connected this fibre into the Ericsson baseband unit BBU. The monopole site was surrounded by metal fencing, appropriate health and safety signage and a coded lock was put into place for site security.

GEN2
The end pod of the GEN2 cabinet contains the power system and the manifold for the fibres entering the cabinet. In all GEN2 cabinet designs, all cables enter the cabinet in the end pod area. The main earth rod for the cabinet is also located in the base of the end pod and can be installed when the cabinet is situated at site.

GEN2.5
The end pod of the GEN2.5 cabinet contains only the power system for the cabinet. In all GEN2.5 cabinet designs, only the power cables enter the cabinet in the end pod area. The main earth rod for the cabinet is also located in the base of the end pod and can be installed when the cabinet is situated at site.

There is an additional brushed port in the internal cab wall to allow for additional cables to be run from EndPod to main chambers if required. There is also a generator port in the external wall of the cabinet where cover can be removed, external generator cable inserted and plugged into the 16A socket, then cover reattached using the cut-out for the external cable.

All cabs
In all cases the end pod contains:

- Consumer Unit
  - Surge protection
  - Automatic RCBO
  - Breaker for Fan (Heater if in cabinet)
  - Breaker for 13A unprotected sockets
- Mains Isolation switch
- Single 13A socket
- Breaker for Fan (+Heater if in cabinet)
- Transfer switch
- 16A Commando socket for external generator

The direct DNO connection will include the DNO isolation fuse box (installed by supply engineers).

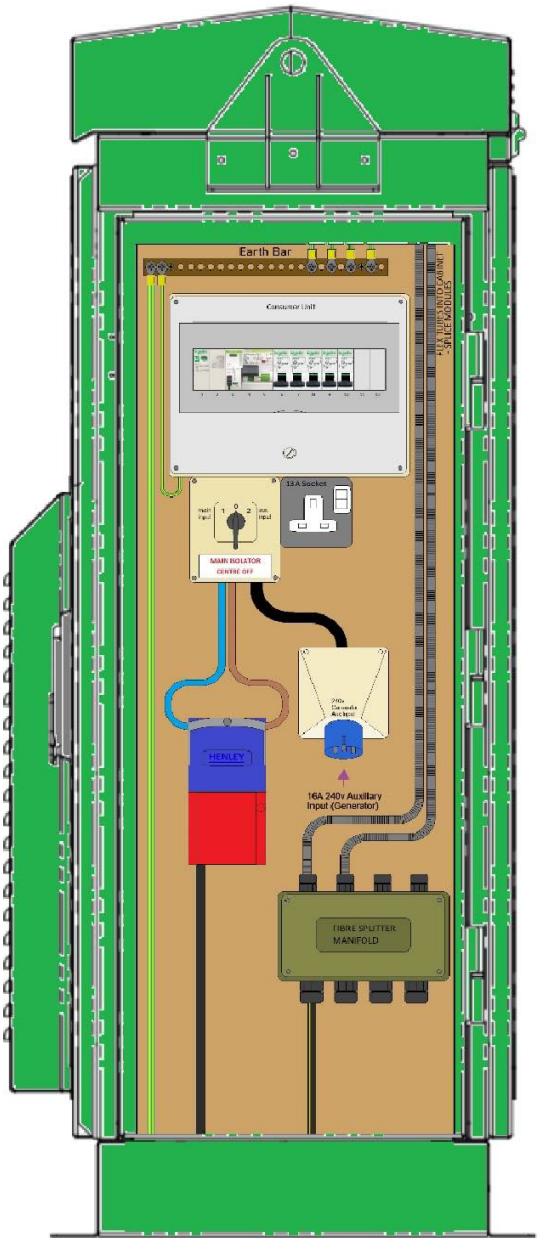
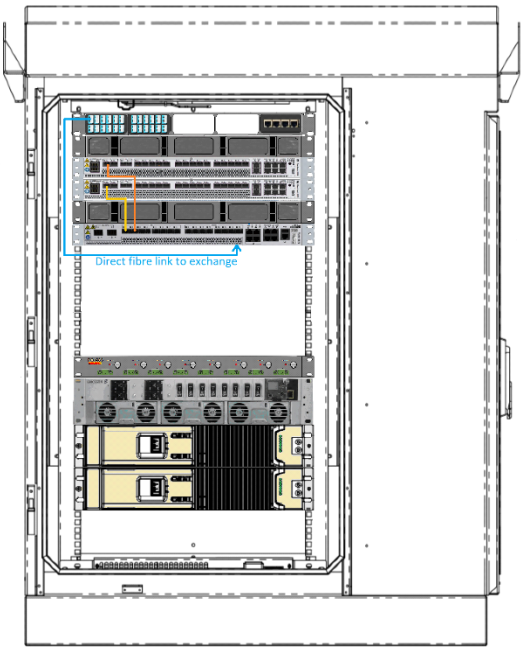


Figure 3.4a: Cabinet Specifications

Single Bay - 20u Racked Cabinet with power chamber

Rack U



1	Fibre splice cassettes - LC-UPC 48x
2	Cable Mgt & Spacer
3	Ericsson BU 6630 5G
4	Ericsson BU 6630 4G
5	Cable Mgt & spacer
6	Ericsson Router 6672
7	
8	
9	
10	
11	Cable Mgt & spacer
12	9/12 way DC 48v fused PDU
13	Ericsson PBC 6200 48v DC PSU
14	
15	Polarium 50Ah Lithium battery
16	
17	Polarium 50Ah Lithium battery
18	
19	
20	

Figure 3.4b: Cabinet Specifications

3.4 Description of the results

3.4.1 Core network

As the existing core network is fully commissioned, its acceptance tests and verification were completed no further testing has been performed.

3.4.2 RAN

A report has been created to capture the 5G private radio network performance at the three layers identified below:

1. Macro site
2. Adjacent to the CPE
3. Wi-Fi coverage

3.4.2.1 Layer 1 – macro site

The table below displays the radio performance measured at the macro site

Table 3.5: Radio performance of the macro sites

Macro site	Network Type	Performance (at mast)			
		Downlink TCP (Mbps)	Uplink TCP (Mbps)	Latency (mS)	Round Trip Time (mS)
Tenbury Wells	5GPN	323.33	46.99	22.96	45.92
Malvern	5GPN	472.00	42.12	28.36	56.72

As can been seen from the table above the output from the macro sites is capable of delivering the network requirements (See Section 3.3.1.1 Table 3.3: Minimum Network Requirements) to support the minimal requirements for the use cases. These are the maximum possible measures and will be degraded the further the signal travels due to topology and physical obstructions e.g., hills, buildings, and trees as well as other environmental factors, e.g., weather.

3.4.2.2 Layer 2 CPE

Table 3.6 below shows the radio performance measurement (native measurement) adjacent to the CPE where one exists or from a nominative area within the building where one is not present. Only sites using the 5G Private Network are considered.

The ‘A-End’ denotes the location of the patient or the subject of the examination whilst the ‘B-End’ is the location of the healthcare specialist e.g., doctor, physiotherapist, or nurse.

Table 3.6: Radio performance measurement adjacent to the CPE by site

Site	Area	Use Case	End	Network Type	CPE Type	CPE location	Down Link (Mbps)	Up Link (Mbps)	Latency (mS)	RTT (mS)
Old Rectory care home	Tenbury	Connected Worker	A-End Patient in care home	5GPN	5G EE 2021 Wi-Fi	First Floor	368	1	22	44
Tenbury Wells GP	Tenbury	Connected Worker	B-End GPs or nurses	5GPN	N/A	GP and Rural Care Practitioner room (ground floor)	No native private 5G utilised as only 4G signal available due to deployment decision			
Tenbury Community Hospital	Tenbury	Connected Worker	B-End Nurses	5GPN	N/A	Inside in the nurse’s area	120	5	14	28
Tenbury Community Hospital	Tenbury	Health XR	B-End Physios	5GPN	N/A	Inside in the physio’s area	202	18	27	

Hastings Residential care home	Malvern	Connected Worker	A-End Patient in care home	5GPN	5G EE 2021 Wi-Fi	Ground Floor breakout area	32.43	12.29	82.6	165.2
MHSP	Malvern	Health XR	A-End MSK patients (Critical Friends)	5GPN	5G EE 2021 Wi-Fi	nexGworx (for Phase 2 of Health XR)	620	44	9.5	

3.4.2.3 Layer 3 – Wi-Fi coverage from the CPE

The sites listed in the Table 3.7 below represents the coverage provided from the CPEs. Only sites that provide coverage from the 5G Private Network and are defined 'A' ends for the connected worker use case are recorded.

Table 3.7: Coverage provided from the CPEs

Site	Area	End	Network Type	CPE Type	CPE location	CPE Wi-Fi coverage comments
Old Rectory care home	Tenbury	A -End	5GPN	5G EE 2021 Static router via Wi-Fi	First Floor	Single 5G router covers most required areas
Hastings Residential care home	Malvern	A -End	5GPN	BT deployment is of the 5G EE 2021 static router via Wi-Fi. (not accepted by care home)	1st floor Residential Lounge	Single 5G router does not cover more than 50% of required residential rooms on site.
				WCC / nexGworx deployed 3 x 5G EE mobile routers via Wi-Fi (accepted by care home)	Mobile routers are taken around with the headset when in use	Final deployment to Hastings Residential utilised 3 5GPN mobile routers (one for each floor and each headset)

NOTE: There is a report (Appendix P) Network Data by Type and Testbed, which shows the signal strength tested by each of the residential or operational rooms at the B-End both as data and heatmap; and is further explained in Section 7.

From Table 3.7 above it can be seen that each site requires specific understanding of coverage and number of CPE devices required to the provide a complete guaranteed coverage.

In the case of Hastings Residential care home due to the size of the building and the number of physical obstructions (e.g., walls and floors) it is not possible to provide full coverage of the building using one CPE. Whereas in the case of Old Rectory care home the construction of the building provided less obstructions allowing for almost full penetration of the building with the one CPE.

Those deploying to a site need to map the patient flow and work with the location to determine the best option for deployment. Users of the technology should not be

expected to understand the parameters of a network, or the devices being used. Therefore, a practical solution should always be designed and not a technical solution.

3.4.2.4 Using a combination of mobile deployments to deliver mobile connectivity to the trial sites

Below is a summary of the network utilised for each site:

Table 3.8: Identifies which type of network serves each trial site

Site	Area	Network Type	Use Case	End	Network Access Delivery
Haresbrook Park	Tenbury	Commercial 4G	Connected worker	A-End	4G via Wi-Fi routers
Old Rectory	Tenbury	Private 5G Commercial 4G (initially)	Connected worker	A-End	5G via Wi-Fi router 4G via Wi-Fi routers
Tenbury Wells GP	Tenbury	Private 5G	Connected worker	B-End	Via NHS network or 5G (native via tablets)
Tenbury Community Hospital	Tenbury	Private 5G	Connected worker	B-End	Via NHS network or 5G (native via tablets)
Tenbury Community Hospital	Tenbury	Private 5G	Health XR	B-End	5G via Wi-Fi router
Howbury House	Malvern	Commercial 5G	Connected worker	A-End	5G via Wi-Fi mobile router
Malvern Health Centre	Malvern	Commercial 5G	Connected worker	B-End	Via NHS network or 5G (native via tablets)
New Court Surgery	Malvern	Commercial 5G	Connected worker	B-End	Via NHS network or 5G (native via tablets)
Malvern Community Hospital	Malvern	Commercial 5G	Health XR	B-End	5G (not progressed as Phase 3 abandoned)
Hastings Residential	Malvern	Private 5G	Connected worker	A-End	5G via Wi-Fi mobile routers

The selection of the network used at each site highlighted in Table 3.8 above is basically down to the best coverage obtained to support the use case. This could be attributed to:

- Proximity to the radio site.
- Penetration of the radio signal.
- Availability of 5G services.
- Alignment with Wi-Fi networks already in place within the site

3.4.3 Mobile backhaul

3.4.3.1 L2 Ethernet connection between MHSP and Tenbury Wells Exchange – nexGworx

Initially, the connection was reported as a successful install. However, the ability to test the connection was limited to ping testing by Openreach engineers once the circuit was 'lit up'.

These results were purely indicative, and no actual data could be recorded / reported until modems were connected at each end of the entire infrastructure connection (Tenbury Wells RAN to core).

The final throughput capability of the Layer 2 Ethernet connection was as described above. The network performance, even with multiple user devices connected to the network, did not reach a level that would have impacted the performance of the connection.

3.4.3.2 On-site connection between MHSP radio and MHSP core – nexGworx

This connection had no alterations to it and although some radio head enhancements took place for coverage range, the fibre operated as it had done previously. Being able to perform low latency, high bandwidth data flows from the MHSP RAN equipment from outdoor to the Ericsson Core located in MHSP Phase 3 building.

3.4.3.3 Tenbury Wells Exchange to Tenbury Wells farm – Airband

Airband tested the connectivity of the optical fibre connection from the exchange to the cabinet at the monopole by using a calibrated exfo testing machine and results showed light levels within tolerance levels as list below:

OPM (Optical Power Meter) Results

The results below show that for each fibre its wavelength and the corresponding power level measurement highlighted in green. The wavelengths listed in the OPM Pass / Fail Thresholds shows that measurements all sit within the min/max absolute power tolerances of -28 to -5 dBM.

Table 3.9: OPM (Optical Power Meter) Results

OPM Results

Fibre ID	Wavelength (nm)	Measurement (dBm)
F9.1	1310	-7.15
F9.2	1490	-8.00
F9.3	1550	-8.73
F10.1	1310	-7.12
F10.2	1490	-7.94
F10.3	1550	-8.66

OPM Pass / Fail Thresholds

Wavelength (nm)	Absolute Power (dBm)	
	Min.	Max.
1310	-28.00	-5.00
1490	-28.00	-5.00
1550	-28.00	-5.00

3.5 Impact of the results including benefits

3.5.1 Mobile backhaul

3.5.1.1 L2 Ethernet connection between MHSP and Tenbury Wells Exchange – nexGworx

A consistent element within the entire infrastructure from the Tenbury Wells 5G broadcast mast site to the core at MHSP, this leg of the connectivity between postcodes WR15 8AP and WR14 3SZ which is (approximately 40km), represents the majority of the distance covered by network cabling and as such requires resilience and industry leading service levels.

As a fixed connection on the major Openreach network, with Layer 2 functionality this type of technology is fully understood by the partners who design, commission, and maintain it. As the engineering resourcing, pricing, and ordering is within controlled frameworks, its use for connecting locations across the network for backhaul connectivity (as such) will remain instrumental in deploying rural cellular networks of the future.

3.5.1.2 On-site connection between MHSP radio and MHSP core – nexGworx

Peace of mind is provided by building resilient local infrastructure on enterprise sites. Represented here is a solution that has been deployed with future enhancements in mind.

Increased traffic from local 5G Testing within the MHSP (approx. 10 user end points at a time) to wider Malvern coverage of around 2km, with the potential to carry +20 additional user end points from this project, has not created any concerns over capacity and therefore no adaptations or upgrades were required. This saved time and expense when planning for use of the MHSP macro.

3.5.1.3 Tenbury Wells Exchange to Tenbury Wells farm – Airband

Providing the project was deemed successful, it could benefit Airband by being able to contribute to Airband's existing assets for a rental fee.

3.5.2 RAN

Dependent of the coverage offered it can be seen that the sites were supported by either 4G, 5G private network or 5G commercial network. Parallels can be drawn with that of any mobile offering whereby the service in terms of speed and latency has to be balanced with availability based on the penetration and location of the radio signal.

To guarantee a service over a specific area will require a host of various services or networks. This can also be extended to adoption of service provided (where appropriate) by fixed broadband/ethernet connectivity already existing onsite.

As laid out in the Use Case Low Level Design (LLD) the Health XR use case requires high speed connectivity. Theoretically the 5G mobile network offers the

speed and latency capable of sustaining the demand on data from a public wireless technology.

Without a 5G network the only other solution available to deliver the service is fixed broadband / ethernet services. Although there is a lot of activity occurring to deliver broadband services to rural areas there is no guarantee the patient themselves have a fixed broadband connection (or alike) to enable a remote diagnosis to be performed. But for this service to be exploited coverage is vital to enable high end mobile data delivery.

As a proof of concept this project has provided the opportunity to understand that there is not necessarily a single solution to deliver a service. It has provided the network provider with an insight into the end user experience of a given solution. For the case of care homes providing 100% internal coverage from the macro site is not guaranteed and will require the deployment of CPEs to guarantee service. Even if this is achievable it maybe the end devices being used may not have the capability to support a test PLMN, so Wi-Fi is the only way to access the network.

However, it needs to be considered how these CPEs interact with other access points already in place as conflict between them can cause the networks to crash. Where a single CPE does not broadcast Wi-Fi across the whole estate, the use of network Access Points should be considered to extend this range but still utilise a single Service Set IDentifier (network's name - SSID). This will avoid the user having to select another Wi-Fi network.

Deployment of a dedicated private 5G network may not be a viable solution to provide coverage to a dispersed clientele (e.g., patients in their own homes), but for those looking to provide a local coverage with a secure network delivering a baselined service this could offer the following benefits not afforded by a public network:

- Exclusive access to the network and services
- Exclusive use of bandwidth offered
- Dimensioned to support five use cases in use simultaneously
- Limited to only use cases so won't be impacted by subscribers utilising high usage streaming products
- Only a given number of subscriptions can access the network
- Unimpacted by large subscriber migrations e.g., holiday traffic, concerts, etc

3.5.3 The benefits of Health XR over 5G

The benefits of the Health XR app can be seen in Section 7.5.2.

3.6 Key learnings

3.6.1 Core / RAN network

The selection of a vendor supplier for emerging technologies does pose a risk as their progression along the delivery roadmap is not guaranteed. Waiting for the technology to become established would lead to delays in entrepreneurs developing applications, services and devices which may exploit the network.

When selecting a hardware vendor, the timescales to deploy the same equipment into BT Labs to facilitate testing need to be considered.

Establishing working relationships with new and existing partners to understand their culture and processes in order to manage expectations. Going forward, working with these partners will become easier as the protocol and timeframes are fully understood.

Close alignment of the Use Case Low Level Designs (LLDs) and the Network LLDs need to be considered to ensure that any risk / failure to deliver network coverage or service is clearly communicated so that the impact to the trial can be mitigated.

Delays in the deployment of the trial had resulted in change of personnel engaged in the project thus impacting on the understanding of the rationale for decisions. It would be beneficial to maintain the same agents involved in the project and to avoid delays in the rollout.

Due to the service provided to the end user within the use cases not being optimal and practical, this led to dis-engagement by those users and provided more of a challenge to re-engage with. Further details can be found in Section 7.6.4.2.

3.6.2 Mobile backhaul

3.6.2.1 L2 Ethernet connection between MHSP and Tenbury Wells Exchange – nexGworx

Planning activity early on in the process with Airband and BT / Openreach ensured that the complex product was ordered correctly and in such time that no delay impacted the RAN deployment schedule.

Upon evaluating the success and challenges of the deployment of this connection, there is a limited amount of information that can be gleaned.

The connection was ordered as a BT product that sits within the Openreach governance / process. Therefore, any activity that occurs within said governance / process is not shared with nexGworx or the project who act as the customer in this relationship.

As the termination point (B-End) in Phase 2 building in MHSP is a Openreach order location, this demarcation and presentation type is fully understood by both Openreach and the Estates Team onsite at MHSP who patched the connection across site, as required.

This cannot be said at the Tenbury Wells Exchange; where the connection presentation type, location and patching activities are conducted less frequently.

In addition, when a fault occurs across the network in its entirety, the two less transparent areas are the Local Fibre into the A-End exchange and the ethernet presentation at the same location.

It would be prudent if the Local Fibre supplier, who is completing the activities to bring these connections together, in this project Airband, placed the order for the

Layer 2 Ethernet. It would therefore ensure that communication on fault assessment, demarcation acceptance and connectivity planning would no longer be through a third party.

3.6.2.2 On-site connection between MHSP radio and MHSP core – nexGworx

The fibre connection was deployed with future developments in network performance being accounted for. It provides justification that previous specifications were made correctly and therefore encourages other network data cabling specifications to be designed in the same way.

3.6.2.3 Tenbury Wells Exchange to Tenbury Wells farm – Airband

Closer consideration is required for higher capacity back up UPS and batteries should the mains power go off. A better understanding is required of the power requirements for the kit as the breaker had to be upgraded after the initial installation (from 3A to 16A).

A clear line of responsibility and demarcation points need to be established for when issues arise. When there was an issue proving the connectivity from the exchange to the monopole, it was hard to pinpoint where the issue was and whose responsibility it was to fix it.

More detail in the LLD to understand cable requirements, SFPs and also, whether anti-climb and cable management was available on the structure.

There were certain challenges when working with other partners:

- Airband were required to apply to Weston Power Distribution (WPD) for a connection to the cabinet. This was a one-off request and small revenue; it took a few months for the connection to take place. Airband applied for the connection on 18 April 2021 and did not receive a quote until 18 May 2021. The actual connection did not take place until 15 October 2021.
- As standard, Airband apply for unmetered connections but as the 5G equipment required a 2kw load the connection required a metered connection which added additional complexity.
- WPD also required their own wayleave from the landowner to carry out the works adding additional time to the connection date.
- Airband then encountered further delays when trying to get a meter fitted. As the market was so volatile at the time, when they received an offer by the time they had the paperwork signed, the offer was often invalid and had to be re-drawn. In the meantime, Airband had to look at alternate power options.
    - The first alternative was looking at an onsite generator. However, as the generator had to run overnight without the need to be topped up, and also had to have the ability to run continuously it had to be quite large. As the location of the monopole was fairly rural this presented difficulties with physically dropping the generator on site.
    - Airband opted to temporarily tap into the private power supply existing on the farm in the barn adjacent to the monopole. This required further negotiations with the landowner and a new agreement to be drawn up.
- When laying the fibre from the exchange to the monopole Airband came across several blockages within the existing ducting.

- Airband then required a road crossing which meant the need for complex traffic management and permits. If ducting could be proven earlier in the process and blockages cleared, this would speed up the laying of the fibre. Unfortunately, it is not possible to identify blockages until such time that fibre is being blown through ducting. Collapsed ducting needs to be identified and once identified then possibly require unblocking, new ducting, or alternative traffic management.

4 Deploying 5G in Rural Areas: A Case-study

4.1 A new model for rural delivery introduction and hypothesis

It is widely recognised that the growing demand for data and improved digital connectivity is only projected to rise. The demand transcends both 'static' fixed line connectivity and the expectation for 'connectivity on the move', that is largely supported by cellular mobile connectivity. Mobile data consumption rises each year, the average monthly data use increased by 27% between 2019 and 2020. Also, the way end users access their devices, whilst connectivity is expected on the move there is a trend in 'static' use of mobile technology, from users preferring to use their mobile connection whilst at home, in the office or at another other location; households and businesses using mobile solutions as their primary or back-up fixed connectivity requirement and of course a growing number of connected sensors and equipment.

The importance of mobile connectivity to rural areas is acknowledged in the introduction. A Commons Library Briefing Paper (6th April 2022) provides background context on the state of 'Rural mobile coverage in the UK: Not-spots and partial not-spots', providing a solid perspective on the challenges facing many rural areas and Government targets around mobile connectivity, specifically citing that the Levelling-Up White Paper included two targets for mobile coverage by 2030. First, that 4G mobile coverage is available nationwide, and second, that the majority of the population has access to a 5G signal. (N.B. The Government said the 5G target will be reconsidered as part of its forthcoming Wireless Infrastructure Strategy).

Previous experience of new infrastructure deployments by the Mobile Network Operators (MNO) have seen urban areas covered first, with rural areas following in behind, or not being covered at all, as an example the Ofcom Connected Nations 2021 report, highlights in September 2021, 81% of premises had 4G data coverage and 93% of premises had indoor voice call coverage from all four mobile operators (EE, Three, O2 and Vodafone) in September 2021. That 92% of the UK landmass had 4G coverage from at least one operator and 4% of the UK landmass had no 'good' mobile signal at all. This being around a decade on from the deployment of 4G networks in the UK.

Local data gathering through drive, walk and rail mobile coverage assessment trials in Worcestershire in 2017 and 2019 identified that when compared to Ofcom expected coverage reports, found that the coverage was actually less than the modelled coverage suggested at the time.

Recognising the challenges of 'rural deployment', previous experiences of earlier generation mobile rollouts and the upcoming 5G deployment across the UK, the WMR5G project set out to explore if by working with Fixed Wireless Broadband providers and utilising their assets it might be possible to increase the speed of deployment in rural areas and reduce both capital build cost and ongoing operational costs of managing the infrastructure estate.

To support this thinking, data was collected across a small number of infrastructure assets during the planning and build phase of the project and compared against a known 4G rural deployment elsewhere in the UK. A desktop planning exercise was undertaken to understand how an MNO might utilise fixed wireless assets in a theoretical 5G deployment across a 'case study' area.

4.2 A Mobile Network Operators (MNO) vision to deploy 5G across the UK

As an MNO and partner contributor to the WMR5G healthcare proof of concept, BT were invited to provide a summary of their strategy, challenges and opportunities relating to nationwide 5G deployment.

BT are committed to addressing rural connectivity and are taking part in a Shared Rural Networks approach to help extend coverage to around 95% of the UK. These combinations of mobile and fixed infrastructure are being designed to ensure that rural communities enjoy better communications. To extend mobile coverage BT's mobile network, EE, is driving 4G connectivity deeper into rural areas, adding over 4,500 square miles of new signal by 2025.

The new 700MHz 5G spectrum, recently secured in Ofcom's auction, will be deployed across most EE sites, offering stronger indoor and wider rural coverage. Redditch, Morecambe and Cramlington have been announced as the first UK towns that will benefit, with customers able to access the signal from a growing range of 5G handsets. In addition, BT's increasing role in the deployment of Neutral Host systems, third party infrastructure that can be used by multiple networks, will support better 4G and 5G coverage in busy environments like airports, stadia, and campuses.

The following press releases provide further detail and explanation of BT's mobile coverage strategies.

- EE to offer 5G solutions across the entire UK, as BT Group unveil new mobile and convergence ambitions
- Our efforts to tackle rural coverage are gaining momentum (bt.com)]

4.3 A Case-study: Ludlow, Tenbury Wells, and adjoining area

The WMR5G rural health and social care case studies utilised private 5G networks within the localities of Tenbury Wells and Malvern. To supplement the findings of this project, BT, Airband and WCC wanted to explore the potential benefits of ongoing collaboration between the partners. To do this, the teams worked together to answer the question – '**would ongoing collaboration between BT and Airband bring improvement to the deployment of 5G coverage in rural settings**.'

To explore this concept, the teams produced a report *West Mercia Network Deployment Desktop Survey - Ludlow & Tenbury Wells Area* (see Appendix E), which selected a sample 10-mile square area between the towns of Ludlow and Tenbury Wells. The collaboration then analysed the current methodology and predicted coverage that would be achieved by a sole BT deployment. This detail was recorded, with the analysis then repeated, this time incorporating the existing Airband cellular infrastructure within the area. A comparison of the two models was then undertaken to estimate the potential improvement that would be realised due to asset sharing.

The case study established that by utilising a shared infrastructure model, 5G coverage could be increased to 85% in the rural area between the towns of Ludlow and Tenbury Wells. This represented a 2% performance improvement when compared to a single MNO deployment.

Throughout the course of this project there have been further studies undertaken to explore the potential benefits of asset sharing and reuse of existing fixed wireless infrastructure.

4.4 Findings from the WMR5G testbed network planning and deployment

At the outset of the WMR5G project one of the key aspects of the project was to explore if a new model for deployment of 5G in rural areas, through the utilisation of existing ‘fixed wireless’ assets, does or does not have an impact on the deployment timeline and costs.

WMR5G chose to identify a number of metrics to compare the WMR5G deployment against a known baseline, these metrics are included in Table 4.1 below.

To establish a baseline the capital and operational costs and deployment time taken of a known 2018 / 19 rural deployment of 4G mobile infrastructure, from elsewhere in the UK. This deployment formed part of an MNO’s solution as part of a Building Digital UK (BDUK) project. ‘Target’ figures were established based upon an initial expected benefit of circa 10% of the baseline.

Due to changes in the WMR5G project plan, only one new mast site was built as part of the project. However, in line with the original plan, five sites were originally identified and progressed through the identification, acquisition, and planning phases to the point at which infrastructure build activity could commence. Two additional sites were considered but not progressed. The five sites ranged from a ‘greenfield plot of land’ and ‘wooden telecommunications poles’ through to ‘monopoles’ and ‘lattice masts’.

It should be noted the site chosen to be built as part of the WMR5G project was a ‘greenfield’ site, therefore the ‘site build’ and ‘site installation’ in the figures apply to the Tenbury Wells mast site only. It should also be noted that the ‘site build’ and ‘site installation’ costs and days taken, associated with a ‘greenfield’ site, would be assumed to be higher than the costs and days taken, associated with a site that already had a suitable mast or a site only requiring a mast upgrade (e.g., having

suitable power, backhaul, concrete base, compound etc.). The site agreement and planning costs and timescales were taken across all five sites.

For avoidance of doubt the Malvern mast utilised as part of the WMR5G project was not an Airband asset and does not form part of these figures as neither the planning nor build of the mast would be reflective of an operator's time or material cost. The 'site installation and commission cost' is provided as a reference point only as 'costs incurred to the project'. There was no 5G RAN baseline set, as the figures were not made available to the project, nor is it an accurate representation of 5G RAN equipment cost as the radio equipment was provided on a 'lease basis'. Finally, due to the change in project partner, network design and operational model, the OPEX costs, were not applicable as the network was not used commercially by the MNO.

Table 4.1: Summary of Baseline, Target and Actuals for Infrastructure Planning and Build

Metric	Baseline Figures (cost / days)	Target Figures (cost / days)	Cost / days within project	Location(s) within project
Deployment cost (CAPEX) - Site Agreement and Planning Application (£)	£7,068.00	£6,714.60	£2,000.00	Average over 5 sites planned
Deployment cost (CAPEX - Site build (civils, power, backhaul) (£)	£37,805.74	£35,915.45	49,089.61	Tenbury Wells
Deployment cost (CAPEX) Site Installation & Commission (£)*	N/A	N/A	£138,775.00	Tenbury Wells (75% of total) Malvern Hills (25% of total)
Maintenance cost (OPEX) - Rent and Rates (£)	£7,054.76	£6,702.02	N/A	N/A
Maintenance cost (OPEX) - Backhaul (£)	£1,111.11	£1,055.56	N/A	N/A
Deployment time (days) - Site Agreement and Planning Application (days)	247.6 days	235.2 days	100 days	Average over 5 sites planned
Deployment time (days) - Site build (civils, power, backhaul) (days)	31.6 days	30.02 days	30	Tenbury Wells
Deployment time (days) - Site Installation & Commission (days)	61.4	58.33 days	32.4 days	Tenbury Wells

Based on these figures, the greatest time and cost efficiencies can be summarised as:

- The CAPEX costs associated with site agreement and planning applications could be reduced by over two thirds, whilst the time taken to complete this phase could reduce by over half,

- The deployment time taken to install radio equipment and commission the site could also be almost halved.

Whilst not included in Table 4.1 above, the CAPEX deployment cost associated with site build, civils, power and backhaul (excludes RAN equipment) was c.20% higher than the baseline data. This is not unexpected, as noted above, a greenfield site was chosen, therefore there were no efficiencies linked to this phase. Speculating, the increased cost, may be linked to inflationary aspects of materials and labour, as the baseline data is now c.4 years old; alternatively, the cost may be linked to the fact MNOs can obtain lower material and build costs associated with procuring at scale.

The success rate of progression from the site location / acquisition, wayleave permission and planning to reach the 'ready to build' stage was 100%, which is unheard of in a traditional commercial cellular deployment. Avoiding unnecessary cost and time on sites that do not progress is another unmeasured benefit of re-using fixed-wireless assets.

Recognising the limited datapoints available, the potential for significant reductions in timescales and costs, particularly associated with the 'site agreement and planning' phase of the deployment, are clear.

When identifying a 'preferred' site for a new mast there are a number of factors to consider, some of which re-utilising an existing 'fixed-wireless' site can help address, these benefits were instrumental in reducing the cost and timeline we saw in 'site agreement and planning' within this project, including:

- **Land availability** – The benefit of Airband owning or knowing the availability of the site, reduces the need for land searches, 'land ownership' searches, making cold contact with landowners and negotiating land purchase or rent with those unfamiliar with telecommunications infrastructure.

- **Land access / wayleaves** – Required for both build and operation of the five sites, through their existing relationships, Airband already had a set of wayleaves in place, largely removing the need for this difficult process of identifying the landowner, agreeing access rights, and avoiding outright refusal. Minor amendments were required to be made to these wayleaves in order to include use of cellular equipment on the wayleave and it was identified at least one site required an amendment to the 'timeline for notice to access site' to meet Service Level requirements of an MNO in a commercial environment. If other 'fixed-wireless operators' were considering making their assets available to MNOs in future, a recommendation could be to review their wayleave template and existing wayleave agreements to meet the requirements of an MNO, in advance of promoting their assets to the MNOs, further reducing potential delays down the line.

- **Planning permission** – The electronic communications code (ECC) grants rights / powers to registered operators to deploy new equipment e.g., masts (up to a certain height) and cabinets, and upgrade height and width of existing masts; in some instances without the need for planning permission under

‘permitted development’ or through a ‘prior approval’ process which is shorter than a full planning application. These rights dramatically reduce the timeline and potential uncertainty in a cellular network deployment. In addition, when masts already exist, communities are less likely to object to a site upgrade than a new site entirely, although this is not always the case. Whilst these powers apply to the MNOs and agents acting on their behalf they can apply to fixed-wireless operators, including Airband too. By upgrading an existing fixed wireless pole or mast, often means taller masts can be deployed with less planning process required over a new ‘greenfield’ site. It should be noted that whilst planning permission can be reduced through this deployment method, it remains important to reputation to engage with local communities; Airband’s relationship with and knowledge of local areas also means local stakeholder engagement has often already occurred and difficult stakeholders may have been identified. The benefits of utilising existing assets are amplified in areas of outstanding natural beauty (AONBs) and their immediate surroundings. The recommendations for ‘fixed-wireless operators’ would be to ensure they are registered as having ‘operator rights’ within the ECC.

- **Power** – Access to an economic power supply is an important factor in siting a mast, the majority of fixed-wireless assets already have a power supply to them. However, not in all cases. It is also important to identify the rating of the power supply and type of connection as some fixed-wireless sites require less power than ‘cellular’ sites, so may still require upgrading. In addition to ‘cost’ providing power to a site can also cause significant delays to deployment timescales (power company delivery timeline and access to highways / streetworks), having a supply or duct in place can reduce these timelines significantly.

- **Backhaul** – As with power supply, having existing fibre backhaul to a site reduces cost and risks to delivery timeline. Another benefit of ‘fixed-wireless’ operator owned infrastructure may also be the fixed-wireless backhaul solution if fibre provision is too costly.

As stated above, the fact a ‘greenfield’ site was the only site to progress to deployment, due to the ‘descope’ of the overall WMR5G project, it has limited the project’s ability to provide hard evidence the deployment costs of a mast upgrade in height / width, or the existing presence of ‘power’ and ‘backhaul’ would be less than a new ‘greenfield’ build. In fact, the costs incurred in the project indicate this mast build cost more than the average cost baseline data suggested. We surmise that the additional costs found may be linked to inflation or indeed lower costs associated by the purchase power of larger MNOs. It is important therefore, should an MNO work with a fixed-wireless provider that conversations tale place regarding any existing commercial arrangements, call-offs, or access to preferential rates for equipment or labour costs.

However, based on the Airband estate provided, the WMR5G project takes a reasonable assumption that for existing sites requiring only an upgrade to host ‘cellular 4G / 5G equipment’ there would be reduced costs and improvements in timeline to deployment associated with:

- **Use of existing footings / foundations / mast base** – in some instances, it is recognised that new bases may be required to support additional load of 4G and 5G equipment
- **Masts** – In some cases the existing masts were already high enough to deliver coverage requirements and had capacity to take the additional load of 4G and 5G equipment – which would have the biggest impact on cost and timeline to delivery. In most cases across the estate the poles/masts would require upgrade, for some this would be 'bolt on' sections, for others, ground up rebuilds, with benefits/efficiencies dependent on the level of upgrade required.
- **Existing base station cabinets in place** – Appropriate cabinets often existed at the base of the fixed-wireless masts to host required 'cellular equipment'.
- **Power supply / backhaul** – Same points associated with planning costs, for build, not only reducing timeline for delivery but also cost of upgrade
- **Environmental benefits** – Re-using an existing site / asset is likely to have a lower carbon and ecological impact than building a new greenfield site

4.5 Operational efficiencies and opportunities linked to fixed wireless asset usage.

At the outset of the project, other benefits of an MNO working in partnership with a local fixed-wireless operator were identified, unfortunately due to the de-scope within the project, these were not able to be explored. Specifically, we believed that there was an opportunity for MNOs to work with fixed-wireless operators by accessing the fixed-wireless operators engineer base. This could include training the fixed-wireless operators engineers to work on cellular equipment and get necessary vendor accreditation. The idea being it helps build the necessary engineer base and specifically in rural areas will assist in improving issue-resolution response times.

4.6 Understanding the case-study and findings in a wider UK setting

MNOs will certainly continue to review options that will allow them to accelerate the deployment of 5G connectivity in the most effective ways, clearly from a commercial perspective, whilst equally looking to limit the impact on the environment and local populations within the desired geographies.

The above referenced case study took a sample area and explored the potential benefit that could be offered to an MNO (BT) if they were able to leverage existing infrastructure owned by a third party (Airband). Full results and methodology of the exercise are detailed within the report, however at a high level the report concluded that only marginal benefits could be achieved through a sharing of assets in the selected area.

The main rationale for these findings is the proximity of the BT and Airband assets within the radius of the selected area. The network infrastructure for both organisations are located within a small distance of one another. As a result, there is limited benefit associated with the sharing of assets when in effect the network coverage broadcast areas overlap, therefore negating any potential advantage.

It is certainly worth reiterating that these findings were observed in a limited sample area. It is certainly the opinion of the author of this report that the outcome could vary significantly had another sample area been selected. If we assume a test radius where existing BT and Airband assets were distributed, it is conceivable to expect there being a high probability that a shared asset approach would allow increased commercial 5G coverage to be deployed at a reduced cost to the MNO. This would mainly be achieved through the removal of the costly and time-consuming process associated with the expansion of a physical mast network. Through a shared or neutral host model, an MNO could reduce or in some cases avoid planning permission applications as well as the cost of deploying and maintaining an additional physical asset.

As MNOs continue to scale commercial 5G deployments, shared asset utilisation should not only be limited to third party fixed-wireless or mobile operators. There is huge potential to be realised through agreements with a variety of land and facility owners to allow cellular coverage to be distributed through existing infrastructure. Examples of such being railways, local authorities, and other public sector locations.

4.7 A new model for rural delivery conclusions

Notwithstanding the acknowledged limitations of our case-study and cost comparison exercise in terms of statistical validity, the project believes that considering the large number of existing fixed wireless assets across the UK, there would be efficiencies, in both the cost and time of network deployment, from reusing them. Recognising that in some cases the existing fixed wireless sites may be close to existing cellular sites, due to the fact they have been situated to serve areas of population, in these cases, is there an opportunity to converge sites.

There were significant time and cost benefits seen in the planning phase of a mast build and it should be noted the additional costs seen in the greenfield mast build were not indicative of the benefits that would be associated with a fixed-wireless asset upgrade. Despite not being able to demonstrate the operational efficiencies and potential benefits of MNOs working with fixed wireless operators, we still believe in the principle of the hypothesis that efficiencies and new improved service models could be found.

To address the challenges of making the business case for ubiquitous rural mobile coverage pay, the re-use of fixed wireless assets would only be part of the solution. Anecdotally, the project is of the view that the ongoing work with open-ran and suggestions of neutral host models will also have a significant part to play as will the benefits seen from Project Gigabit / BDUK progress into delivery of fibre networks into hard to reach areas. Whilst the use of public sector infrastructure, such as lighting columns, will have limited benefits in truly rural spaces, as they are often not present in these areas, some of the more densely populated small towns in rural areas may benefit. Potentially the hardest to reach areas may be reliant on low earth orbit (LEO) or mid earth orbit (MEO) satellite, with more work being done on how receivers could be made more useable on the move or how it could be used as backhaul to support a wireless network at the edge, with other mobile solutions coming from Wi-Fi enabled services such as Voice over Wi-Fi. Other key

considerations include the availability of spectrum in rural areas, explorations how ‘private networks’ may fill some gaps in ‘public’ coverage and how public and private networks may operate together effectively for public services, businesses and residents in rural areas. The project believes there is a funding need and more work needed to be done, to fully explore the challenges identified above and that DCMS, working with regulators, industry, and local public services, is best placed to support the way mobile connectivity is delivered in rural areas.

A number of public sector partners within the project also raise the concern that there are significant discrepancies between the modelled coverage reported by Ofcom and operators for public 4G, 3G and 2G, that are overly optimistic, compared to the coverage and service that is experienced by end users on the ground. The evidence to support this statement can be seen from extensive vehicular and walk testing in Worcestershire prior to the project, community crowd-source data and wider stakeholder feedback received. It is important for both the ‘Shared Rural Network’ and future rural low-band 5G deployments to recognise these discrepancies, challenge the modelled data and address the issues to improve the rural connectivity experience.

5 Customer Premises Equipment – CPE Technical Details Supporting the Use Case trials

This section will look at the Customer Premises Equipment (CPE) that had been identified to allow connection to the private 5G, as well as the commercial 5G and 4G. It will also expand on the hardware and applications that were required to successfully run the use case trials, which were Connected Worker and the Health XR app.

5.1 What is CPE?

CPE is an acronym for Customer Premise(s) Equipment, which refers to any piece of connected equipment that is used for accessing the Internet or generally accessing services on a provider network, whether directly or indirectly connected to that network. The CPE(s) will sit on the customer side of the network and can be a demarcation point between the provider network (WAN) and the customer’s home network or (LAN).

5.1.1 Why was there a requirement for routers?

Within the use cases the drive was to utilise the 5G network natively. However, this was not possible due to:

- Apple products used in the iOS developed Health XR app required a Config file to enable it to work natively on a private 5G network. Therefore, as this was not forthcoming, the only solution was to connect the apple device to a private 5G connected router via Wi-Fi.
- The RealWear HMT-1 headset available at the time of the project did not have native 5G abilities (4G was available as an optional extra) and therefore the headset had to be linked to a private 5G connected router via Wi-Fi.

5.2 CPEs used

5.2.1 Routers (static and mobile versions)

The routers deployed for the Connected Worker were:

- **the 5GEE 2021 static router** which is considered the best in its class by the Senior BT Vendor Manager supporting the project where a single static placement could be determined that broadcast with enough signal strength across the whole site.

  This router offers a high gain to enhance better in-building penetration. It also supports speeds as fast as fibre broadband, the 5GEE Home Router will support gaming, streaming, and downloading in Ultra HD and 4K – with average speeds of 146Mbps.

  The router can support 64 simultaneous connections to the internet.

- and **the 5GEE mobile router (**EE 5GEE Wi-Fi) for sites where a single static router did not cover the whole site. They were also deployed in sites where the Wi-Fi broadcast from the static routers interfered with the inhouse Wi-Fi network already set up for clinical systems. See below for technical details.

For Health XR the original drive was to use the Apple devices natively on the private 5G network. However, due to the Config file not forthcoming, it was decided that each device required a 5GEE mobile router. The modem deployed for the Health XR use case was the EE 5GEE Wi-Fi.

- The 5GEE Wi-Fi from EE is a battery powered mobile broadband device that will overcome the issue of iOS devices connecting natively to the network. It also offers portability weighing just 195g and with dimensions of 128 x 100 x 17.9mm it is designed to be carried around.
- It can support 64 devices online simultaneously and support for Wi-Fi 6. It provides one ethernet port to allow one wired connection. It supports an average speed of 150Mbps which will comfortably meet the demands of the use case. With a 30-metre Wi-Fi range the device can be located to optimise the best radio signal whilst enabling connectivity to the IoT device.

5.2.2 Tablets (Samsung Tab and Apple iPad)

The project decided to include the use of tablets within the B-End of the Connected Worker use case, enabling the clinical staff to use the private and commercial 5G. Within Tenbury Community Hospital and GP surgery, Samsung Galaxy Tabs were used and were connected natively to the private 5G network. In Malvern, the hospital and GP surgeries were not covered by the private 5G network and therefore used the commercial EE 5G network. This meant that Apple iPads could be used.

As part of the Health XR use case, the physios used Apple iPads to review the patient's avatars as well as the live sessions.

- In Tenbury Wells, due the private 5G network constraint the Apple iPad had to be connected to a router

- In Malvern, the iPad could be connected natively to the commercial EE 5G covering the sites.

5.2.3 Phones (Apple iPhone)

The Health XR A-End (patients) were provided with Apple iPhones. As these were not able to use the private 5G network without the Config file, each phone was to be allocated a dedicated EE private 5G mobile router. As Phase 3 was not instigated this was not required and an alternative single static private 5G router was used for Phase 2 (described in Section 6.4: Health XR).

5.2.4 Bluetooth speakers

As part of the ongoing trials, it was requested by a GP that we look into a method where the GP could talk directly to the patient, and not through the care home assistant wearing the headset. A Jabra Bluetooth speaker was decided on as the only connection available from the headset was via Bluetooth.

5.3 Hardware and applications

5.3.1 Connected Worker use case

Head mounted cameras provide ‘you see what I see’ capability to field based care workers. This allows real-time connectivity back to the site of clinical expertise and will reduce the need for patient and clinician transport.

5.3.1.1 Hardware

For the Connected Worker use case, RealWear’s HMT-1 headset was used.

- The Connected Worker use case utilised a ‘RealWear’ HMT- 1 headset with a microphone and camera attached to provide a ‘you see what I see’ functionality. The HMT was connected on the network via Wi-Fi over private 5G network. The remote B-Ends (clinician sites) used Laptop / tablets for native connectivity to the 5G private or public network.
- This deployment provided real-time one to one consultation between patients and clinical Specialists. The mobile solution allowed expert clinician consultation in the care home settings. High quality optics with optical zoom enabled wide angle context as well as detail such as skin tone to be discerned. Hands-free operation allows patient manipulation and user convenience for examining and monitoring conditions such as bed sores.
- The RealWear HMT-1 has been the market leader in industrial wearables since its launch in 2018. Purpose built for the modern frontline workforce, it connects the frontline worker to information and expertise needed to successfully complete job tasks safely and efficiently.
- The RealWear HMT-1 requires the recommended bandwidth – 2 Mbps Download speed, 1.5 Mbps Uplink Speed with maximum latency of 40mS. Ideally 5G to deliver high quality video streaming for diagnostics and monitoring from a remote location.
- The RealWear HMT-1 provides the foundation for Connected Worker programmes. It is suitable for use in wet, dusty, hot, dangerous, and loud industrial environments. As a fully rugged head mounted device, it optionally snaps into safety helmets or attaches to bump caps and can be used with safety glasses or corrective eyewear

- The communication between the participants in the use case was executed through the Microsoft Teams (MS Teams) platform. The client on one side connected through the internet and then ultimately reach the 5G private network core, which then connected to the radio network and through a 5G modem to the head mounted camera via Wi-Fi.

Figure 5.1: RealWear HMT-1 product specification

In response to feedback from some GPs, Bluetooth Jabra speakers were purchased and connected to each headset in the Malvern area. The Jabra device was chosen due to the ability to connect via Bluetooth but also because it was enabled to work with MS Teams specifically.

5.3.1.2 Software

MS Teams was chosen by BT as the tool required within the HMT-1 to enable the video conferencing between the A and B-Ends of the trial. MS Teams was chosen as it has end-to-end encryption therefore supports data protection but also because of its familiarity of use with GPs and others.

5.3.1.3 Deployment

A-End Care Home:

1. RealWear HMT-1 headset

2. 5G / 4G EE routers provided by BT:
   HMT-1 headsets connect via Wi-Fi and Bluetooth and for the purpose of this trial Wi-Fi was used.
3. Microsoft Teams account
4. At Malvern care homes the Jabra Bluetooth speakers were also set up with each HMT-1

B-End – Remote clinicians at a GP practice or a community nurse base (or clinician home):

1. Desktop computer / laptop computer connected to GP clinical systems or community trust PAS systems
2. Alternatively, clinicians can also use tablet devices supplied by the project. However, they have no connection to GP clinical systems or community trust PAS systems
3. Microsoft Teams account provided by the relevant NHS organisation

5.3.2 Health XR use case

When the project started there were very few mobile devices which could use 5G, mainly high-end services from Samsung and Apple. VRSS's development team had direct experience of Apple iOS platform.

5.3.2.1 Hardware

- The Health XR app requires the higher quality multiple camera system and depth perception in order to mirror the movements of a patient more accurately. The Apple iPhone 12 Pro Max and iPad Pro models were chosen as they incorporated the LiDAR camera and cellular 5G (in the case of the iPad Pro).
- The Health XR product is hosted on Heroku (AWS), the storage server is hosted on AWS S3.
- The Health XR app requires the recommended bandwidth - 100 Mbps download speed, 100 Mbps upload speed. Ideally 5G as the rational is the need specifically to upload large video content which can take several minutes on a lower bandwidth speed.
- The product uses a cloud back office database, MongoDB Atlas hosted on AWS.

5.3.2.2 Software

- The final software product was built for an Apple iOS platform.
- The product was built using the Unity Games Engine – as a development studio VRSS have a team well versed with Unity – such a games engine allows VRSS to manipulate a 3D character / avatar using extended reality.
- The Application Programming Interface (API) server is built on NodeJS and the key languages used are C# & JavaScript (These are the key languages used by the VRSS development team).
- The product security protocol includes user authentication in the app, all passwords are encrypted with a one-way hash algorithm, VRSS have also included signed URLs with limited time expiration for uploading the live sessions.

- The database allows the Health XR app to record all sessions from the patients as an avatar and then allow clinical leads to draw down these recorded sessions as required. This content being shared by the patient to the clinical leads is avatar-based overlays of the patients. VRSS does not keep any actual video or images of patients either on the iPhone (patient's device), the cloud services or the iPad once the sessions have been downloaded (clinical leads device).

5.4 Key learnings

5.4.1 CPE

Clearly defined scope of works (SOW) is required to ensure what is in scope and out of scope.

Clearer specification on the level of indoor coverage expected to support use cases needs to be clarified early on in discussions and the level of investment required to guarantee coverage.

Full site audits need to be conducted to understand:

- what communications are already in place that needs to be considered, i.e., interference to existing Wi-Fi networks.
- where CPEs can be deployed due to power requirements and connectivity to the cellular network.
- whether a single router device, multiple router devices, access points (AP) networks, mobile routers, native connectivity etc is the best solution.
- tailor the solution to the specific site.

Once an informed deployment plan has been drafted for a specific site, deploy, and then do a full audit of the network, use case devices and associated software before signing off as deployed.

The minimal viable product (MVP) approach for the deployment of CPEs needs to consider the practicality of the end user and how they go about their work without having to power on / off equipment in line with the end user and what is being expected of them. If the requirement is that the end users are using the network deployment and use case devices to provide a clinical service, then the technical solution needs to be revised to a practical technical solution in partnership with the site user.

For example, the technical solution deployed by BT was for a single static tower that had to be powered on and off and moved around during a remote consultation session. This was not accepted by any of the care homes as a practical solution due to:

- the added pressures to the care home staff
- the time taken to relocate the device and setup call again (estimated at least as 5 minutes each time)
- knowledge of the best location to add the device for connectivity purposes by the care home staff

- the amount of equipment, on top of their care home equipment that they would have to move etc

The solution for receiving the broadcast transmission would in practice be upgraded to an internal 5G small cell receiver / broadcaster. Especially where Wi-Fi mesh networks are likely to impact / interfere with existing solutions. This would require site surveys and deployment designs to be conducted and implemented ahead of the network going live.

The project plan was for technical specialists to survey each of the testbed sites early in the project and provide a report on the optimum solution required tailored to each site's access to the network and internal requirements. This type of solution would have potentially increased costs significantly but would have provided a better end user experience and adoption of the new technology.

5.4.2 Apple devices

The Health XR was developed on the iOS platform and could only be used on Apple devices. As the WMR5G project was initially working solely with a private 5G network this meant that a Config file had to be developed and installed on all of the devices being used. As mentioned previously, the end solution, which was a hybrid of public and private 5G and public 4G, allowed the partial use of the devices. Either direct to the public 5G or by connection through Wi-Fi to a private 5G router.

If the app had been developed within an Android platform, this may not have been an issue as seen by the simple change in an APN value within the Samsung Tabs being used for the Connected Worker use case connecting natively to the private 5G network.

5.4.3 Bluetooth speaker

Through the real world trial of the RealWear HMT-1, it was suggested by some GPs that having the speaker close to the person wearing the headset meant that individual had to relay the message to the patient. The GP felt that it would be better to communicate directly with the patient (resident) and therefore a trial of a Bluetooth speaker was done.

While there was no issue connecting the speaker via Bluetooth to the headset, the problems that were encountered were:

- The sound coming through the system via the Bluetooth connection occasionally became 'robotic' and therefore difficult to understand.
- Depending on the distance of the headset from the speaker there could be a slight delay in responses.
- Once the Bluetooth speaker was connected to the headset, the functionality of speakers and microphone moved to the speaker. This was OK in relation to a conversation between the patient and the GP. However, as the headset has voice operated commands – such as "Zoom Level", "Leave Meeting" etc – this became difficult for the person wearing the headset as they were a distance away from the microphone and therefore not always picked up.

6 Health & Social Care Use Cases

6.1 Introduction

In addition to the wider infrastructure challenges identified in Section 2.4, the healthcare industry is having to digitally transform at scale and rapid pace. Subsequently health and care professionals are looking for ways to:

- increase their patients' access to care,
- enable individuals to become self-activated,
- adopt healthy behaviours and action.

With a context of increased demand, only magnified by the impact of the Covid-19 pandemic, the health and care sector required approaches that find more cost effective and resource friendly ways of working to maintain and improve the quality of health and social care without increasing cost.

Fortunately, innovations in digital technology are making it easier for health and care professionals to communicate with their patients. This is breaking down the traditional barriers that can hinder a patient's access to medical care, allowing them to receive relevant information, advice, and guidance remotely. With the help of live video, audio and remote monitoring, patients can now interface with healthcare providers from the comfort of their own home or any other convenient location. This is especially beneficial for those who live in rural communities, who would otherwise need to drive long distances to their local doctor's surgery or to see a specialist.

This journey to a digitally transformed health and social care system is hindered however by a lack of ubiquitous connectivity and leaves rural communities at risk of being left behind. Some of the key "*United Nations Sustainable Development Goals*" (UN, 2019) look to achieve a better and more sustainable future for all.

If, however, our rural communities can address these health and infrastructure challenges, this knowledge becomes valuable to the global economy, as an estimated 45% of the global population (World Bank data) live in rural areas.

The local demographic challenges to Shropshire and Worcestershire can be seen in Section 2.5.

6.2 WMR5G testbed

The WMR5G testbed wished to explore opportunities that benefited both economic growth and population wellbeing, by demonstrating:

- how 5G can be rapidly deployed using existing infrastructure,
- how it can deliver innovative health and care capabilities, and
- to what extent a collaboration between the Anchor Institutions** of local government and health and social care, working in partnership with private sector partners, can bring forward appropriate and affordable solutions to rural communities.

** **Anchor institutions** refers to large, typically non-profit, public sector organisations whose long-term sustainability is tied to the wellbeing of the populations they serve.

WMR5G's intention was to identify opportunities where improvements to health and wellbeing could be achieved. Explicitly their key targets were to:

- Identify SMEs and use cases utilising 5G to deliver health benefits for rural communities
- Establish collaborations between health and social care, industry, and patients
- Support the co-design, implementation, and real-world validation of 5G use case solutions
- Drive the adoption of viable 5G innovations at pace and scale
- Understand the opportunity that private 5G networks present over existing commercial networks

6.3 Use case selection process

Following the successful bid to DCMS (2019), a Health and Social Care Use Case subgroup was established in April 2020. The subgroup consisted of representatives from all partner organisations including clinicians, social care professionals, academics, and digital and useability / accessibility experts. The initial task of the subgroup was to identify use case themes which then enabled the recruitment of UK technology / industry partners to design, deliver, test, and evaluate, innovative 5G-enabled 'digital health and assistive technology' use cases.

The full details of the use case selection process that was followed, together with an overview of shortlisted use cases, are presented in Appendix F. The following **five use cases** were shortlisted:

1. The innovative use of extended reality (XR) to support the remote monitoring of patients for rehabilitation **by VRSS**
2. **Dignio** Methodology & 5G Technology: Demolishing Distance as a Barrier to Quality Healthcare for All
3. **Inhealthcare** Remote Monitoring Platform
4. **Cascade3d** Connected Care uses sensors and videocalls to support vulnerable people in their own homes
5. 5G-enabled wearable video to improve healthcare delivery and save resources in rural community by **RedZinc**

As described in Section 3: Network design including security, the original network partner withdrew from the WMR5G collaboration, which resulted in the subsequent change to the network coverage being offered by the new network partner, BT.

Following a discussion between the Project Board and BT, the following two use cases were endorsed.

- **Health XR**: The innovative use of extended reality (XR) to support the remote monitoring of patients for rehabilitation **by VRSS**
- **Connected Worker**: 5G-enabled wearable headset, providing live video and audio streams, to improve healthcare delivery and through remote consultations save resources in rural community **by BT**

The rational for the above pragmatic decision, in particular the change of technology partner of the connected worker use case, is due to BT's deployment of similar solutions in urban areas such as hospital / community settings in London and Birmingham (Supporting the NHS through Digital and Always-Connected Solutions (bt.com)). The ability to rapidly adapt and scale the proven solution to rural areas has been taken into consideration.

Section 6.4 and 6.5 (below) provide full details of each of the two chosen use cases, together with deployment specifics.

6.4 Health XR

Through the initial selection process identified (see Appendix F), an SME called Virtual Reality Simulation Systems (VRSS) presented their extended reality software with a vision and belief that they could support Musculoskeletal services to address the following perceived problems.

6.4.1 Problem statements

1. Telehealth and telemedicine had limited tools and measures that used tablets and phones with software that enabled video calls. Those solutions in use did not give the doctor or clinician ability to visualise precise data regarding the patient.
2. Assuming usual physio appointments are 30 minute slots a physio can review (and feedback via email to the patient) videos uploaded by several patients within that time. This is where 5G helps as it would enable downloading of videos much more quickly. So, in rural areas it saves both patient travel time, which is on average higher compared to urban areas due to poor transport links, and the physios can manage a higher workload.
3. The pandemic associated with Covid-19 highlighted a need for remote physical therapy monitoring of patients mitigating the health concerns associated with in-patient rehabilitation.

Early indications to the Health and Social Care Use Case subgroup, suggested that the development of a remote monitoring system for patient's health through the creation of a 3D avatar or hologram would have value as the first use case. It would allow the therapist or medical professional to undertake a virtual consultation informed with recorded pre-clinic activity to shape clinical decisions and exercise prescription.

The solution created by the SME used a real-time XR bespoke telemedicine platform for remote patient monitoring initially operating on off the shelf hardware - Apple iPad Pro and iPhone Pro Max with LiDAR. Through the software an augmented view (avatar) of a patient can be used in any place that human motion is desired to be studied, such as in the study and analysis of physical therapy, Parkinson's Disease or in the study of athletes in sports performance contexts.

The Health XR, a '5G Kinesio-visualization' observer system, uses augmented reality on a tablet for real-time interactive kinesiological analytics. The platform combines body tracking in augmented displays with server-based body-pose estimation for real-time AR kinematic analysis.

The app had the following key functionalities:

- Ability for live one to one consultation between patients and clinical specialists
- Opportunities for a patient to record a session and send to a therapist to review through the replication of the patient as a 3D avatar to track progress of each user *(it is the ambition of the SME if the accuracy of the avatar becomes sufficiently robust that an AI solution can review the multiple episodes and report on patient's progress)*
- Ability for therapists to set exercises for patients remotely with supported videos either locally filmed or from central resources.

6.4.2 Technical specification of Health XR app.

For details on the technical specification of the Health XR app this can be found in Section 5.3: Hardware and applications:

6.4.3 Creation journey of the Health XR app

The SME built the app focusing on three key technical development stages of the product:

Stage 1: Track movement and replicate the patient as a 3D avatar

Stage 2: App tracks their motion through the LiDAR enabled camera (using an iPhone or iPad)

Stage 3: The therapist is able to view the patient representation on a tablet through the virtual clinical operating system.

Further details of the technical specification together with system architecture of the Health XR app could be found in Section 5.3.2.

6.4.4 Importance of 5G

VRSS recognised that 5G has the potential for far superior downlink and uplink and lower latency than 4G, enabling faster download and the play of streamed content to begin almost, if not, instantaneously. The SME considered that 5G with these benefits over public 4G, offered the opportunity for a rapid development and deployment of their app. In particular as, with an average consultation time of 30 minutes, if the app required 10-12 mins to download the avatar it was unlikely to be adopted in any non 5G environments. We also found when testing the app over 4G we had increased numbers of performance issues with stuttering, lag, and jerky video, leading to a poor experience of the end users. The use of 5G network will allow for the data loads expected to be handled effectively to meet the requirements of the software.

While higher frequencies, with the approved power levels and devices available to us, we found the 5G signal only travelled approximately 1.5km and as largely anticipated did not pass well through walls and other obstacles. Whilst we did not test capacity, we understand 5G is very good at supporting a large number of simultaneous users. This is important if potential demand from NHS is exponentially

going to increase through digitally transformation programmes resulting in more devices being connected and subsequent increased in data demand.

6.4.5 Equipment to support the 5G context

Hardware deployed:

- Apple 5G iPad Pro (loaned to clinical Leads)
- Apple 5G iPhone 12 Pro Max (loaned to patients)
    - iPhone stand (loaned to patients)

Figure 6.1: Apple iPhone 12 Pro Max and iPad Pro

Various connectivity options were tested using the Apple devices (iPhone and iPad) to provide results that could then be compared:

- Private 5G natively (not actually tested due to unavailable Config file)
- Private 5G via a router (Wi-Fi)
- Commercial 5G natively
- Commercial 5G via router (Wi-Fi)
- NHS's and SME's standard commercial broadband connections (Wi-Fi)

Connectivity was tested in NHS environments using Wi-Fi and in both commercial and private 5G network environments.

The SME's aspiration was to enable both handset and tablet to operate via a native connection (direct through the network SIM on board the device) to the network. However, as the Health XR app had been built on the iOS platform and so could only be run on Apple devices, a Config file was needed to enable the devices to connect to a private 5G network. The requirement for a LiDAR technology function, also heavily restricted possible end user device options.

The project was unable to secure a Config file for the apple devices (due to technical and Non-Disclosure Agreement (NDA) issues with Apple) which meant that both the Apple iPhones and iPads could only be connected via Wi-Fi to a router linking it to the private 5G network. However, there is not a requirement for a new Config file to be applied to the Apple devices if they are natively connected (via a SIM) to commercially available mobile networks. Therefore, there needs to be consideration around the platform any software is built within – Android or iOS – if required on a private 5G network.

Note that through changing the APN values on the Android devices these were able to connect to the private 5G network with minimal setup changes.

A secondary plan for Phase 2 and 3 was explored using private 5G mobile routers for each device (iPhones and iPads) using localised Wi-Fi as no wired (USB-C to iPhone) tethering options could be utilised. This would have enabled the trial cohorts

to cover both Malvern and Tenbury Wells test sites. However, the supply of these mobile routers proved challenging for the MNO and was a factor in the decision to extend Phase 2, over commencing Phase 3.

For Phase 2 to progress a single private 5G tower solution was provided by BT so that the Critical Friends could upload their avatar records when on site at MHSP. This largely limited the cohort trial (Critical Friends) to those based at MHSP.

6.4.6 Implementation and validation journey in real world setting

Adoption and deployment of new technologies in the NHS is widely recognised as challenging both as a heavily regulated market and one that is cautious of technology push overwhelming demand pull. In supporting the SME and its economic aspirations it was also important to

- **Stage 1: Undertake a market analysis and potential patient journey**
  This analysis allowed the SME to firm up exactly what areas of MSK they should focus on for initial prototyping.
- **Stage 2: Engage with stakeholders to confirm demand**
  Through workshops and focus group discussions coordinated by use case
- **Stage 3: Confirm technology and adoption readiness (beyond the initial selection process identified earlier)**
  Following the feedback in Stage 2 (above) further technology development by SME was undertaken
- **Stage 4: Design and revise an iterative development, deployment, and testing plan**
  A three phased new plan has been developed:
  - **Phase 1:** Four sprints to accelerate development and ensure the app was sufficiently robust to move to phase two (critical friends)
  - **Phase 2:** Deployment to convenient sample of critical friends
  - **Phase 3:** Deployment to healthy volunteers from general public in testbed locations.

In planning the deployment and testing of the Health XR prototype in a 5G environment, it was important to confirm the problem statements identified by the SME above, as factors for demand pull rather than pure R&D.

Further details of the above 4 Stages can be found in Appendix I.

At the end of each of the three phases (within Stage 4) above a systematic and shared assessment was undertaken to confirm if the development journey could continue to the next phase (Go / No-Go point) or if further modification to the plan was required. To facilitate this process additional localised support was enabled from the Worcestershire County Council Use Case Product Expert (within the PMO) to the SME.

Throughout Phase 2 (Critical Friends) testing the reliability of the system was monitored, to:

- see the patient avatar in 3D and how useful this was,

- how accurate the handheld device acquired motion data and converted into useful visual and activity,
- how easy it was to record activity, send data and for the therapist to use the data to make decisions.
- How useful the patient management system built into the app enabled the therapist to manage and review exercise and care regimes.

Revisions to the modified plan were required as the connectivity solution in Tenbury Wells could not be facilitated due to unavailability of the mobile private 5G routers. Furthermore, as feedback from critical friends came in, and software issues were raised with stability and ease of use a decision was made to defer Phase 3 – deployment to healthy volunteers from general public to enable longer term data gathering at Phase 2. It is the ambition of the SME to progress to Phase 3 when the final feedback is received following completion of this project.

By limiting the scale of the project to this one location a safe but real-world environment was maintained to validate and de-risk the 5G technology solution, with the aim of supporting and accelerating its potential adoption once stability and acceptability was confirmed.

6.4.7 KPIs of Health XR

In addition to the criteria used to progress through Stage 4 of the implementation plan, the SME have set out their own KPIs which will drive the benefits and commercialisation of Health XR. Furthermore, they inform the revised perceived benefits of the app as the SME look to meet the requirement for registration as a class IIa medical device see https://www.gov.uk/government/publications/medical-devices-software-applications-apps

- High quality of the information delivered between patient and clinical expert. This is at least in part because of the design of the user interface, which replicates good history taking and clinical assessment algorithms. This radically reshapes the flow of the subsequent consultation, allowing for much more time to be spent on shared decision making and collaborative problem solving.
- Quantifiable cost savings for both patient and practises. (less travel and increased efficiency).
- Higher user satisfaction than more traditional methods (both for patient and clinical expert).
- Direct income generated from the product for VRSS.

6.4.8 Company benefit

VRSS recognise this project as an opportunity to invest in Research and Development (R&D) and to shape the development of a new product. The opportunity to gain feedback directly from healthcare professionals, university and digital experts has been invaluable. This feedback has enabled the SME to shape their thinking and has helped the business invest resource in the most relevant areas. In addition to ongoing investment into software development and hardware

the SME have commissioned a medical consultancy practise who are working through the stages required to register the product as a Class A medical device. The business will continue to invest into the platform and look forward to a wider roll out of gigabit connectivity as there is a dependency on high speed infrastructure (cellular and fibre) to be more readily available for this app to succeed.

6.4.9 Initial learning for VRSS

- **The patient (Hardware)**
  VRSS commenced the project looking at a combination of Xsens Motion sensors and full body suit for the patient. In the initial stages of testing this technology with users, and speaking to clinical professionals, it was determined that these IoT solutions would be too intrusive, and the weight of the sensors and movement required to put on the tracking suit would actually be detrimental to the patient. As a result, a new solution was put forward which did not require any physical or wearable technology for the patient. The LiDAR camera on the iPhone 12 Pro Max was determined to be good enough to prototype tracking a human body, recognising basic limb movement. VRSS designed a solution which created an avatar which was overlaid onto a human body – this 3D avatar attempts to replicate any movement the patient made in real-time to be used by a clinical expert to view progress. As explained in Section 2.11.2 the use of an avatar helps with GDPR and data security, as the only data transferred and stored is that of a standard avatar and the movement it makes – there is no personal data stored within the system. Due to the reduced security requirements the overall running of the app will therefore be lower, and this will have a knock-on effect to those the cost of purchase by those using it.

- **The therapist (Hardware)**
  The initial design of the hardware used by the physio or doctor was to be the Hololens smart glasses. However early feedback from end users raised a number of concerns:

  - users felt the smart glasses were heavy on the head and could only be used for short periods of time,
  - they also felt the devices were complicated to use and the limited field of view could actually distract the user rather than support them to make an assessment.

  One platform that staff were more familiar with was the iPad, and therefore the project sourced a 5G-enabled iPad which could be used by clinical staff with very limited training. The Health XR software, along with the iPad / iPhone devices still allowed for the use of an extended reality avatar and remain engaging for the end user.

6.4.10 Revised perceived benefits of Health XR following the 5G pilots

- **Resilience and reliability**
  The use of extended reality (XR) technology has a potential to improve both resilience and resulting reliability for therapists. The ambition is that the virtual

systems tested will be flexible enough to support remote clinical staff, self-isolating patients, and even temporary loss of practice premises (for instance when a practice was taken over as a Covid-19 control centre). For practices with premises spread over a wide geography (such as Shropshire), this benefit extends to the ability to switch resource usage quickly, such as when staff in one area are forced to self-isolate or when staff are moved to different locations. This would also be the base for patients isolated due to flooding.

NHS trusts and newly formed Integrated Care Systems (ICSs) are increasingly under pressure to introduce digital pathways; therefore, this is not a plan B solution. This is a timely testbed with really useful lessons to support addressing ICS challenges.

- **Access**
  VRSS estimate that waiting times could be reduced from three weeks down to one day on implementation of Health XR system across a physio. By designing a digital tool to support communication directly with a patient reduces the need for that patient to have to set up as many face-to-face meetings with the physio. The time it takes to set up a face-to-face meeting and wait for an appointment would then be dramatically reduced by the use of an app based shared communications platform. This reduction is able generate additional benefits: reduced patient complaints on the time taken to access clinics, saving even further time, and improving the experience for both staff and patient.

  It is likely, that on successful implementation that due to reduced travel the patient can save money on transport costs as well as time. Wider benefits are seen as the NHS seeks to enhance their low carbon credentials through the NHS NetZero drive.

- **Time to care**
  Virtual consultations using XR can be beneficial to manage those who are less vulnerable and can be taken off waiting times for acute interventions, by increasing compliance with exercise regimes through the prompts that the Health XR app provides potential for reduced referral and episode length.

- **Improved efficiency and reduced costs**
  Once accuracy and utility of the avatar is confirmed, the use of 5G enables transmission of high-quality images and large data packages which allow for more efficient consultations and decisions to made more quickly. The cost of Health XR app is anticipated to be low since it is built on existing technology which enables scalability once effectiveness is proven. For this pilot the SME have used Apple products, however it's recognised that after proof of concept and a wider rollout is required then further work to develop an android version, which would mean that the app would be available on the two main platforms.

- **Private 5G networks**

Within the project it was seen that a Config file had to be created for the Apple devices used to connect to the private 5G network. This was in comparison to the Android devices used where a quick APN change enabled the device to connect. Once the proof of concept of Health XR has been deemed successful and the SME develops an android version, this should be easier to set up within a private 5G network.

6.4.11 Next steps for VRSS

From a VRSS company point of view the product is key to their product development in healthcare, it will support them in the following areas:

- with a possible patent application, the SME have started the process to register the platform as a Class A medical device (this work is being completed by Patient Guard).
- The product will increase longer term spend and commitment to R&D with an anticipated further R&D investment of £50k into the product to support its longer-term commercialisation.
- Direct job creation, the income generated as a result of the product will support the company in employing 5 new staff over the next 18 months.
- The SME intend to license the product and associated technology at a low cost, per person per month, this license income on a SaaS (Software as a Service) model will support the company in generating a new source of income, anticipated at over £700k per annum within 18 months. This figure is forecast to increase to over £2m within 5 years.

6.5 Connected Worker

Utilising 5G-enabled wearable headsets, that provide live video and audio streams, to improve healthcare delivery and through remote consultations save resources in rural communities.

Over the last year (summer 2021 to end of project), the Health and Social Care Use Case subgroup has led on the design, deployment, training, and reporting for the Connected Worker use case working with BT, WCC and nexGworx.

6.5.1 Background:

There are many challenges for healthcare in remote settings, such as:

- limited remote visual access,
- no access to additional resources at isolated / remote locations,
- time delay vs critical ‘Golden Hour’ and
- the rising costs to deliver care at remote locations.

The hypothesis is that mobile telemedicine can make the NHS more efficient and can enhance the preventative role played by domiciliary, residential, and nursing care providers by utilising a hands-free camera with a 5G network to deliver high quality video streaming from remote locations. WMR5G project intended to determine if 5G-enabled technology improves health and social care delivery by

implementing a set of 5G-enabled telemedicine and domiciliary / residential care scenarios for wearable video in a rural context.

6.5.2 Key functionality

This virtual telemedicine solution allows expert clinicians to have real-time one-to-one consultations, to support patients or field-based clinicians in the various scenarios listed below.

Head mounted cameras provide “see what I see” capability which connects field-based patients / clinicians with an offsite clinical expert. High quality videos with zoom capability allow for wide angle context as well as detail, such as skin tone to be discerned. Hands-free operation allows patient manipulation by the field-based worker and user convenience for examining and monitoring conditions.

The following scenarios were taken into consideration, with a view to select one scenario to implement:

- **Scenario 1:** 5G Wearable Video for Rural Paramedics with an emergency event:
  linking the rural paramedic to an A&E consultant
- **Scenario 2:** 5G Wearable Video for Rural Community Nurses:
  linking the patient to a community nurse over video to prevent avoidable home visits
- **Scenario 3:** 5G Wearable Video for Domiciliary care workers in people’s homes:
  linking domiciliary care workers to a range of practitioners who are able to advise, guide and support
- **Scenario 4:** GP / community nurse virtual care home visits:
  linking care home patients to GP/ community teams for both regular ward rounds as well as to seek advice, guidance, and support on an as required basis
- **Scenario 5:** Field based training: a senior clinician advising a trainee / junior clinician visiting patient homes:
  junior clinicians being able to seek advice, guidance, and support from remote senior clinicians

Due to the practical difficulties of deploying within the short timeframe for this testbed project, some of the scenarios above were ruled out. Key considerations were:

- Case volume during the trial period
- Complexity around providing stable 5G connectivity inside patient homes and the associated time factor, cost, and ongoing support / trouble shooting

After due considerations to the above factors, Scenario 4: GP / community nurses virtual care home visits: linking care home patients to GP / community teams for both regular ward rounds as well as to seek advice, guidance, and support on as required basis was selected and supported by the Project Board.

6.5.3 Goals and aspirations

Deployment of the connected worker solution to connect rural care homes and their respective GP practices and community nursing teams, with the provision of virtual consultation capability, was identified to have the following benefits:

Clinical benefits:

- More rapid and appropriate treatment for patients
- Less risk of contagion in hospital
- Early identification and prevention
- Help reduce the burden on urgent care services

Economic Benefits:

- More efficient use of NHS resources by using real-time video consultations rather than transporting patients or transporting clinicians, in cases where video consultations could be conducted
- Early interventions to deteriorating patients to avoid unnecessary ambulance transfer and hospital admissions

Specific Clinical Scenario Benefits:

- More efficient use of pre-hospital NHS resources (saving ambulance transfers)
- Enhanced patient outcomes - accelerated treatment through early intervention
- Reducing cost for medical support for frail / elderly cohorts
- Accelerating time to treatment for medical support for frail / elderly cohorts
- Operational efficiency improvements
- In cases of dementia patients, reduce the anxiety and stress impact that transport to / from and waiting at non-familiar clinical surroundings may have on the patient

Research Benefits:

Answers to key research questions:

- Can a 5G (N78) network, configured as currently being deployed by commercial operators, reliably support video-based health and social care use-cases in rural areas.
- Quantification of economic and operational benefits of 5G mobile telemedicine in rural settings
- Testing potentially scalable solutions in the operational delivery of virtual care in care homes

The results and evaluation section (Section 8: Impact of the results including benefits) attempts to measure some of these benefits, but in certain cases quantification of benefits is not possible due to the limited number of activity volumes; some of the benefits are qualitative measures with no baselines.

The specific efficiencies this project looks to realise were in minimising the time that high skill clinicians spend traveling to patients. As such, the project has measured the travel time of the clinicians involved, among other metrics. As this was an R&D the travel time was minimal, however if this was activated for communication between the hospital and the care home initial modelling has suggested that up to two working days per resident.

6.5.4 Technical specification of Connected Worker

For details on the technical specification for Connected Worker this can be found in Section 5.3.1: Hardware and applications.

6.5.5 Use case description

Virtual care home ward round through the Connected Worker solution is a web-based real-time video communications service delivery platform which connects remote clinical workers - GP, Rural Care Practitioners or Community Nurses - to care home patients via video link (720p).

A head mounted camera (RealWear's HMT-1) worn by a care home assistant provides 'see what I see' real-time connectivity. The aim is for the trained medical professional (B-End) to be able to see and hear the patient (A-End) and discuss their medical issues and provide a clear diagnosis without having to travel to the location. For example, the GP could direct the care home assistant to remove a dressing, review the wound and then watch them reapply the dressing.

A sister project providing remote access to patient's vital signs is also being deployed in some care homes and the use of the Connected Worker working alongside the Docobo project provided the clinical staff with a rich picture of information to act upon.

In terms of the detail of how it works, technically (as illustrated in Figure 6.2 below), the communication between the participants at both ends: A-End (care home) and B-End (remote clinician) has been executed through the MS Teams platform.

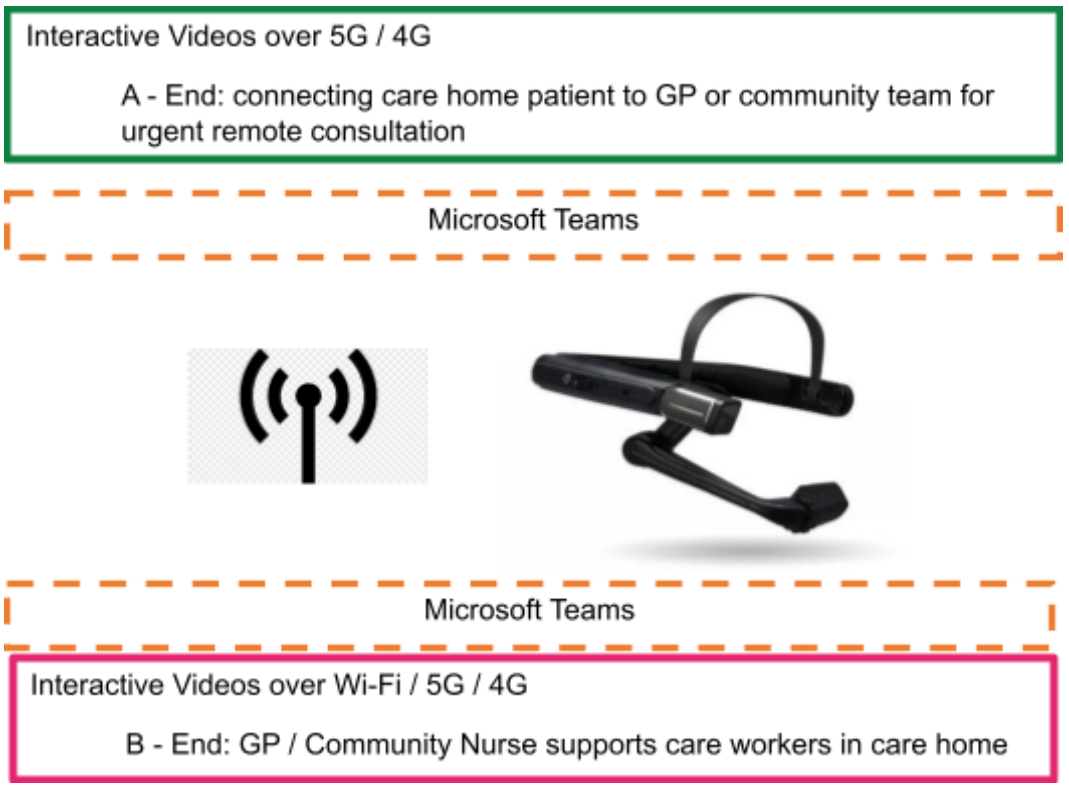


Figure 6.2: A-End and B-End communication

In the case of a scheduled care home ward round:

1. Either the clinician or their admin support team schedule a MS Teams meeting with the care home's virtual headset MS Team's account, which has been provided to them for the purpose of this project.
2. Clinicians or their admin support team informs the care home of the scheduled virtual visit time via their usual preferred communications route – phone / calendar
3. At the time of the scheduled remote ward round the clinician starts the MS Teams meeting
4. The care home assistant joins the meeting from the care home
5. The clinician accepts the care home assistant to the MS Teams call
6. The ward round continues for all patients by the care home assistant visiting each patient's room
7. The care home assistant come out of the MS Teams Call and reconnects each time they move between the residents' rooms – this is for security and privacy
8. The meeting / ward round ends once all patients have been visited

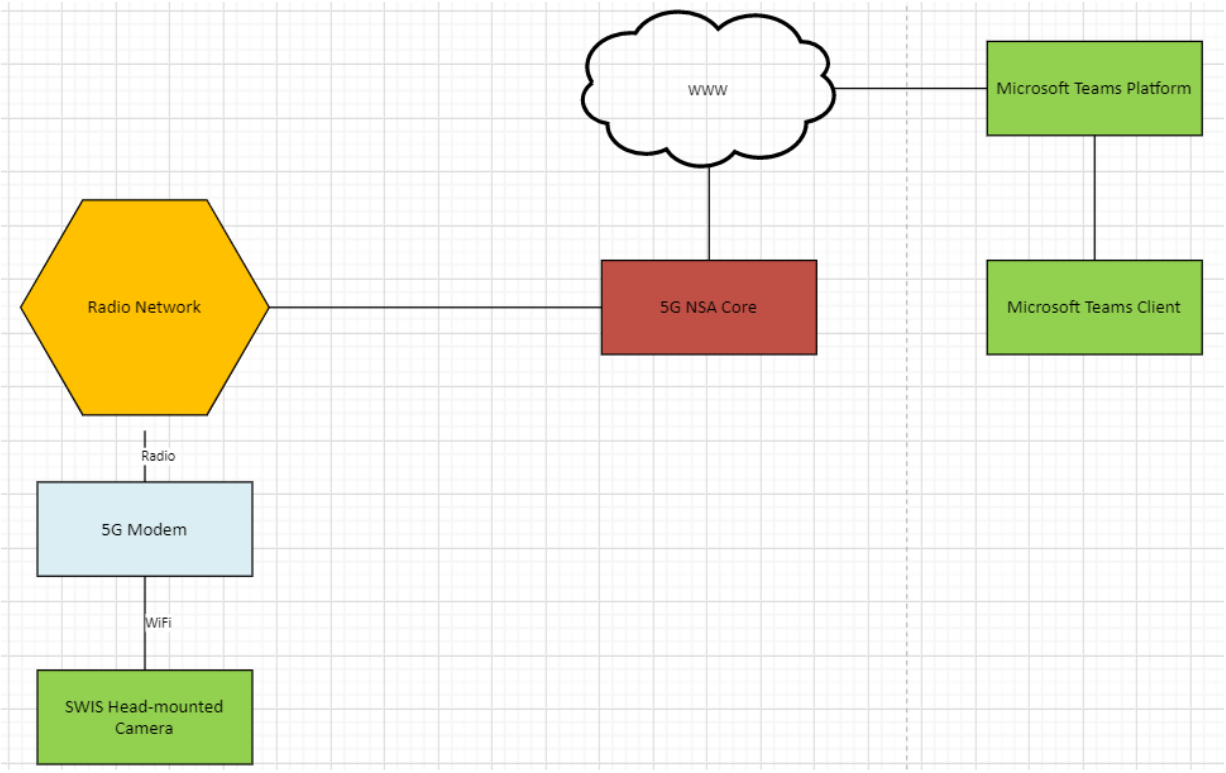
In the case of an unscheduled request from the care home to seek urgent clinical assistance:

1. The care home rings the GP practice reception or community admin team seeking urgent clinical assistance from a clinician
2. The GP receptionist or community admin team schedule a MS Teams meeting with the care home's virtual headset MS Teams account
3. The GP receptionist or community admin team informs the care home of the scheduled virtual visit time via their usual preferred communications route – phone / calendar
4. At the time of the scheduled remote appointment the clinician starts the MS Teams meeting
5. The care home assistant joins the meeting from the care home
6. The clinician accepts the care home assistant to the MS Teams call
7. The visit continues remotely by the care home assistant visiting each patient room needing medical assistance

6.5.6 System architecture

The client on the B-End (remote clinicians) will connect through their internet connection and ultimately reach a private 5G network core, which will then connect to the radio network through a 5G modem to the head-mounted camera via Wi-Fi (see Figure 6.3 below).

Figure 6.3: System Architecture for Connected Worker



6.5.7 Use case deployment

The use case has been deployed in two locations within West Mercia area – Tenbury Wells and Malvern (please refer to Appendix G for the location maps). Participating care homes, GP practices, and community team bases were determined by expected private 5G coverage set up as part of WMR5G project and was adapted post Go Live (December 2021) due to broadcast issues in Malvern (explained in Section 3.3.1.1).

It was recognised, whilst undertaking surveys that some locations were on the edge of the private 5G network modelling, as a result, Haresbrook in Tenbury Wells remained on 4G throughout the trials. Malvern Health Clinic, Howbury House and Malvern Community Hospital were initially expected to be covered by the private 5G coverage. However, as mentioned in Section 3.3.1.1 these trial sites were not covered post Go Live.

Two solutions were investigated and acted upon by the project team:

1. A commercial EE 5G network (700MHz) that had been deployed whilst the project was underway was used for the three sites that were in scope
2. The Health and Social Care Use Case subgroup quickly onboarded a new care home (and associated GP surgery) that was covered by the new direction of the private 5G broadcast.

6.5.7.1 Tenbury Wells area

- ***Community team base (B-End):*** Tenbury Community Hospital: 4 Worcester Rd, Burford, Tenbury Wells WR15 8AP

- ***GP Surgery (B-End):*** Tenbury Wells Surgery: 34 Teme St, Tenbury Wells WR15 8AA
  Rural Care Practitioners (B-End): **Tenbury** Wells Surgery: 34 Teme St, Tenbury Wells WR15 8AA
- ***Care Homes (A-End):***
  Haresbrook Park: Off/Berrington Rd, Tenbury Wells WR15 8EN
  The Old Rectory: Tenbury Wells WR15 8BP

6.5.7.2 Malvern area

- ***Rural Care Practitioners (B-End):*** Malvern Health Centre: Prospect View, 300 Pickersleigh Rd, Malvern WR14 8EN
- ***GP Surgery (B-End):***
  Malvern Health Centre: Prospect View, 300 Pickersleigh Rd, Malvern WR14
  New Court Surgery: Prospect View, 300 Pickersleigh Rd, Malvern WR14
- ***Care Homes (A-End):***
  Howbury House: Pickersleigh Grove, Malvern WR14 2LU
  Hastings Residential: Sanctuary Care, 130 Barnard's Green Rd, Malvern WR14 3NA

6.5.8 Governance

Adherence of patient safety and data protection protocols were ensured through a Data Protection Impact Assessment (DPIA), which was signed off by the Project Board. It was developed in line with relevant NHS and Information Commissioner's Office (ICO) guidance and has also been signed off by the Hereford and Worcestershire CCG's Senior Information Risk Owner. See Section 2.11 for further information.

6.5.9 Stakeholder engagement

Photo 6.1: Tenbury Wells onboarding event at the library – a mixture of online and in person attendees

A number of onboarding events with both the care home staff, GPs and nurses were conducted in Autumn 2021. Following these onboarding events, bespoke end user engagement sessions, training and familiarisation sessions were held. Both clinicians and care home teams were invited to the events held in Malvern and Tenbury Wells with events being well attended in person and online due to the ongoing impact of Covid-19 at this time. These events were particularly useful to create a benefit lead discussion, discuss the vision of the project and longer-term benefits. During the events, the use case was demonstrated using 4G technology

that was available. The Tenbury Wells event was led by the Senior Stakeholder Engagement lead.

6.5.10 4G trials

The original deployment plan (Jan 2021) of the private 5G network was delayed a number of times due to various reasons as described in Section 3.3. The private 5G networks finally were broadcasting late December 2021 in both Tenbury Wells and Malvern trial areas.

In order to compensate for the delay and utilise this time efficiently, a decision was taken to deploy 4G technology to all care homes so that use case trials could commence using 4G, with a view to transfer to 5G as and when available. Deployment of 4G technology to care homes took place in Autumn 2021.

A sufficient number of 4G modems were allocated to each care home to sufficiently provide connectivity to all patient rooms. The installation, set up and testing of the 4G network within the care homes was done by the project team whilst adhering to Covid -19 restrictions and guidelines in place at the time.

6.5.11 End user training

6.5.11.1 A-end users (care homes)

Training was provided to care home teams at respective care homes from November 2021. This was provided by the Health and Social Care Use Case subgroup as and when the care home site became active with the 4G network. Training took place on site to minimise the abstraction time of the staff and the impact to the care of their residents. Aide Memoire were created and provided to the care home teams following their training – with additional support being provide on the WMR5G website – Use Case Support - 5G Innovation within Rural Healthcare & Social Care (wmr5g.org.uk)

i. Basic HMT commands
ii. Using Microsoft Teams on your headset
iii. HMTs – Frequently asked Questions
iv. Getting started with your HMT device
v. About the Head Mounted Tablet (HMT) device

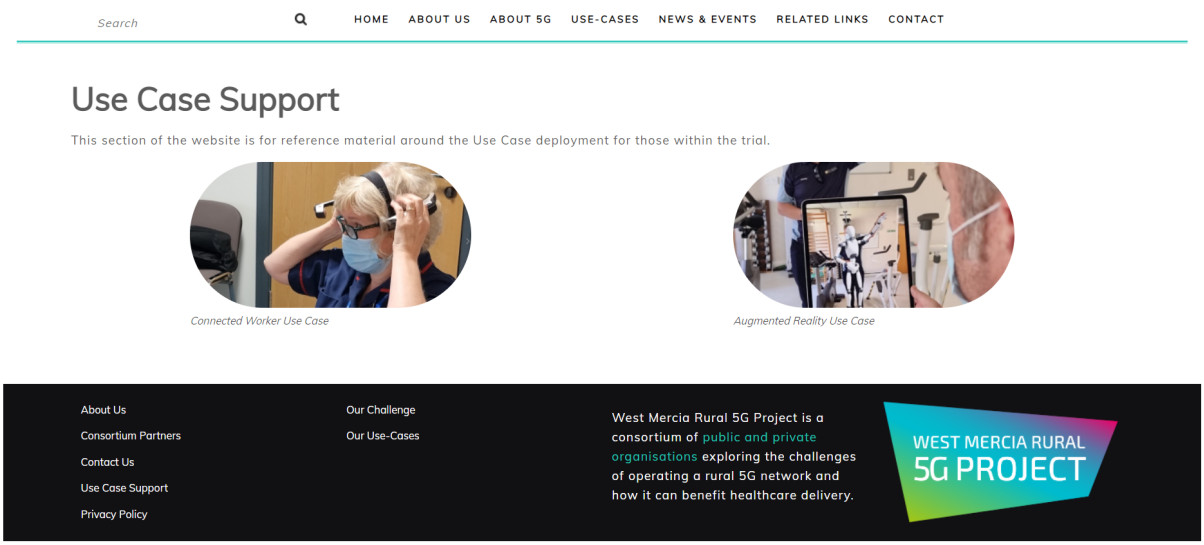


Figure 6.4: Screenshot of WMR5G website page - Use Case Support

Although Covid-19 restrictions at the time made logistical arrangements more challenging, training was delivered successfully by the end of November 2021. Some care homes were visited more than once due to the number of staff looking to be trained vs the abstraction of the staff from their core duties. Follow up sessions were also done at the requested of care home staff.

At the end of the first training session, headsets assigned to each care home were handed over to the care home manager for their senior staff to use. Staff were encouraged to use the headsets in a friendly environment without real patients or B-End users to ensure familiarity.

6.5.11.2 B-end uses (clinicians)

The training requirement of B-End clinicians was minimal as they have been using MS Teams for day-to-day business purposes already through their own desktops / laptops. The training sessions held with them focused on the process flow and what they could expect to see through MS Teams via the headset. This was demonstrated in real-time via a live trial video session with the care home connected over MS Teams as part of the on boarding process. This was reinforced by the findings on user acceptance in Section 7.6.4.1.

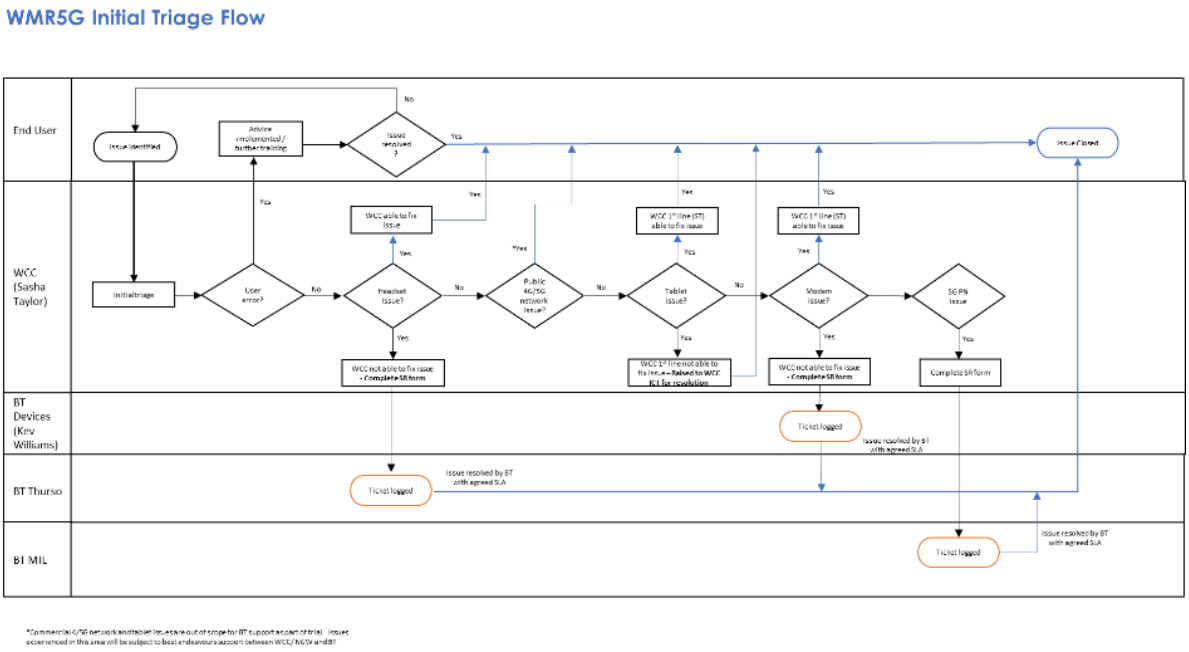
GPs and Community teams have experience of using MS Teams for other business as usual (day-to-day) purposes. Therefore, there was no need to train them on how to use MS Teams. A live demonstration of the functionality provided through the headsets within the remote warding did help the GPs and Community teams to understand the process and see the benefits of the Connected Worker use case and was well received.

6.5.12 Ongoing support – Connected Worker

The following model was set up to support the Connected Worker use case. If an end user (A or B-End) experienced a problem this was raised to the Use Case Product Expert (within WCC PMO) so that they determined whether:

a. There was further training required to resolve the issue
b. The issue could be fixed locally by the Use Case Product Expert
c. The issue could not be fixed locally, and the Use Case Product Expert made the decision as to which partner was required to support, i.e., network or device issue. In these cases, a spare replacement device would have been swapped with the faulty device to ensure that the trial could continue at that location without major interruption.

The diagram below is a step-by-step flow diagram with specific questions that were used to determine how to best resolve the issue for the end user. A PowerPoint version of the WMR5G Initial Triage Flow diagram can be seen in Appendix J.



*Commercial 4/5G network and tablet issues are out of scope for BT support as part of trial. Issues experienced in this area will be subject to best endeavours support between WCC/MCW and BT

Figure 6.5: WMR5G Initial Triage Flow Diagram

6.5.13 5G trials

Those testbed sites that fell within the private 5G broadcast range were migrated to 5G connectivity during January and February 2022. Due to the final broadcast direction from the Malvern mast this included approaching and rapidly onboarding a care home that was identified as being within the private 5G broadcast area and GP surgery that serviced them.

Each location had its own challenges in relation to the connectivity provided as to whether there was a private 5G network or not – only one of the three initial care homes had sufficient coverage (Old Rectory, Tenbury). The other two care homes were either not in the broadcast direction (Howbury House, Malvern) or did not have sufficient stability according to BT (Haresbrook Park, Tenbury).

At each location a Wi-Fi connection was required between the headset and the router for a connection to be made, as the current model of the headset does not have native 5G capabilities.

The solution put forward by BT for those within a commercial and private 5G network was a single 5G modem tower unit solution as they viewed this a R&D test concept.

However, it was identified early on that at Howbury House (commercial 5G) and Hastings Residential (private 5G), as the sites are large, a single router would not be sufficient to provide blanket coverage.

BT's technical solution was to test the 5G routers at these sites by the care home staff moving the router from location to location as required to provide a strong enough signal for MS Teams to be run. There were a number of issues with this methodology:

- BT did not provide a site map where they had identified the locations that the care home staff could move the device to. This would have overcome the issues of:
    - Where the router would receive a strong enough 5G signal
    - Where the router could be plugged in (spare socket)
    - The broadcast reach of the router from that location
- Expectation on the care home staff to understand requirements for router placement
- The time for the GP to be waiting in a MS Teams meeting while the care home staff move the router and reconnect
- The stress that this would place all participants under

Due to the issues above this technical solution approach from BT was not accepted by any care home as a practical workable solution. An alternative proposal was put forward by WCC and nexGworx and was accepted by the care homes as a workable test.

For success it is key that there is sufficient Wi-Fi coverage throughout the site either via a native solution (if available), a mobile router that is able to connect at all points to a cellular network, or by creating a sufficient internal Wi-Fi coverage throughout the site at an additional cost (i.e., mesh network).

Given below are the final network coverage status of each testbed site (also see Section 7.6):

Table 6.1: Final network coverage status of each testbed site

Site	Status / Workaround

Howbury House care home, Malvern	No sufficient private 5G network coverage at the site. BT Solution/ workaround: A single EE commercial 5G tower device was set up by BT and tested in a single location at Howbury House. This solution did not allow full building coverage and also caused interference with critical infrastructure being used. WCC / nexGworx solution: The solution implement was to provide a headset (HMT-1) that is linked via Wi-Fi to an iPhone 12 Pro Max using the phones Hot Spot ability. This meant that the Wi-Fi signal from the device would be a "bubble" around the user, this would move as the user moved, and would only be in use with the headset. A single mobile EE commercial 5G router connected to one headset has now been deployed at Howbury House. Additionally, the use of the Bluetooth speaker has been pulled for the scenario due to technical issues.
Hastings Residential care home, Malvern	BT provided a single EE private 5G tower device for this location, this did not cover the entire care home building. The workaround solution implemented at Hastings Residential by WCC is that each floor has its own headset which is linked to its own mobile private 5G router device – three of each device. This enabled the care home staff to be mobile around their floor and still have a good connection.
Haresbrook Park care home, Tenbury Wells	No sufficient private 5G coverage at the site. No commercial 5G networks available in Tenbury. The site continues to use commercial 4G network installed in autumn 2021 – four 4G routers providing Wi-Fi coverage across the site.
Old Rectory care home, Tenbury Wells	Sufficient private 5G network coverage at the site. However, the site suffered from a lack of end user motivation, lack of technical maturity and high staff turnover. The site is covered by a single private 5G EE Tower Router
Tenbury GP, Tenbury Wells	Sufficient private 5G network coverage at the site to provide native access via tablets if required – however, not within the end users consultation rooms. GP and nurse conduct MS Teams calls on their desktop computers connected to NHS LAN.
Malvern Health Centre, Malvern	No sufficient private 5G network coverage at the site. There are two GPs operating from here one servicing Howbury House the other Hastings Residential. Clinicians have been provided with iPads with commercial EE 5G SIMs to support consultations. In addition, they can conduct MS Teams calls on their desktop computers connected to NHS LAN.
Tenbury Community Hospital	Sufficient private 5G network coverage at the site to provide native private 5G network access.

6.5.14 Use case evolution

As the use case evolved during the project several practical difficulties were identified at various stages. Below is a list of the issues which required workarounds to be implemented.

Table 6.2: Use case evolution and work arounds

Scenario	Workaround / Change Introduced
No sufficient private 5G coverage at Malvern testbed sites – e.g., Howbury House care home and GP sites (also at Malvern Community Hospital – Community Nurses)	Deployment migrated to commercial EE 5G. After the project team identified presence of commercial 5G in these areas, BT provided EE public 5G SIMs and Modem (Howbury House care home) as appropriate
No sufficient private 5G coverage at Haresbrook Park care home at Tenbury Wells	The deployment reverted back to commercial 4G as there is no public 5G available in Tenbury Wells area
No sufficient 5G (public or private 5G) coverage in certain patient rooms further away from 5G router	Care home assistants were given a mobile router to carry to patient rooms. An additional burden to the care home assistant to carry more equipment to patient rooms and the associated increased complexity of them having to handle multiple devices.
	HMT-1 connection tethered though a 5G-enabled mobile (public EE 5G or private 5G). It was identified that the HMT-1 did not allow wired tethering through the USB-C cable to a mobile device. The HMT-1 can be connected via Wi-Fi to a mobile router, but this is an additional device to be carried round.
Clinicians are unable to communicate directly with patients due to non-availability of a strong enough built-in speaker on HMT-1s	An external Bluetooth speaker connected to the headset was introduced. Disadvantages: An additional burden to the care home assistant to carry more equipment to patient rooms and the associated increased complexity of them having to handle multiple devices. In addition, the HMT's voice command feature was disabled as the Bluetooth speaker overrode the function – mic was now in the Bluetooth device. The sound quality through the Bluetooth device was not good on some occasions.
Commercial EE 5G signal interfered with vital infrastructure being used at a care home	Connectivity to headset tethered over Wi-Fi to a mobile device such as an iPhone or mobile router. Analysis showed that the mobile router was a better option and deployed at Hastings Residential / Howbury House. Use of mobile router also ensures that the interference due to the Wi-Fi is limited to a "bubble" around the device as well as only presenting an issue when switched on (very limited time).

Operational complexity of HMT-1 headsets i.e., a hierarchy of commends to reach Microsoft Teams	The use case product expert , with the assistance of RealWear, managed to soft lock the HMT-1s so that the only option shown on the home screen is to launch MS Teams.

7 WMR5G – Evaluating the Health Use Cases

7.1 Introduction

The WMR5G partners looked to address the challenges highlighted within Section 2.3.

There was a requirement from both DCMS and the Programme Board that cost benefits were measured and reported on. To sustain opportunities for the collaboration after the testbed it was also important that the impact of the benefits informs local authorities' connectivity and digital transformation plans. An adaptive evaluation strategy was developed for the board on how this impact would be measured and how the evaluation is projected to be delivered (see Appendix Q). The evaluation looked at how the theoretical ambitions of the bid would operate in 'Real World Environments' (RWE). Which is essential knowledge for Local Authorities, Health and Social Care Providers (commissioners) alongside small and medium-sized enterprises (SMEs) and Mobile Network Operators (MNOs) (suppliers) if the opportunities generated by the health and social care market are to be realised. The ambition of the strategy was to develop further evidence that could support commissioners to develop a business case to adopt both 5G connectivity and associated products more widely in rural settings.

In addition, the wider benefits that 5G New Radio (NR) and cross sector collaborations are also explored

7.2 Context of adaptive evaluation strategy

7.2.1 Core principles

In delivering the evaluation strategy, key focus was on the compliance with DCMS requirements for the project funding as well as equally addressing the local information needs to support shaping future digital transformation strategies. However, recognising, the test and learn nature of the testbed and the need to develop proof of concept the evaluation approach needed to evolve as the network connectivity, service models and the SME needs changed during the lifespan of the project.

For these reasons the evaluation strategy was underpinned by the following key principles:

- **Social and Clinical Engagement** – in developing this approach health and social care partners were invited to comment and prioritise questions
- **Subsidiarity** – the design was done with care homes, the NHS, app developers and SMEs under the terms of the collaboration agreement produced by DCMS

- **Situational Co-production** – visits to delivery sites, SME and NHS premises so that product design would take account of specific aspects relating to 5G connectivity
- **Safeguarding and Ethical Norms** – the methodology is based on convenient sampling and transparent recruitment of volunteers as a proxy for future patients so that when moving to proof of concept the knowledge is transferable. For Connected Worker the privacy of individuals was addressed
- **Scalability** – key research questions were shaped so that the convenient sample and methodology can be scaled up to wider public trials if funding becomes available

7.2.2 Governance

As this was an exploratory test and develop study, it was important to ensure the rights and protection of both individuals and organisations were central to each phase of development. All use cases were overseen by the Health and Social Care Use Case subgroup and overseen by the Project Board.

All parts of the evaluation that used human subjects were reviewed, approved, and registered by the Ethics Committee of the University of Chester.

Data privacy impact was considered and assessed by the team and shared with all parties prior to sign off.

The evaluation strategy (Appendix Q) was signed off by the PMO May 2021 with subsequent adaptions and modifications in response to findings being brought to the Health and Social Care Use Case subgroup for confirmation and approval.

7.2.3 Testbed area

As previously described the two testbed areas were Tenbury Wells and Malvern.

7.3 The use cases

The evaluation used both qualitative and quantitative methods to examine the two use cases described in Section 6, namely

- Development of the Health XR app (see Section 6.4)
- The Connected Worker (see Section 6.5)

Further details on the methodological approach, evaluation aims, and objectives can be found in Appendix Q.

7.4 Collaboration impact and opportunity

As well as the partners delivering on the challenges raised as part of the WMR5G project, it was also important to the project team to understand the benefits of this type of cross system collaboration through this multidisciplinary ecosystem of Network Operators, Local Authorities, Health and Social Care Services, Care Homes, SMEs alongside the other Testbed and Trials sites.

This was, as stated in Section 2.8, because the belief that existing commercial models make it difficult for rural connectivity to be invested in since it is difficult for the major network providers to get the required return on investment.

Additionally, it is worth noting that this principle of cross system collaboration and reduction of competition are also key components of the Health and Care Act 2022

By observing the project systems and processes during testbed delivery, and through content analysis of interviewed participants, the lessons learnt were identified to shape future opportunities beyond health and social care (see Section 9).

7.5 Use case measurements

7.5.1 Connected Worker Phase 1: Measurement

The key evaluation questions explored were:

- What is the level of user acceptance for the head worn camera by clinicians and carers?
- What is the level of engagement between teams at GP practice and the care staff at the care home?
- What added value, if any, does the care provider perceive that the technology gives their care outcomes?

Photo 7.1: Use Case Product Expert within the PMO wearing RealWear's HMT-1

to

7.5.2 Health XR phase 1: measurement

As described in Section 6, it was important to the SME and the Health Use Case Group that the measurement and evaluation plan was iterative due to the fact only early stage work had been done and pitched to the Health and Social Care Use Case subgroup.

As described in Section 6.4 this plan consisted of four stages:

- **Stage 1** – undertake a market analysis and potential patient journey.
- **Stage 2** – engage with stakeholders to confirm demand and concept,
- **Stage 3** – confirm technology and adoption readiness using validated tools (see Appendix L)
- **stage 4** – design and revise an iterative development, deployment and testing plan.

As described in Section 6.4 it was important that a market analysis was undertaken. This was supported by the University of Chester in September 2021 and focused on activity prior to the pandemic. It identified that the population of the surgeries in the testbed areas had similar proportions of MSK activity - New Court Surgery (4.5%) and Tenbury Wells Surgery (4.6%) of referrals / admissions.

It also identified that the types of MSK (Musculoskeletal) conditions (see Figure 7.1 and Figure 7.2 below) was arthrosis which is a common degenerative bone condition associated with aging. This was expected recognising the demographic profile described in Section 2.5 – rural context).

Table 7.1: Admissions Profile for Tenbury Wells Surgery (pie chart below is of this data)

Admissions Profile for Tenbury Wells Surgery relating to MSK				
Practice Code	**Primary Diagnosis Chapter**	**Admissions**	**Per 1000 of List Size**	**Compare**
M81042	Arthrosis	75	7.97	2.58
M81042	Other joint disorders	36	3.83	1.28
M81042	Inflammatory polyarthropathies	17	1.81	-0.12
M81042	Other soft tissue disorders	16	1.70	-0.03
M81042	Other dorsopathies	14	1.49	-0.24
M81042	Disorders of bone density and structure	8	0.85	-0.17
M81042	Spondylopathies	7	0.74	0.13
M81042	Other disorders of the musculoskeletal system and connective tissue	6	0.64	0.33
M81042	Other osteopathies	3	0.32	0.01
M81042	Deforming dorsopathies	1	0.11	-0.20
M81042	Systemic connective tissue disorders	1	0.11	-0.10
M81042	Chondropathies	1	0.11	-0.10
M81042	Disorders of synovium and tendon	1	0.11	0.00
	Total	**186**		

Figure 7.1: Admissions Profile for Tenbury Wells Surgery (Table 7.1 above is the data for the pie chart image)

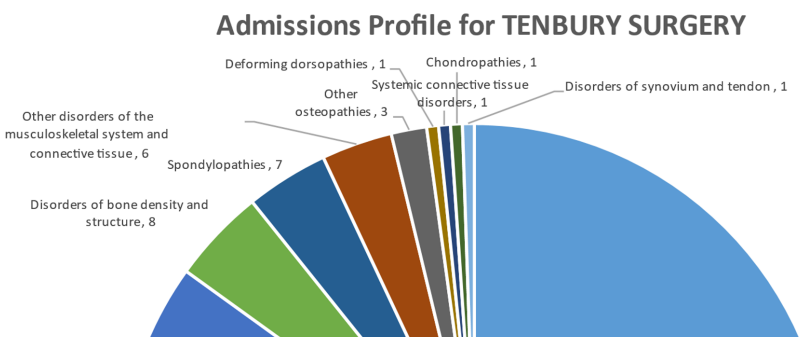
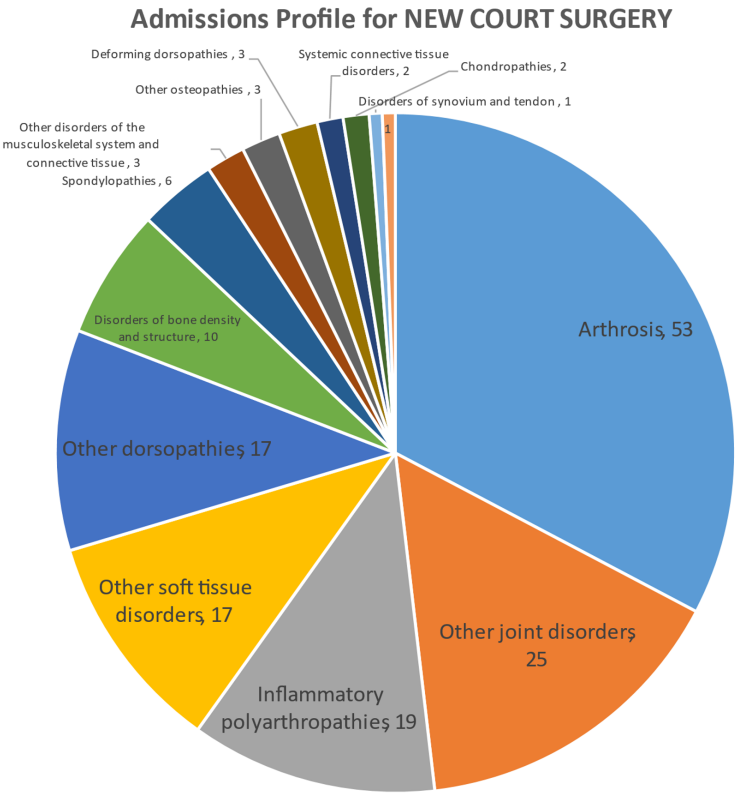


Table 7.2: Admissions Profile for New Court Surgery (pie chart below is of this data)

Admissions Profile for New Court Surgery relating to MSK				
Practice Code	**Primary Diagnosis Chapter**	**Admissions**	**Per 1000 of List Size**	**Compare**
M81629	Arthrosis	53	5.39	-2.58
M81629	Other joint disorders	25	2.54	-1.28
M81629	Other soft tissue disorders	19	1.93	0.12
M81629	Spondylopathies	17	1.73	0.03
M81629	Other dorsopathies	17	1.73	0.24
M81629	Inflammatory polyarthropathies	10	1.02	0.17
M81629	Other osteopathies	6	0.61	-0.13
M81629	Systemic connective tissue disorders	3	0.30	-0.33
M81629	Disorders of bone density and structure	3	0.30	-0.01
M81629	Disorders of synovium and tendon	3	0.30	0.20
M81629	Other disorders of the musculoskeletal system and connective tissue	2	0.20	0.10
M81629	Disorders of muscles	2	0.20	0.10
M81629	Chondropathies	1	0.10	-0.00
M81629	Infectious arthropathies	1	0.10	0.10
	Total	**162**		

Figure 7.2: Admissions Profile for New Court Surgery (Table 7.2 above is the data for the pie chart image)



In addition, stakeholder engagement was undertaken, which enabled the SME to undertake further work on the offline content functionality (access to videos, recording of videos and submitting when connectivity was available etc.) in case the patients could not access the private 5G network all the time.

Photo 7.2: SME and University of Chester providing example of how the Health XR is viewed by the patient

Clinical staff also suggested a focus on specific limbs and parts of the body in the early prototype to reduce any risk of falls and harms to frail patients with the associated arthrosis.

Positive feedback from the clinical staff was that if successful the platform could help them significantly in terms of:

a) Ensuring patients compliance with the series of exercises recommended by the therapist
b) Provision of a catalogue library of videos for patients
c) Allowing a clinical member of staff to look back at previous avatars to see how well a patient is progressing
d) Embedding clinically validated tools to improve therapeutic assessments

Stage 3 was about confirming the technical solution was ready for adoption and since there had been issues on the NHS Wi-Fi network simulated practice and speed tests were undertaken Each file was then uploaded to the server and time recorded of upload speed. Prior to the upload a speed test was undertaken using the Ookla platform (Speedtest by Ookla - The Global Broadband Speed Test) and note taken of the latency, upload speed and download speed. A healthy volunteer was asked to undertake a standard set of exercises that consisted of two left lateral arm raises, two right lateral arm raises and a single squat and were asked to be completed this exercise on five occasions with a note taken of the length of recording and the speed of upload in the different simulated environments.

A similar process was followed to download a clinician review process. A standard login was followed to view each session.

Once the session was initiated the avatar was placed mid screen.

Each file was downloaded to the device and time recorded of upload speed. Prior to the download a speed test was undertaken using the Ookla platform and note taken of the latency, upload speed and download speed. Records were made of the size of the data file, the time of recording and how long to upload and download. These tests were replicated in the same sequence on the alternate environment described.

These tests were replicated in the same sequence on the alternate environment described.

After the initial tests were undertaken it became clear that in the real world patient exercises would be more than just the two reps used for baselining and would take more than the average 25.07 seconds found in the baseline test. A new exercise regime was developed that extended the time to the maximum 1 minute that the app allowed for a recording length. Again, the upload time and download times were tested.

In addition to the network connectivity tests further consideration was given to usability of the images and the proposed timeframes for the following factors:

- Time as % of standard 15 minute appointment
- Ease of use – record image
- Ease of use – view image
- Stability of image

These were rated on a four-point scale from strongly disagree to strongly agree based on the following statements.

- The time used to upload / download the image met reasonable expectations
- I found it easy to record the image and upload the file
- I found it easy to see the image in a way that was meaningful to me
- The image displayed met my expectations on stability

To minimise bias a volunteer was asked to review the image and record the files.

Concurrently the project had been collaborating with Liverpool 5G Create testbed as they looked to develop their Adoption Readiness Level (ARL) tool. This online tool, which had been evaluated separately, helped the Health and Social Care Use Case subgroup time to confirm that a rapid acceleration of development was required once the 5G environment was confirmed. A full report on this collaboration can be found in Appendix L.

The tool covered five critical dimensions that needed addressing if VRSS wished to enter the health and social care market. These were

- Market Readiness
- Human
- System and Workflow Integration

- Finance and Procurement
- Motivation

A pictorial image of the readiness of the tool to be used in NHS environments was then acquired which alongside the initial report on simulated practice confirmed the need for accelerated app development and a reclassification of the Technology Readiness Level (TRL) from the TRL5 to TRL2. This required some further testing in non NHS environments. This was undertaken in Stage 4.

Stage 4 (described in Section 6.4.6) was delivered in three phases that consisted of:

- **Phase 1:** Four sprints to accelerate development and ensure the app was sufficiently robust to move to phase two (Critical Friends)
- **Phase 2:** Deployment to convenient sample of Critical Friends
- **Phase 3:** Deployment to healthy volunteers from general public in testbed locations.

Similar to the testing in Stage 2, a standard set of simple exercises that consisted of two left lateral arm raises, two right lateral arm raises, and a single squat were agreed to be used in Phase Two of Stage 3.

Following an open recruitment campaign of a convenient sample from volunteer workers at the MHSP the volunteers attended a workshop at MHSP to be trained on the application, demonstrated the set of exercises, to sign consent and be provided with participation information sheets (see Appendix K).

The volunteers were provided with an Apple iPhone 12 Pro Max with the application uploaded and unique accounts for each participant so that their data could be analysed – Patient 1, Patient 2 etc. Each device was locked so only the Health XR app could run.

It was initially anticipated that the device would run native on the private 5G network. However, as the MNO project partner was unable to provide a relevant configuration file (Apple Config File). This is because each private 5G network uses a different bespoke setup to the wider used commercial 5G which was available from the MNO. To address this challenge the Critical Friends had to be a cohort that visited the MHSP site regularly so that they could upload their files via Wi-Fi to the cloud servers of VRSS via the dedicated private 5G tower router.

7.6 Findings

7.6.1 Network coverage

A new private 5G network was established in Malvern and Tenbury. Within the Low Level Design document this new private 5G network was to provide connectivity for two care homes in Tenbury Wells (Haresbrook Park and Old Rectory) as well as a care home in Malvern (Howbury House). After the private 5G was switched on to broadcast through the Tenbury Wells and Malvern masts, the private 5G network was only found to cover Old Rectory in Tenbury Wells and a new onboarded care home, Hastings Residential, in Malvern – due to the fact that Howbury House ended

up not being within the coverage area (detailed coverage maps can be found in Appendix M).

As described in Section 3, it was important to understand how the network coverage within each care home operated and how well indoor coverage operated both in native private 5G (Old Rectory, Hastings Residential, and Tenbury Community Hospital), commercial 5G (Howbury House) and within the commercial 4G environment (Haresbrook House). Woofferton House was excluded due to the network being removed as no more patients were under the care of participating GP or Rural Care Team. This indoor coverage testing is important as both for ethical and implementation reasons care home and clinical staff need assurance that the devices that underpinned the health use case could reach all patients. The importance of this was noted as one of the reported calls was requested for an urgent reason and in that instance the signal coverage did not satisfy the need of the clinician covering the practice remotely. Since this instance, additional 4G routers have been installed to provide better coverage.

Section 5.4 outlines the important lesson learnt that is the need for network operators to undertake local customer based equipment audit within the context of the clinical workflows. The purpose of this is to understand the connectivity beyond that of the radio signal, already installed equipment and fitting in with the end users' clinical workflows. Subsequently the Health and Social Care Use Case Group designed a comparative mapping process that measured local coverage in the locations across the clinical areas and the resident bedrooms. This identified that some patients were at risk of devices receiving a poor signal. Copies of the heat maps can be found in Appendix P.

This demonstrated that although a network operators' solution may interpret that technically a strong signal may exist, if they wish to enter the health and social care market and accelerate the adoption of 5G in customer premises then the local design and purpose must also be validated. Equally health and social care customers will need more system integrators that can help communicate the clinical need and risks to network operators. Furthermore, when they are planning the investment into new network coverage, it is recommended to invest a small part of the deployment budget into securing independent network coverage models to inform procurement specification.

Additionally, the heatmaps demonstrate the importance of understanding the dataflows (type, size, and direction) anticipated with current and future use cases. We can see that the current private 5G network operates similarly to a commercial 5G network with downlink disproportionate to uplink (See Section 3.1 for further information). The Health XR use case required high uplink and downlink to maximise time efficiency and access to the data, equally the connected worker needed high uplink to share the real-time video with practices.

7.6.2 Value proposition of Connected Worker

The implementation of the Connected Worker is described in Section 6.5. The value proposition being that the use of head mounted tablet (camera) enables

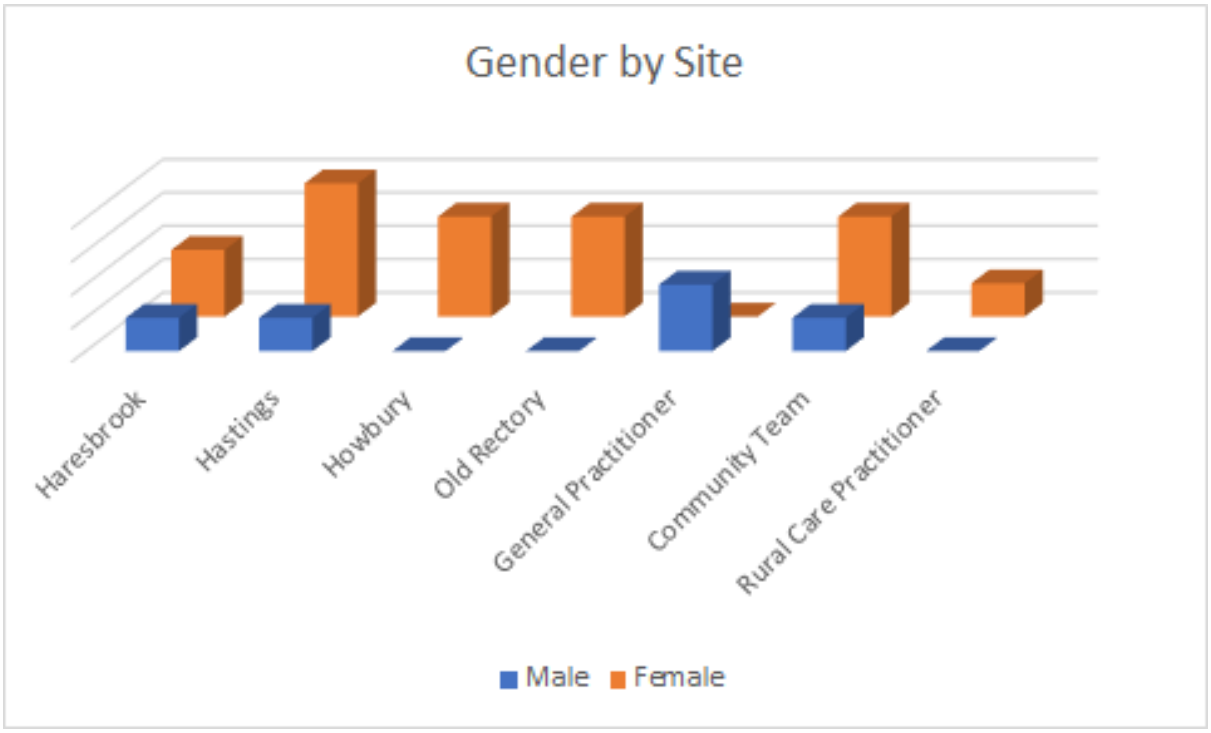
communication between the care home and the remote clinician to be enhanced with positive impact on both patient and staff alike. Participants in the use case were asked to complete a questionnaire after each use. The number of episodes were controlled by the primary care physician, so a convenient sample size was taken to be 20 ranging from care home staff to strategic leads and managers.

During the trial, the evaluation lead invited the sample to complete the questionnaire, which was designed to capture and rate user perception. However, this had very limited success due to low engagement. (A copy of the survey can be found in Appendix K)

Table 7.3: Gender by trial site

	Haresbrook Park	Hastings Residential	Howbury House	Old Rectory	GP (Malvern / Tenbury Wells)	Community Team (Tenbury Wells)	Rural Care Practitioner (Tenbury Wells)
Female	3	5	4	4	0	4	1
Male	1	1	0	0	3	2	0

Figure 7.3: Gender by trial site



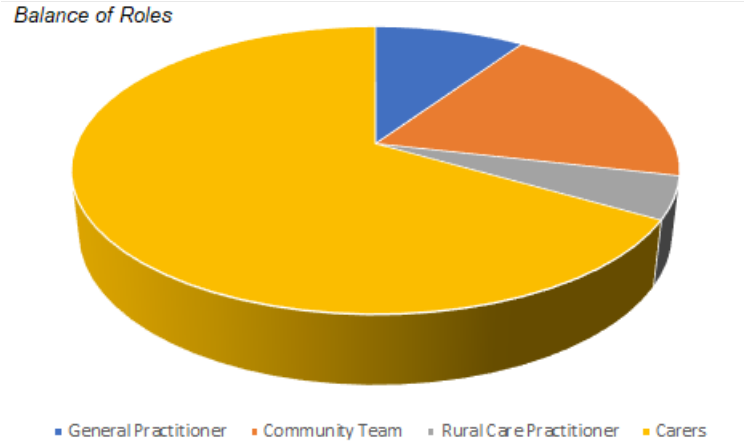
The actual response rate was 23% although it must be noted that 100% of these came from General Practice. Follow up interviews were also undertaken.

The majority of users (70%) were female and had some concerns relating to using new technology (n=11). The roles were split across various levels of seniority although 100% of them would be considered middle to senior management.

Type of Role	Balance of Roles
General Practitioner	3
Community Team	6
Rural Care Practitioner	1
Carers	20

Table 7.4: Balance of Roles (data)

Figure 7.4: Balance of Roles (as pie diagram)



On 5 occasions (71%) it was thought that a visit to the care home was avoided and that residents benefited from the early response.

Each interview took approximately 40 minutes, which it is acknowledge added pressure to staff whose time was already constrained by delivery pressures.

Staff questionnaires were shared with practice and care homes.

The reviewer had no direct relationship with the respondents but observed the experience of the use of the service so could be seen to add bias to the interpretation of responses. However, this is mitigated against by the use of Independent Supervisor to review approach and evidence.

7.6.3 Value proposition of VRSS's Health XR App

The implementation of the Health XR app is described in Section 6.4. The value proposition was initially thought to be that by the use of the app that effectiveness and efficiency of physiotherapist care of patients with musculoskeletal conditions would be enhanced. This was subsequently modified to one that focused on the principle that the use of 5G would enable an SME to develop data heavy applications to proof of concept without need to move to big urban settings supported rural economies.

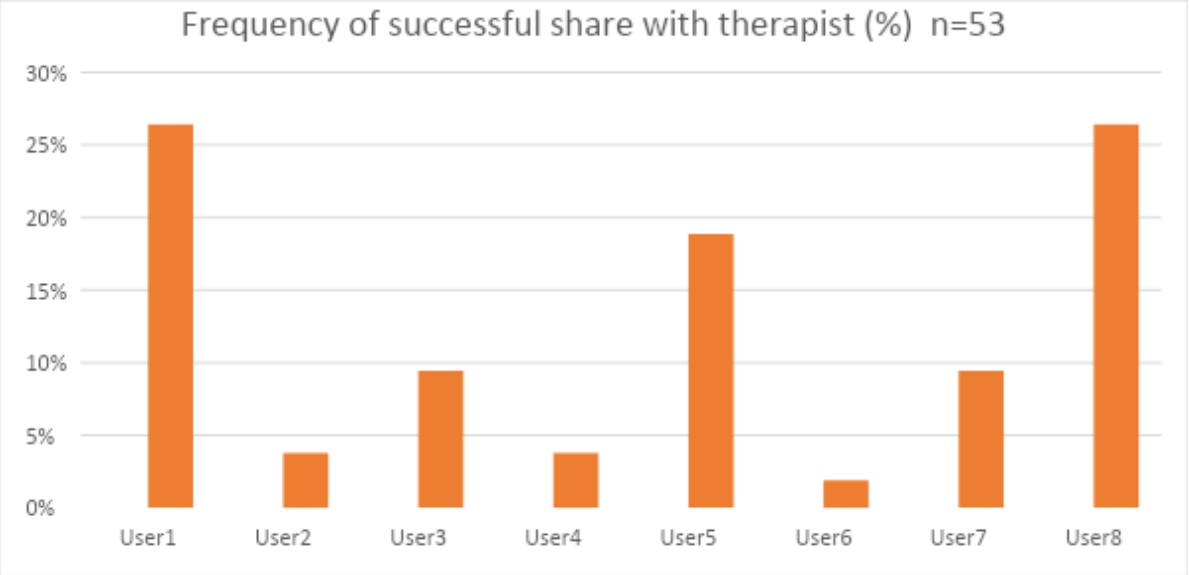
Due to low sample size on addition to the critical friend's usability survey, a series of interviews were also undertaken with a sample of volunteer users. The sample size was proposed to be ten, ranging from critical friends, physio therapists to potential commissioners and managers. This however was lower with only eight devices available within the timeframe. The frequency of use by each volunteer was tracked as was the support callout figures.

The devices were used in a total of 53 occasions during the second phase of Stage 4, although the success of completed reporting of exercise varied across users from 1 (lowest success) to 14 (most successful user).

Table 7.5: Frequency of successful share with therapist (%) n=53 (data)

	User ID							
	1	2	3	4	5	6	7	8
Freq. of successful share with therapist (%)	26	4	9	4	19	2	9	25

Figure 7.5: Frequency of successful share with therapist



7.6.4 Health outcomes

7.6.4.1 Connected Worker

Following the trial calls across the care homes, care home staff and clinical staff were both asked to complete a questionnaire in paper or online respectively. This was also followed up with interviews on the experience and value of the tools.

What was the level of user acceptance for the head worn camera by clinicians and carers?

Feedback from the care homes workers although not via the online questionnaires;

- Identified challenges with the multi-factorial connectivity and the time taken to get all the devices to work synchronously –"*you need to have Bluetooth speaker, mobile phone* (pointed to mobile router) *and then wear the headset, it is just strange much easier if doctor came here*".
- For another it was more about "*it is great having the extra pair of hands, but the headset keeps slipping down over my eye*. *The headband is way too big*". It is worth noting that although the headband is adjustable, for those of a petite nature the strap does not close enough. This was feedback to Realwear for future development. Healthcare is different to field operations in gas and telecoms, where device was originally used. In those fields the headset clips on to the hardhat. It maybe that a webbing or overhead strap could address this issue.

- One care assistant who was new to the project however did positively view the headset after using it stating: "*that was simple to use, not sure why the others are worried about it."* Again, it may be worthwhile to note in that instance no peripheral devices were used.

These qualitive findings were consistent with the quantitative findings of the survey where GPs reported a neutral score of 3.42 against the question "*The care home staff found it difficult to get the video to work to my satisfaction".* It is interesting that on the two questions related to ease of use to GPs "*I found the process simple to use*." and "*I would like other care homes under my care to have access to this equipment." These* were more positively seen with scores of 4 and 4.42 respectively. If we look at that in the context of the balancing negative statements of "*I would not want to use this technology again beyond the pilot."* and "*The device added no value to the care I was able to provide."* would also suggest that the concept was acceptable but that the complexity of the delivery mechanism was less acceptable.

It is argued that alongside the findings from the local network mapping (see Section 7.6.1) where the importance of this integrated workflow mapping is articulated, a further argument exists that manufacturers of these and future devices need to build devices with integrated 5G connectivity. Currently this ecosystem continues to be in its infancy but if we are to improve acceptability and market pull then rapid development is required.

What is the level of engagement between teams at GP practice and the care staff at the care home?

This project has identified positive engagement between practices and care staff with a willingness to participate in the trial, for some care staff they felt it was exciting to have focus on them rather than hospitals. At one of the training sessions a member of staff expressed "*this might make other carers see our job as sexy and cutting edge*!"

It was interesting, but not significant, that of the reported calls one was for an urgent care episode suggesting potential benefit, however, the statement "*By using the device the care home staff were able to stop me or my team having to visit the care home* had a neutral response score of 3.71.

These results are summarised in Table 7.6 and presented in Figure 7.6 below.

Note: The axis 0 – 6 reflects the individual score given by the user – 6 being Strongly Agree with and 1 being Strongly Disagree with the statement.

Figure 7.6: Responses to Connected Worker Questionnaire

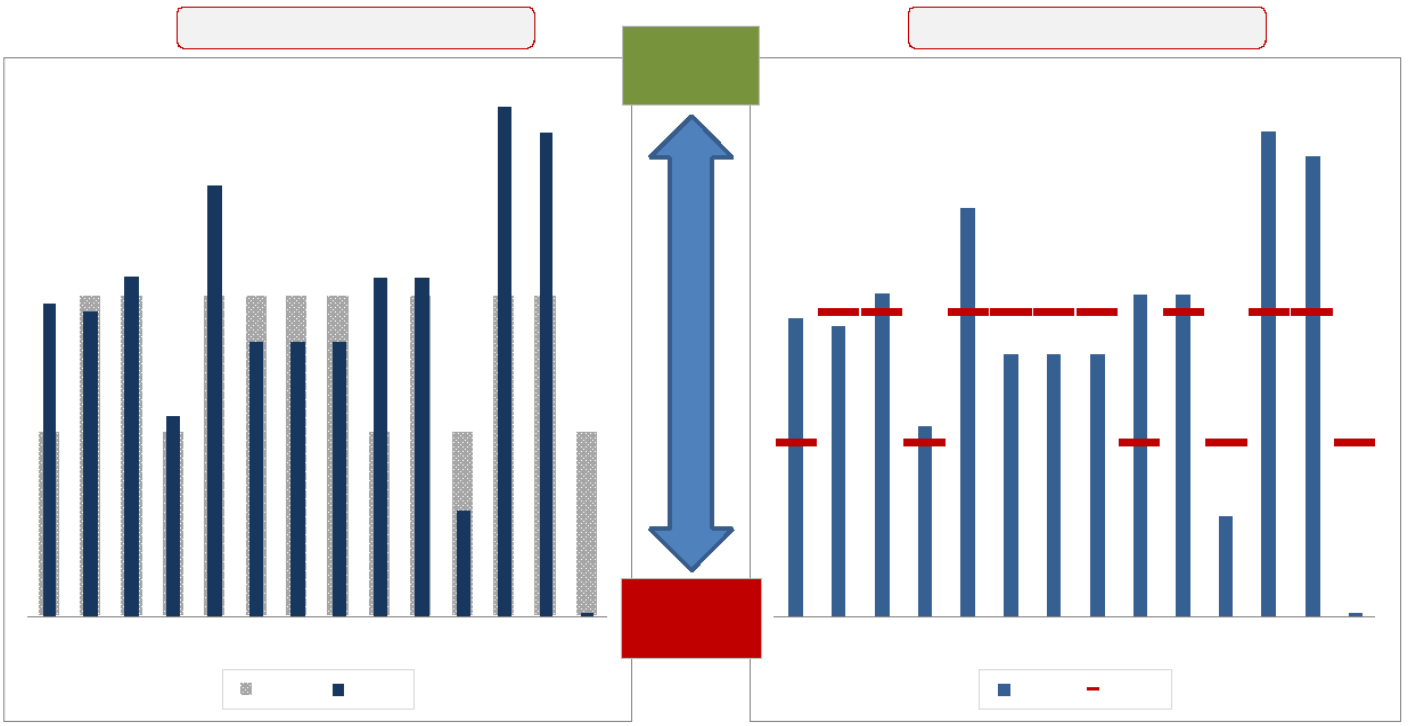


Table 7.6: Data behind Figure 7.6: Response to Connected Worker Questionnaire above – showing Question Text, Target Value expected and Actual Value Recorded.

Chart Data			
	Question text	***Target***	***Actual***
Q6	The care home staff found it difficult to get the video to work to my satisfaction	2.0	3.4
Q7	The device provided good quality visuals to support my decision making about care needed	3.5	3.3
Q8	I found the process simple to use	3.5	3.7
Q9	The headset frequently lost connection to the network	2.0	2.2
Q10	I would like other care homes under my care to have access to this equipment	3.5	4.7
Q11	I found it easier to accommodate the call rather than visit the care home	3.5	3.0
Q12	The device improved my ability to support the people I care for	3.5	3.0
Q13	I found it useful to have the headset to support discussions with the care home staff	3.5	3.0
Q14	The device added no value to the care I was able to provide	2.0	3.7
Q15	By using the device, the care home staff were able to stop me or my team having to visit the care home	3.5	3.7
Q17	It was reported that the people I saw through the headset were frightened by the headset	2.0	1.2

Q18	I would be happy to use digital tools again in the future	3.5	5.6
Q19	I feel more confident in using digital tools after this study	3.5	5.3
Q20	I would not want to use this technology again beyond the pilot	2.0	0.0

7.6.4.2 Health XR

As the Health XR app did not reach a stage where it could not be tested in clinical field no health outcomes could be evidenced. It is important to note however that a significant number of the participants questioned the value proposition, rather they felt that if the app had been designed as clinical information aide rather than a therapeutic intervention then more value, interest and compliance would be achieved.

This was particularly noted in three of the interviews were the participants lost enthusiasm and became frustrated with both the application and themselves for lack of reliability. A simple process of engagement prompts or integration with local diary management tools would add value.

The two most significant concern, coming through all five interviews were:

- The inability of the LiDAR camera to fix accurately on to the body, the expectation that individuals would have access to a clear room of sufficient size at home without inanimate objects being unrealistic.
- The need for a second person to support capture and recording of the exercise regime was also seen as a key issue that would exclude significant populations.

7.6.5 Process outcomes (e.g., net zero and wider societal benefits)

7.6.5.1 Connected Worker

When considering the question "*What added value, if any, does the care provider perceive that the technology gives to their care outcomes?"* it is worth noting that the negative statement "*It was reported that the people I saw through the headset were frightened by the headset"* was strongly disagreed with scoring *1.33* as was the statement "*I still needed to advise the home to call out an ambulance / emergency care team despite using the headset to support my clinical review"* with a score of 1.14

The evidence from the literature on the benefits of using remote consultation are overwhelming when considering the early works of Costa et al (2017) Grenier et al (2003), Perkins et al (2014), Russell et al (2015) Sweeny & Gutierrez (2002). It was important to understand what specific benefits existed from the head mounted tablet in contrast to the traditional methods used by other units, particularly where other consultation tools were made available by the NHS as seen in the Russel et al (2015) study. This was also confirmed by the interviews with clinical staff who

outlined in their training sessions how they had used multiple handheld tools to enable the patients to connect with practices and family members.

We can see that over the period of the trial:

- Reduced impact on ambulance x 1 episode over 12 weeks.
- Family Members – nil
- Mileage saved 78 miles on 7 occasions (plus a further 6,127 miles on 2 occasions as B-End users were in Austria and USA – this would replicate the situation of receiving input from a leading specialist in another country). This saved 1.37 metric tonnes of carbon.

Additionally, the care homes were able to access remote trial support using the headsets from United States and Austria further demonstrating the time and carbon savings. This reflects the opportunity not just from a health and social care perspective but also how rural businesses could shape global markets regardless of sector.

7.6.5.2 VRSS – Health XR

Although the application has not reached a stage where it is ready to market, the economic value has been partly outlined by the company in Section 6.4.8 benefits to company. Looking at the value of the expert advice and access to health service personnel provided to the SME. The programme is seen to contribute circa an additional £15k to the SME above that of the grant provided. It has not been possible to identify a return on investment as the development is yet to reach phase three.

7.6.6 Activity growth capacity

7.6.6.1 Connected Worker

The Care Quality Commission in their guidance regulating care homes highlight reasons why care homes may still need to close their doors to visitors beyond the pandemic. Developing the user's confidence and acceptability of the head worn camera means further growth opportunities do exist especially if they target links with the wider clinical data streams.

Across the NHS in England there are approximately 39,000 care homes (Skills for Care, 2020). In Shropshire and Worcestershire there are also Rural Care Units who could benefit from expert Acute Hospital remote visual support treating 3,246 admission per year (NWOPD, 2019). This would allow support to extend beyond clinical decision making but also training and supervised practice.

7.6.6.2 VRSS Health XR

Feedback from Stage 2 has indicated that the current value proposition is unproven, with strong suggestion that the USP (unique selling proposition) of the device needs to address less therapeutic interventions, or as a minimum, improve the reliability of the avatar possibly by the use of IoT sensors. Learning may be acquired from the Norfolk and Norwich Rehabilitation trial. The activity figures below do demonstrate a market for the SME however it may be better to focus on supporting patients to

complete exercise regimes, get access to videos as prompts to build confidence and competence rather than remote consultation and review.

As described we can see that the market opportunity for an SME within health and social care exists if sufficient 5G coverage is enabled if we consider the extent of Musculoskeletal activity in the testbed area.

Detailed APC admissions profile for M81042 and M81629 between 1 March 2019 and 28 Feb 2020 due to Covid-19

Table 7.7: All APC Admissions and Diseases of the MSK system and connective tissue for Tenbury Wells Surgery and New Court Surgery

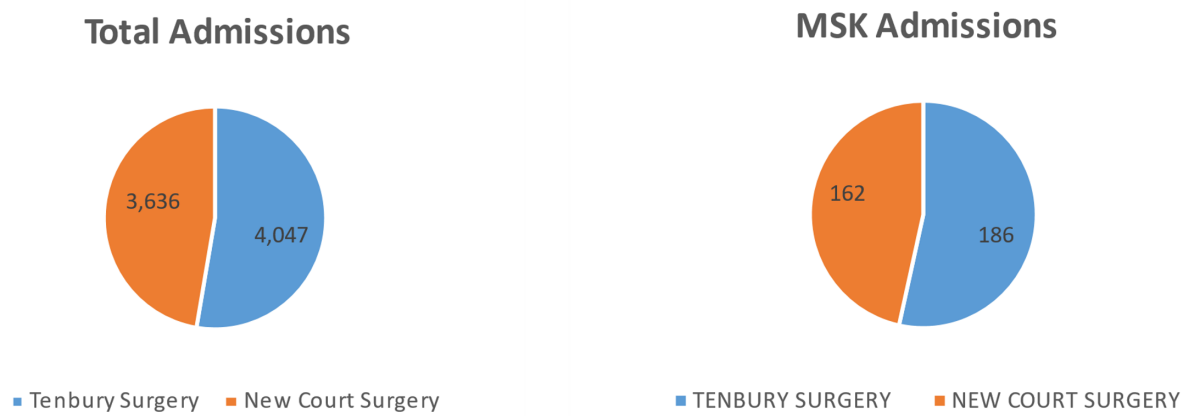
All APC Admissions for the 12 months period

Practice Code	Practice name	All ages 2018-19 List Size	Admissions	% of Admissions
M81042	Tenbury Wells Surgery	9,411	4,047	43.0%
M81629	New Court Surgery	9,840	3,636	37.0%

Diseases of the musculoskeletal system and connective tissue

Practice Code	Practice name	Total Admissions	MSK Admissions	% of Admissions	% of List Size
M81042	Tenbury Wells Surgery	4,047	186	4.6%	2.0%
M81629	New Court Surgery	3,636	162	4.5%	1.6%

Figure 7.7: Total Admissions compared to MSK Admissions for Tenbury Wells Surgery and New Court Surgery



(data shown in the pie diagrams are from the tables above)

For this ambition to be realised though VRSS need to consider the functionality of the Health XR app for clinical use both within network connectivity and user experience on both existing NHS connected environments and a 5G environment.

Table 7.8: Health XR application download speeds across networks

Environment	The time used to upload / download the image met reasonable expectations	I found it easy to record the image and upload the file	I found it easy to see the image in a way that was meaningful to me	The image displayed met my expectations on stability	Average score
5G	2.14	1.57	2	1.71	1.86
University	2	1.43	1.0	1.0	1.36
4G	1.91	1.57	1	1	1.37
NHS corporate	1.83	1.71	1.57	1.72	1.71

As we can see, the speed times were slightly improved for a 5G network but from a clinician point of view there were still questions on the meaningfulness of the data and stability of the image. This was fed back due to the need for the following:

- Image was fixed and could not rotate so the therapist had to get up and move the iPad to get the 360° view.
- Delay with image activating which was not clear if this was connectivity or delay with patient having to walk from camera before avatar locked on.
- Question on viewing avatar solely did not contextualise image against the standard exercise so change in function is hard to identify.
- Multiple files appearing after upload so duplicates appearing and not logically being listed or recorded as viewed. It was hard to identify which file to use for the test if we had not noted the file size previously, something that the therapist would not routinely do.
- On six occasions across all the environments the download failed and gave an error message. In the 5G environment it was thought that this was related to servicing of the cloud server by Amazon.
- The need to have a second person to record the image was perceived to be an issue, when trying to record alone it was not clear if an individual was in the image and it was not possible to review the recording. This concern was heavily emphasised as a potential safety risk and also as a digital inclusion risk by interviewees. A simple solution could be the use of a stand or reliance less on the LiDAR feature and use the front camera with IoT sensors.

7.7 Conclusions

The significant benefits of the 5G network and testbed reported by respondents across both use cases were:

- Usability and resilience to high data demands
- Reduction in risk for infection control purposes
- Time saving for staff in comparison to manual visits

For specific use case additional benefits were seen as:

- Quality of real world information to shape development (Health XR)
- Consistency of exercise compliance (Health XR)

There were some limitations expressed about usability for those with smaller heads also for quality of audio due to three way dialogue. This may be a further opportunity for the device manufacturers to work with the NHS to address.

No evidence could be found on impact on length of stay but this is not necessarily a desirable outcome (Seaton et al, 2016).

7.8 Recommendations

7.8.1 Connected Worker

As described this validation was significantly restricted by the limited sample size and response rate, it is suggested that a broader cross sample be taken for a future follow up review. This would, subject to ethical approval, include residents' perceptions and not just the carers.

Consideration of contrasting platforms such as AccurRX and additional information system supply on headset may also increase functionality although user experience will still be a constraining factor.

7.8.2 Health XR

It is suggested that the product still be considered as a development product, with a requirement for further testing and development before application in a clinical scenario.

The added value of the avatar was questioned due to stability issues within the technology, so it may be important to contrast LiDAR against a sensor based (IoT) approach. However, in the short term it may be useful to share the video file in addition to the avatar if a clinical decision is to be supported – this will require a more detailed DPIA to be carried out due to the transmission of personal data.

It is also important that rather than a clinical intervention tool, the app is considered as an aide memoire and information giving device, still requiring 5G, but increasing the compliance of the patient with exercise regimes using nudge techniques rather than direct interventions.

Although this review found that this testbed had limited reach into the health and social care market (20% n=1), it is recommended that an increased focus on extending the reach would be beneficial as 5G becomes more available.

8 Impact of the Results and the Benefits Realised

As established in Section 2.3, the WMR5G project was a collaborative project across the counties of Shropshire and Worcestershire. The collaboration brought together new and sustainable partnerships across public and private sectors the impact of which saw new relationships evolve both as Business to Business (Airband & BT) and Business to Academia (Airband, BT with the Universities of Chester and Worcester). This collaboration was further enhanced and strengthened, as seen in Section 7.4, once pan testbed cooperation was established. Evidenced by the advice and guidance of the Liverpool Adoption Readiness Level tool being embedded and shaping the development of the Health XR app (see Appendix L for further details).

Contributions to wider collaboration with other DCMS 5G Trails and Testbed (5GTT) projects around ‘skills’ and ‘security’ were also made as well as engagement and support of UK5G ecosystem events across a variety of topics.

In addition to the findings described in Section 7.6 and the lessons learned (Section 9: Key Learnings), the project was able to identify benefits of the project through its impact on the following:

- Investment Stimulation
- Technology Readiness
- Network Use cases
- Knowledge Creation
- Health Use cases

The project reported on these benefits at each milestone to DCMS. A copy of the final Benefits Realisation report is attached in Appendix R. A summary of the benefits is described below.

8.1 Investment stimulation

The project generated an additional £84,157 investment in Research and Development above the public funding received. It also generated private sector investment into Research and Development of £163,775.

8.2 Technology readiness

The project started with the use case having either a concept formulated or tested only in experiential lab / desktop settings and were needed to be progressed to be validated in real world environment.

All the use cases progressed at least one TRL level with two products progressing three levels, namely Airband’s alternate model and BT’s connected worker technology.

An initial anticipated benefit of the Health XR app, the use of VRSS sensors, was not realised as the company moved to the new LiDAR camera. Subsequently, the technology level had to be adjusted. However, the Health XR app still progressed one level from TRL 2 to TRL 3 during the WMR5G project.

8.3 Network use cases (a new rural model)

The planning of and delivery of private 5G network infrastructure in Tenbury Wells provided the opportunity to establish any efficiencies available through the repurposing of fixed-wireless sites for cellular deployments. It is widely recognised that additional mast infrastructure is required to deliver 4G and 5G into rural areas. The project demonstrated in the planning phase costs could be reduced and time taken for site acquisition and planning could be greatly reduced. At the outset of the project Airband identified over 5000 rural structures, many in 3G and 4G not spots. Assuming cost efficiencies in the planning phase of c.£5,000 and 147 days saving in in planning time per site, and that only 10% of the sites were required to host Cellular infrastructure, then £2.5m and up to 5 months of delivery time could be saved across these assets for one MNO operator in the planning phase alone. These figures

would be higher if they were extrapolated to include fixed-wireless assets across all rural areas of the UK and consider the deployment needs of other MNOs.

The largest cost savings of this model were predicted to be generated through the reuse of existing assets; in particular, reducing build and operating costs. Unfortunately due to the 'greenfield' site that had to be selected to deliver the use cases and the change in network partner, the project has been unable to evidence these savings, however, provides assumptions on how further savings and time could still be delivered here.

8.4 Knowledge creation

The testbed developed and reinforced partners knowledge on the importance of stackable 5G use cases and the development of the place-case (designing a network for a group of use cases and prioritising the needs of those with the highest value), evidenced both by development of case study documents that are accessible to partners and the wider public through the testbed communication plan.

The current ecosystem of products that can natively use 5G networks is still in its infancy and does need rapid scale up if the true opportunities of 5G are to be exploited. Both in general in terms of only having one device and not reliant on external modems or another technology e.g., Wi-Fi, but also in particular in health and social care settings when products need to be regularly cleaned and used in scenarios that they may physically interfere with service delivery or may themselves be at risk of being interfered with by patients.

The testbed did develop an appetite for rural connectivity amongst consumers that generated exportable knowledge globally.

The project was able to repurpose infrastructure without meeting local resistance and also deliver savings.

8.5 Health use cases

For the purpose of the testbed and to maximise the opportunity for market entry and wider adoption in health services a separate evaluation study was designed and delivered during the testbed. This study measured the impact within the timescales of the testbed but will also be followed up to understand the longer term impact of the project.

Locally the testbed was able to show benefits to the individuals, organisation, and society. Namely:

8.5.1 Individuals

The use of the testbed improved acceptability and skills for digital tools in areas of workforce that were historically underinvested in.

The importance of a specific role of system integrators to bridge the narrative and technical, and that investments in these roles will speed up implementation of new technology.

8.5.2 Professional

The use of 5G network did reduce the need of primary care staff to visit care homes but that human nature still requires the visual connection rather than just data streams.

8.5.3 Societal

The testbed has shown that delivery of this testbed can improve rural connectivity and has the potential to reduce the carbon footprint of health and social care services as they seek to move to a net zero model, assuming that installation takes place on existing infrastructure and its components used are ultimately recyclable.

That collaboration between the different anchor institutions of the NHS and Local Government is critically important. This has not least been physically evidenced by an increased level of communication, around digital, technology and connectivity, between the Local Authorities, NHS and Academic partners involved in the project, outside of the scope of the project itself. With work being undertaken on potential funding opportunities, aligning local strategies and new partnerships with other public and private sector partners.

9 Key Learnings

In progressing the testbed, the evaluation team used an adaptive approach that enable the team to learn and identify key lessons that could be re-invested into the project or shared through the multi-channel engagements the team undertook. A summary of these lessons is identified below alongside the key audiences that would wish to pay attention to the learning.

The lessons learned, follow the thematic structure of the report, however as they may have also been applied to, or modified other themes reference to the primary source is provided.

Table 9.1: Lessons learned, rationale, audience, and reference to section within document

Lesson Learned	Rationale	Audience	Ref.
The MNO spectrum licence does not permit the operation of aerial drones. Shared and R&D licenses required specific permission and were predicted to slow down license applications beyond 12-week lead time.	*There was a potential of having a use case using drones, however the MNO spectrum licenses and the N77 spectrum Shared Access Licence does not permit the operation of drones. Initial investigations into this were explored with Ofcom. However, due to time constraints the project did not pursue an 'aerial drones' use case.*	DCMS	2.4
Previous experience of digital applications and process significantly influence user expectation and acceptability of new technology.	*A high volume of GP care home consultations had moved over to remote methods such as mobile phones, AccuRx and due to lockdown restrictions and therefore connected worker use case was initially well received. This however became more challenging as clinical understanding of the information flow grew and realisation that A-B communication model does not always work rather it becomes an A&A* - B model. Reverting to tablet-based tools such as AccuRX became important to clinicians despite any underlying Infection Control risk.* *Volunteers for Health XR had significant previous experience of using smart phone applications.* *In both cases this led users, during the trials to contrast and compare the current use cases and express frustration and disengagement if not meeting their expectation. This was also partly due to the network approach not considering the workflow fully in the design process, as stated earlier.*	All	2.6.4
Health XR technology readiness levels (TRL) in 5G	*Following the initial change from IoT sensor to LiDAR sensor that saw the Health XR software written for a web-based application hosted on iPhone / iPad, the testing of the workflow and impact on clinical interventions had not been fully validated for pilot testing to be launched.* *Following engagement with clinicians, roadshow feedback and nexGworx; lab-based testing for stability and application, modifications and direction changes, it was recognised that the application was at TRL level 2.* *It was important for the SME and volunteer users that the application reached sufficient stability to achieve TRL level 5 testing. The Development and Deployment Plans created by Health & Social Care Use Case Group to monitor and manage app development and progression of TRL from 2 to 5 was established utilising a phased approach: Phase 1 - development of app; Phase 2 - further development of app and testing with critical*	SME	2.9.1

	friends; Phase 3 - testing with healthy volunteers. TRL level reduced from 5 to 2 in 5G context. *This methodological approach alongside the application of the Adoption Readiness Level tool (collaboration work with other projects), will equip the SME for any future developments of both the Health XR app or other products seeking to enter the Health and Social Care market.*		
Routine appointments delivered by remote consultation benefit cognitive impaired clients	*Reducing the need to transport a patient to an appointment enables a cognitively impaired patient to stay in familiar environment reducing behaviours associated with anxiety, reduce travel costs and carer disruption.*	Health and Social Care Providers	2.9.2
Early consideration of increasing allowable power to N77 radio in Tenbury Wells to bring greater alignment to N78 at Malvern	*If more consideration had been given to increase allowable power level (within standards) to the N77 solution, considered early in the project, rather than the switch to the Ericsson NSA solution, which was then considered the most appropriate for the coverage requirements for this project potentially greater and increased coverage may have been achieved. Specific differences to note:* ***Technology maturity** – The N78 solution currently deployed at MHSP offered a tested solution with reduced operational and performance risk compared to the adoption of the relatively new N77.* ***Coverage capability** – The N78 solution offered a more efficient spectrum coverage solution more suitable for a medium range outdoor solution compared to the N77 based solution, ensuring a comparatively better indoor and outdoor performance.* ***Delivery time** – By using the existing core infrastructure at MHSP BT were able to mitigate delivery risks related to the introduction of a new platform.*	Network operators	3.2.2.1
Need for common language and interface between Infrastructure Providers, Mobile Network Operators, Software & Field Engineers and Customers	*The project design & network build process required frequent translation and debate between Health Use Case Group, Network Group and Mobile Network Operator to ensure customer workflow expectation and network deliverability were consistent and had a common interpretation.*	All	3.3.2.1
Procurement routes through multiple partners are complex and can prove too time consuming and challenging	*Throughout the project there have been examples where the procurement routes have proven to be too time consuming and challenging. For example, the decision to order EE 4G commercial SIM cards through BT. WCC stepped in and managed to order the required EE 4G commercial SIM cards at very short notice to ensure the project progressed at this critical point. Similarly, there was an issue procuring router devices through BT within an acceptable time frame. Internal processes can prove*	DCMS	3.3.2.1

	very problematic and time consuming and there should be an upfront understanding of these challenges so that they can be factored into the project plan and delivery. Finding a work around was a challenge but possible and did cause knock on issues and complexities. This needs to be laid out in the early milestones and bidding process.		
Early consideration of pre-existing infrastructure both commercial and private fit with customer workflows	*By overlaying existing Mobile Network Operators, infrastructure and broadcast maps onto customer premise locators and delivering the information to field engineers insitu identifies early misdirection concerns.*	Mobile Network Operators, Network Providers	3.2.2.3
It is important that for Customer Premise Audits that clinical workflows are integrated to accelerate adoption.	*If looking to implement a commercial model of support for non-NHS premises then consideration of staff inhibitors are required. Clinical workflows are a good proxy for these as local management plans will have already accounted for some of the building & structural inhibitors to deliver care to the residents.*	Mobile Network Operators, Network Providers	3.4.2.3
Earlier planning on communications plan is important and should be part of the first milestone	*The challenge is that given the current 5G public perception, although changing, a communications plan and clear strategy to respond to any enquiries or complaints became far more important than anticipated. Ultimately this delayed approach resulted in a lack of focus on the communications opportunities from many of the partners and missed opportunities to raise awareness and provide positive messages to public and potential customers.*	All	4.4
Airband's involvement as network provider in reutilising existing assets enabled benefits to be achieved in: ● **Land Availability** ● **Accelerated access and Wayleaves** ● **Planning Permission** ● **Power Flow** ● **Backhaul Flow** **However new technologies were not covered by the wayleaves.**	*There was an expectation that with Airband's involvement that efficiencies would be gained by utilising existing masts, which should have sped up deployment, saved time and money, and avoided planning challenges by improving existing assets rather than having to build new ones. Whilst this approach worked in terms of reducing planning and acquisition timelines. It was realised that* *wayleaves could be a stumbling block. During the Tenbury Wells mast build, despite all wayleaves already being in place, these did not cover the different technologies being used, i.e., 5G, and therefore needed to be updated. Airband's local relationships meant this issue was minimal, it is recognised it could have had an impact on the foreseen timescale benefits.* *We recommend that rural fixed-wireless network operators should review their wayleave template and existing wayleave agreements to meet the requirements of an MNO to deploy cellular or 5G technology, in advance of promoting their assets to the MNOs, this would reduce potential delays down the line.* *Planning permission was accelerated for 'fixed-wireless operators' who are registered as having 'operator rights'*	Local Authorities Network Operators	4.4

	within the Electronic Communications Code (ECC) which as with Airband WMR5G project would recommend. *By using existing assets where existing supply or ducts were present both cost and timelines were reduced as limited adjustment were needed to consider contractor availability.*		
Improvement and / or upgrade of masts already in place do not always deliver build efficiencies expected.	*For the reasons identified above despite the initial assumption being tested that the majority of existing infrastructure is suitable for improvement and upgrades and can carry additional kit, was not always the case. We discovered most sites would require some sort of improvements and upgrade, whilst efficiencies were recognised they may not be as large as predicted.*	Local Authorities Network Operators	4.7
Network descriptors and design built through understanding of clinical management workflow and workforce is essential to build user confidence and competence.	*In addition to the technology frustrations, any network design process must extend beyond the MNO and Field engineer but also consider the premises and workflow application. This is essential if any future business case is able to show a return on investment for customers such as care homes or the NHS.*	Network Operators NHS	5.4.1
Inability to carry out full 5G site survey until the 5G network is live and operational with proxy lab at Malvern only adding value for prototype testing not for integrated clinical workflows.	*Learning from previous projects demonstrated that the network performance may differ when the network is actually turned on and operational rather than modelled. Therefore, a full 5G site survey is required however this cannot be carried out until the network is broadcasting.* *Due to delays in the network deployment, a 4G solution was implemented to bridge the gap before the 5G network was implemented. This enabled project team to carry out site pre-emptive surveys and familiarise themselves with site locations as could care home staff with technology. Learning from these surveys should and could be used by a Network Operator in final design model for optimisation.* *Actual 5G connectivity is only measurable once the service is live and optimised.* *A 5G Lab however adds value for software engineers in developing prototypes prior to live testing and can demonstrate potential impact.*	All	5.4.1
Technical solution is not necessarily the practical solution	*It has been seen on several occasions within the project that while there may be a cost-effective technical solution - as in the case of Connected Worker where BT's solution has one CPE deployed and moved - this may not be a practical solution if not adopted by the use case participants.* *The BT solution for Connected Worker where a single CPE had to be relocated each time the HMT was out of Wi-Fi range was not accepted by any of the care homes as an appropriate solution for their staff. The care home staff are not technologically skilled to determine the best*	All	5.4.1

	location to deploy the 5G routers so that they obtain the best 5G signal (or 5G at all) or the best broadcast internally of the Wi-Fi to the HMT. This also does not consider the time taken to return to the base unit, unplug, move, reboot, and reconnect the HMT and then re-join the MS Teams meeting – tested to be around 3-5 minutes. During this period the busy nurse or GP is waiting to be reconnected to the remote consultation and felt this was not a good use of their time. *There was also the consideration that the single router could be used within the trial for a limited number of patients of the GP. However, this meant that the GP would have to visit the site and would therefore use this method as well for those highlighted for the trial – as face to face is a better service if already on site. Projects must take into consideration real world practicalities and challenges and ensure that any proposed solution being implemented and trialled is workable. Alternative solutions are required to be investigated with a workable practical solution being implemented. This may mean additional cost of devices or a greater chance of conflicting devices.*		
Remote working and the pandemic increased demand for robust communication tools and the experience of project team and customers. It however could not wholly replace opportunities for tactile experiential learning.	*Although many meetings were done via video conferencing, it would have been beneficial to carry out several sessions in physical locations with partners. This would enable them to "touch & feel" equipment and for Network Providers to understand workflows beyond a desktop exercise. This was evident during the first evidence gathering session in the Tenbury Community Hospital. Even though the session went well, it would have been more beneficial to have all partners and clinicians in the same room for health use cases demos*	NHS partners SMEs	6.1
Conducting technical demonstration sessions online is not the most effective when seeking to rapidly build confidence and competence with new tools.	*The pandemic demonstrated the importance of remote tools such as zoom, Teams, Remo etc to both keep staff informed and when well managed engaged with learning.* *However, when seeking to build confidence and competence with new hardware a robust support programme built with experiential face to face support remained important.* *This was because all training and demonstration needed to be synchronous and as such are time consuming and without a "touch & feel" approach the full benefits of the hardware could not be demonstrated. This was with both use cases and was across the demographic profile of users regardless of digital experience. It was important that the project therefore arranged several small group presentations and demonstrations whilst adhering to Covid-19 social distancing guidance at the time.*	Local Authorities NHS	6.5.11

	Physical face to face demonstrations helped to convince clinicians over remote demos where they did not experience the full impact of what was being proposed. This was evidenced in the post implementation interviews. *Feedback was that the online sessions were difficult to follow, not easily understood, time delays, connectivity issues etc. Face to face provided better engagement and uptake of devices and software but did then involve the presenters to be flexible around delivery time and locations. Providing face to face sessions within the clinical settings meant a better understanding of real-world issues but meant occasionally interruptions to the sessions. Strict operating procedures were put in place around social distancing and cleaning equipment between those participating in the in-person events.*		
HMT access simplification and security for user convenience	*To simplify the use of the HMTs (and to aid security but without hard lockdown of functionality), a policy was implemented to present the user (care home assistant) with one option - launch MS Teams - for the purpose of the trials.* *However, due to opportunity of the wider functionality of the HMT, the alternate video communication platforms used by care home staff referenced earlier, opportunity exists to expand the provision of digital social care.* *There is a balance between locking down access to all elements of a device against a broader use of the functionality within a device for operational use which strongly suggest a need for a more flexible approach when providing devices to staff. The appetite for risk of the care home and health and social care system would need to be considered but within the context of these additional benefits existing risk controls?*	All	6.5.11
Deployment of devices – importance of single point of access to support mechanism	*Throughout the trial the ongoing support of the devices deployed and clarity on who has the responsibility within the project became a key driver. This will continue to be the case when considering of rollout of the trial as business as usual. Locally it was decided that responsibility for the trial would lie within the PMO as there are many elements that may causes issues such as the network, the network devices, the HMTS/iPhones/iPads, software, user issues etc.* *This initial point of contact will then triage the issue, resolve if possible or present to the correct consortium member to resolve. This also included curating the aide memoirs and support tickets.* *Consideration needs to be given as to the business-as-usual model moving forward that integrates this support into existing mechanisms however due to complexity of IT support arrangements and need to identify what is a connectivity issue and what is*	Network Operators SMEs	6.5.12

	hardware issue this will not be without its challenge. It raises the question if public sector organisations need to consider 'Operational Technology' (OT) support or ensure the right OT requirements are included in re-designed services.		
Importance of onsite technical site visits to determine where to deploy the devices within locations	*In addition to considering site clinical management plan and human issues technical site visits need to be completed so that an understanding of the technical/structural challenges each site poses can be formed.* *In Health and Social Care, buildings are not necessarily owned or managed locally. Location of devices within the site may need the assistance and authorisation of third-party organisations who manage the site.* *A technical site visit needs to be completed with the understanding of how the use case will run at that location. This will then provide a technical site report as to the proposed solution, how and what will be installed. It is essential to ensure early engagement with all parties involved to minimise disruption when deployed.*	Network Operators SMEs	6.5.14
Extending the evidence base of market demand with adaptive development model that understand NHS clinical processes may limit multiple changes to software build and focus a value proposition and USP.	*Multiple changes in direction of the use case, for example in the VRSS from a MSK assessment tool to a live session, as an information portal to a recorded exercise regime were led by and informed by clinical engagement and exploring how these processes work in practice. As physiotherapy services, similar to care homes, are not subject to a homogenous service delivery model in addition to the use of healthy volunteers, questions were raised about value of avatar, need to support information giving and user compliance and any additional functionality needed within the software - i.e. VOIP.* *Similar to early iterations of remote consultations in primary care within a secure environment the challenges to getting invite and log on details to user were reported. This would need resolution before market testing this would also include how the tool would and could integrate and accommodate current local OPD diary management protocols whilst remaining a viable product for users and the SME.* *Interviews have suggested that an SME looking to the develop a unique USP would need to validate workflow and demand with multiple stakeholders prior to investing in further builds.*	SME	6.4.4
Deployment of devices - hardware/software needs require early information on site specific nuances	*In identifying the use case a transparent selection process, specification and criteria was used and shared with prospective SMEs/ use case providers. However, for expediency reasons, when selecting test sites a convenient sample and volunteer model was used. There is an argument that a clearly defined selection*	Network Operators SMEs	6.5.7

	criteria developed from the technical visits would have benefitted all parties primarily as there was an initial assumption that all sites were at the same level of technology readiness, for example the use of MS Teams, staff skill level, access to power, building ownership etc. However, it was seen that there were some sites that were using MS Teams already while others had never used the solution. There was also an assumption that all sites were using technology to a greater degree already, such as monitoring bed movement etc; however, the level of technical experience within the limited sites varied from those using modern technical solutions to provide care to their patients to those that did not use technical solutions.		
Consider timelines for design & approval of clinical protocols.	*Design of clinical protocols to support the implementation of use cases took longer than expected due to the complexity of organisation's influence sign off. It was also seen that there was an additional requirement for a change management capacity which was taken up by those delivering the health and social care use case.*	Network Operators SMEs	6.5.8
Deployment of devices - hardware/software is subject to local protocols that can hinder roll out or create interoperability issues.	*Health and Social Care providers do not necessarily use the same communication tools, and in social care a less prescriptive model exists. This resulted in some care homes using Zoom, WhatsApp, Google Meet, AccuRX and more latterly Docobo in addition to or as an alternate to MS Teams. The HMT-1 headset can accommodate these differences however local protocols may not.* *Subsequently as part of the requirement for Connected Worker which used MS Teams, there was an expectation that each site would already have this. This was not the case. Ideally, any new accounts set up would have been within the Health and Social Care systems (NHS) but the subsequent setting up of NHS Teams accounts for non-NHS care providers highlighted a strenuous process of sign off and implementation. MS Teams itself however is not homogenous implementation across the NHS and is subject to the vagaries of the different organisational tenancies which can be set up differently. It is suggested therefore a standard MS Teams specification is required for further implementation.* *In this project to address the constraints the use case team proceeded with a nexGworx MS Teams account for each care home. This was subject to a broader Data Privacy Impact Assessment.* *Any future adoption of this technology would need to ensure that the sufficient time to set up official NHS MS Teams accounts is taken into consideration or greater flexibility being afforded to clinical teams to use platforms specific to the care home. It must be noted that each of*	Network Operators SMEs	6.5.8

	the platforms have had differing risk assessments undertaken in Health and Social Care settings.		
Clinician / Practitioner feedback on the use case proposals is important in shaping design, implementation, and adoption	*The NHS has faced multiple challenges in embedding new technologies and innovations. Clinicians can be somewhat sceptical about new technology and connectivity due to previous failed attempts for example the Connecting for Health project.* *Subsequently alongside the workload challenges, it took a lot of persuasion and effort to onboard them. Physical face to face demonstrations helped to convince clinicians over remote demos, as they were able to trial the technology as well as be more focused on the session. Providing real world examples, trialling the equipment, and showcasing these face-to-face has on boarded clinicians to the trials as they can visualise the benefits for themselves and their patients.* *This may be further enhanced as the new Integrated Care Systems address their new duties to promote innovation.*	NHS SMEs	6.5.9
Engaging with GPs took longer than anticipated	*Because of Covid-19 vaccination pressure on GPs as well as general work pressures due to Covid-19 restrictions, getting engagement from GPs took much longer than anticipated. The CCG health leads ended up in discussion with relevant PCNs to introduce a programme to backfill GP time, so that dedicated GP time to the project was available. GP time is very restricted and therefore early planning is essential for engagement and roll out as is consideration of their working pattern and clinical workflows. Knowing the right person to connect to within a surgery has helped as well as senior leadership being on board.*	SMEs NHS	6.5.9
Delivery of initial onboarding to the project – sharing this time with others does not always provide anticipated clinical time efficiencies.	*Running alongside the testbed the Health and Social Care system was delivering on separate Remote Monitoring of Care Homes using Docobo, learning from Liverpool 5G project. Initially both projects on occasions shared engagement events to minimise the abstraction of clinicians from their place of work to deliver two projects. Although initially from a system perspective this may be considered a good use of time and reducing overall costs, as the projects were independent of each other it led to longer sessions, attendees having information overload or amplified time pressures and some project confusion. It is suggested rather that awareness presentations should be shared but the onboarding and familiarisation should be done as separate pieces enabling focus on what is being delivered.*	All	6.5.9
Collaboration across parties strengthen business case for under invested areas.	*It is clear from interviews with both fixed network providers and other policy leads that the current commercial models deployed by both MNOs and Fixed Wireless Providers still present significant challenges for rural communities and persistent risk remains that these*	All	7.4

	dispersed communities may remain part of the hard to reach 10% identified in "Levelling Up" (DLUHC, 2021) despite significant investment. The collaboration across parties and programmes has been identified as a positive platform to address this challenge.		
Clinicians feedback around Health XR use case is important to build a business case for market entry	*Clinicians were engaged with throughout the journey and modifications including clinic management and user identification. As with the network design it is important that any SME wishing to enter the Health and Social Care model has designed the application through a co-creation approach that reflects the plurality of commissioning models. The value of models such as the Liverpool Adoption Readiness Level tool were evidenced.*	SME	7.5.2
Consideration for deploying devices and hardware must include an understanding of impact on clinical management plans.	*As the testbed deployment plan for each site involved the use of routers, it was quickly identified that in the clinical locations the power sources are being used by critical, essential or day to day equipment and therefore there is often a lack of spare power sources for the routers.* *Therefore, future deployment plans need to consider location of the routers/access point devices, types of devices needed within the context of availability of power and optimal coverage – GPs surgery and residents in care homes for example.* *As well as the practical issues to be resolved, deployment of new devices needed to understand the human and associated Health and Safety issues such as trip hazards, dangling wires, patients who may fiddle with the devices (especially cognitively impaired patients) etc.* *It was important that technical site visits were conducted to address these issues and provide guidance since they were not only around turning up with the devices but also to have access to cable ties, ducting etc or in managed services locations, pre-arrange meeting with onsite facilities lead.*	Network Operators SMEs	7.6.1
The importance of pan project collaboration to support adaptationist delivery and evaluation models.	*The DCMS model of clustering use cases enabled maximum knowledge exchange between projects. This approach enabled wider verification of challenges and proposed solutions as well as cross fertilisation of tools such as the Adoption Readiness Level. This improved access has significantly value to SMES who may be located outside the natural communication channels of the other testbeds.*	DCMS	7.5.2
Handover of HMT devices between Wi-Fi routers impaired the practical application of headset within the 4G network at location	*It was found that as the care home assistant moved between the resident's rooms as part of the online ward rounding consultation, the HMT often dropped call from local connectivity due to handover between the individual 4G access modems. Although was a known risk that was being monitored as part of the baseline work this challenge reinforces the need for technical site visits*	Network Operators	7.6.4

	including clinical management workflow plans for local network coverage. This also reduces the risk of unintended consequences from network conflicts. *A short-term local solution was implemented through the ongoing operational support with care homes staff instructed that best practice is for the GP / Nurse to remain in the MS Teams call while the care home assistant (via the HMT) came out of the meeting when they finish with a resident and are moving to the next location. This enables sufficient time for the HMT to lock on to the new stronger signal.* *This also helps with DPIA as the residents are being consulted in their own rooms / private room and there is no broadcasting of "accidental" video / audio captured as the care home assistant is moving between locations.* *Issues associated with Access Point zones, strengthens case for 4G/5G native devices or cellular Private Networks and potentially newer generations of Wi-Fi technology.*		
Support required to innovator SMEs to understand critical aspects of market pull and user acceptance rather than technology push.	*The project quickly saw that support is required to innovators (such as VRSS) to improve usability aspects of the technological developments, a key component of market demand and regulation.* *To maximise market pull and user acceptance there needs to be early engagement with clinical teams and patient groups to shape and co-create the design, keep system close to intuitive so those with no IT knowledge can run the app.* *Early findings also suggest that consideration of the use of apple products within a P5GNR environment so that early data demand and software development needs be understood. This can be assessed by early use of the ARL tool.*	SME	7.6.4
Use of LiDAR cameras in the Health XR software	*The software (and lidar hardware) provides a solution in relation to MSK movement assessment but has been built from a technology view. The software has not gone through proper User Testing / Real World Testing and therefore issues were found in the user journey. It is strongly suggested that User Acceptability and Testing specialists are needed to review the software before being presented to the project to ensure that UAT will go smoothly and limited calls for support once deployed. This will maintain participant enthusiasm and compliance. For example, feedback from some users suggested that the greater value could be achieved by the application integrating into their own smartphones and diary management by automatic prompts to comply with exercise regime.*	SME	7.6.4

	The Project team became more involved in the UAT side to support the SME in understanding this requirement. If the SME wishes to proceed to Class IIa accreditation it will still need to review process and software before engagement with clinicians and patients and follow robust development, deployment, and operational models. *The project also recognises that LiDAR technology on smartphones is restricted to a small number of high-end models and that trade press articles have been questioning if LiDAR will be dropped from all handsets due to current cost challenges.*		
Do not assume the digital skills of those using the devices and software	*There is often an assumption with technical projects that end users will have an interest in and high level of knowledge of technology. Across the projects and their implementation training it became clear that there were different levels of digital ability and digital inquisitiveness within the end users. Therefore, it cannot be assumed that all individuals who are required to use the technology will know how to or have an interest in. As part of the onboarding process it is suggested that projects determine those with the digital skills and those that don't and provide tailored support to each and offer some sort of digital upskilling as part of the onboarding process.* *For future projects as part of the change management process, there needs to be digital skills analysis of the people within the locations set up in the trial area. Ideally we would use those with high digital skills as ambassadors or change agents however due to time constraints, traditional working practices and inability ethically, within such short term timeframe practically to incentivise these champions this did not occur.*	All	7.6.4
Health XR connectivity was best suited to the more balanced / less contended Private 5GNR network than existing NHS and commercial offer.	*Although software has been written for a web-based application hosted on iPhone / iPad, testing of the data exchange between devices had not been undertaken in a 5G / 4G environment or any assessment of impact on clinical workflow prior to joining the testbed. By using a standard simulated exercise undertaken in four separate connected environments: NHS Wi-Fi broadband, 5G commercial network, 5G private network and commercial broadband evidence was collated on the importance of P5GNR network with upload/download speeds modelled against a standard 15-minute appointment time in the NHS for therapist to see their patient. There is clear evidence that the download time in a non 5G environment would be unworkable for NHS time with up to 97% of an appointment being used waiting for download of the recorded baseline video.*	SME	7.6.6

	Equally interviews with users demonstrated frustration with upload times in non-private network environment although this has less commercial impact.		
Engaging with care homes and access to care homes requires careful planning and strong communication between network operators and care staff.	*Engaging with care homes and access to care homes proved to be difficult throughout the project due to Covid-19. This ranged from the total lockdown of sites early within the pandemic, to following specific onsite protocols minimising the risks to the care home residents and staff. At times, access to care homes was refused as outbreaks of Covid-19 had been registered and the site went into full lockdown.* *The project utilised various routes to gain initial access to the care home sites via the NHS and WCC property services to establish the correct decision maker contact and secure appropriate permissions.* *Project members that accessed the care homes followed local processes in place at each site but had to have a negative LFT result from that day, an acceptable temperature range and to fill in an appropriate Covid-19 form before entering the site. Therefore, this needed to be factored into the time allocated to the site visit, up to an additional 30 minutes per site.* *The situation at each care home was fluid, and where access was denied due to not following their local process, an outbreak of Covid-19 on site, or only allowing critical visitors onsite, the project respected that directive.*	Network Operators	7.6.6
Health XR moving away from original sensor suit to iPads did not provide sufficient accuracy to satisfy user need.	*VRSS decided to move away from their original hologram/sensor suit idea to replace it with IoT pads due to Covid-19 considerations and other aspects such as mobility of patient. The IoT devices did offer flexibility as they attach to clothes rather than full shirt or trousers (such as in the East Anglia Rehab Model, 2021), however as concern was expressed by therapists that the patient is not an expert in placement so data captured may be inaccurate.* *Noting further improvements were seen within the 5G Apple devices which means that there was an opportunity to use the LiDAR camera to assess movement without the requirement for sensors to be attached to the patient. It was decided that this less interventionist model would provide the simplest solution.* *In the field however it was noted that the LiDAR camera fixed on many points including non-animated objects, which although amusing did not provide sufficient accuracy for any AI based software to accurately reflect movement to a clinical standard.*	SME	7.6.6
Although time consuming the nature of	*The project team found that although it is more time consuming to provide face to face engagement around*	NHS	10.15

end user engagement still requires face to face interactions to get buy in.	*the onboarding this process it allows for better understanding and more frank discussions surrounding on-going patient safety and liability which was linked to consent.*		
The Meridian platform of West Midlands Academic Health Science Network alongside the locally developed shortlisting criteria were an efficient and effective way to onboard future partners.	*Recruitment of partners was undertaken using the Meridian Platform and subsequent use case shortlisting criteria template was shared with DCMS for use on other projects. It effectively contrasted several use case submissions against a number of different priorities / criteria, ensuring the decisions made were documented and processed and embedded in the project processes.*	All	10.6

10 Appendices

10.1 Appendix A: glossary of terms

Abbreviation	Full Terminology
WMR5G	West Mercia Rural 5G
LA	Local Authority
CCG	Clinical Commissioning Group
GP	General Practitioners
ICS	Integrated Care Systems
RCC	Rural Connected Communities programme
DCMS	Department of Digital, Culture, Media and Sport
VRSS	VR Simulation Systems Ltd
WCC	Worcestershire County Council
WMAHSN	Midlands Academic Health Science Network
NSA	Non-Standalone
SA	Standalone
MNO	Mobile network operator
TRL	Technology Readiness Level
LiDAR	Light Detection And Ranging; or Laser Imaging, Detection And Ranging
HMT	Head Mounted Tablet
5GTT	5G Testbeds and Trails Programme
NPN	Non-Public Networks (i.e. private networks)
Mbps	Megabits per second
Gbps	Gigabits per second
mS	Millisecond
ISDN	Integrated Services Digital Network
PSTN	Public Switched Telephone Network
NR	New Radio
N77	New Radio operating band, covering the frequency range of 3.3GHz to 4.2GH
N78	New Radio operating band, covering the frequency range 3.3GHz – 3.8GHz, a subset of the n77 frequency range
Ofcom	The Office of Communications; the government-approved regulatory and competition authority for the broadcasting, telecommunications and postal industries of the United Kingdom
VoLTE	Voice over Long-Term Evolution (4G)
PMO	Project Management Office
CR	Change Request
AR	Augmented Reality
AONB	Area of Outstanding Natural Beauty
SSSI	Sites of Special Scientific Interest
STP	Health Sustainability and Transformation Plan
LEP	Local Enterprise Partnership
SRN	Shared Rural Network
APPG	All-Party Parliamentary Group
XR	Extended Reality

DPIA	Data Protection Impact Assessment
SIRO	Senior Information Risk Owner
PIA	Privacy Impact Assessment
MHSP	Malvern Hills Science Park
RAN	Radio Access Network
NDAC	Nokia Digital Automation Cloud
LTE	Long Term Evolution
NR	New Radio
TDD	Time Division Duplex
OSS	Operation Support System
E-OSS	Enterprise Operation Support System
LLD	Low Level Design
LAN	Local Area Networks
A-End	The remote termination location of an Ethernet circuit or A-End – the patient end of the use-case solution
B-End	The customer's Premises location or B-End – the GP/Clinician/Nurse/Physio end of the use-case solution
SIM	Subscriber Identity Module
APN	Access Point Name
PN	Private Network
PDU	Power Distribution Unit
WPD	Western Power Distribution
BBU	Base Band Unit
DNO	Distribution Network Operator
RCBO	Residual Current Breaker with Over-Current
CPE	Customer Premises Equipment
TCP	Transmission Control Protocol
5GPN	5G Private Network

Anchor institutions - refers to large, typically non-profit, public sector organisations whose long-term sustainability is tied to the wellbeing of the populations they serve.

Digital Technology Assessment Criteria (DTAC) – The DTAC for health and social care gives staff, patients and citizens confidence that the digital health tools they use meet our clinical safety, data protection, technical security, interoperability and usability and accessibility standards.

10.2 Appendix B: consortium partners, logos, and brief description

Consortium Partner	Description
Shropshire Council	Shropshire is the second largest inland rural county in England, and one of the most sparsely populated, with just one person per hectare (1.01 persons; 323,136 population). Ensuring our population has equitable access to good digital connectivity and supporting them to use innovative technology as their preferred way to work and transact remains a key objective for the Council. https://www.shropshire.gov.uk/
Herefordshire and Worcestershire CCG	NHS bodies in Herefordshire & Worcestershire work together in partnership (as an Integrated Care System) to deliver healthcare and improve health outcomes NHS organisations in Herefordshire & Worcestershire work collaboratively (as an Integrated Care System) to deliver healthcare and improve health outcomes for the population of over 800,000 people across the two counties. This partnership includes NHS Herefordshire & Worcestershire CCG, Worcestershire Acute Hospitals NHS Trust, Wye Valley NHS Trust, Herefordshire & Worcestershire Health & Care NHS Trust, alongside Herefordshire & Worcestershire County Councils and Primary Care providers (GP practices and PCNs). The partnership is already at the forefront in healthcare innovation, and we firmly believe that digital initiatives and programmes are key to enabling us to deliver our vision of providing truly integrated care. Ensuring a 21st Century digital infrastructure is a key priority to help us achieve this, which is why being a partner in the WMR5G project is so important to the NHS. Innovations in technology and improvements in network connectivity offered by 5G, have the potential to transform health and social care and bring efficiencies in how services are delivered. This supports the NHS 'net zero' ambition, the decentralisation of healthcare (by providing more services and support away from main health sites) and the NHS Long Term Plan. https://herefordshireandworcestershireccg.nhs.uk/
Worcestershire County Council	Worcestershire has one of the fastest growing economies in the country with an array of highly reputable, fast growing, and successful companies from SMEs to large Multi-national Enterprises. We are aiming to become a financially self-sufficient Council, to achieve this aim we will promote and support businesses in the county, businesses looking to relocate to the county and those businesses we work closely with.

	http://www.worcestershire.gov.uk/
British Telecom (BT)	BT is one of the world's leading communications services companies. We serve the needs of customers in the UK and in 180 countries worldwide. Our main activities are the provision of fixed-line services, broadband, mobile and TV products and services as well as networked IT services. We are a leading communications services provider selling products and services to consumers, small and medium-sized enterprises, and the public sector. https://www.btplc.com/
Airband Community Internet	An alternative broadband provider in rural areas, bringing fast, reliable internet to homes and businesses in Devon, Somerset, Shropshire, Wales, and Midlands. https://www.airband.co.uk/
University of Worcester	The University of Worcester is a public research university, based in Worcester, United Kingdom. Worcester is the only university serving the English counties of Worcestershire and Herefordshire. https://www.worcester.ac.uk/
West Midlands Academic Health Science Network	The WMAHSN leads and catalyses collaboration between academia, industry, health and care providers, commissioners, and citizens to support continuous improvement of the region's health and wealth. As part of the national AHSN network, funded by NHS England, we seek out, test and accelerate the adoption and spread of innovative ideas and technologies with the potential to transform health and social care in the West Midlands and beyond. https://www.wmahsn.org/about-us
University of Chester	The University of Chester is a public research university, working in partnership with Shropshire Council and the Marches LEP through the University Centre Shrewsbury, established research centres of Digital Solutions and CREST (Centre for Research into Environmental Science and Technology). These centres, aligned with the LEP's Growth Plans for its digital and related sectors, provide support through research and

University of Chester	specialist advice, helping SMEs to develop innovative ideas and products before bringing them to market. The University is the fifth oldest higher education establishment in England, with only the universities of Oxford, Cambridge, Durham and London outdating it. https://www1.chester.ac.uk/
Virtual Reality Simulation Systems (VRSS) VIRTUAL REALITY SIMULATION SYSTEMS	VRSS are a specialist software development company based in the West Midlands, focusing on the development of highly engaging and interactive virtual and augmented reality products. One of its key sector areas is Healthcare where they have championed products for the NHS such as the UK's first VR frailty simulator and various Mental Health and wellbeing platforms using Virtual Reality. https://vrss.co.uk/

N.B. Hutchinson 3G Limited commenced as the one of the technology partners on the project, however they subsequently withdrew and were replaced by BT.

10.3 Appendix C: project governance information

10.3.1 Organisational structure implemented:

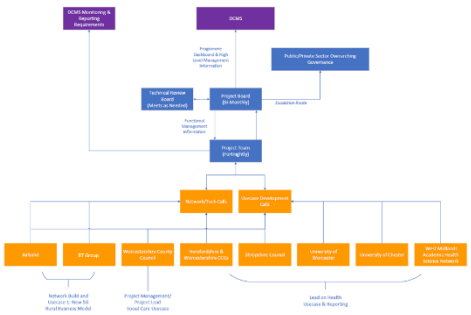


Figure 10.1: Organisational structure implemented

To view the organisational structure chart shown to the left, open the PDF version below:

WMR5G Organisational Governance

Project Management principles were applied to the project and formal documentation completed at the relevant milestones that had been agreed.

10.3.2 Change requests

There have been six change requests within the period of 1 April 2020 to 30 June 2022 including a three-month extension. The Change Requests that were agreed by DCMS are summarised below:

- **CR001** – Request to detail the required changes to the project as a result of 3UKs withdrawal and their replacement in the consortium by BT.
- **CR002** – Additional information to support CR001 specifically to add detail around the initial health and social care use cases aiming to be delivered by the project.
- **CR003** – WCC requesting the change to the grant profile to defer unclaimed amounts from financial year 2021/21 into financial year 2021/22 with associated changes to milestone dates.
- **CR004** – Request to change the milestones, milestone deliverable and claim schedule, following urgent review meeting and changes to the project plan and High-Level Design.
- **CR005** – Request change to milestones, milestone deliverables and claim schedule following recent resource review. Project team will undertake period of 4G testing
- **CR006** – Updating of project end date following DCMS's three-month extension. Changes to milestone 7 and 8; change of Health XR from Talkout VR to VR Simulation Systems Ltd; Changing the status of University of Chester from non-funded partner to a full partner.

10.3.3 Project milestones

The project milestones have been reviewed and updated through the Change Requests. A summary of the milestones is set out in the attached document:

Summary of West Mercia Rural 5G Proje

10.4 Appendix D: BT business PIA: 5G private networks – West Mercia Rural 5G Private Network Non-Standalone Ericsson core

As the Connected Worker use case leads, BT performed a PIA to ensure that GDPR was being adhered to. The following document is their PIA.

BT Business PIA 5G Private Networks – W

The following document is the DPIA produced by the Health and Social Care Use Case subgroup.

DPIA - WM5G - Connected Worker Dr

10.5 Appendix E: West Mercia network deployment desktop survey - Ludlow and Tenbury Wells area

10.5.1 Summary

Overall, the total coverage that can be achieved in the rural area between the towns of Ludlow and Tenbury Wells is up to 85%, utilising both BT and Airband infrastructure i.e., 4 masts (2 by BT and 2 by Airband). There are still coverage gaps around Tinkers Hill and Caynham Fort Hill (blue in Figure 9 within the document below). It is recommended that in order to have adequate coverage in the desirable area BT utilise additional masts.

The desktop survey identified that only marginal coverage improvements could be realised as a result of utilising Airband infrastructure to supplement the existing BT estate. This equated to <1% improvement within the towns of Tenbury Wells and Ludlow, and <2% improvement across the sparsely populated area between the towns.

Whilst options to deliver 2% improvement would consider further investigation, our investigations suggested that any such improvement would be offset by the additional costs that BT would encounter through the application, rental, and maintenance of 3rd party assets.

The full document can be viewed below:

Airband%20Deskto p%20Survey%20(006

10.6 Appendix F: use case selection process and overview of shortlisted use cases

10.6.1 Introduction:

The successful WMR5G bid application, submitted to the DCMS in 2019, has identified the need for sustaining new models of care with proven use cases. The responsibility of identifying such 5G-enabled use cases, applicable to rural communities, was assigned to the Health and Social Care Use Case subgroup by the Project Board.

The Health and Social Care Use Case subgroup was established in April 2020. The subgroup team consists of representatives from all partner organisations including clinicians, social care professionals, academics, and digital experts. The initial task of the subgroup was to identify use case themes which will enable the recruitment of UK tech / industry partners to design, deliver, test, and evaluate, innovative 5G-enabled 'digital health and assistive technology' use cases.

As an initial step, the subgroup has collated over 50 use cases for consideration. The proposed evaluation criteria split into two stages).

- **Stage 1** to determine the health use cases and
- **Stage 2** to be considered for the evaluation of use cases proposed by health tech providers making a submission in response to the Meridian 'call to action'. WMAHSN Meridian platform was selected as the vehicle to promote the campaign to seek tech partners and manage the selection process. Meridian, a **West Midlands Academic Health Science Network** (WMAHSN) development, is an online tool allowing health and care challenges to be shared/promoted across a wide range organisations and sectors (health, care, industry, universities, and research organisations etc… seeking support, collaboration opportunities etc.

To view the full document please read the PDF document below:

10.6 Appendix F
Use case selection p

Attached documents:

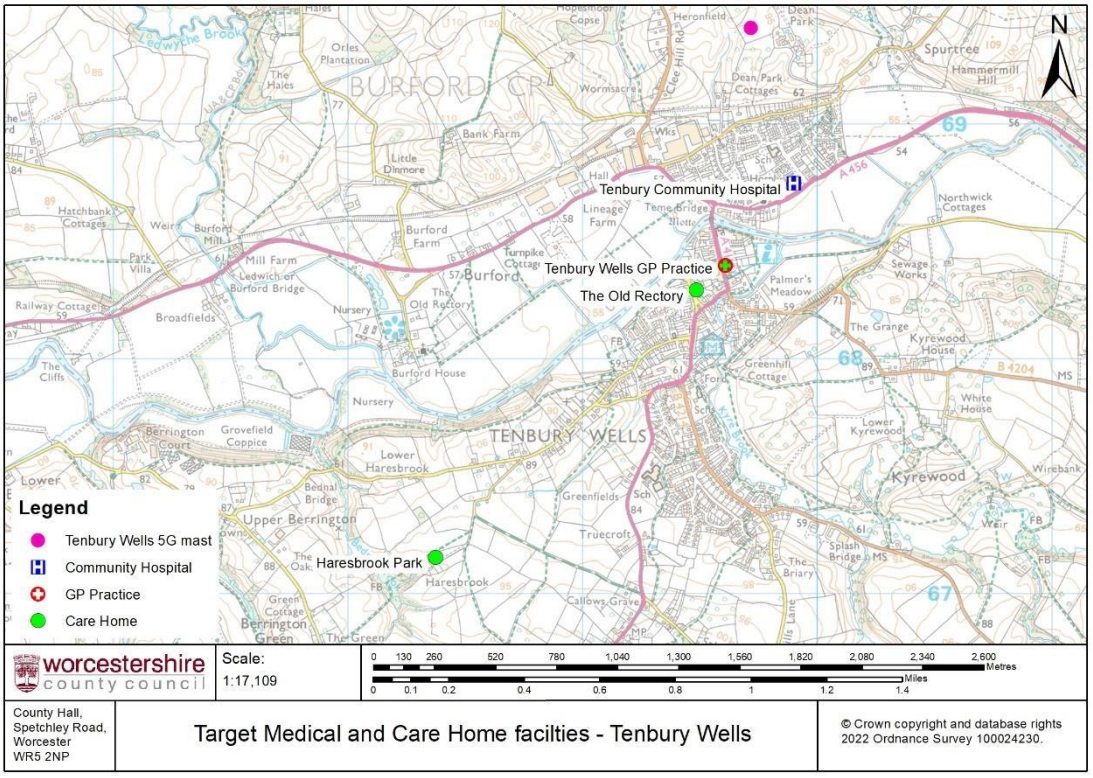
West Mercia Rural
5G USe Case Selecti

West Mercia Rural
5G Test Bed – Indus

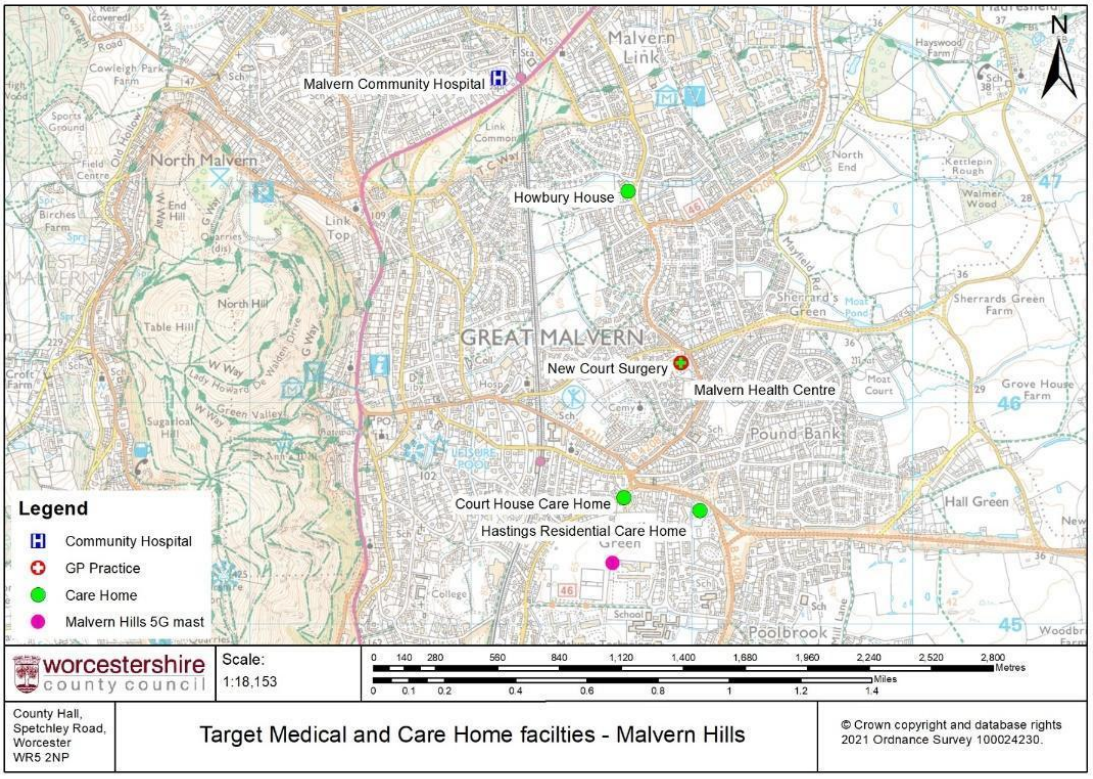
Use case
submission templat

10.7 Appendix G: Location maps

10.7.1 Tenbury Wells testbed locations map



10.7.2 Malvern testbed locations map



10.8 Appendix H: Health XR development plan change logs

The following spreadsheet is a log of the Sprint meetings, outcomes, and progression on the development of the Health XR app by the Health and Social Care Use Case subgroup.

VRSS Log sheet post sprint 20220127.xlsx

10.9 Appendix I: Health XR development and deployment plan 2022

The following spreadsheet shows the plan drawn up by the Health and Social Care Use Case subgroup to plan the development of the Health XR app from TRL2 to TRL5 through development sprints, as well as the deployment plan for Phase 2: Critical Friends and Phase 3: Health Public Volunteers.

Health XR Gantt project planner v1.0.x

10.10 Appendix J: WMR5G end user support initial triage flow diagram

The following document shows the flow diagram for triaging issues raised by the end users within the Connected Worker use case.

WMR5G_Fault Triage Flow_V0.3 ST.pptx

10.11 Appendix K: Survey questions

10.11.1 Questionnaires after completion of a Connected Worker session

Online and paper based questionnaires for users to complete after each session using MS Teams through the headset between the A-End (care home assistant / resident) and the B-End (GPs and nurses).

Questionnaires after completion of a Conn

10.11.2 Connected Worker end of trial telephone interviews

Telephone interviews with Connected Worker individuals to discuss usage of the Connected Worker product.

Connected Worker End of Trial Telephon

10.12 Appendix L: Report from Liverpool Adoption Readiness Level collaboration

10.12.1 Background

The Liverpool 5G Testbed project finished in November 2019. As part of this project the ARL self-assessment tool, developed by the eHealth Cluster, was used to assess, and aid the products trialled as part of the use cases. The tool was a useful way to capture the practical lessons learnt relating to the adoption of technology in health and social care settings. The tool was useful to both product developers and commissioners of health and social care services.

The tool can be found on the eHealth Cluster website:
http://www.ehealthcluster.org.uk

The full report is included below as a PDF.

Report from
Liverpool Adoption R

10.13 Appendix M: Radio network predictions from BT

10.13.1 Prediction for mast at MHSP, Malvern

Radio Network
Prediction MSHP.pd

10.13.2 Prediction for mast at farm, Tenbury Wells

Radio Network
Prediction Tenbury

10.14 Appendix N: Validation journey of Health XR app in real world setting

The SME alongside the Health and Social Care Use Case subgroup undertook the following implementation journey in stages

Appendix N
Validation Journey

10.15Appendix O: Health XR implementation journey

Appendix O
Implementation jou

10.16 Appendix P: Network data by type and testbed site

The following document shows the data captured for the testbed sites – Haresbrook Park, Old Rectory, Tenbury Community Hospital, Hastings Residential and Howbury House. The networks tested for upload and download speeds as well as ping, were a mixture of commercial 5G and 4G native, private 5G native and via the broadcast Wi-Fi from a private 5G connected router, as well as the Wi-Fi from a commercial 4G connected router, depending on what covered the site. At Tenbury Community Hospital the public NHS network was also used for comparison with the understanding that this may be throttled so that critical systems have precedence.

Appendix P
Network Data by Ty

10.17 Appendix Q: Evaluation strategy

WMR5G Evaluation strategy approved July 2021 by Project Management Office and Health Use Case.

WMRG Evaluation
Strategy POST PMO r

10.18 Appendix R: Benefits realisation return to DCMS

Benefits realisation -
End of Project - June

10.19 Appendix S: List of appendices, photos, figures and tables

Appendix S - List of
Appendices, Photos, F