Final Report
Liverpool 5G Create: Connecting Health and Social Care

Deliverable D 10.1

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Contents

Note: Work Package Reports that are not part of other deliverable documents have been included as Appendices to this final report.

1. Executive Summary

The Liverpool 5G project was delivered during unprecedented times during the COVID pandemic. Whilst this created logistical challenges in terms of access to services, resources and imposed remote working, it also demonstrated the need for affordable, reliable connectivity.

Connectivity for schoolchildren at home and the impact of digital poverty has been brought into the spotlight. The use of remote monitoring as part of health and care services is now accepted and the roll out of NHS virtual wards is now proceeding at a pace that would not have been imaginable prior to the pandemic.

Despite the challenges, we created the largest 5G Stand Alone network at street level in Europe. DCMS and the partners worked together to overcome challenges and develop the UK supply chain to create a high performing network. We proved that the technology is available and can be deployed and used to support live public services. This project was a trailblazer and the activities have contributed to developing the industry. Over the next few years more devices will become available, based on the activities initiated and supported by this programme.

The planned Use Cases were extremely challenging given the constraints on health and social care services during the pandemic and the time available in the programme. However, partners adapted and we did manage to gain positive outcomes from the use cases in terms of both impact and R&D outcomes. Several of the use cases are remaining in place after the end of the programme to continue being used and developed.

The biggest challenge we now face is developing a public sector approach that will take the innovation beyond the project phase to support a wider roll out. The approach is driven by social value, addressing current needs within both communities and public sector services. To be delivered at scale the approach needs a coordinated approach to the business plan across public sector bodies and services. The approach cuts across infrastructure, digital and service responsibilities and needs a central point of ownership to manage the opportunity for innovation. Savings in connectivity costs and improved performance will be recognised across many disparate existing service budgets. Funding for a wider roll out of the network needs a collaborative approach to the business model.

The need to control revenue costs is paramount at the moment due to funding constraints and the impact demonstrated by rising energy costs. Connectivity is rapidly becoming a basic utility. The need to explore different ways of providing affordable, reliable connectivity for all citizens, with service level agreements to meet the needs of new monitoring services, is essential.

The switch from telephone analogue land lines to digital connectivity will cost local authorities significantly more in delivering telecare services. In SIM card costs in Liverpool it will cost at least a further £600k per year at a time of reducing budgets, This project demonstrated that it is possible for the public sector to have control both in costs and specific service level agreements and have the ability to transform the way services are delivered to communities.

The Liverpool 5G consortium is continuing to maintain and run the network while we work with wider stakeholders to address the needs of communities and support the development of digital public services.

2. Introduction

2.1 Background

The Liverpool 5G Create Connecting Health and Social Care project is the second DCMS 5G Testbed and Trials project awarded to the Liverpool 5G consortium and ran from September 2020 to September 2022. The project builds on the previous Liverpool 5G Testbed delivered as part on the first phase of DCMS testbed and trials projects and completed in November 2019. The project expanded the existing network in Kensington, Liverpool to incorporate cellular capability and create a Stand Alone 5G network for delivering public services. In addition to Health and Social Care use cases the project also covers education, providing connectivity to school children in their own homes.

The consortium is led by the University of Liverpool with partners Liverpool City Council, Blu Wireless Technology Ltd, Broadway Partners Ltd, Liverpool John Moores University, CGA Simulation Ltd, Docobo Ltd, NHS Liverpool Clinical Commissioning Group and Merseycare NHS Foundation Trust. The project is managed and supported by the eHealth Cluster Ltd with further services supplied by Telet Research (NI) Ltd, AIMES Management Services Ltd and Real Wireless Ltd. In the final six months of the project Telet Research moved from being a subcontractor to the University of Liverpool to a full partner.

As a result of the DCMS funded project the consortium have built the largest 5G Stand Alone network at street level in Europe. The network has been used to deliver public services in Kensington, Liverpool. The investment objectives for the Liverpool 5G business case were defined as follows:

- To **improve the quality of public service delivery**, for **improved user outcomes.**
- To **constrain the growth in service delivery costs** associated with an ageing population.
- To **reduce operating costs** where possible.

The project was delivered during an unprecedented and challenging time with the pandemic progressing, worldwide shortages in the supply chain and Health and Social Care services under immense pressure.

2.2 Project Documentation

This report summarises the key activities completed and findings from the project. There are a range of further deliverable documents that provide more detail on the specific project activities. The relevant deliverable documents are as follows:

DCL 3.1 Collaboration Report
DCL 3.2 Collaboration Lessons Learned
D 7.1 Final Cost Model
D 8.1 Use Case Reports
D 9.1 Blueprint Documentation
D 9.2 Benefits Realisation Report
D 10.2 Use Case Report

In addition, partners have produced individual Work Package reports providing information on the project activities completed. Where these activities are not covered in other deliverables, the individual works package reports are included as appendices to this report. These work package reports included are as follows:

WP2 Set up a Delivery Company	Appendix 1
WP3 & 5 Network Planning and Deployment	Appendix 2
WP8 Communications	Appendix 3

2.3 Objectives

Within the project the technical innovation focus was:

- to exploit specific innovative features of 5G NR Stand Alone (SA) technology (notably end-to-end Quality of Service and segregation of traffic)
- to exercise Ofcom's innovative Shared Access Licence model of spectrum access in an urban area
- to demonstrate cost-effective use of mmWave mesh back-haul for small cells

The project aims to reduce digital poverty for vulnerable people in need, providing safe, free and accessible connectivity to services including health, social care and education. The specific project aims can be summarised as follows:

- Change people's lives by reducing digital poverty, and providing digital health, social care and education support where it's needed most
- Help people with long-term health conditions live independently at home for longer by using our 5G supported health and social care technology, freeing up valuable health and social care resources and saving money
- Provide the technology for children to use at home to support their school work.
- Enable health and social care providers to offer robust, reliable digital health applications as an alternative to face-to-face interventions
- Create a safe, reliable and robust private 5G network with ubiquitous coverage across the network area
- Support the UK's Covid-19 recovery by enabling British built technology and innovation to thrive in a meaningful and sustainable way
- Create practical, affordable digital solutions to replace the analogue telehealth technologies which will be turned off in 2025
- Deliver a blueprint for using 5G networks to deliver public services.

3. Description of what the project did

3.1 Project Activities Completed

During the project we have:

- Deployed a private, Stand Alone 5G network for delivering public services
- Built on the previous successful Liverpool 5G Testbed
- Upgraded our existing network technology
- Used the latest, new to market, world-leading 5G technology
- Increased the physical area covered
- Trialing new-to-5G, and in some case entirely new, devices and apps in health and social care.
- Working with key organisations from the NHS, the social care sector, local government, national government to develop the use of private networks in delivering public services.

3.2 Needs addressed

- The network is designed to provide the Service Level needed for health and social care applications
- Connectivity is provided via Wi-Fi or cellular with no charge to the resident, meaning remote monitoring is available to all, even where there's no broadband
- Liverpool 5G bear the costs of deployment and maintenance – residents will not incur any usage costs
- Health services, care homes, supported living, and home care can access for free (or less than current costs), freeing up spend for frontline services.
- A unique health, social care & education 'network-of-networks' that incorporates mmWave 60gHz mesh network, small cell radio technology.

3.3 Methods including technologies used and deployment approaches

In summary the deployment made use of the following technologies and approaches:

- compact 5G SA Small Cell base-stations in band n77 on street furniture,
- 60GHz mmWave back-haul with static mesh paths,
- private fibre back-haul,
- a hybrid 4G/5G Open Source 5G Core,
- physical installation planning and design drawing on established methods for deploying lighting, signage and auxiliary surveillance cameras on street furniture,
- coverage estimation and mmWave line-of-sight planning making extensive use of Google mapping and street-view tools with a simple statistical model for propagation,
- network design adapted from ISP and data-centre architectures to support re-use of established processes,
- 5G SA smart-phones for interactive video use-cases (Docobo),

- 5G SA mobile/WiFi routers to adapt to WiFi and Ethernet-connected use-cases (MySense),
- script-based partially automated remote configuration and update of the small cells,
- SNMP and Web-sockets monitoring technologies with and Open Source Network Management System (LibreNMS) for visualisation and recording of availability with programmable alerts by email,
- proprietary Network Management System (developed within the project) for configuration, monitoring and forensic investigation of the mmWave devices and network,
- TR-069 device configuration using an Open Source platform (GenieACS),
- centralised, project-specific pre-configuration, kitting and logistics (Finch),
- shared platforms for site survey (Fulcrum), deployment planning and record-keeping (Sharepoint), site-to-base communication (Whatsapp),
- secured remote access by IPSec for base-station and Core developers and for connection of remote base-stations for laboratory and exhibition use.

3.4 Use Cases Deployed

The following use cases were deployed as part of the project:

- Pressure Ulcer Management System – Mobile technology which uses AI imaging techniques and emerging camera technologies to categorise pressure ulcers remotely and send high-quality images to practitioners for diagnosis
- Chill Panda – A playful, interactive app which helps children manage their anxiety. It uses a built in AI driven recommendation engine to create personalized anxiety reduction content for users.
- Urine Monitoring Unit – Uses optical technique to detect infections in urine, and transmits ultra-resolution images to GP surgeries for analysis, and performs at the same high level as current standard tests in NHS
- MySense – A new range of telecare equipment, which uses AI to monitor nutrition, hydration, independence, and activity via IoT (Internet of Things) sensors around the home, and alerts support networks to any changes in behaviour or deterioration
- Vitalerter – Sensor for under a care home bed that monitors the vital signs of the resident. Using AI, it notifies staff when the resident is about to get out of bed, reducing the number of falls.
- Telehealth Monitoring via Docobo Devices – the Care Portal device is used by the patient, includes a built-in ECG monitor, and connects to Telehealth Hub staffed by nurses and HCAs.
- Education – Providing connectivity and Chrome Books for pupils at home in Kensington
- Sensory vest – Haptic shirt to allow care home residents to receive remote hugs from family, reducing isolation and loneliness in care homes
- 5G WAN Pilot for NHS Sites – providing 5G connectivity to NHS sites for public access and clinical use. This reduces costs of a fibre-delivered WAN network and provides low latency, high bandwidth, secure WAN network for ongoing increase in digital clinical services.

3.4 Approach to security

The Liverpool 5G project was largely based on established technology – with mature and often verified security. As such, our focus was on the inherent risks that we created by rolling out the project and operating as a connectivity provider.

- The security of data as it transits the L5G network
- The security of services or devices that use the L5G network
- Managing and mitigating threats to the L5G network for the areas that we can control

We endeavored to take a secure-by-design approach throughout and a secure-by-default approach wherever possible. This is often difficult when working in collaboration, working with emerging technology and ideas, and dealing with a set of, as yet, unknown issues.

Overall, the project aimed to work towards:

- Developing an 'appropriate' security governance framework that protected and secured the network without stifling innovation or development.
- Understanding the requirements for working with diverse partners in a secure and controlled manner to run a stable, secure and resilient network.
- Developing new draft policies and procedures to ensure that security is taken into account
- Focusing on security and design during the project but also prioritising security in relation to configuration, management and monitoring.

Further detail on the security measures applied can be found in the Deliverable 9.1 Blueprint Documentation (Part 2) and Appendix 2 to this report (WP3 & 5 Report Network Planning and Deployment).

4. Description of the results

The full benefits, outcomes and impacts are detailed in deliverable D9.2, Benefits Realisation Report A summary of key benefits and impact is included below:

- Increased investment in R&D and business investment

    - Additional funds spent on R&D due to the funded project was a total of £1,530,232
    - Third party investment attracted: £950,000

- Improved connectivity for services and individuals

- The NHS Informatics Merseyside 5G WAN Pilot for NHS sites showed that the Liverpool 5G network had Increased speed and reliability, with less jitter, lower latency, and lower round-trip time.

- Increased technology development

- 80% of the products reported on during the project showed an increase in TRL level
- 60% reached their target TRL level1 by the end of the project

- New and Improved 5G-capable health technology products

- Video consultation was developed by Docobo to be fully integrated into the DOC@HOME® system that is used by Mersey Care. This was demonstrated to give good quality video consultation over the Wireless L5G network.
- New features of the Docobo telehealth system were developed, and participation in the L5G project has prompted Docobo to consider new developments that will take advantage of the wider bandwidth and low latency.
- CGA Simulation refined their Chill Panda app, updated software installation and connection protocols, and identified new hardware that will work with the product
- LJMU created a decision support tool was developed which standardised pressure ulcer categorisation using AI modeling techniques.

- Better health and wellbeing outcomes for individuals

- During the period of Vitalerter monitoring in care homes while there was a 112% increase in the number of falls, there was a 100% reduction in the number of residents hospitalised due to falls
- Vitalerter monitoring showed a reduced number of turns were needed for each patient, allowing them to get undisturbed sleet, leading to better health
- Using the CuteCircuit Hug Vest showed a reduction in loneliness in service users, with a 64% decrease in those who said that they often or sometimes felt lonely
- MySense Telehealth monitoring users showed an increase in reported wellbeing and in increase in feeling safe

- Users of MySense Telehealth monitoring reported a 40% reduction in the annual number of days spent in hospital (the experience of a small number of users over a short trial, this should not be seen as definitive)
- Video consultation was developed by Docobo was demonstrated to give good quality video consultation over the Wireless L5G network, improving the patient experience

- Improved Health and Care services

- New Clinical Care Pathway question sets were developed by Docobo and Mersey Care for HF Oedema Monitoring and Wound Care
- The work undertaken by Docobo to add new features to their monitoring system will form the basis of future new, more effective services, which are of interest to Mersey Care with a view to future deployment.

- Reduced costs to Health and Social Care services

- The Liverpool CCG 5G Wan Pilot for NHS sites reduced the cost of connectivity of GP sites, with an annual cost saving per surgery of £2,026. Applied to 86 surgeries in Liverpool, this could be an annual cost saving to the NHS of £174,236
- Vitalerter monitoring showed a reduction in falls and turns needed, leading to potential annual saving of £7,737 per user per year, after costs.
- Using the CuteCircuit Hug Vest showed an average 19% decrease in estimated costs, saving £841 per user over the trial

  Note on costs: when allocating costs to each use case, site costs (see section 3.4.4) were allocated as if the whole cost was incurred by that use case. In practice cost would be shared by several use cases in the same location. Additionally, most cost benefits become progressively more cost effective as more patients use the network, supporting the concept of stackable use cases.

- Improved learning, engagement and life chances for pupils

- As part of the Liverpool Council Education offer, 49% of pupils at Phoenix Primary School identified as not being connected were connected, enabling pupils to access education from home, and engage more fully with education
- Decreased poverty and stress for local residents in one of the poorest wards in the country
- Liverpool Council Education offer – families of pupils using the network incurred no additional data or connectivity costs
- MySense telehealth monitoring users had improved wellbeing, leading to increased social value of £1,800 per user, which represents additional money the average individual would need to improve their wellbeing over the trial period.

Non-Use Case Benefits

Technology Readiness Levels (TRLs)
10 products/services were reporting on TRL Levels during the project:

- 1 was at the intended TRL at the start of the project
- 8 reported an increase in TRL over the project
- 6 reached their intended TRL target during the project

Investment Stimulation

- Additional funds spent on R&D due to the funded project was a total of £1,530,232
- Third party investment attracted: £950,000

Knowledge Creation

- Chill Panda app trademarked

Publications

- Modelling and Analysis of Performance Characteristics in a 60 Ghz 802.11ad Wireless Mesh Backhaul Network for an Urban 5G Deployment by Michael Mackay, Alessandro Raschella and Ogeen Toma, School of Computer Science and Mathematics, Liverpool John Moores University
- Pressure Ulcer Categorisation using Deep Learning: A Clinical Trial to Evaluate Model Performance, Paul Fergus, Carl Chalmers, William Henderson, Danny Roberts, Atif Waraich, Liverpool John Moores University
- Liverpool John Moores University: 2 journal articles pending
- University of Liverpool: one prototype created

Dissemination

- Liverpool 5G Create mentioned in over 85 press and media articles.
- Radio interviews took place with BBC Merseyside (2) and BBC Wales
- Liverpool 5G representatives and project partners took part in over 58 events and dissemination activities
- Twitter: over 640 likes, 250 retweets, and 440 comments in the past year.
- Liverpool 5G website: 8503 visitors & 23038 individual visits January 21 to end September 22
- Two successful dissemination and information events organised by Liverpool 5G and partners:
    - Liverpool 5G Showcase event held 9/3/22 - audience 195 (80 in person, 115 online)
    - Use Case Demonstration Event held 29/6/22, attended by DCMS, L5G and supplier representatives. Video of the event produced

Award Nomination/Shortlist

- Prolific North Tech Entrepreneur of the Year Award (Rosemary Kay, Liverpool 5G Project Director)
- Maximum Citizen Impact & Reach at UK's 5G Showcase Awards
- Digital Leader of the Year (Ann Williams, Health & Social Care Authority, Liverpool 5G)
- Most potentially disruptive business model, 5G Week Award

Award Wins

- Best Individual Contribution (Ann Williams, Health & Social Care Authority, Liverpool 5G), at UK's 5G Showcase Awards

- 5G Innovation of the Year (Liverpool 5G planning tool, CGA Simulation) at DigiLeaders100 Awards.
- Connecting People Award, at Cambridge Wireless' Technology and Innovation Awards.
- Tech for Good' award at the 2021 Prolific North Tech Awards.

Other Benefits

- 41 staff across all organisations were allocated to working on the project at start, rising to 65, with 35 of these newly employed specifically for project
- 8 staff and 24 people working with use case devices were trained during the project

4.1 Network established

At the time of writing the network provided:

- coverage from 56 active small cells within and around Kensington and Fairfield (see map below),
- back-haul to these and fixed sites was provided via 24 fibre points of presence,
- 101 intermediate mmWave sites on lamp-posts,
- connections to 5 buildings by mmWave,
- a connection to 1 building by fibre to the premises (which then hosts a small cell),
- a street-level WiFi network around the Phoenix school catchment.

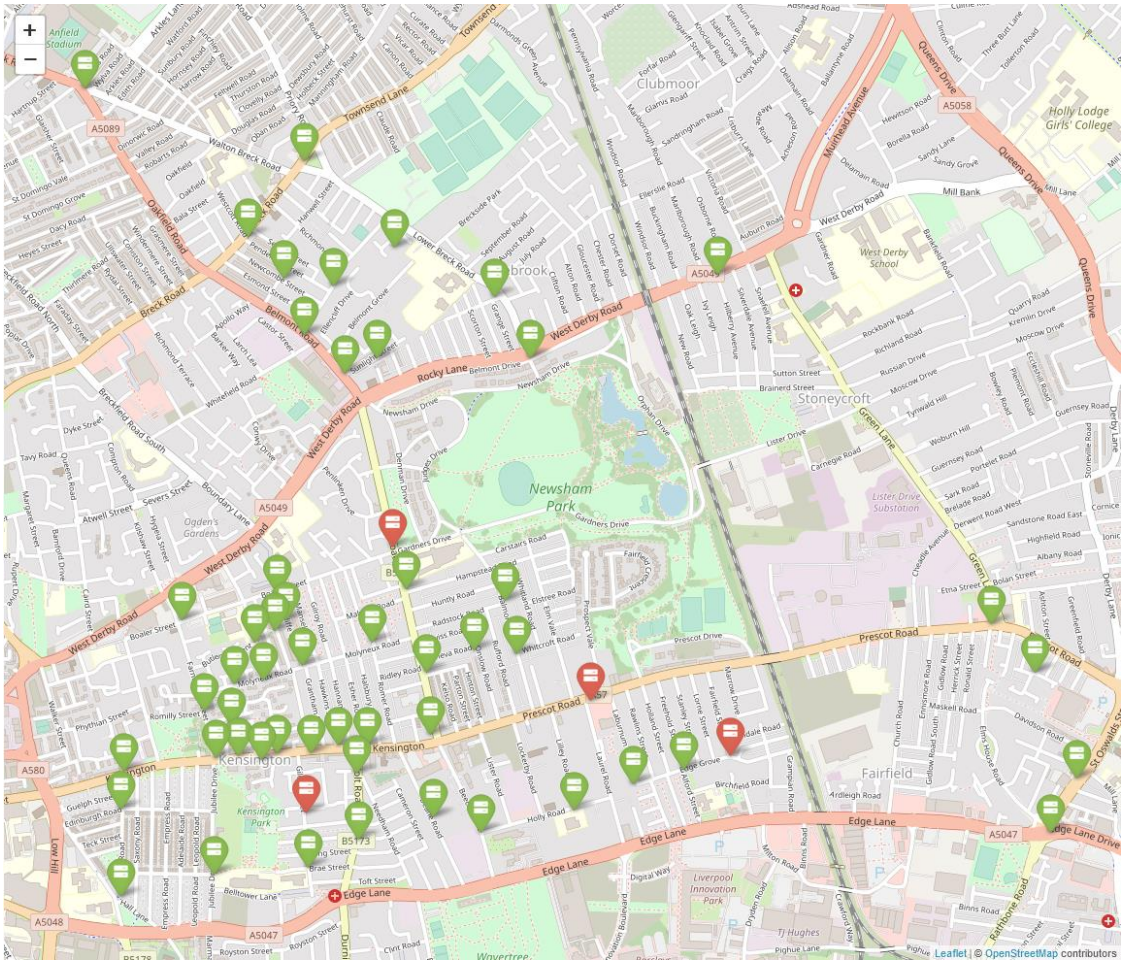
This phase deployed:

- 138 'DN101' single mmWave nodes and
- 57 'DN201' bidirectional nodes.

A small number of nodes from the previous project continue to provide service at two buildings where rework was impractical or inappropriate for the objectives of this phase.

The mobile network Core functions are co-located at the AIMES data-centre on dedicated hardware (with no compelling justification to distribute them for our purposes). A subscription-based dynamic web filter provides protection from inappropriate material and transfer of material from malicious sites. A redundant cluster of Virtual Machines provides a platform for the mmWave network management, forensic and configuration tools, the WiFi management system and the network's global availability monitoring tool (PRTG). Service usage monitoring is implemented within the data-centre's existing infrastructure with granularity to individual connections if required.

Back-haul from the field sites is aggregated at a pair of intelligent switches close to Hunter Street which also support per-port monitoring.



4.2 Business model and use of private networks for public services

The project has been working towards a developing a business case to roll out the network across all of Liverpool and subsequently the Liverpool City Region. The cost model was supplied as deliverable D7.1 and the key findings are shared in the D9.1 (Part 1) The Blueprint Documentation. The key findings/challenges can be summarised as follows:

Business As Usual (BAU)

The Green Book business model approach starts with BAU as the baseline. After reviewing the cost model produced, we do not believe that the current BAU gives a feasible comparison over the 8-year period. When the PSTN is switched off in 2025 the existing analogue telecare solutions will no longer be supported. In addition, BAU cannot support all the example use cases, therefore does not compare like with like against a private network.

The current cost model assumes that the reliability of service levels provided via existing public MNO infrastructure will be sufficient to provide many of the services analysed. Although this maybe the case with some services it does not take into account the enhanced service level agreements required for home monitoring for health and social care, the scope for future innovation and the stated investment objectives.

Developing the supply chain

The Liverpool 5G deployment was a trailblazer in the field. As early adopters, the availability of equipment was limited and unit prices were high reflecting their R&D status. Although the cost model assumes prices will come down, we are now aware of new devices in development. In particular the DCMS FRANC programme is supporting the development of integrated units which will reduce costs in terms of unit cost, installation, power consumption and maintenance.

Determining acceptable levels of optimism bias

The current cost model has applied and optimism bias of 55% on capital spend and 20% on operating spend on the private network option. At 55% optimism bias on all capital equipment on the private network comparisons become distorted. For example, under the current cost model:

- telehealth and telecare equipment in the home attracts the 55% uplift, which is not a true reflection of the risk associated.
- The 55% uplift is applied across the 8 year period, including a total equipment refresh in year 5. As the unit prices will become more stable over time and typically reduce over time, this does not appear realistic.
- There is also no pessimism bias against Business as Usual to reflect the poor service level agreements and the limited performance of the existing networks

Determining benefits attributable to a private network

It has been challenging to quantify the benefits of a private network in terms of the Green Book approach. The obvious benefits, in line with the investment objectives are the lack of connectivity costs and the improved service level agreements.

The current outline business case monetises the benefits from telehealth and telecare services. However, the real impact the use of a private network will have on these services is the lack of connectivity charges, increasing the budget available for frontline services and support to new, innovative services e.g. 3 way video calls, analysis of pressure ulcers using Artificial Intelligence.

The current outline business case acknowledges that a private network will support additional use cases that cannot be supported under the other options considered. However, the benefits from these use cases have not been monetised. For example, providing connectivity at home for school children has not been monetised as the benefits fall outside the 8 year period. Providing high bandwidth fixed access points for care homes and GPs to enable them to access current and future NHS services, or connecting residents with their families has not been monetised.

Service Level Agreements

Commercially available options do not provide the service levels needed to support more critical monitoring in the home. The costs included for alternative options only include current levels of support. The private network option includes enhanced response times, local monitoring of the network and potentially devices on the network.

Incorporating Social Value

The Liverpool 5G Project has been driven by social value. Social value is not an add on. The need to reduce the digital divide and make public services accessible to all has been the core driver behind the project.

Our current outline business model shows no monetised benefit for providing connectivity for school children at home, or for connecting care home residents with families.

Although the recent changes to the Green Book guidance includes the use of Net Present Social Value (NPSV), this is not yet common practice and is not reflected in our outline business case.

Defining Stackable Use Cases

Across the 5G Testbed and Trials project there is consensus that no single use case will justify the investment in a private network. In our cost model we looked at a range of generic use cases across health, social care and education. However, these are only a selection of the potential applications. A private network will create the infrastructure for use cases across the sectors we have explored, but also in housing, transport, environmental services and many more.

The current cost model, based on the example use cases, estimates that only 12.5% of available network capacity is forecast to be needed, demonstrating the need and capacity for further use cases.

Coordinating and Combining Stackable Business Cases

To support stackable use cases there needs to be stackable business cases to support the deployment of a private network. This is a significant challenge as the benefits of the network will be spread across existing budgets across a range of public bodies. As such, it is difficult to identify a single budget holder to make key decisions on the Green Book business case and take overall ownership.

The approach to using private networks for public services is new and innovative. It cuts across infrastructure, health, social care, education and many more public bodies. To progress, we need to generate joined up thinking across public services.

Based on the findings from the DCMS funded Liverpool 5G Create project we have proved the technical feasibility of a private network for delivering public services but the business case still needs further development. To achieve this, we need to identify a Senior Responsible Officer to reflect the cross sector benefits generated and take key decisions on the business case.

For the purpose of developing the cost model we used generic use cases rather than the specific equipment trailed in the project. The cost model produced included the use case service costs and the network costs. The tables below show the network costs and use case costs. Note, these figures include no optimism bias or discounting over the 8 year period used.

If we compare the total cost per use case across the 3 options considered:

Stackable Use Case	Option 1 BAU	Option 2 Standardised connectivity via service provider's 4G/5G SIM over public networks (will become BAU)	Liverpool 5G
GP surgeries (NHS)	N/A	£1,952,415	£0
Care homes (LA)	N/A	£2,633,490	£0
Mobile workers (NHS/LA)	£1,985,706	£3,229,199	£249,284
Supported Living (LA)	N/A	N/A	£96,718
Education (LA)	N/A	£1,536,695	£104,523
Telecare (LA)	£34,623,069	£63,449,488	£35,297,488
Telehealth (NHS)	£13,410,079	£18,756,962	£11,857,376
Liverpool 5G Network	N/A	N/A	£54,435,979
TOTAL	**£50,018,854***	**£91,558,249***	**£102,041,367**

*Note that options 1 and 2 do not provide the connectivity or full range of services required for all use cases, therefore does not give a true comparison.

The analysis shows that under the Liverpool 5G option revenue costs are reduced for all use cases and new use cases are enabled, improving outcomes for citizens. In addition, we need to consider the capability to support further use cases and support wider innovation in public services. The example use cases above are only using 12.5% of the network capacity, demonstrating the potential for wider applications.

The cost model also applied sensitivity analysis for a range of scenarios. In the case of using medium powered licenses with no optimism bias, the total costs for the Liverpool 5G option, including use cases, became:

Medium Power Licenses Scenario	Capital	Operating	TOTAL
Liverpool 5G	£37,980,332	£41,532,878	£79,513,210

More detail on the above costings is provided in the Blueprint documentation. This is an area of work that we are continuing to pursue with the Liverpool City Region. We plan to incorporate the potential social value generated and determine acceptable levels of optimism bias.

5. Impact of the results including Benefits

How are the results better than what has come before?

We have proved that a 5G stand Alone network can be used for delivering public services in people's homes and in community settings. We have proved the performance of the network, the extract below is from the project use case for GP surgeries, led by NHS Informatics Merseyside:

"*Provision of a 1GB service via fiber from MNOs would cost, on average, over £12,000 to install, be subject to wayleaves, traffic management delays etc. and cost approximately £10,000 per annum in rental as well. At those prices it would be hard to justify providing that capacity to NHS sites unless they were of significant social value i.e., Hospitals.*

5G WAN Mesh networks can provide a better value deployment of higher bandwidths coupled with an agility to deploy that cannot be matched by fiber services."

How will the results affect your or someone else's business?

Using a private network for delivering public services at the point of need is disruptive and has not been tried before at the scale we have achieved. In the current financial climate, there is a growing acceptance of the need for public sector reform to reduce revenue budgets and address the digital divide. Our project has generated much interest from other public bodies and has highlighted the opportunities created by the use of private networks.

Could similar results have been achieved without 5G?

Many of the use cases deployed in project could have been run over 4G. However, our challenge was twofold:

- To demonstrate enhanced performance over a 5G network, demonstrating the case for the development of 5G supported end user devices
- To demonstrate the reduced operating costs over a 5G private network.

5G Technology has enabled more widespread use of private networks. Throughout the project we have promoted the motivations for using public sector owned mobile wireless network in terms of:

Agility: service can be delivered to anyone, anywhere within the coverage area, immediately
Cost: retain control of revenue model to promote innovation (e.g., no per user or data charges for health and care applications)
Service: monitoring, response, resilience integrated with the applications
Assets: efficient use of physical assets and contractors
Openness: support for the broadest range of use-cases in the public interest

This section should answer the 'So what?' question

Our approach has been disruptive. It has challenged thinking about the way public services are delivered and the opportunity of innovation in service delivery. The removal of data charges and enhanced service level agreements open up new possibilities.

An example of this is highlighted by a discussion with a cardiologist who wants to manage his waiting list more effectively. He wants to be able to monitor patents at home while they are on the waiting list, in this way he can assess how urgently they need treatment in real time, rather than periodic assessments. This is an example of how monitoring at home will change the way services are delivered.

Our proposal enables these services. The same solution could be delivered over commercial networks but the cost would be much higher and the service level could not be guaranteed. The use of a private network will facilitate the wider use of monitoring technology in the home.

Another example is the work with Phoenix Primary School in Kensington. The headteacher estimates that 50% of the pupils do not have access to connectivity at home. Liverpool City Council, as a partner in the project, have provided 100 Chromebooks for the children to use. The children work on the Chromebooks in school but then take them home where they connect to our network and enable the children do their homework online.

In discussing the lessons learned, we recorded a number of positive outcomes that have come from the project. We have:

- Reduced the digital divide by:
  Being on the people's side of the digital divide
  Providing positive stories of how 5G can be used to benefit people
  Having a successful impact on individuals and services
  Providing a model that can help deliver services effectively
  Developing the project to meet social need, rather than solely testing a piece of technology
  Gaining recognition for the project as one that disrupts business as usual in favour of the poorest in society and gaining national good will with everyone wanting it to succeed

- Fostered effective cross-sector collaboration, by:
  Involving a good, broad set of partners, from the public, private and academic sectors
  Successfully attracting and 'on-boarding' use case suppliers and showing that they can work together
  Partners and suppliers have benefited from meeting others, for example, a commercial partnership between Docobo and MySense is being explored.
  Provided a pioneering pathway for other public sector organisations, including:
    Starting/adding to the conversation about digitalisation in health and social care, and how 5G can help
    Disseminating knowledge on 5G and its possibilities to wider communities e.g. Health and Social Care, and NHS Future Wireless project
    Challenged OFCOM's thinking on what 5G is and can do – emboldened them to think about public services
    Showing that the concept of private 5G network for Civic use cases works
    The benefits of having a social driver, which encourages digital requirements being built into all departments, as well as digital integration across departments.

- Developed a unique and disruptive network, including:
  Building what is effectively a heterogenous network (HetNet) (=mixed tech)
  Creating [what is believed to be] the largest urban deployment of small cells at street level in the world
  Building a positive reputation for technology innovation - including security devices, and collaborative working
  Supported UK industry and the technology ecosystem in tech diversification and in innovative technology, by:
  Disseminating knowledge of 5G implementation within the tech community
  Broadening the definition of 5G
  Supporting innovation in other organisations - for example we have directly influenced/helped accelerate Cable Free, Affarii, Amarisoftware development and application

We were able to work with British vendors for the mmWave network, critical aspects of the Radio Access Network, notably the transceiver IP and hardware, and integration and manufacture of the gNodeB base-stations and ancillary mechanical and electrical components and services. The RAN Software Defined Radio is French and, interestingly, the specialist Radio Frequency sub-systems and Core network software all originate from South Korea.

6. Key learnings

6.1 Key take aways from the lessons learned

Throughout the project we have gathered lessons learned from all partners and reported as part on the benefits realisation reports. Each work package report details the lessons learned related to specific activities. This section draws out the overarching take aways from the lessons at the conclusion of the project.

6.1.1 Take away 1 - Innovating at the very forefront of technological development needs flexibility and access to the right skills when needed

The focus of the DCMS 5G Testbed and Trials program was on working at the bleeding edge of 5G technologies. Specifically, within the project the technical innovation focus was:

- to exploit specific innovative features of 5G NR Stand Alone (SA) technology (notably end-to-end Quality of Service and segregation of traffic)
- to exercise Ofcom's innovative Shared Access Licence model of spectrum access in an urban area
- to demonstrate cost-effective use of mmWave mesh back-haul for small cells

To deploy the 5G small cells the project benefited from the skills and proactive working relationships of Telet Research. Telet Research worked collaboratively with the vendor and their software supplier to not only identify issues but also resolve them and provide a real world application to prove the performance of the devices. This activity was mutually beneficial for all those involved and is evidenced by the fact that although originally a subcontractor, Telet Research became a partner for the last six months of the project.

The mmWave nodes supplied for the backhaul were a higher specification than used in the previous project. This meant that processes used in the previous testbed were not applicable. In addition, key resources within Blu Wireless were no longer available to support the deployment.

The level of design engineering skills needed to deploy the mmWave devices was beyond the scope of installers, therefore additional development engineering support was brought in through the eHealth Cluster to support the mmWave deployment.

This approach was possible due to the range of skills available, capacity and commitment of the partners. Changes to resourcing levels across partners were supported through DCMS via change requests.

The key takeaway from this is that no matter how well planned at the beginning, working at the bleeding edge of technology innovation will always generate unknown challenges. Flexibility in the approach is needed from both partners and funders in order to achieve the project outcomes. Having a flexible resource base and the capacity to deploy additional skills as required is essential.

6.1.2 Take away 2 – Bringing the full range of key stakeholders onboard and maintaining links throughout the project, even when stakeholders change

Over the 25 month project we saw many changes in the public bodies we were working with. Both NHS Merseycare and NHS Liverpool Clinical Commissioning Group (CCG) were partners in the project. The formation of Integrated Care Systems (ICSs) was developed during the project and the Cheshire and Merseyside ICS was established on a statutory basis on 1st July 2022, the CCG then became part of the ICS. In addition, NHSX was integrated with the Transformation Directorate at NHS England on 4th February 2022.

Change and restructuring of public bodies is inevitable over a 25 month project, but keeping the links established with key individuals is essential. We achieved this by setting up an Advisory Group at the beginning of the project. The board included representatives from the Liverpool City Region, Cheshire East Local Authority, UK5G and NHSX. The Advisory Group met bi-monthly to keep members updated on the project and members attended project events. Members took an active part in reviewing findings from the project and facilitating wider connections.

The Liverpool 5G project was based on live services being delivered in the community. To build a network without understanding the potential applications would not have generated any long term value.

To support the use cases we had to work with the full “stakeholder chain” including patients, their families, equipment providers, health professionals and commissioners of services. This was difficult during the pandemic as health and care staff had to switch priorities many times during the project, but without maintaining close links with the full stakeholder chain we could not progress and more importantly, move onto more widespread adoption of the services.

As a result of these links, at the end of the project, the majority of the use cases intend to continue running. Through NHS Informatics Liverpool we have now submitted a bit to the NHS Future Connectivity Trails to continue the NHS Use Cases and develop an NHS business case.

6.1.3 Take away 3 – With a wide mix of partners, partner priorities and resourcing levels will change over time

A key strength on the project has been the wide range of partners involved. The Liverpool 5G Create project has only been possible due to the mix of partners involved. Partners have come from industry, academia, local authority and NHS. The project brought together this full range of perspectives to both deploy and apply the network.

It has been challenging to coordinate such a wide range of partners but without this approach we could not progress from the technical implementation to the actual adoption of the private network approach for delivering public services.

Flexibility in approach has been key. Public sector partners have seen unprecedented challenges during the pandemic. However, the need for providing connectivity at home and the impact of digital poverty has become much more widely recognised.

The overall project Technical Authority role moved from Blu Wireless to Telet Research within the first few months of the project. Inevitably, over the 25 month period of the project, investment priorities within key private sector partners have changed and it has not been possible to get the level of resourcing required, but with a flexible approach between partners and DCMS we have managed to achieve the project objectives.

6.1.4 Takeaway 4 – Technology innovation is relatively easy compared to the adoption of innovation within public services

We managed to achieve the deployment of the largest 5G Stand Alone street level network in Europe, but to date we are still working on a business plan that will enable the public sector to deliver public services over a private network at scale.

The investment objectives for the business plan were set as follows:

- To **improve the quality of public service delivery**, for **improved user outcomes.**
- To **constrain the growth in service delivery costs** associated with an ageing population.
- To **reduce operating costs** where possible.

Through the use cases and the cost model we have been able to demonstrate these objectives being met, however there are numerous challenges in developing a Green Book business case to access public sector funding.

The innovative approach of using a private network to deliver public services does not fit neatly into a single public body or local strategic priorities, it cuts across many. This makes it difficult to identify one Senior Responsible Officer to make decisions on the approach to the business case.

At the end of the project we are a lot clearer on the approach needed in the business case but still need to gain full support for a wider roll out. Essentially, we are ahead of our time and the market for devices needs to develop further with unit prices decreasing. The Green Book business case approach is developing to take social value into account, but this is not yet common practice.

6.2. Suggestions for policy regulation

6.2.1 Medium Power Licensing

Ofcom have commented themselves, the fee structure for this type of deployment merits review based on potential efficiencies in processing applications in batches. The Low Power limit, although perfect for indoor office deployments, is needlessly restrictive for outdoor deployments. At less than the radiated power permitted for most classes of user equipment, the limit results in a density of deployment of relatively expensive infrastructure that challenges the business case for community networks. We would recommend a level that tips the link budget balance unambiguously (by 10dB) in favour of the downlink to +30dBm 5G router equipment, around +40dBm EIRP in a 20MHz channel (just below the existing Medium Power limit).

6.2.2 Medical Device Regulation

During the project timescales. there were changes in the Medical Device Regulatory environment with Brexit meaning the Government introduced a UK CA Medical Device approval scheme in parallel with CE MDR certification. This is a significant change which provided a major challenge for the deployment of any new medical devices. This is summarised below

- The UKCA (UK Conformity Assessed) marking is a UK product marking used for certain goods, including medical devices, being placed on the Great Britain market (England, Wales and Scotland).

- Manufacturers of medical devices can use either the UKCA marking or the CE marking on devices they place on the GB market until 30 June 2023. (Previously 1st Jan 2022) From 1 July 2023, a UKCA marking will be required in order to place a device on the Great Britain market.

- Where third party conformity assessment is required, a UK Approved Body is needed.

- Although the UKCA mark will be available for use in Great Britain (England, Wales and Scotland), a CE marking will continue to be needed for devices placed on the Northern Ireland market and EU rules will need to be met. To place a CE marking on your device for circulation in both Northern Ireland and the EU, you must use an EU-recognised Notified Body to undertake any mandatory third-party conformity assessment.

- For the purposes of the Great Britain market, UK Approved Bodies can conduct conformity assessments in relation to the UKCA marking, for medical devices, active implantable medical devices and in vitro diagnostic medical devices under Parts II, III, and IV of the UK MDR 2002. UK Approved Bodies are not able to conduct conformity assessments in relation to the CE marking.

With the requirement that Northern Ireland requires CE Marking from a EC Notified Body and UK CA requires assessment by a UK Notified Body which are no longer recognised by the EU creates double the amount of testing because of the variations in the requirements and therefore additional cost will be required to address the whole of the UK market as well as consideration of the EU Market and beyond.

6.2.3 Public Sector Business Models

We are working with key stakeholders, both locally and nationally to highlight the challenges in the Green Book process.

We have demonstrated that the use of a private network will reduce ongoing operating costs although at the moment the capital cost is higher than potential savings. We believe this balance will change as lower cost devices become available. We also believe we can work with the existing network and regulators to refine the current network dimensioning to significantly reduce the number of nodes and small cells in the network.

We also need to include the full potential social value that a private network can create. If we cannot provide reliable, affordable connectivity for residents in our city digital poverty will increase. We have seen

this during the pandemic and current cost of living increases will only exacerbate the situation. The impact on health inequalities and life chances will significantly worsen for some groups.

Technological advances in communications mean that private networks can now be owned and managed by public bodies. This approach reduces ongoing revenue costs and can provide connectivity for public services in individual homes and community buildings. The approach is disruptive and innovative but the DCMS funded Liverpool 5G Create project has been the first to create a stand alone “civic network” to deliver public services.

To create a true circular economy, where public services are not a drain on the economy but an asset that can be used for good, we need equally disruptive and innovative approaches to business models. Without creativity in our approach to funding we risk stifling innovation and reducing opportunities for residents.

6.2.4 Joined up services to support a “digital first” approach to service delivery

Public services reform will not happen effectively without the infrastructure services to support new ways of working. The Liverpool 5G Create project has been challenging at it has not been classed as an infrastructure project, however it cuts across health, social care and education services. In the Liverpool City Region, digital and infrastructure projects are within the remit of the Regional Mayor, but health, social care and education services are the responsibility of the Local Authorities and Integrated Care System.

The public network will support Local Authorities, NHS services across the community, hospitals and primary care services. With the wide range of applications needed to justify the use of a private network comes the challenge of coordinating a large number of public bodies.

As the wider 5G Testbed & Trials programme has demonstrated, stackable use cases are needed to justify the investment in a private network. Our project has gone further than this to demonstrate that stackable business cases are also needed. The connectivity savings will come from many different, existing public sector budgets. The challenge is in coordinating a business case across different public sector bodies.

6.3 Future Work

6.3.1 Business Model

We have the opportunity to:

- Explore the business case for expanding the civic network within priority areas in the Liverpool City Region
- Build a circular economy, where public services fund the network and residents get the benefit
- Increase the Social Impact across the LCR through:

- Giving more school children connectivity at home
- Increasing access to digital Health and Social Care services at home
- Introduce wider applications in Housing, Transport and Smart City initiatives onto the network
- Research how developing the network can maximise LCR assets, e.g. LCR Fibre, Civic Data Trust.

6.3.2 Supporting the existing network

As the DCMS project comes to a close the project partners plan to keep the network operational and continue the existing use cases where applicable while we continue to work on the business case.

We also intend to use the network for continuing research purposes. Both Liverpool John Moores University and the University of Liverpool plan to use the network for ongoing research project.

6.4 Learnings from security

The project set out (and was required) to include security in its design from the outset and proposed a model of transparency to use-case operators, governance and innovation to tackle the diverse eco-system. We observed that live use cases anyway adopt a ‘Zero Trust’ policy for devices to access each other or central resources alongside an assumption that any intermediate network is not private. Whilst not addressing availability, the use-cases place little or no reliance on the network for confidentiality or integrity.

To address the relative complexity of the multi-party eco-system we proposed the adoption and further development of an innovative tool to help stake-holders visualise security aspects of a complex system. With the little progress we made towards the adoption of this innovation it may be tempting to assign lessons learnt to the approach or the tool itself. It is more credible that the appetite for innovation in a supporting technology comes with availability of the asset it supports, in this case deployment of a serviceable network which, for other reasons, came very late in this project.

Appendices

Appendix 1 - WP2 Report - Set up a Delivery Company

Appendix 2 - WP3 & 5 Report - Network Planning and Deployment

Appendix 3 - WP8 Report - Communications