Liverpool City Region High Demand Density Project

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Final Project Report

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NAME OF PROJECT: Liverpool City Region HDD Project	
List of partners	University of Liverpool AttoCore Ltd CGA Simulation Ltd ITS Technology Group Ltd Liverpool City Region Combined Authority Liverpool John Moores University Qualcomm Technologies International Ltd Radisys UK Ltd Telet Research (N.I.) Ltd Asset Market Ltd – Partner left
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Executive Summary

The ambitious Liverpool City Region HDD Project aimed to assess how OpenRAN deployments can be secure by design with complex supply chains and changing configurations; demonstrate automated provisioning, monitoring and deployment lifecycle management; extend the RIC framework for multi-RAT aggregation, incorporating Wi-Fi and deliver an innovative approach to xApp and rApp development through simulation and machine learning. These capabilities were validated in live deployments at the ACC Arena in Liverpool and the Salt and Tar event space in Sefton.

The project aimed to support the commitment of global partners Radisys and Qualcomm to accelerate investment in the UK and support ITS and Telet in promoting the adoption of high-performance 5G OpenRAN neutral host networks. The work on the xApps has enabled the Hartree Centre to incorporate OpenRAN concepts in their UK Artificial Intelligence / Machine Learning skills training. CGA Simulation and Liverpool John Moore's University have led this work along with Hartree, a course on xApps was developed and delivered. The work undertaken during the project has enabled partners such as CGA Simulation to diversify and expand their business offering to include xApp development.

In addition to the aims and objectives initially set out that have been delivered through the project we have gained knowledge and experience about the importance of effective partner and supplier collaboration; this approach could be the difference between success, or failure when deploying OpenRAN networks.

The learning from the project will be built upon, with ongoing research and development centred on the networks deployed during the life of the project.

Deployment Summary

The project deployed:

- Open RAN radios, both outdoor and indoor and associated antenna systems
- Open RAN CU/DU software
- RAN Intelligent Controller software and demonstrator xApps
- an Orchestrated, virtualised software deployment environment
- specialised Open RAN edge-compute hardware platforms with wide environmental characteristics and redundant DC power
- integrated sub-6 and mmWave gNodeBs
- infrastructure for timing and synchronisation
- intra- and inter-site fibre data transmission infrastructure
- Wi-Fi with fixed and mobile back-haul
- a range of user-equipment to support fixed, mobile and personal use-cases
- group QR code eSIMs
- central data-centre infrastructure for mobile core networking, firewall and internet access, monitoring, software deployment and applications

The design of the deployments aimed to deliver the potential for exceptional performance in conjunction with the project's optimisation innovations through a balance of MIMO and spatial multiplexing, using sectorisation while maintaining the flexibility and economies of a small-cell approach. In execution, the deployment built as far as possible on the tools, skills and processes of established contractors and suppliers to maximise acceptability and compatibility with each venue, while adding to the confidence of these teams in working with 5G components and practices.

Project partner Qualcomm worked alongside Telet, LJMU and other project partners to lead the deployment verification bringing unique insights into RAN behavioural analysis.

Software deployment adopted an orchestrated approach, bringing security, repeatability and flexibility. The project developed a fully cloud-native software inventory, including functions with direct dependencies on specialised platform hardware (primarily network interface cards and hardware encryption accelerators) and deployed the software using a UK-developed and owned Orchestration product.

Description of the products or use cases.

The project's approach to procurement aimed to address Open RAN's perceived high cost while exploring procurement risks in a development environment, through new suppliers, new products or product variants, adoption of Open Source generic functions and supply-chain investment. To this end the project sourced Intel-based compute platforms from Taiwan's MiTAC, with specific telecommunications edge network features, RUs from Ireland's Benetel enabling a new indoor band variant, integrated sub-6 and mmWave gNodeBs from Airspan, in a unique configuration, and user equipment from a number of vendors through a competitive public procurement process. Consortium partners Radisys brought CU/DU software, Attocore brought the mobile core and market leader Accelleran provided the RAN Intelligent Controller.

Results and Benefits Achieved

We have achieved:

Live, private/neutral host Open RAN 5G SA deployments at two HDD venues, the M&S Arena with a capacity of 12500 and Salt and Tar events venue with a capacity of 3500 . The overall solution includes a RIC plus all-in-one and SA mmWave coverage, Wi-Fi and a dual-RAT core and a new multi-threaded UPF.

During the project we learnt of the challenges facing venues, including access to basic connectivity for ticket and operational needs due to public network congestion, and in supporting enhanced experience opportunities in large venues, beyond the capabilities of installed state-of-the-art neutral host and Wi-Fi. The high-performance networks that we have installed address these challenges.

Adding value to event-goers' experience before, during and after the event provides opportunities for artists to access additional revenue enabled by improved connectivity. The venues in Liverpool have an ambition to set the standard for others, creating demand which will stimulate investment amongst suppliers to compete with the capability achieved within the project.

The project deployed 5G SA mmWave coverage in the M&S arena for mobile use providing assured, very high capacity for applications including continuous media streaming.

Secure, flexible, repeatable, reliable, automated (Orchestrated) software deployment achieved efficiencies in time and associated costs:

Automation of Cloud Infrastructure: Cell-Stack agents provision the Operating System and take care of the installation, configuration and customization of the cloud platform. **Automation of CNF Cloud Network Function / VNF Virtual Network Function**: the deployment and installation of the CNF and VNFs is automated. Together with the Cloud Infra automation, this has reduced the time to bring up the network to just a few hours, compared to days.

PNF Physical Network Function to CNF Cloud Network Function automation: the architecture and the creation of the metal agent will allow for a seamless migration from PNF to CNF leveraging the automation built in the orchestration layer. This brings a unique competitive advantage to OpenRAN for upgrades and updates and shows flexibility in the deployment, allowing HDD environments to grow and adapt as required.

A prototype platform for more meaningful xApp development using game-based pattern-of-life modelling of user behaviour and a standard RIC interface (to either a real network or simulated behavioural model)

The Radio Planning simulation activity led by LJMU resulted in effective radio network planning and network optimisation activity. When added to CGA Simulation's pattern of life simulator, incorporating typical movement and behaviour of people at events, the gap has been bridged between the simulated and real world environments for the development of the networks and xApps, this is an industry first.

Whilst xApp development appears to be an industry topic of interest, the project found that there was relatively little activity in actually producing xApps to work on deployed networks. Through live, multi partner xApp development sessions, CGA Simulation led this work, resulting in a fully developed xApp demonstrated in both a simulated and end-to-end live network environment. The learning from this cutting edge work has been captured and delivered in a course on xApps, delivered in partnership with LJMU, CGA and Hartree. In addition, the Liverpool 5G Lab created to expedite this development will continue as research and development space for ongoing development of x and r Apps.

Cost Reduction

We have reduced the costs of open RAN network deployments through supply chain diversification. Resulting in financial savings including, 50% of the cost of compute through exploring suppliers away from the industry 'go to' suppliers and by using Open source software leading to $2800 year saving per gNodeB, synchronisation model saving $1000 per network element. These cost savings have progressed the interest of Open RAN within

the private networks market significantly, because the project has demonstrated that the costs of these networks do not have to be prohibitive.

TRLs and New Products

The project has given partners a unique chance to develop, advance and test products in the field. All partners have significantly advanced the development of their products with TRL level increases across the partner and suppliers products. Also leading to new products available to the UK market, for example Benetel developed a 550 indoor radio in band N77 to meet the needs of the project, this is now available to others. A bespoke and innovative Antenna array was designed to give the most effective coverage inside the venue.

For the venues, the deployments delivered network capacity and features that go beyond the existing provision enabling new facilities for event goers and operators, specifically

- enough bandwidth to support interactive applications for large audiences
- public access through group-QR eSIMs and Wi-Fi
- edge-compute to support new applications on site
- protected capacity for venue and event operations (point of sale, signage)

For the consortium the project brought

- experience with new technologies and suppliers building confidence in proposing Open RAN for future networks
- collaborative relationships that will out-last the project
- show-case deployments to illustrate capability to potential customers
- advanced product TRLs and prototype new features
- greater use-case awareness

A significant benefit to business arising from the intervention is through bringing together commercial, academic and public sector bodies provoking new understanding of opportunity, developing solutions and creating new markets.

Through supporting use-case development projects at the venues in the coming year, in the creative media and related sectors Liverpool will create a bench-mark for connectivity at venues across the country that others can draw on to achieve the same benefit

Security

We have established security standards and worked with partners to manage the security of the project in a collaborative way. This has been carried out using a combination of existing frameworks, best practice and innovation.

Overall, our security approach has reflected this necessary collaborative and varied nature of the O-RAN ecosystem. We have applied traditional, established security and, as far as possible, explored a Zero Trust approach to protecting the network. This makes no assumptions about security and allows access only when identity is authenticated and authorised, and policy fulfilled.

When dealing with such a diverse ecosystem of suppliers and technologies it is important to apply a uniform approach to security whilst being pragmatic about how this is applied. A set of appropriate policies and procedures have been developed and implemented; and disseminated via an online platform built on Microsoft SharePoint.

Supplier standards have been assessed using templated forms with follow ups for clarification and understanding. Progress in this area was monitored dynamically and was available in SharePoint for all members of the project to view. While this required a broader understanding of various vendors, it also provided valuable opportunities for comparing approaches to security.

We have focussed and aligned efforts with the initial security strategy. This was challenging due to the involvement of different and emerging technologies from various new vendors.

Several aspects of our initial security strategy are highlighted below:

Asset management - In line with the documented asset management policy, all assets were recorded to include full details of the asset, planned and final locations, and ownership.

Supply chain: Supplier standards have been assessed using templated forms with follow ups for clarification and understanding. There are two templates – one for ‘admin’ or service type providers who carry less risk, and another based on the NCSC framework for more critical suppliers of hardware and software.

We have the general supplier assessment which looks at security governance within an organisation, taking an overall view of policy and procedure. This assessment is carried out by requesting relevant documents from the organisation and following up with questions for clarification. and we also have a form based on the full NCSC vendor assessment. This is completed by the supplier and returned the information is then checked for completeness.

Service protection policies and processes: Liverpool 5G, as the organisation managing the project, developed the project security framework. Including: policy & procedure, configuration and asset management . The security framework was based on the original project security strategy and disseminated through policies and procedures created in the

project. These documents were constantly built upon and were available to all parties in the project SharePoint portal.

Identity and access control: Alongside standard identity (strong passwords, MFA, least privilege etc.) and access control methods (VPN, SSH, VLAN etc.) we have explored Zero Trust Network Access. Led by LJMU, the proposed zero trust architecture works by allowing only secure network access to resources (data, devices and services) and limiting this to subjects (users, devices and services) that are authorised and approved. It is built on an identity-centric approach based on the execution of a policy-based engine. LJMU have developed a comprehensive plan for integrating ZTNA principles into O-RAN, focusing on preparation, design, deployment, testing, monitoring, maintenance, and continuous improvement.

We have worked extensively to understand the interaction between OpenRAN architecture and available standards/best practices. Firstly, mapping the Telecommunications Security Act (TSA) 2021 requirements to the project architecture. This allowed us to identify the key areas where the existing architecture either supports or fails to meet the requirements of TSA.

We also looked at how the architecture meets the controls in the current O-RAN specifications.
Finally, we outlined a comprehensive plan for integrating ZTNA principles into O-RAN where the various network elements, interfaces, software components, and data flows involved, along with the roles of human subjects and non-person entities in managing and interacting with these assets are all documented.

Lessons

The Liverpool HDD project has been ambitious in its deployment, and we have learnt a considerable amount – with further learning and investigation still to come. Key lessons include:

Carrying out security assessments can be a lengthy and involved process for both the assessor and the entity being assessed. The iterative process can take a considerable amount of time particularly when dedicated supplier resource is not always available. Standardisation of these assessments across the industry would allow the suppliers to respond with readily prepared documents – reducing time and effort on both sides

The large number of devices (UE's) in the project took considerable time and cost to manage and dedicated resource (and budget) should be included from the project outset. We used Hexnode to manage the devices which has allowed us to remotely manage settings, deploy apps and ultimately to be confident that configurations are correct.

Working with Zero Trust Network Access (ZTNA) has highlighted that it will take time and much more work to implement. Theoretically it is one of the ways (and possibly the best way) that we can protect this diverse network but, in real life situations, it will prove challenging to implement.

Next Steps:

Asset management although effective for the project needs to be further developed as we move towards potential commercial use and agreements at the two Liverpool sites. The full asset lifecycle including maintenance schedules, security checks will need to be included in the management model that we have built.

The **ZTNA** journey that we have started, is well worth progressing and we will look to carry out further work in the future. As the number of suppliers and technologies grows, and particularly as the use of RIC platforms becomes more widespread, guaranteed security without the benefit of perimeters is increasingly important.

The new generation of devices and machines, including IoT sensors, manufacturing robots, internal communications systems, production machinery are often in demand for private 5G networks. The attack surface is increased, and Zero Trust principles can establish access and identity through context and security posture.

Standards coming together to make things easier for operators, suppliers and venues or end user customers is also important. Establishing standards and guarantees that are easier to follow and understand is critical when building neutral host or MOCN deployments.

High level summary of project costs

The project costs to DSIT and project partners changed considerably throughout the 18-month project. This section outlines the changes from the baseline position at the point of acceptance of the bid to the predicted final position at project completion.

1. Baseline/Bid Acceptance position

TOTAL PROJECT	Grant Total	23/24	24/25
Labour costs	2,705,682	667,319	2,038,363
Overheads	667,914	150,522	517,392
Materials	1,299,003	1,022,200	276,803
Capital usage	1,258,000	692,000	566,000
Sub contract costs	2,660,174	748,576	1,911,598
Travel & subsistence	146,469	46,450	100,019
Other costs	134,165	27,000	107,165
TOTAL	**8,871,407**	**3,354,067**	**5,517,340**

Table 1.1 – Baseline by category and financial year

BASELINE	TOTAL	UoL	Telet	CGA	ITS	Tractum	Attocore	Qualcomm	Radisys	LJMU	LCRCA
Baseline Total Grant	8,871,407	2,835,393	571,209	342,000	564,617	205,633	575,263	249,042	2,082,952	1,144,893	300,403
Partner Contribution	5,145,608	708,848	380,806	228,000	564,617	137,089	383,509	373,563	2,082,952	286,223	0
TOTAL	**14,017,014**	**3,544,242**	**952,016**	**570,000**	**1,129,235**	**342,722**	**958,772**	**622,605**	**4,165,904**	**1,431,116**	**300,403**

Table 1.2 – Baseline by partner

2. Year 1 Spending Constraints

There were significant delays in signing the GFA and collaboration agreement due to the ongoing negotiations with Radisys across multiple projects. Although project partners started work at risk, without contractual agreements in place the anticipated installations, capital and material purchases could not be committed as planned. As a result of the delays and not being able to carry budget over to the following year significant grant budget and associated partner contribution was lost in year 1.

Yr 1 Actual vs Budget	TOTAL	UoL	Telet	CGA	ITS	Tractum	Attocore	Qualcomm	Radisys	LJMU	LCRCA
Fy 1 Baseline	3,354,067	1,197,859	158,427	98,600	138,000	98,100	211,939	88,668	372,952	890,087	99,434
Fy 1 Actual	2,698,144	999,303	91,527	112,163	68,035	16,734	195,069	29,141	371,633	741,601	72,938
Variance	**-655,922**	**-198,556**	**-66,901**	**13,563**	**-69,965**	**-81,366**	**-16,870**	**-59,527**	**-1,319**	**-148,486**	**-26,497**

Table 2.1 – Actual year 1 spend by partner

3. Year 2 reprofile

Following the underspend in year 1, in April 2024 a review was undertaken of the changes needed to support the reduced budget. Change Request 4 was prepared, covering 4 sites rather than the original 5 and a full reprofile of year 2 costs.

On 28/6/24 DSIT instructed the project to stop work on sites 3 and 4. CR4 was rejected on 27/9/24 and a new Change Request 7 was requested reflecting only the first 2 sites. DSIT requested the following further changes in CR7:

- Removal of Year 2 management fees from University of Liverpool
- Movement of Liverpool 5G subcontract labour to University of Liverpool labour category

	DSIT Funding (£)	Financial year 1 (£)	Financial year 2 (£)
		23/24	24/25
Labour_costs	2,704,394.40	695,079.04	2,009,314.86
Overheads	609,366.42	136,471.62	472,894.79
Materials	886,932.30	681,630.37	205,301.93
Capital_usage	941,647.60	488,647.20	453,000.40
Sub_contract_costs	2,252,030.02	681,877.58	1,570,152.44
Travel_&_subsistence	59,686.17	10,921.14	48,765.46
Other_costs	49,243.12	3,517.50	45,725.62
Totals	**7,503,300.04**	**2,698,144.45**	**4,805,155.50**

Table 3.1 – CR7 Spend by category

CR7 - Fy 2 Forecast	TOTAL	UoL	Telet	CGA	ITS	Tractum	Attocore	Qualcomm	Radisys	LJMU	LCRCA
FY2 Grant	4,805,155	1,383,472	260,707	217,115	413,726	0	363,324	122,792	1,666,900	266,250	110,869
Partner Contribution	3,238,009	345,868	173,805	144,744	413,726	0	242,216	184,188	1,666,900	66,562	0
TOTAL	**8,043,164**	**1,729,340**	**434,512**	**361,859**	**827,451**	**0**	**605,540**	**306,981**	**3,333,800**	**332,812**	**110,869**

Table 3.2 – CR7 Spend by partner, Year 2

4. Final position

At the time of writing, the final claim is currently being prepared. Claim 5 was submitted in February 2025 with all partners providing a reforecast until the end of the project (CFP8). These figures are included below.

CFP8	Total spend	Grant claimed
Labour costs	4,620,263	2,711,135
Overheads	1,003,539	602,149
Materials	1,068,552	814,009
Capital usage	1,078,203	862,163
Sub contract costs	3,622,914	2,194,463
Travel & subsistence	76,645	38,840
Other costs	22,991	12,019
TOTAL	**11,493,107**	**7,234,779**

Table 4.1 CFP 8 by category

CFP8	TOTAL	UoL	Telet	CGA	ITS	Tractum	Attocore	Qualcomm	Radisys	LJMU	LCRCA
Final Grant Forecast	7,234,778	2,254,533	343,298	344,043	337,654	16,734	558,392	149,933	2,038,533	1,007,851	183,806
Partner Contribution	4,258,328	563,633	228,866	229,362	337,654	11,156	372,261	224,900	2,038,533	251,963	0
TOTAL	**11,493,106**	**2,818,166**	**572,164**	**573,405**	**675,309**	**27,890**	**930,653**	**374,833**	**4,077,066**	**1,259,814**	**183,806**

Table 4.2 Forecast (CFP 8) by partner

5. Key learning points

- The subsequent reversal of financial decisions accepted during the bid stage and initial claims has led to an unstable position for project partners.
- The length of time taken to agree changes has generated more rework and has led to partner investment budgets being lost. Having multiple change requests with delayed agreement, open simultaneously created an unclear baseline position for both activity and finances.
- The change request process is not fit for purpose, the length of time taken to approve change requests resulted in partners having no option but to work at risk and financial forecasts were constantly subject to change.

We have included the following benefit in the benefits realisation reporting:

Significant reduction in Open-RAN deployment cost overheads, notably compute hardware (50%), synchronisation (>$3000 per network element), Open Source virtualisation ($2800/year per platform)

Project Highlights

Salt and Tar Music Weekender

The Salt & Tar music weekend in August 2024 was a significant highlight with an Open RAN network deployed and providing service at this pioneering venue for event operations, traders and the public via 5G-connected Wi-Fi access points and group QR code eSIMs. This event, the first in the programme, brought together venue liaison, the technical deployment, processes and structure for on-site user support and technical support.

Collaboration in Action

The partnership model was collaborative, the leadership of the project provided a flexible approach to dealing with project challenges which were both technical and non-technical. This encouraged combined resolution of project challenges and ownership of achievements and outcomes. Key partners have committed to continue working together to further

enhance and progress the installed networks and associated applications, building on the strong foundations laid during the project.

Industry Firsts:

Benetel Radio
The project delivered or seeded several cost-effective hardware solutions relevant to the UK market including the n77 variant of Benetel's indoor RAN550 radio, adoption of commodity transport infrastructure in Open RAN networks enabled by G.8275.2 synchronisation, adoption and proving of low-cost sector-specific computing platforms and development of an easily installed single-site antenna array for arena settings.

mmWave
The project deployed 5G SA mmWave coverage in the M&S arena for mobile use. We understand this is one of the first of its kind (as opposed to its wider scale use outside the UK for point-to-multipoint fixed wireless access).

xApp Development

The ground-breaking approach to xApp development using game-based pattern-of-life and behavioural models culminated in a number of interactive coding workshops chaired by CGA Simulation and a training course. Bridging the gap between simulation and real-world environments for xApp development using the technology developed within the project is an industry first.

Orchestrated Software Deployment
The project showed that the entire software system, including the hardware-dependent DU functionality, could be deployed using Orchestration by a UK vendor's product (Weaver Labs' CellStack) in virtualised, cloud-native form.

Open RAN Economics
The Liverpool 5G project has successfully tackled the economics of building and deploying Open RAN networks. Through a combination of supply-chain partnerships, expanded use of Open Source for generic software, focused engineering investment in avoidable costs and an Orchestrated approach to software deployment, Liverpool 5G have created a model that removes tens of thousands of dollars of capital cost and thousands of dollars recurring cost per base-station.

Centralised Antenna

In contrast with classical approaches to event-space coverage the project commissioned a highly sectored, single-site antenna array. Although the benefits of near-far signal-to-interference are diminished, the centralised design allows greater control of coverage overlap in azimuth and reduces the cost and disruption of spatially distributed antennas.

Project Conclusions

Demand and Opportunity

The project engaged with an events arena, exhibition and conference centre and an outdoor event space as part of a regeneration project leading to deployments at both. We also engaged with a railway station, bus station and sports arena understanding the opportunities and deployment context. In each setting, gaps in connectivity leading to at least inefficiencies in operations and consistently un-served opportunities were immediately put forward by the settings' operators and owners. The strongest themes identified were:

- the cost of (or losses associated with) protection of critical connectivity for operational information or revenue collection, specifically distribution of video feeds for crowd management and reliable connectivity for point-of-sale terminals. It was clear that operators of the settings were investing in targeted (i.e. largely single-use) provision in this area;
- consistent public access to generic internet-based services, especially during times of high density and/or demand, including access to services provided by or for the setting (e.g. ticketing). Settings had mostly made investments in Wi-Fi for public provision, but none regarded it as sufficient in capacity or manageability with poor 'reliability' expressed as the strongest weakness. The more sophisticated settings have invested in MNO DAS systems. Neither Wi-Fi nor DAS public access have provided a quality of service/experience that has enabled significant return on investment in terms of new revenue other than supporting a competitive offer;
- flexibility on operations emerged as a common theme, specifically in the ability to deploy and view video feeds for crowd management or security according to need both at the venue and for the staff involved and for the deployment of devices, notably signage, point-of-sale, access and entry screening;
- with the venues where we were able to deploy and engage fully, the demand to support new revenues was already well established with artists focusing more on revenue from performances. This opportunity was expressed as a demand for greater audience engagement before, during and after events making connectivity essential to the need with good support for multi-media prerequisite.

Market Development

Previous interventions have rightly prioritised collaboration, and we have seen again that these rare opportunities to bring supply and demand together have yielded new ideas, specifically in a lab-to-venue offer providing a pathway to accelerate new performance revenues enabled by connectivity. The project has considered how to engage, communicate, support application development and investment decision-making and what roles and functions are needed to crystallise the journey from potential to realisation.

Education and Research

A lack of sufficiently trained, educated and motivated young people ready to join and create telecommunications and wireless start-ups and established companies in the UK has been cited consistently in recent years as an inhibitor to growth in both the supply side and deployment of networks that support the health and well-being of the UK's economy (although investment has a role to play too). The project has supported network research in LJMU and contributed training material delivered via STFC. With a commitment to well-informed policy and decision making in government promoted by coherent engagement nationally and internationally, the UK is well-placed to benefit from the strengths of its wireless and telecommunications supplier eco-system.

Supply-Side: Deployment

We found well-established deployment frameworks at each venue with clearly identified specialist contractors (e.g. for rail), policies, standards and processes. Although varying in cost, we identified no blocking or onerous requirements in working with any of the settings contacted during the project. Mobile communications equipment, radio planning, antennas and back-haul were new to almost all of the settings and contractors approached during the project, but we found that confidence in working with these technologies was readily built.

Supply-Side: Transit

The networks deployed made wider use of in-building point-to-point fibre (rather than copper technologies), e.g. for RU front-haul. In the metropolitan and longer range transit networks the mobile and Open RAN network requirements were well-understood and fully supported.

Supply-Side: Operations and Service

For test, events, subscriber and SIM management, support, on-site service and monitoring the project made use of personnel and facilities from Telet, Liverpool 5G, ITS, the

universities, other partners and contractors according to the specific needs. Where the need was technical or developmental (e.g. Qualcomm's forensic coverage and signalling investigations) the Telet (Operator) team adopted a coordinating role with technical experts, notably within Radisys and Attocore. For events Liverpool 5G provided customer-facing support with Telet, ITS and other partners fulfilling technical operations roles.

Operationally we saw two opportunities for innovation, one associated with the specific needs of the new vertical-market use-case enabled by the Open RAN deployments and the other associated with Open RAN's technical and vendor architecture. Broadly categorised as event and community venues a clear lesson from their operations is the need for flexibility and adaptability in serving the needs of each event within standard capabilities and protocols to ensure cost efficiency and safety. Whilst apparent in the venues' operations these qualities are new to conventional telecommunications. The tool-kit of operations and service facilities deployed in the project including Orchestration to eSIM technically and Liverpool 5G on-site and ITS NOC service covered the needs for flexibility and capability, laying a foundation for vertical-specific service models. Open RAN technical operations carries forward the generic challenge of coordinated working across multiple vendors' proprietary products. In the project the resulting engineering support teams were large and relied on considerable interaction for both development and problem solving.

Supply-Side: Hardware

We had identified the availability of cost-effective hardware for Open RAN as a key challenge before the project and undertook supply-side engagement to tackle this topic. Key findings are:

- cost-effective compute can be accessed readily although there is a degree of nervousness over integration with platforms seen as different;
- it was difficult to access the most efficient (especially in energy) architectures, notably the use of in-line acceleration for Layer 1 processing. We see this as largely the result of the development and promotion of strong single-vendor eco-systems (e.g. Flex-RAN by Intel) offering software developers shorter time to market at the cost of the need for additional compute and energy use;
- the UK's n77 Shared Access band is adjacent to a mass-market band but still requires manufacturers to create at least a variant of existing products with the consequent hurdle in achieving economy of scale.

Open RAN: Feature and Performance Benefits

The project demonstrated Open RAN performance and technical feature parity with conventional networks in terms of throughput at moderate range and hand-over with

variability clearly attributable to differences in maturity rather than potential. The project Open RAN network did not show competitive power consumption in its deployed form. With our work on the RIC and xApp development environment it was immediately clear that this aspect of Open RAN delivers its unique potential in terms of feature and performance benefits related to stronger interaction with applications and use-cases and network optimisation across a larger number of network elements. At the start of the project it was our view that accessing these benefits was hampered by a shortage of development environments with sufficient connection to user and application behaviour – the project confirmed this prejudice, and we have gone some way to addressing the shortage. During the project we also formed the view that the interfaces and framework for xApp development defined by the current eco-system does not support a vibrant and diverse community of developers with much too much weight on purist software development concepts and insufficient weight on wireless and application design.

Open RAN: Product Landscape, Readiness, Challenges and Economics

RAN software is at the heart of Open RAN products and the project has given us additional insights into the vendor eco-system and road-maps. We see these characterised as:

- corporate vendors (e.g. Radisys, CapGemini) with strong products, strong development teams and a focus on Tier-1 system integrators and partners
- local focus (e.g. SageRAN) with a focus on supporting local or regional eco-systems
- early/mid-stage vendors (e.g. IS-Wireless) with a focused road-map and the agility to support newer and smaller integrators
- Open Source (e.g. SRS RAN) harnessing community resources with creative approaches to funding and maintaining pace and quality of development

While corporate vendors seem to prioritise opportunities with large scale it is clear from our project and others that verticals and private networks feed innovation for them. Whilst we are not aware of a truly ‘free’ Open Source solution for the RAN the trade-off between cost of licence and community support is interesting for small and private network operators with in-house integration skills. The decision to use IP in software as the basis to develop fully integrated products including hardware has clearly been faced by many vendors with the consequence of competing with potential customers.

RAN Intelligent Controller software and xApps deliver the performance differentiation for Open RAN deployments but their vendors carry a heavy burden of investment. The natural customer for these vendors therefore brings scale although it is not clear that the national networks benefit from these products. While ‘Southbound’ interfaces between RIC and RAN (E2, O1) are standardised, applications written for a specific RIC are not readily portable between RICs.

The project has established a framework for xApp development in a simulated environment that is more engaging and complete than existing products with the objective of making this key differentiator in Open RAN better exploited.

Hardware platforms for Open RAN suffer from a degree of vendor lock-in (e.g. Intel FlexRAN) and early-stage lack of economy of scale. While the latter will be just a matter of time as the market develops, the former requires commitment to more efficient approaches (e.g. RANSemi's inline accelerator) but then lose the impetus of a corporate sponsor. The Liverpool project has tackled some of the hardware and generic software cost challenges directly.

Open RAN: Supply-Side Diversification Opportunities for the UK

The potential for supply-side diversification based on Open RAN (but certainly not exclusively) has been demonstrated by the growth of a UK 5G network eco-system either directly or through connections and association. The project has forged contacts through direct participation, collaboration or conversation with:

- ITS: all-UK telecommunications company
- Attocore: all-UK core vendor
- CGA Simulation: all-UK modelling and simulation house
- Telet: all-UK private network operator
- Weaver: all-UK software, systems and market development
- Benetel: Irish RU vendor

along with both Liverpool universities and two multi-nationals with a strong UK presence. On this evidence the UK's strengths are in innovation, software and services (including physical deployment and delivery) which aligns well with industry expectations although the programme as a whole has supported hardware and product companies including Antevia in the UK and SRS RAN in Ireland.

Next Steps

At the close of the project, the ownership of the networks insitu at Salt and Tar and the Arena will transfer from The University of Liverpool to Liverpool 5G Ltd. An agreement will be in place to this effect. Liverpool 5G is a not-for-profit organisation, transfer of the assets will comply with subsidy rules.

The leadership of both sites have agreed to keep the networks in place for research and development purposes over the next twelve months. An agreement between each site and Liverpool 5G Ltd will be drawn up and Liverpool 5G Ltd will ensure appropriate insurances are in place.

Key partners have agreed to continue to support the networks over the next twelve months on a ‘best efforts’ basis with operational costs being very low or zero. The sites have agreed to cover the electricity costs for running the networks.

The focus over the next twelve months will be to identify and test ground-breaking, innovative use cases, Liverpool 5G will co-ordinate this activity with approaches to creatives, researchers and suppliers in order to maximise the potential opportunities and use of the networks.

Over the next twelve months the business model will be developed, taking into account the scope and impact of the applications/use cases identified, including the potential for income generation and dynamic pricing for additional customer experiences.

The consortium members will continue to prioritise network improvements where possible with a limited budget and explore further opportunities. Liverpool 5G will continue to host a meeting once a month for this planning and further discussion, and Liverpool City Region Combined Authority will host a quarterly 5G Forum bringing in regional stakeholders to discuss innovation and expansion opportunities.

There are multiple venues and sites across the city region that expressed an interest in hosting a network during the project, several will explore replicating what has been produced during the project, on a commercial basis. These discussions are underway.

Liverpool 5G will continue discussions with the Music Futures leadership team to agree access to the network for proof-of-concept testing of creative innovations identified though the five-year programme.

Additional opportunities for funding through research projects will be explored with partners and venue leads.

The ambition at the end of the next twelve months is to have a full business and cost model in place.

Media Library

Project Overview video:

Liverpool City Region HDD Project Overview Video

Liverpool City Region HDD Press Releases (posted on the University of Liverpool news site):

13 September 2023
£9M project to enhance digital connectivity in high density areas - News - University of Liverpool

Associated X post:
University of Liverpool News on X: "£9M funding from @SciTechgovuk for project to address poor digital connectivity in places such as sports and music venues. Led by @LivUniEEE, the innovative project involves @LpoolCityRegion and a consortium of partners. More info: https://t.co/qeggAZtEfg https://t.co/LkRT4eFoaM" / X

Coverage:
BBC Radio Merseyside
14 September 2023
The University's £9m digital connectivity project is featured in news bulletins and includes comments from Prof Joe Spencer, Department of Electrical Engineering & Electronics . It also featured on the Helen Jones drivetime show where Prof Spencer was interviewed.

Liverpool Business News
TheBusinessDesk.com
ISPreview.co.uk
Mobile Europe European Communications

1st trial:
Liverpool City Region HDD project trials new digital technologies at Salt and Tar weekender

Coverage:
Liverpool City Region HDD project trials new Open RAN at Salt & Tar Festival

2nd trial:
Liverpool City Region HDD project trials Open RAN technology at Comic Con event

3rd trial:
Liverpool City Region HDD project tests low carbon credentials of Open RAN technology at Act 1.5 event

Legacy Site

Liverpool City Region High Demand Density (LCR HDD)

Posted content on Web Sites

TechUK

UKTIN Liverpool City Region HDD

UKAuthority Liverpool festival tests RAN networking tech

Telecoms.Com High-density Open RAN trial deployed at Liverpool music festival

LJMU tests low carbon credentials

Telet Liverpool City Region HDD

LJMU Liverpool City Region HDD project trials Open RAN technology at Comic Con event

LCRCA New digital technologies to boost connectivity at mass events trialled at Salt & Tar weekender

ITS partner in consortium delivering Open RAN (5G) to high capacity venues

Liverpool 5G Success for LCR HDD project first trial

Weaver Labs YouTube video

Blog from 14th September ONE Competition announcement event – Ann Wiliams

A project showcase event took place at the ACC Arena on March 12th 2025, this successful event with over one hundred registered delegates from industry, the City Region and interested venues presented the aims, ambitions and outcomes from the project. A tour around the Arena site, hosted by the ACC group leadership team, enabled delegates to see the installed network in place and functioning. More information can be found here:

Liverpool City Region Open RAN High Density Demand Showcase unveils key findings - News - University of Liverpool

We currently have a media library of videos and photos on the Liverpool HDD SharePoint site

Media

Social Media Outreach

In total, social posts gained 18,911 impressions. Most of the time, the engagement rate was above the industry average and performed particularly well as LinkedIn, which wasn't surprising as this is where our primary target audience is. This is significant as it demonstrates that our posts have reached the right people and people are interested in the topic.

Newsletter

LCR HDD has been featured in 4 LCRCA Digital newsletters to date, which are sent out to a mix of professionals and people with a general interest in our Digital activity. Collectively the newsletter has been opened over 500 times, therefore it is likely that the story was viewed these many times, increasing the awareness of the project. The stories were engaged with 34 times, again building the awareness of the project. 27 people engaged, which meant they were taken to more detailed information on the project, whether it be a news story on UoL's website, LCRCA's news section or dedicated HDD page.

Webpage (01/07/24 - 28/01/25)

We created a new webpage for the project in July, between then and the end of January 25, the page has received 118 sessions from 56 users. It will be those most interested in the project who have gone to the webpage so it's a positive sign that this many people have made it to this stage. It can also be understood that some of these 56 users will have viewed the page multiple times, which further shows deeper interest in the topic.