Milestone 50 (WP 0.6)

Project REACH **Final Report** (publishable)

REACH (RIC EnAbled (CF-) mMIMO for HDD)

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1. Executive summary

The REACH project set out to **enhance communications in areas with high footfall** - so-called high density demand scenarios - with Blackpool as the key location. In addition, it looked at new networks in the '**not-spots**' of Cumbria to aid emergency calls. The research and development carried out by the University of York was groundbreaking through the creation of the **cell free massive MIMO testbed**.

The project created the **UK's largest private 5G network**, one of the largest in Europe.

Over the eighteen months the project ran, **most of the objectives were met**. Procurement and licensing issues prevented the project being able to perform longer trials and therefore the key benefits are based on limited data only.

Energy optimising xApps were developed and state-of-the-art testing made available through an advanced ORAN Intelligent Controller (RIC).

The project was funded by the **Department for Science, Innovation and Technology** with a budget of £3,192,866 in addition to partner contributions of £1,882,689, a total spend of **£5,075,555**.

2. Aims and scope

We have all been to events with large audiences where we would love to share that experience with our friends and families. Your phone has good signal strength, but you cannot connect at all! The network is simply overloaded as so many people are trying to connect and transmit at the same time. It is a typical High-Density Demand (HDD) scenario. The mobile operators and current technology allow for a certain density of connections at any one point but struggle with HDD events. This leads to frustration from the audiences, often aimed at their operator.

The REACH project has been designed to address these issues. We deliberately chose locations where HDD events regularly occur – in this case Blackpool – or where there is no current mobile signal – Buttermere in Cumbria. This enabled us to develop compelling use cases. We combined this with research and development of the required technology based at the University of York together with infrastructure developments in Leeds and Isle of Man.

This structure has enabled us to create the UK's largest private 5G network.

In addition, the research carried out by the University of York has been groundbreaking for cell free massive MIMO. Two patents have been applied for and a further 9 are under review.

Overall, our original goal of developing new technology to alleviate the HDD issue and combine this with a state-of-the art infrastructure in a real-life scenario such as the Blackpool Promenade, has been fully achieved. Our lead partner, David Grace from the University of York stated at the outset that:

> **"This project will deliver improved data connections in areas which regularly host numbers of visitors and where the mobile networks experience high demand in small areas. The innovative O-RAN software and hardware systems being developed by the partners will develop expertise and support the growth of a flourishing UK ecosystem in 5G and future 6G technologies."**

This we achieved.

3. What we did

Objectives

There were three main objectives of the project as laid out in the GFA:

(a) **O-RAN HDD** neutral host small cell deployment around Blackpool. Small cells will be installed on street furniture, enabling connection into local data centres housing the core network and Distribution Units (DUs). The trial will show how the system can scale to meet the wide variety of temporal and spatial demands seen in this tourist hotspot.

(b) **Massive MIMO** (Multiple Input Multiple Output) (mMIMO) applications within the HDD fixed wireless access (FWA) context, led by AQL Limited (AQL). This will involve trials for multi-tower Gigabit mMIMO architectures, exploiting existing infrastructure from AQL. Installations will be connected into fibre infrastructure and depending on the exact location of the trial, will provide either a permanent installation or temporary event service.

(c) **Cell-free mMIMO** (CF-mMIMO) applications will be developed, initially restricted to lab tests led by University of York. These will undergo in-lab development and testing.

In summary, the first and third of these were achieved fully. The second objective had its challenges and only in the final week of the project have we been able to test the FWA concept.

The project was also linked to a 'sister' project at the University of York – the YO-RAN project – and experiences and knowledge were shared between the two and dissemination of results shared.

Locations

Blackpool was chosen as the prime location, and we had Blackpool Council as a primary partner. This was a significant benefit as Blackpool owned or had access to almost all of the street furniture we used to mount the cells.
Blackpool Council has a very forward-looking vision and strategy for enhanced communication in their region and the project was able to benefit from this direction.

Buttermere was a use case added part-way through the project and was chosen because there are many so-called “not spots” in the area, which is visited each summer by many tourists who often wander into remote areas, and in the event that they require assistance, there is more often than not no mobile signal.

Research into cell free mMIMO was carried out exclusively at the University of York in their Institute for Safe Autonomy.

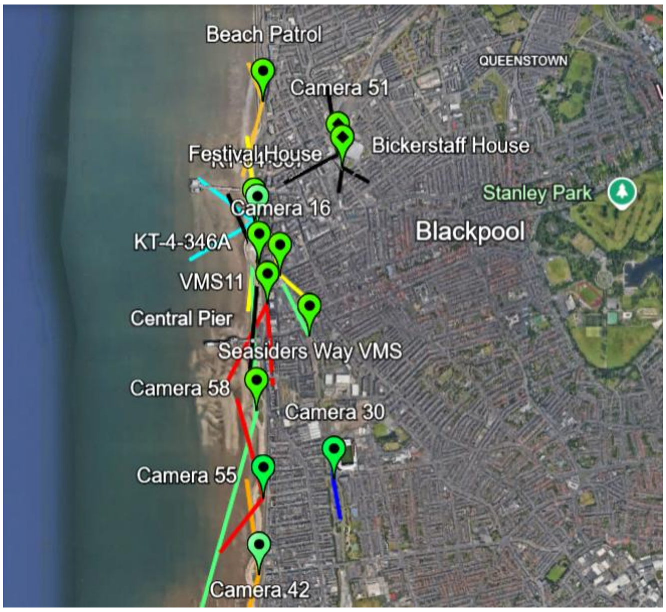
The massive MIMO FWA was carried out linking the Isle of Man, Blackpool and Leeds via our technical partner aql.

Infrastructure

In Blackpool, 18 CellXica cells on a WaveMobile core were installed and configured along the Promenade. This created the largest private 5G network in the UK. Users of this network, once stabilised, include Blackpool Council for trading and general public usage, the Tram Operators for efficiency and the Beach Patrol, the latter assessing the use of drones for improved search and rescue. Our aim was to improve their overall communications capability including digital applications to improve service availability and lifesaving.

The cells were installed on tramway masts and other street furniture to which Blackpool Council had access. The installations on the tramway masts could only be carried out at night between 12:00am and 4:00am as the power to the system had to be turned off.

The installations were carried out by our sub-contractor TNP.



Cell locations in Blackpool

Daytime and night-time installations

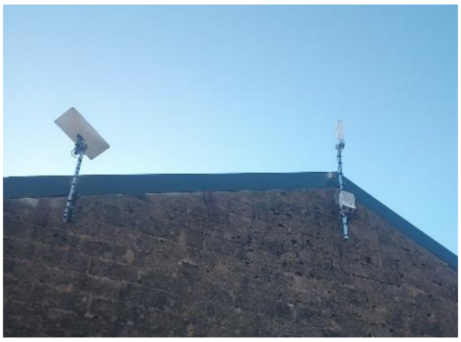
In Buttermere, an area popular with walkers and climbers but with notorious not-spots, we tried to facilitate better communications, particularly for emergencies, with cells at the Honister Slate Mine, the Bridge Hotel and Gatesgarth Farm. Backhaul was provided by a Starlink satellite connection, although this will ultimately be replaced in Buttermere with fibre as the Project Gigabit deployment by Fibrus progresses. The Honister site had fibre installed by BT in early 2025.

As with Blackpool the service was delivered by WaveMobile, using the same approach, centring around deploying low-power, small-cell infrastructure tailored for rural locations, aiming to allow communities to enhance local connectivity independently of major carriers like Vodafone, O2, EE, or Three. Backhaul was provided by a Starlink satellite connection, although this will ultimately be replaced in Buttermere with fibre as the Project Gigabit deployment by Fibrus progresses. The Honister site had fibre installed by BT in early 2025.

The service offers basic 4G mobile connectivity with mobile roaming calls, SMS and WhatsApp calls and messaging, although it defaults to 2G when overloaded. Statistics from the network operations show that between July and Sept 2024, approximately 240,000 unique devices had connected to the network. Most will have been visitors to the region.

WaveMobile operates using a small spectrum allocation, typically within the 1800 MHz guard band, which they use for their GiLTE (GSM-in-LTE) technology. This approach combines a 3 MHz LTE carrier with a carve-out for GSM/GPRS services.
The network provides 2G for voice and telemetry, along with 4G for basic internet access, supporting speeds of up to 5 Mbps. This setup is aimed at rural or underserved areas, focusing on delivering essential mobile and internet services rather than high-speed broadband. A 5G cell was also installed at Gatesgarth.

By March 2025, up to 50 999 emergency calls have been made using the new network, which otherwise would not have been received.



Installation of small cell at Honister Slate Mine.

4. R&D

University of York

The development of the xApp and rApp progressed well and is continuously being improved with new algorithms. However, rApps are further behind the industry development curve compared with xApps. Integration with VIAVI for the RIC testing went well and the next step is to integrate with the test bed.

CF-mMIMO and CF-mMIMO Testbed

The original aim was to develop a testbed that would combine signals only from 2 base stations to illustrate the principles of CF-MIMO practically. This has been significantly exceeded over the course of the project.

Cell Free mMIMO testbed at University of York

The CF mMIMO testbed has resulted in at least two patent applications with more in process. It has also spawned the potential for a spin-out organisation with the iCURE Explore programme helping its inception.

During the project, we have:

- demonstrated a full uplink 5G CF-MIMO implementation based on 4 base stations with standard UE attach and AI controlled optimised base station signal combining, enabling scalability - a world first!
- IP identified (up to 11 items) in the CF-MIMO area, including for resilience and ultra-low latency communications. Applicable to multiple use cases: factory of the future, mission critical;
- development of xApps to optimise different aspects of CF-mMIMO completed, with performance quantified. Number and level of optimisation significantly greater than that foreseen at proposal stage. These use AI algorithms to perform the optimisation.
- commercialisation of the technology is underway (Abdulhamed Waraiet accepted on to Future Founders programme)

- proposed further work to extend the testbed to include downlink CF-MIMO and the demo bi-directional MIMO. Quantitative test of CF-MIMO performance. Software switch between conventional and CF-MIMO variants
- tested software based on ns3 to test CF-mMIMO, with an aim for commercialisation. This aims to achieve what Viavi test tools have done for small cell and mMIMO, but for CF-MIMO. This could be a closed source solution, based on open-source software (similar to the way Ubuntu works).

Energy efficiency testbed

This was not foreseen at the start of the project. In conjunction with YO-RAN we have developed and tested a system that allows the energy efficiency of non-O-RAN wireless equipment to be interfaced and controlled via an O-RAN adaptation layer. This has been protected by patent. Commercialisation is underway via iCURE Explore/Exploit programmes, with a spin-off company RIC Connect expected to be launched in 6 - 9 months. Market discovery process suggests 80% of equipment providers would like to use this technology.

Further development of the adaption layer software is underway, to further enhance the functionality and saleability.

The technology was showcased at MWC Barcelona (via the YO-RAN stand)

RIC xApps Development and test

The project aim was to have a 3-stage test of xApps.

- Stage 1 simulation,
- Stage 2 emulation using a real RIC,
- Stage 3 practical trial on real equipment.

This level of test was not foreseen at the start of the project and should assist in proving validity and interoperability. Small cell xApps have been developed to monitor KPMs and used by AI algorithms to control the energy efficiency and network slicing.
These have currently been tested to stage 1/2, with the aim to test fully to stage 3, possibly in Blackpool trials.
In addition, mMIMO xApps - xApps have been developed to monitor KPMs and control mMIMO system. These were tested to stage 1, with stage 2 foreseen.

Integration of Viavi test tools for RIC emulation.

This was not envisaged at the start of the project.
We have:

- Completed basic integration of OSC RIC, which enhances commercial potential of the test tool for Viavi.
- Furthermore, we aimed for integration with IS Wireless RIC with the Viavi test tool, with similar benefits for both IS Wireless and Viavi.

The project is particularly pleased with the collaboration between the staff at VIAVI and University of York. The teams met regularly and have a very high level of joint responsibility for deliverables and associated collaboration.

Papers have been written and submitted for presentation and patent applications are being prepared for parts of the work.

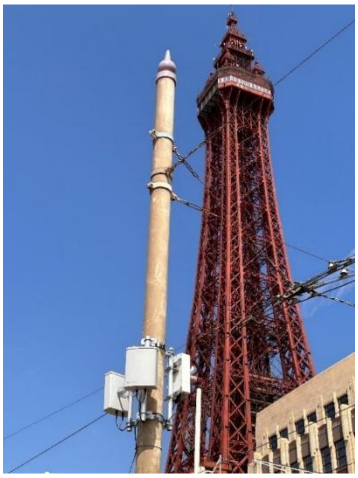
5. Use cases

We developed several ideas for use cases following consultation with stakeholders and these were distilled down to fewer more realistic use cases by the end of the project.
The following highlights the main use cases and their potential benefits. The numerical references refer to the specific benefits as listed in the Benefits and Realisation spreadsheet.

Blackpool

Network Performance (BLA 1, 2, 4, 5, 6, 9)

The use cases in Blackpool were almost all concerned with improving the experience of visitors to the region. In addition, we developed a few use cases focused on keeping visitors safe. Due to time constraints, it was not possible to create a public network, so quantifiable results concerning improved positive experiences of general public were not possible. However, results from the private network we installed were showing improved communications along the promenade, with fewer 'dropouts' and increased data throughput. Video calls were also made along the Promenade.



Energy Efficiency (BLA -3)

We were able to demonstrate through the development of xApps how we could optimise energy efficiency and usage on the network and initial figures estimate we can reduce energy by around 20%. This was evaluated using a RIC / xApp the TeraVM AI RSG test tool from Viavi, which used a model of the Blackpool promenade network, where the xApp was used to turn off key parts of cells when there was a limited demand.

BLA 10 and 11 concerned improving card payments for traders and parking machines, which were not able to be addressed.

5G Coverage

We were able to demonstrate 5G connectivity via a private network in Blackpool. This was both outdoor (BLA 7) and indoor at the Winter Gardens (BLA 8). In both these instances, the use cases we aimed at improving the experience of visitors to the specific locations. Visitors are generally in 'holiday mode' and are therefore more likely to want to share their experiences on-line and real-time. The new network will eventually allow this to happen, with videos and photos able to be shared either along the seafront or from within the Winter Gardens (with appropriate permissions).

Both networks will eventually, be available to the general public, once they have reached appropriate maturity and adequate load testing has been completed. This will probably take place together with a major MNO provider. The two systems could mature at different rates and therefore come online for the general public at different times.

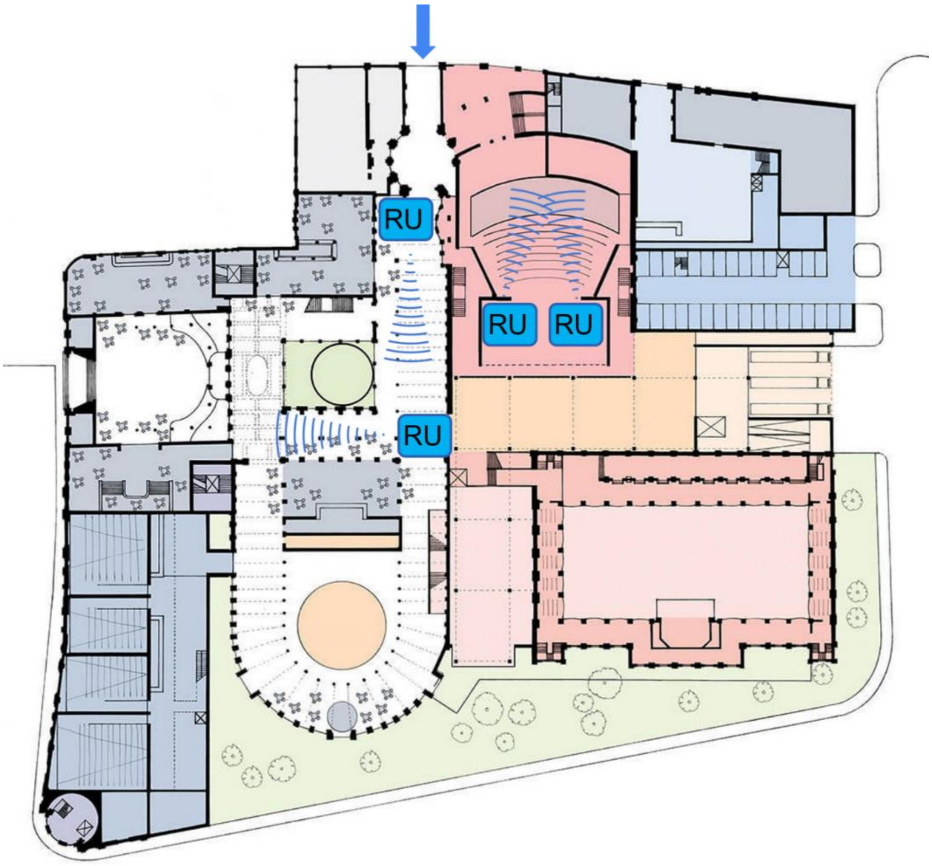
Mission Critical (MCR 1-4)

These were potentially the use cases with the highest impact, as they could lead to the saving of a life. We worked closely with the Blackpool Beach Patrol to investigate ways to improve their internal communications between team members when an incident has occurred. Furthermore, we were able to demonstrate to them how the use of drones could facilitate rescue through transmission of video streams from, for example, just offshore. The drone we demonstrated was even able to land in the water and take-off again from there (on a relatively calm day!).

Drones in action along the Blackpool Seafront

Winter Gardens

This use case came in quite late during the project and we used different cell provider for the equipment. The testbed includes the CU/DU/RIC software from ISW, purchased across YO-RAN and REACH projects and 4 Benetel RAN650 outdoor radios purchased on REACH.



The diagram shows the location of the 4 radio units installed in the Winter Gardens.

The two cells inside the Opera House have been operating correctly during the tests.

The cell on the left-hand side of the stage has the Physical Cell ID (PCI) 3 and the cell on the right-hand side of the stage has PCI 4.

With every UE location, there are four associated numbers which represent the Reference Signal Received Power (RSRP) of PCI 3 in dBm, RSRP of PCI 4 in dBm, DL throughput in Mbps (tested via Ookla) and UL throughput in Mbps.

It is clear that the ground floor seating areas have received good coverage from the two cells. The stage areas have also received good coverage (potentially from reflections) even with the antennas pointing at the opposite directions.

The two cells in the Floral Hall did not perform as expected. The cell with PCI 1 (near the Church Street entrance) has been operating correctly during the tests but there were issues with the cell with PCI 2. There was likely a fault at the fibre link between the RU and the basement cabin (where the FH switch is located) which requires further diagnosis. On the 31st of March 2025, the York team tried several pairs of fibre patch cables between the RU and the termination of the main fibre, as well as fibre cables between the patch panel (inside the basement cabin) and the FH switch to narrow down the potential faulty components.

Tests were, however, carried out with the one operating cell and some coverage was measured. The remainder of the area supposed to have been covered by the other cell was unable to be measured.

Installation at indoor venues has its own challenges and we needed more time to prove out this use case. The Winter Gardens is a very popular venue which creates both a compelling use case, but also hinders our ability to perform adequate testing.

Buttermere

We intended two main use cases in Buttermere and Cumbria:

- Improve the network in area with no current coverage (BUT 2);
- Liaise with the Cockermouth Mountain Rescue Team to enhance their teamwork and rescue abilities through improved communications (MCR 5-9).

Unfortunately, the work with the Mountain Rescue Team did not materialise into a viable use case mainly due to the team being resistant to change, especially as far as radio communications were concerned. Resistance to change is a lesson learned.

We were successful, however, in installing a communications network in Buttermere, an area popular with walkers and climbers but with notorious not-spots. We installed cells at the Honister Slate Mine, the Bridge Hotel and Gatesgarth Farm. As of March 2025, there have been around 250,000 connections made on the network and at least 50 999 calls, which otherwise could not have been made putting lives at risk. The system has proved most valuable in allowing walkers on the fells to get messages to friends and relatives when they are late, avoiding time consuming and costly Mountain Rescue Team call outs. It has also demonstrated the benefits of capturing near real-time data on visitors to the area – which is useful to the National Park and Tourist Board

University of York

The use cases here centred on patent applications, publications and the development of x Apps and rApps in addition to the creation of the CF mMIMO testbed (YO 1 -5). All of these were completed successfully.

In addition, YO-6 was about interoperability and this use case was carried out in conjunction with VIAVI, who themselves had three use cases (VIA 1-3), in which their RAN Intelligent Controller (RIC) was used extensively.

Overall, we addressed to some extent 21 from our 31 use cases listed in the B&R.

6. Results and key findings

The project delivered a great number of results, some of which were breakthrough. In other areas, we were not able to progress as far as we would have liked due to delays in procurement of equipment and spectrum license issues.

The following are key highlights of the achievements:

xApps rApps

- Developed multiple xApps with different levels of complexity for energy saving of the network;
- Improved the energy efficiency of the network by ~20% as presented on VIAVI AI-RSG;
- Developed AI-based xApps and tested them on VIAVI AI-RSG

Currently, no full-stack simulators exist for modelling cell-free networks. To address this gap, significant modifications were made throughout the project to the existing NS3 simulator, especially in the physical layer, to enable support for such networks. Moreover, the developed CF-mMIMO network has been integrated with the Open Radio Network (O-RAN) architecture through the NIST ORAN module, providing a robust platform for the creation and testing of effective xApps. Leveraging this platform, three xApps were successfully developed for load management in CF-mMIMO networks, ensuring users experience seamless connectivity.

To enable AI support, we developed and integrated an AI module into NS3. Additionally, we incorporated the Open Neural Network eXchange (ONNX) interface via the NIST O-RAN module to enable seamless deployment of externally trained models. This allows seamless deployment of externally trained models for intelligent xApps.
Given the lack of a dedicated rApp development platform for CF-mMIMO, we designed and tested rApps in MATLAB, focusing on standardized KPIs while addressing complexity management and latency constraints to ensure their practicality and effectiveness. Notably, a portion of this work was accepted by the O-RAN Alliance for presentation at the Mobile World Congress 2025 in Barcelona.

Cell free mMIMO testbed

The research work on cell free massive MIMO was very advanced. Our work aimed at developing an intelligent private 5G network to serve commercial off-the-shelf (COTS) UEs while addressing the gaps between low and mid TRLs. The major advances of the testbed include:

- Full O-RAN compatible 5G software stack: unlike other CF-MIMO prototypes which mostly only include PHY, our testbed includes all software components required to serve COTS UEs, such as a full 5G RAN stack, a standalone (SA) 5G core, and a RIC with onboarded xApps. The RAN is designed to be scalable with the number of RUs with the support of MU-MIMO for the UL. To the best of our knowledge, we have not yet noticed any CF-MIMO prototypes which can serve COTS 5G UEs with MU-MIMO. Our testbed is also the first implementation of CF-MIMO on the O-RAN architecture.

- Intelligence embedded at the RIC: designed based on the O-RAN architecture, our testbed naturally inherits the AI driven network optimisation from the RIC, which is absent from any existing CF-MIMO prototypes. Many existing O-RAN optimisation methods can be directly applied such as switching RUs on/off for energy saving and proactive UE handover for traffic steering. Novel optimisations for the CF architecture can also be developed, such as UE serving antenna group association (which will be demonstrated later), UE power control and DU/CPU location optimisation.
- Medium Access Control (MAC) scheduler: the MAC scheduler is another critical gap across the existing CF-MIMO prototypes which is essential for serving COTS UEs. The UEs send scheduling requests (SRs) with different patterns and the scheduler needs to allocate appropriate resources from the resource grid, rather than continuous transmission on the same set of physical resource blocks (PRBs), which is commonly used across existing prototypes. The scheduler of our testbed allows coexistence of single-user (SU)/multi-user (MU)-MIMO and provides the PHY the corresponding information for decoding the UE signal.

The CF mMIMO testbed we built is purely based on open-source components. The testbed is designed to validate the CF architecture in an UL scenario which is relatively less restricted (for RAN modifications) compared with DL when serving COTS UEs (which normally do not support more than 4 antennas). Fig. 1 shows the architecture of the testbed.

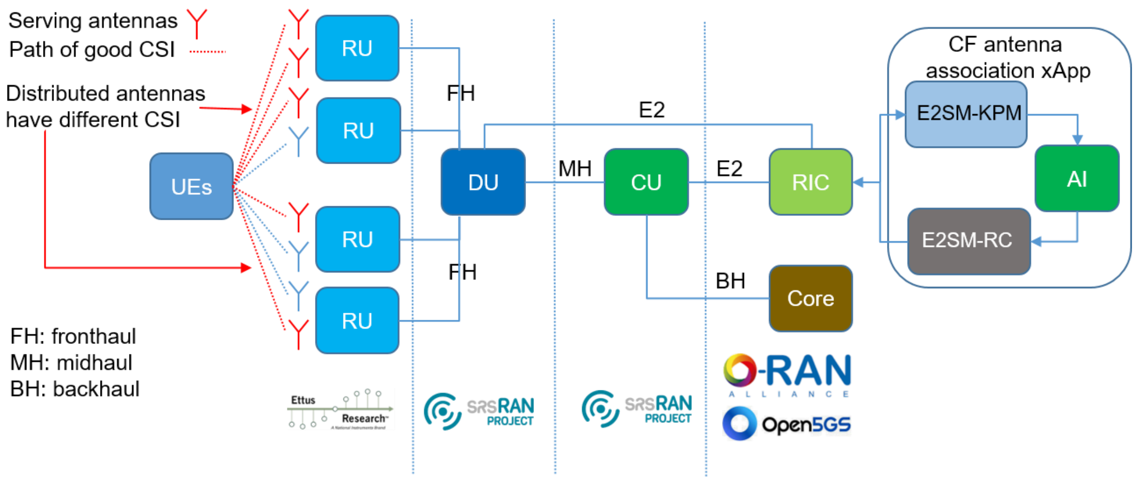


Fig. 1: O-RAN based cell-free testbed architecture

Before the REACH project started, York's research on CF-MIMO was at TRL 2-3, including theoretical study, link level simulations and system level simulations. The CF-MIMO testbed developed throughout REACH has pushed the TRL to 4-5, with the prototype network serving COTS 5G UEs. The development of the testbed has over satisfied the planned objectives by implementing network scalability, MU-MIMO and KPM/RC xApp integration. The direct outputs include a publication at IEEE Communications Magazine, two virtual O-RAN Alliance demos at MWC Shanghai/Barcelona and one physical demo at MWC Barcelona. Sustainability plans have also been made to develop the testbed further after REACH finishes, through other funding sources.

7. Impact and benefits

The impact and therefore the benefits from this project have been limited due to the short time frame. Eighteen months is a very short time for a project of this complexity, combining as it did, early research with infrastructure and use cases.

Key impact and associated benefits we did realise are:

- Creating the largest private 5G network in the UK, and one of the largest in Europe;
- Creating a foundation for enhanced communications in Blackpool along the Promenade, benefiting the thousands of visitors who visit there each year;
- Enhancing the safety of beach goers and swimmers through better team communications for the Blackpool Beach patrol;
- Introduced Beach Patrol to the concept of drone usage with video transmission to facilitate their search and rescue missions;
- Created a physical testbed environment in Blackpool for future communications developments;
- Cemented the position of Blackpool's Digital Strategy 2024-2029 through installation of a working infrastructure, directly contributing to enhancing Blackpool's digital landscape, fostering both commercial and public use;
- Created a new network in a critical 'not-spot' area of Cumbria with the benefit that walkers and visitors can now access a network, especially to make 999 emergency calls;
- Raised awareness in Cumbria with involved parties concerning the lack of mobile service in key tourist spots, potentially leading to follow-on funding and projects;
- Developed xApps to monitor, control and optimise energy usage of the installed cells by an improvement of up to 20%. These were verified via a simulation model of the Blackpool promenade network, using Viavi's TeraVM AI RSG test tool, with the xApp available for future O-RAN HDD systems;
- Created and demonstrated a cell free massive MIMO test bed in York from which at least two patents have been filed;

- Potential Spin-out company in development, with iCURE Explore programme helping its inception;
- Progressed the maturity of the VIAVI RIC testing application through first class collaboration between VIAVI and University of York.

Overall, the project achieved most of the impacts and benefits it set out at the beginning. With more time, we could have achieved much more, and potentially created a unique working 5G network testbed, which could still develop to become the envy of the industry.

8. Security

We were very fortunate on the project to have SafeNetics as a collaboration partner, specialized in Security. SafeNetics have provided the security guidance needed to facilitate robust, resilient and repeatable solutions in the Open RAN space and specifically within the REACH project. As part of this, there is an inherent need to consider security co ncerns arising from the likes of the supply chain structure, trust of components between partners and issues of vulnerability, risk and mitigations, which has been facilitated through discussions with partners.

In addition, we outlined the security strategy wherein we briefly discussed the tenants of Zero Trust that have been framed into guidelines to be upheld by the project partners and thus, discuss the outcomes of such an objective.

Furthermore, we provided insight into the differing security achievements attained in the project, by way of Zero Trust adherence, implantation of risk registers across partners and the ENISA threat landscape adherence.

Highlights regarding security for the REACH project include:

Governance: We assigned all aspects of security to our collaboration partner specialised in digital security. They interacted with each collaboration partner to ensure security was being considered in all phases. Our ambition was to ensure each partner had the same understanding of security by design and security practices in general. These were reviewed monthly during our meetings.

Risk management: Security was a standing agenda item on our monthly project calls and as such, was continuously monitored.

Asset management: Similarly, the installations were monitored in person by our security personnel.

Supply chain: Procurement was monitored monthly and potential vendors vetted as much as possible for possible security risks.

Protecting against cyber-attack.
The project was in early stages on implementation with only private networks in place. As such, the threat of external cyber incidents was low. Connections were checked and access control assessed periodically.

Lessons learned: Therse were captured routinely as part of monthly meeting and have been reported in MS 42, section 5.

Protection of intellectual property (IP)
IP was managed by the University of York and followed their robust and secure IP identification and application processes.

Overall, the project demonstrated that layered security approaches are essential for the resilience of Open RAN systems. Moving forward, future research and development should focus on automating security mitigations, exploring 6G security overlaps, and advancing decentralised system architectures. Reflecting on the achievements and lessons learned, the project offers valuable insights for improving security in Open RAN and future decentralised communication technologies. Further research into software incorporating automated risk prediction and AI system security presents clear opportunities.

9. High level summary of project costs

The cost information is shown below.

DSIT costs per claim

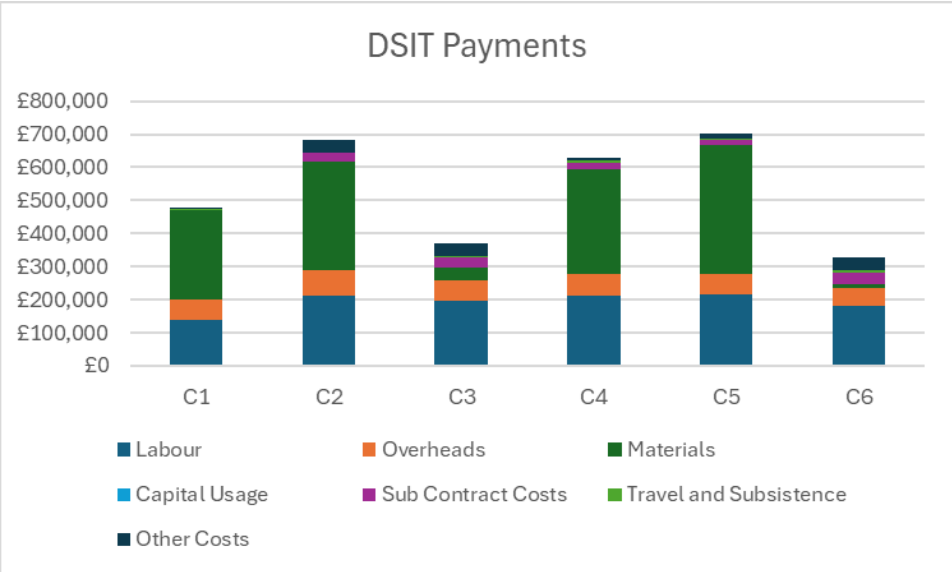
(£'000)	C1	C2	C3	C4	C5	C6	Total
Labour	£140	£211	£195	£211	£215	£180	£1,152
Overheads	£59	£78	£63	£65	£63	£55	£384
Materials	£271	£326	£40	£317	£389	£11	£1,353
Capital Usage	£0	£0	£0	£0	£0	£0	£0
Subcontract Costs	£2	£27	£30	£23	£16	£35	£132
Travel	£3	£2	£4	£6	£6	£7	£28
Other Costs	£5	£37	£38	£9	£15	£39	£143
	£480	£682	£370	£631	£703	£326	£3,193

Comparison between DSIT costs and Partners Contribution

	Total DSIT		**Total Partners**	
Labour	£1,152,349	36.1%	£839,513	26.3%
Overheads	£383,936	12.0%	£201,951	6.3%
Materials	£1,353,022	42.4%	£617,199	19.3%
Capital Usage	£273	0.0%	£410	0.0%
Sub-contract costs	£131,987	4.1%	£168,420	5.3%
Travel and Subsistence	£28,440	0.9%	£14,957	0.5%
Other Costs	£142,859	4.5%	£40,239	1.3%
	£3,192,866		**£1,882,689**	

Labour is quite consistent throughout the project, but the Materials expenditure reflects the investment in the Blackpool networks along the promenade and in Winter Gardens. These Material costs include both the purchase of the equipment and the associated installation costs. Labour counts for just over a quarter of the total costs, while materials about one fifth.

The graph below shows the distribution of grant payments per category.



10. Learnings

There were many learnings from this project. At our monthly Project call or meeting, we had Lessons Learned as a standing agenda item and were able to record these throughout the project. The following is an excerpt from the full list in the B&R of the main lessons:

- We were delayed at the beginning due to our largest partner – VM02 – having complex procurement systems. Expediting such processes within a large organisation proved very time consuming. Operating within smaller companies is quicker, even if they do not carry the same 'weight' as a larger organisation;
- The ORAN hardware and software turned out to be not as well developed as we were led to believe. rApps development was also found to be challenging. The overall framework in O-RAN community for non-real-time RIC is not mature enough and there is no stable non-Realtime RIC available.
- Installation was the easy part, even if that was challenging enough. In Blackpool, once the cells were installed, we spent an extraordinarily long time configuring the cells to work as designed. We eventually discovered power interference from other sites was affecting our cell performance.
- Security: although we had a partner in the consortium specifically charged with security aspects, they found it challenging to gain interaction with the other partners

in a detailed enough way. We applied security by design principles but getting the relevant people together to discuss security issues was always a challenge.

- Going public. At the outset, we intended to trial our Blackpool network at one of the large public events, specifically the Airshow in August 2024, which attracts annually about 300,000 people over the weekend. We decided however, that the risk of the network not performing as planned in a public scenario was too high - the reputation of the major carriers would have been at risk. Instead, we trialled the network privately with the local council security team. This trial was not that successful and proved we were right not to go with a public trial.
- Resistance to change is a real barrier to implementation. Getting organisations to change what they doing takes more than the use of new technology. The real benefit must be clearly visible and the risk of failure of the new system needs to be manageably small.
- There is real social value for wider society in delivering basic 4G services in rural areas with no MNO coverage. Although MNOs find the commercial case challenging, small cells installed with the support of the community have significantly reduced costs to ~£10K / cell. Local stakeholders have given in principle agreement to cover running costs which creates a way forward for other areas without coverage.

11. Conclusion

The eighteen-month REACH project set out to develop new mobile communication technologies for the specific purpose of dealing with high density demand situations. The seven partners collaborated well to bring together both ends of the developmental spectrum – from the research and development at the University of York to the installation and use cases along the Blackpool Promenade.

Time was always an issue and with an additional six months, the results of this project could have been much more beneficial. The majority of the work was completed on time, although with more time, we could have collected significant amounts of data to prove out the efficacy of the new network.

In the end, we have created the largest private 5G network in the UK and one of the largest in Europe. The Blackpool site has now gained a reputation in the industry and the infrastructure put in place can be used as a test bed for further communication developments.

With more time, we would have been able to prove out the use cases with significant amounts of data. Potentially, we would have been able to make the first foray into the public domain with the network, once it had been stabilised and we were confident of its operation.

12. Future Work

The following future directions have been identified to further enhance the capabilities of the developed CF-mMIMO xApps and rApps, the following future research directions are proposed:

Expand the testing of the use cases in Blackpool and Buttermere, with specific focus on load testing in preparation for a public HDD scenario.

Develop the testbed capabilities – initially small scale.

Extend the Capability of the Developed NS3 Platform to Support Scaled CF-mMIMO Deployment;

- Improve scalability to simulate large-scale CF-mMIMO deployments with more APs, UEs, and interference conditions;
- Enhance realism of xApp and rApp testing, ensuring reliable performance evaluation before real-world deployment;
- Study network densification and fronthaul constraints, crucial for large-scale CF-mMIMO adoption;

Extend the Capabilities of the NIST Platform for the Developed NS3 Platform to Enable Testing of More Advanced xApps;

- Improve the NIST O-RAN module to support CF-mMIMO-specific optimizations and AI-driven xApps;
- Expand data exchange mechanisms and performance metrics for better xApp and rApp testing;
- Ensure seamless migration from simulation to real-world testing, enabling practical CF-mMIMO deployments.

Develop Use-Case-Specific CF-mMIMO rApps and xApps with Real-World Performance Requirements in MATLAB and Possibly NS3.

- Extend xApp/rApp development to target industry-specific applications, such as industrial automation, V2X, and private 5G.
- Train AI models tailored to real-world KPIs, optimizing predictive decision-making in CF-mMIMO networks.
- Ensure that CF-mMIMO xApps and rApps are aligned with industry needs, enhancing commercialization potential.

Explore Testing of Some Developed xApps on the Testbed

- Conduct real-world validation of CF-mMIMO xApps to confirm feasibility under practical network conditions.

Scale up the Buttermere solution for other sites around Cumbria – working with local communities.