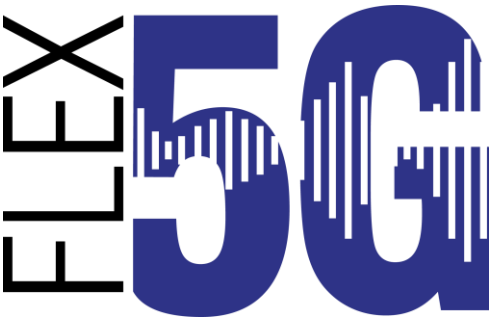
D24: Project Final Report



May 2024

DOCUMENT REVISION HISTORY

Version	Date	Author	Summary of main changes
0.1	**14/05/2024**	Mike Carter	Initial draft submitted to DSIT for review
0.2	**18/06/24**	Mike Carter	Updated following DSIT feedback

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1 BACKGROUND

Flex 5G is a Project delivered under the DSIT FRANC (Future RAN: Diversifying the 5G Supply Chain) Portfolio, which allocated up to £30 million of R&D funding to projects that support the goals of the government's 5G Supply Chain Diversification Strategy. The competition is aimed at helping to incentivise industry to create new products and services to unlock the full potential of Open RAN

The Portfolio set 3 Key Objectives

- Accelerate the development of high-performance 5G Open RAN solutions that meet UK dense urban requirements by 2025.
- Attract new 5G RAN suppliers to conduct R&D in the UK, and foster professional collaborations between potential new entrants into the UK's public network.
- Contribute to the delivery of the 5G Supply Chain Diversification Strategy's objectives of disaggregated supply chains, open interfaces by default, and security being a priority in network deployment.

Flex 5G as a Project set out to achieve outcomes targeting those key objectives

2 STORY OF THE PROJECT

2.1 KEY OBJECTIVES

2.1.1 NETWORK IN A BOX

- Create "Flex-5G", a complete Open RAN 5G StandAlone (SA) network. A compact modular radio base station supporting all bands in 5G NR Frequency Range 1
- Reduce Costs of 5G Network Deployments by improving equipment availability and scalability
- Enhance customisation to use cases, upgradability, deployment options, economies of scale

2.1.2 SOFTWARE MANAGEMENT

- Create and integrate AI-driven spectrum and network management framework to leverage flexibilities made possible by Flex-5G
- Create and validate a rigorous security framework to address the considerations that arise in cases of "softwarisation" and extreme flexibility

2.1.3 TECHNOLOGY ADVANCEMENT

- Development and contribution to ORAN Technology to increase performance and efficiency of 5G networks
- Enable key advances on "Massive MIMO" technology, improving the performance and practicality of high-end 5G network
- Enhancements to development of cutting-edge Radio Chipsets and Boards to improve performance and accessibility to spectrum

2.1.4 SYSTEM INTEGRATION

- Integrate and build on the capabilities of a custom in-house 5G core network
- Integrate packet-based synchronisation technology such that the Flex-5G solution can operate in areas without satellite coverage for synchronisation

2.2 PROJECT PARTNERS

An Eco-system of partners from the domains of Technology, Academia and Business was brought together as a consortium to deliver against the project objectives

All project partner involvements chosen as complementary and necessary for specific tasks in the end-to-end solution

Key project partners development objectives and responsibilities are defined to ensure a successful delivery

AWTG LIMITED (Lead Partner)

Leadership of the project. Development of the management framework (xApps/rApps, as appropriate), security framework, higher-layer capabilities (DU), trials, integration assistance in general, among others tasks. Project Management capabilities.

LIME MICROSYSTEMS LTD

Provision of the hardware platform and software that will be adapted for the project. Adaptation/creation of lower layers/hardware, including provision of new chipset(s). Integration with new Massive MIMO capabilities, among others. Technical Management for the project.

UNIVERSITY OF SURREY

Development/provision of Massive MIMO processing capabilities, RIC, 5G Core Network, higher-layer capabilities (CU), trials and hosting part thereof, among others. Leadership of the project's Advisory Board.

VODAFONE

Provision and expertise on O-RAN network-side testing, and general advice/guidance on use cases and other aspects. Serving as Innovation Impacts Advisor for the project.

COMMSCOPE TECHNOLOGIES

Provision and expertise on integration of advanced Massive MIMO antenna platforms.

Cambridgeshire County Council

Hosting a range of trials in Cambridgeshire. Advice on use cases of relevance/interest from a public perspective. Serving on the Advisory Board

Zain Saudi Arabia

Advice/guidance on use cases of relevance to the operator. Potential testing and consideration of project outputs for deployments. Serving on the Advisory Board.

VIAVI SOLUTIONS

Provision and expertise on configuration/usage of VIAVI mobile device platform for testing purposes.

Emirates ICT Innovation Center (EBTIC)

Development and integration of packet-based timing capability for synchronisation purposes.

Virgin Media O2

Advise/guidance on use cases, particularly w.r.t. private networks. Potential testing and consideration of project outputs for deployments. Serving on the Advisory Board.

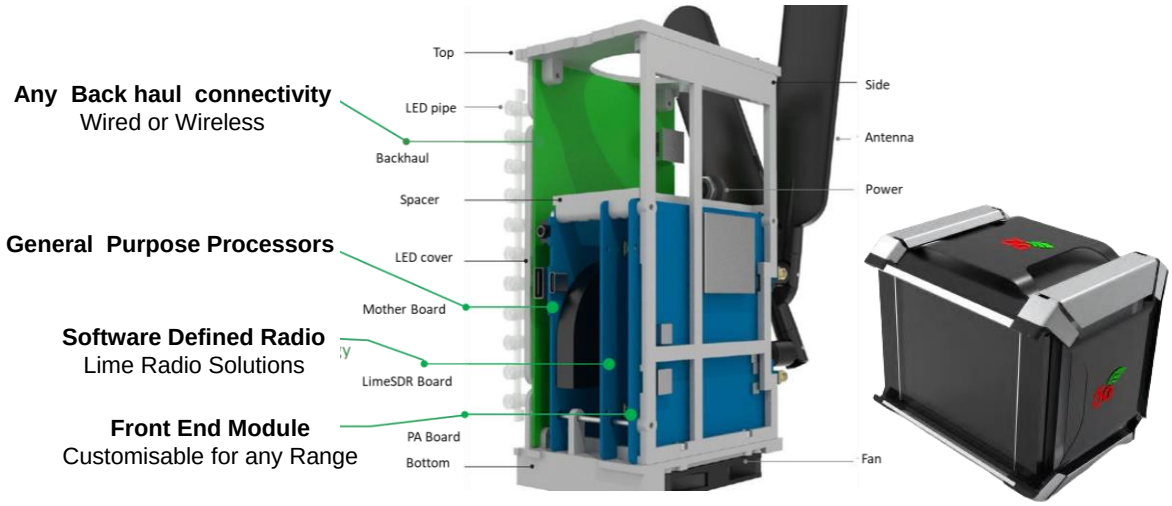
Amazon Web Services (AWS)

Consideration and provision of capabilities for potential Cloud-RAN and other cloud capabilities testing. Serving on the Advisory Board.

2.3 DETAILED OBJECTIVES

2.3.1 MODULARITY AND DIVERSIFICATION

Create a Modular Flexible 5G Network in a Box with advanced functionality overcoming the challenges of Cost as a barrier to entry and scalability



2.3.2 MOBILE NETWORK EFFICIENCY

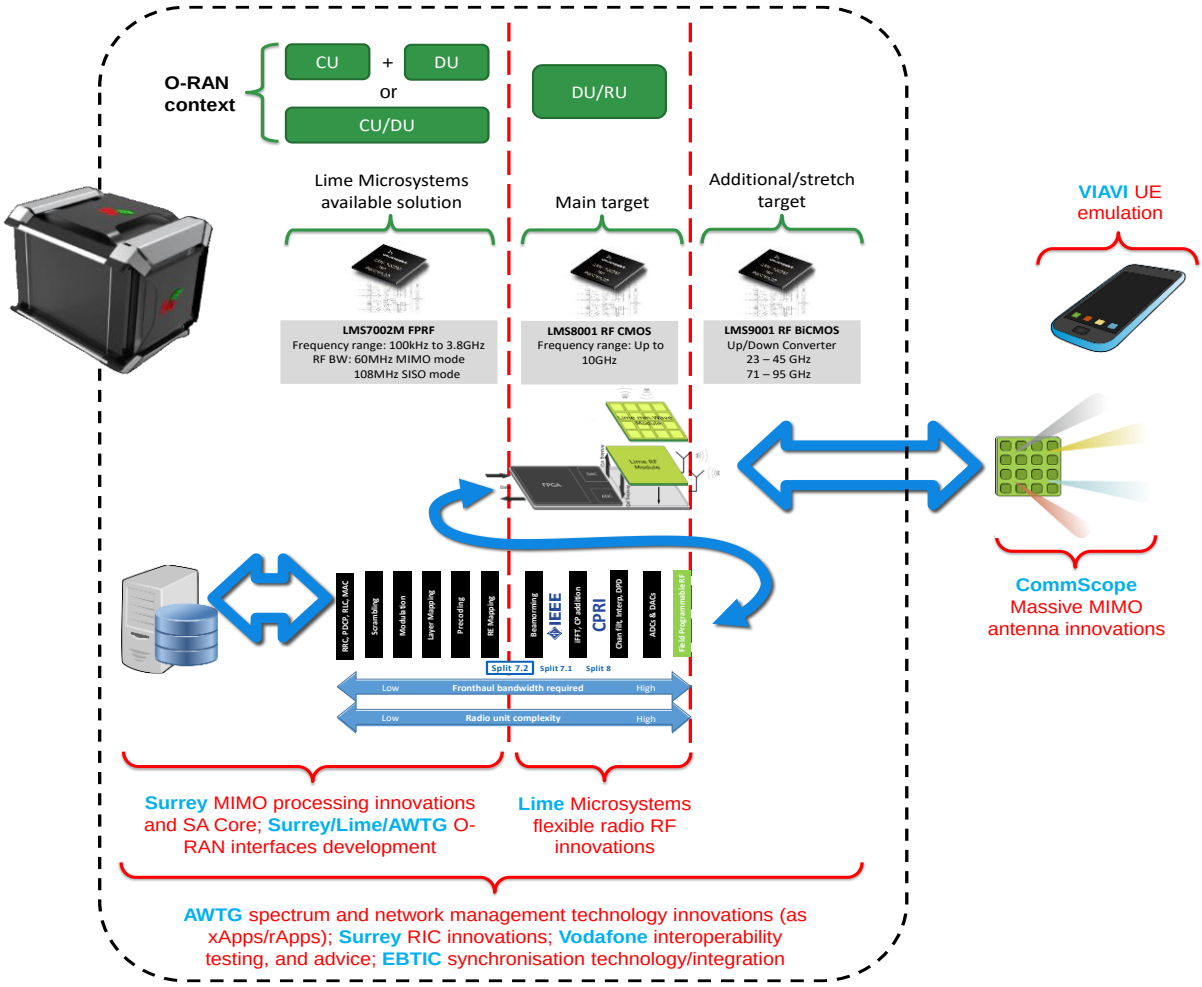
Development of Software Defined Radio (SDR) offering benefits of Wide-band support, Upgradeability, Configurability and capable of delivering advanced performance

Achieve substantial performance improvements through the advancement of Massive MIMO processing innovations

2.3.3 COLLABORATION AND INTEGRATION

End to End Integration from 5G Core to Commscope Massive MIMO Antenna

Developing O-RAN compliant interfaces



2.3.4 TESTING AND VALIDATION

Rigorous Testing and Validation methodologies through the use of emulation, and Tier 1 Operator procedures and benchmarks

Deploy the solution outside of the Lab environment and validate the performance and benefits to User Experience

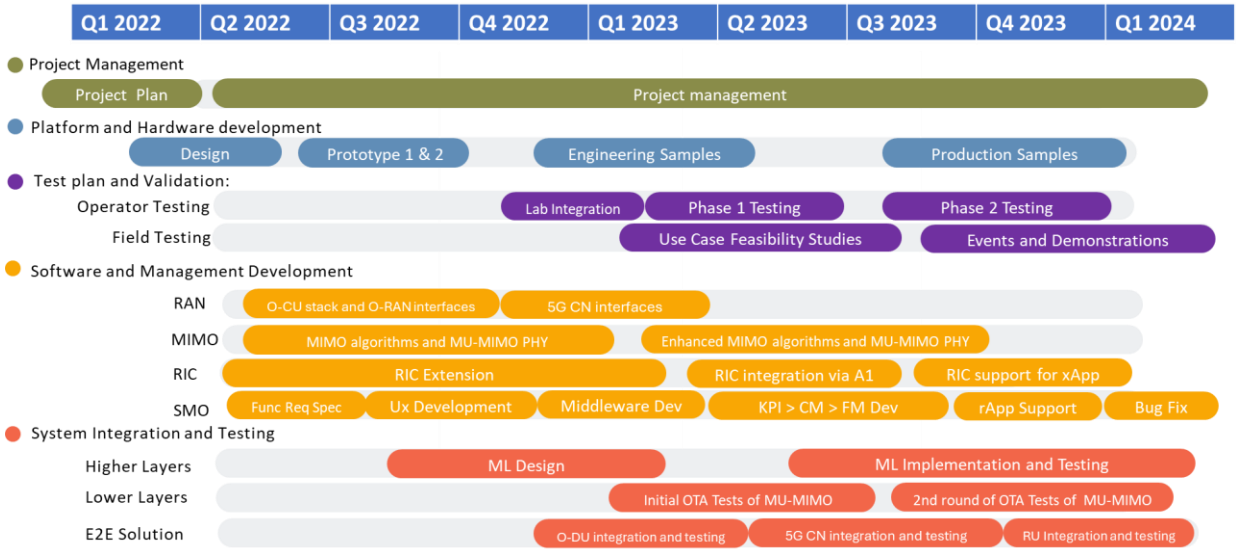
2.3.5 SOFTWARE MANAGEMENT

Extraction of the vast performance and efficiency improvements possible through Flex-5G through Dynamic optimization and Software driven management

Develop and integrate a software platform capable of managing the solution operations, configuration, performance and rigorous security framework

Development of innovative control capabilities in the form of xApps and rApps

2.4 DEVELOPMENT JOURNEY



Starting at the beginning of 2022 defining a Project Plan and robust delivery framework and governance, work soon commenced the Platform and Hardware Design. Early prototype development started in Q2

In parallel to HW development, work commenced on developing the SW elements of the project. The ORAN stack and required interfaces between CU, DU and the 5G Core, analysis of the algorithms associated with MU-MIMO, the capabilities of the RIC and the functional requirements and base platform of the SMO

From late 2022, engineering samples of the HW became available. These were provided by Lime to project partners AWTG and University of Surrey to start testing in their lab, but also into Vodafone to be put through operator led testing. Engagement was made with Cambridgeshire County Council on feasibility studies as to where the solution could be tested in a live environment. Software Development continued at pace using emulation where necessary

Integration work started to accelerate from the middle of 2023 with the various components of ORAN being combined. Interfaces to enable control information to be exchanged with the RIC were opened, Middleware was developed to enable data communication between the SMO and the Flex5G solution, and the advancements made to MU-MIMO algorithms could be tested over the air interface.

In the latter part of 2023 and into 2024, the solution itself was taken to the field with demonstrations of its capabilities at various technology events, with a full showcase of its capabilities at Soham College in Cambridgeshire, allowing students to take part in an AR experience fully powered and made possible by Flex 5G. It was also showcased by Zain Technologies as part of their portfolio at LEAP Saudi Arabia in March 2024

Final product Integration activities continued with rigorous testing, validation and fixes of the E2E solution, culminating in a Final Project Event held at Surreys 6G Innovation Centre, where all partners had the opportunity to celebrate their achievements and showcase the solution and its innovations to colleagues from DSIT

3 PROJECT OUTCOMES

3.1.1 NETWORK IN A BOX

The project developed a Network in a Box Solution, deployed on commodity off the shelf hardware, capable of operating on Wired, Wireless, Local Network and Satellite Backhaul, and non-GNSS based Sync Technology

It received operator validation of its performance and proven Inter-operability with Traditional Networks and is ready for commercial deployment.

3.1.2 SOFTWARE MANAGEMENT

SMO/OSS solution developed, with demonstrated Operational, Configuration and Performance management capability, and integrated RIC functionality.

Defined strategies for Zero Trust Security Framework integration

First xApp for interoperable MU-MIMO rate adaptation using both Linear and Non-Linear processing

3.1.3 TECHNOLOGY ADVANCEMENT

Programmable Radio chipsets in a small form factor for flexible/scalable deployment, Low-power SDR module (LimeSDR X8) with a high number of channels and optimized power consumption

Knowledge contributions and advancements in Open RAN Physical Layer and MU-MIMO Technologies

Development and Demonstrated advanced Non-Linear Processing approaches for MIMO systems, that can provide substantial gains in terms of throughput, number of connected devices and power gains

Developed and Publicly Demonstrated the First Software-Based PHY Design and Implementation Framework for Highly-Efficient Open-RAN MIMO, that also enables future Open-RAN PHY cloudification

3.1.4 SYSTEM INTEGRATION

Proven Integration with different Core Network Platforms, across dis-aggregated HW, and different RAN SW stacks – a truly flexible solution

Advancements in Product Validation Testing methodologies and scenario emulation

Extensive knowledge contribution to Open RAN Interface specifications and Software codebase

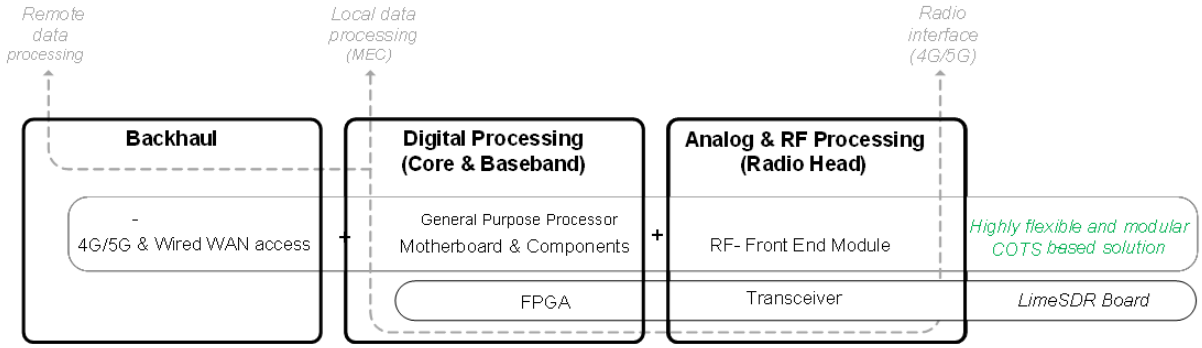
SW Drivers and Libraries for Lime X8 Hardware

3.2 NETWORK IN A BOX SOLUTION

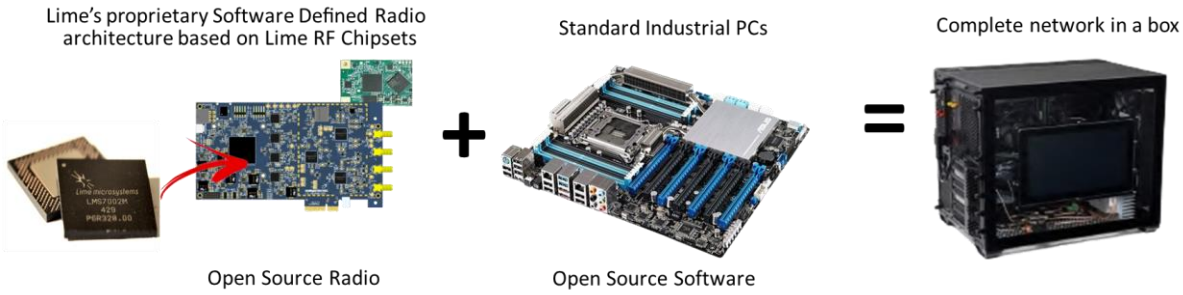
The Network in a box comprises of a General Purpose Processor (GPP) core and high-power Front-End Module (FEM).

Part	*Features and specification*
RF chipset	8x Lime Microsystems LMS7002M FPRF
RF LO frequency	30MHz – 3.8GHz
RF channels	Up to 4 channels with a 4x4 MIMO, or up to 8 channels with 8x8 MIMO
RF bandwidth	4G: up to 20MHz, 5G: up to 100MHz
Default supported bands	4G: any band combination within RF LO frequency range 5G: any band combination within RF LO frequency range
FPGA chipset	Xilinx Zynq UltraScale+ XCZU7EV-2FFVC1156 MPSoC
Location services	Galileo, Glonass, GPS, BeiDou
CPU	Intel Core i9-11900K Processor, 8C/16T
RAM	32GB, DDR5, 6000MHz (up to 128GB)
Cooling	Liquid/Air combo
Storage	1000GB SSD
Flex-5G system Case	Full tower
Complete Flex-5G Case	Indoor, IP20, 25x55x60cm (WxLxH). Houses all hardware parts except Antenna.

Flex-5G consists of three key elements as depicted in the Figure below

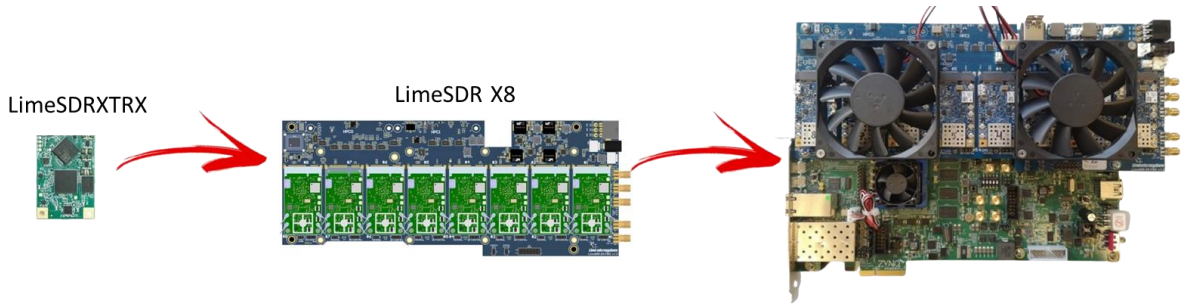


The key component within Flex-5G is a multi-standard LimeSDR Board and links the Analog/RF domain (Radio Head) and digital baseband processing (software).



The Transceiver, Front End and Digital Processing are constructed in a modular fashion using commercially available off-the-shelf (COTS) components. Flex-5G adopts a collection of both open-source and proprietary software solutions for the implementation of 4G/5G baseband and core functions on x86 based processors/servers which makes it an ideal platform for any mobile edge compute (MEC) deployment. On this basis, Flex-5G is not vendor-locked and can be incorporated as part of the IT infrastructure within any organization, maintained and upgraded by IT personnel. Furthermore, the Front End Module (Power Amplifier and Filters) could be customized for any band of interest and geographical locations. This allows Flex-5G to deliver unparalleled flexibility as an standalone network-in-a-box solution or as part of an existing networks where backhauling is possible via wired or 4G/5G radio links.

To achieve MU-MIMO, Lime's Power-efficient LMS7002 to provide a more efficient design compared to alternative chipsets and discrete components



Testing and Validation performed by Vodafone split into 2 Phases

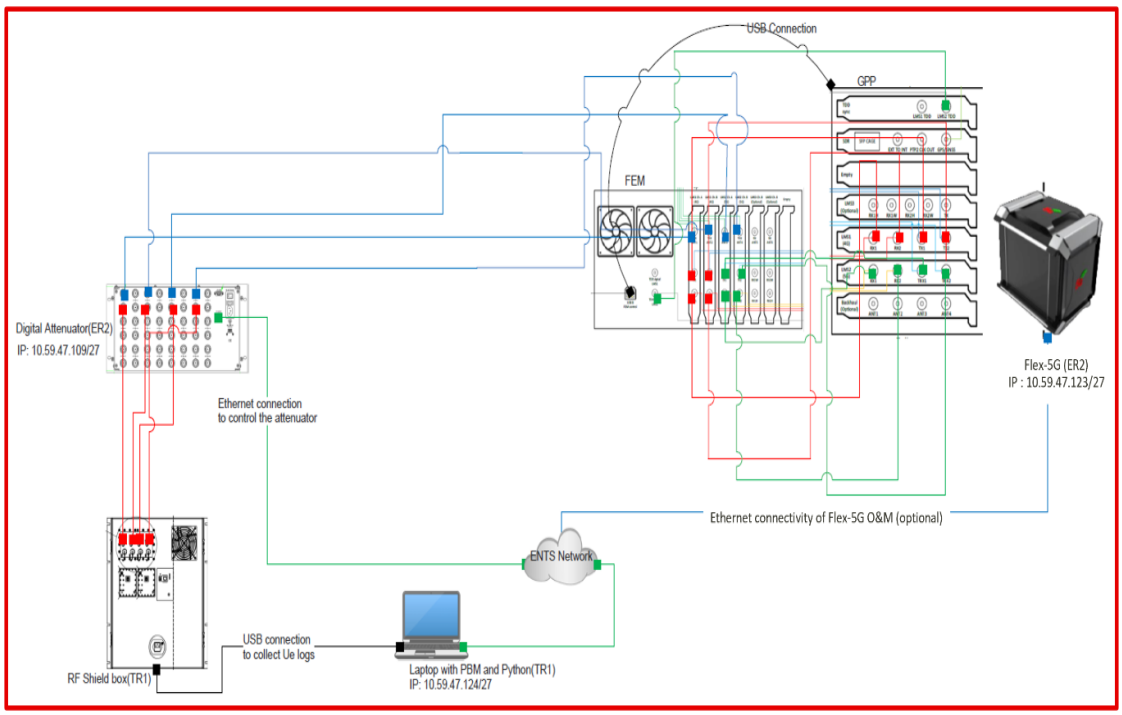
Phase 1

- Standalone Testing of Flex5G solution in isolation (Use of inbuilt Core and IMS components)
- Security assessment of HW & SW solution providing guidelines to harden the solution from security aspects.
- Series of functional test cases executed in automation with Keysight tools.

Phase 2

- E2E Testing of Flex5G solution connected into Vodafone Core Network
- Repeated series of functional test cases, expended to include Mobility testing with alternative vendor

Test Setup in Vodafone Lab

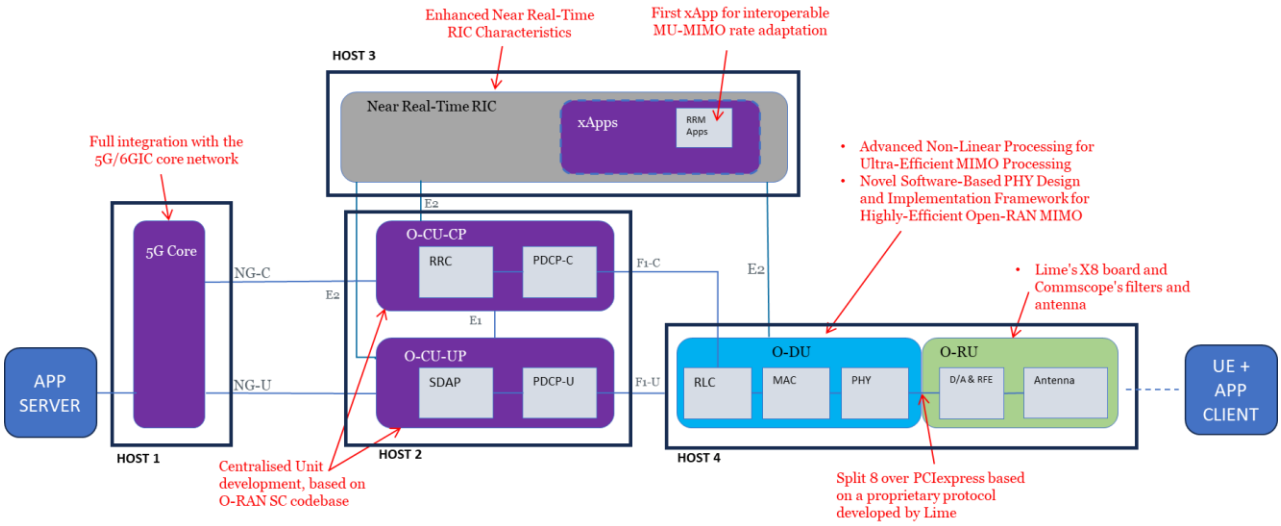


Phase 2 Test results

Lime Testing 4G -5G NSA Phase 2 using Keysight with Lab Core							
Test Scope	Test Scope	Total	Automation	Manually	Total Executed	Pass	Descope
4G-5G NSA-SA KPI Testing	4G	10	8	2	8	8	2
	5G NSA	9	9	0	9	9	
4G End to End	4G functionality	40	5	35	33	33	7
	Mobility	13	0	13	8	8	5
	Performance test	15	15	0	15	15	
	Service Test	37	34	3	34	34	3
	Carrier Aggregation	12	0	12			12
5G NSA End to End	5G NSA Functionality	32	4	28	22	22	10
	5G NSA Performance	15	15	0	15	15	
	5G NSA Service	39	35	4	35	35	4
O-RAN PS Mobility	Intra CU & Inter DU\ORAN- 4G	10	0	10	8	8	2
	Intra CU & Intra DU\ORAN-4G	10	0	10	8	8	2
CSFB_SRVCC	CSFB/ORAN	2	0	2			2
	Fast return to LTE	1	0	1			1
	4G- KPI	1	0	1			1
	SRVCC	1	0	1			1
	Mobility/ORAN	1	0	1			1
	PS redirection/ORAN	2	0	2			2
	Total	250	125	125	195	195	55

3.3 E2E FLEX 5G SOLUTION

Architecture of E2E Flex5G solution, annotated with project development activities



5G SA Core Integration
Successfully integrated CU with Europe's first 5G Standalone Core Network:

- fully release 16 3GPP compliant.
- in-house developed and tested with commercial equipment.
- fully virtualizable and cloud native, deployable on AWS.
- supporting network slicing of user plane.

Integrated NGAP and GTP-U messages software stacks.

- NGAP messages for connection setup, registration and PDU session establishment.
- GTP-U messages for connection setup, forwarding of data.

Centralised Unit (CU)
Centralised Unit development, based on O-RAN SC codebase:

- fully release 16 3GPP compliant interfaces (E1, F1) and stacks (SDAP, RRC, PDCP).
- tested with OAI-DU and O-RAN SC DU.
- separate async tasks, with message/event passing, for components dedicated to interfaces/layers.
- control and user plane split, for network slicing and disaggregated deployments.

Development of stack and messages for UE Initial access, RRC setup, SRB/DRB setup, UL/DL message transfers, F1/E1 interfaces setup and messages.

Near RT RIC

Extended AI interface in Near Real-Time (RT) RIC. Flexible architecture utilizing microservices, Extended E2SM and added new information elements

- Enabling communication with non-real-time RIC
- Improving RIC stability thanks to the resource isolation between RIC and xApps, and also among xApps
- Improving support of xApps through flexible horizontal scaling
- Providing new supports to Radio Resource Management (RRM)

DU, RU, Antenna and Filter Integration

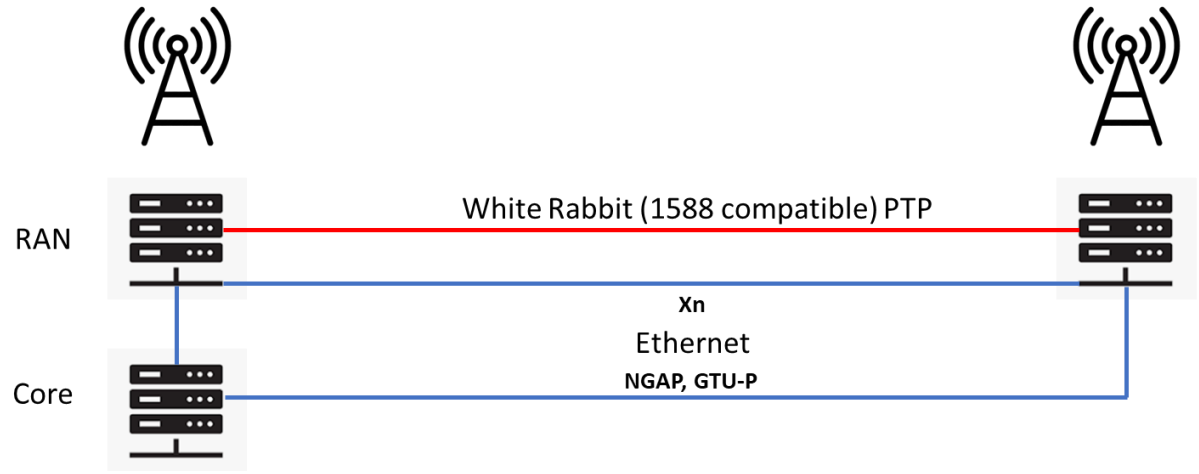
- The Open Air Interface (OAI) software framework is used for the implementations of the Distributed Unit (DU)
- LimeSDR high performance Software Defined Radio (SDR) board is used for the implementation of Radio Unit (RU)
- A jumper connected 8T8R Beamformer Antenna. An off-the-shelf 8T8R AU available with custom filter blocks and supporting jigs necessary to complete the RF chain

Sync Setup

We have demonstrated the capability of vRAN stack to handover when the radios of each Flex5G box are synchronous. The White Rabbit solution used is a standalone (Non-GNSS) based reference where one box follows the other with sub-nanosecond accuracy.

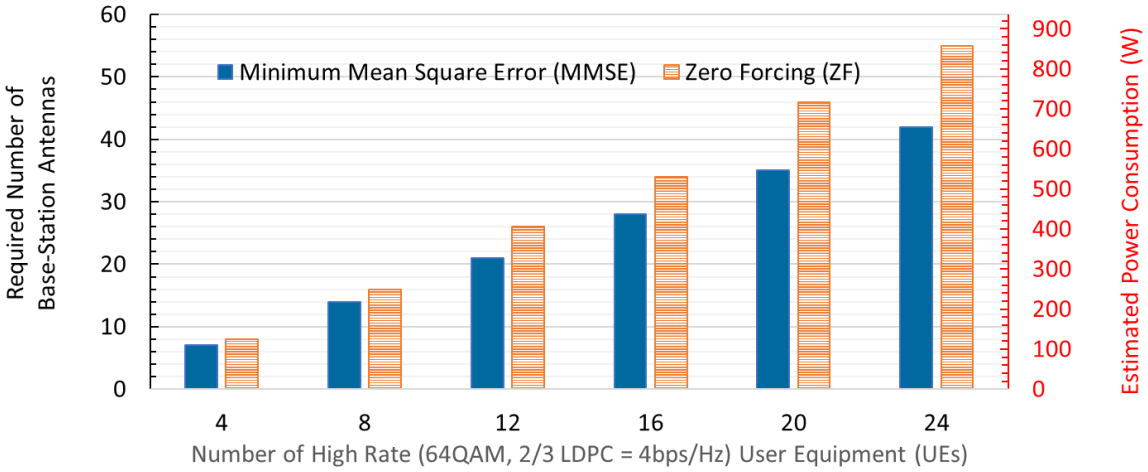
The traffic based offload microservice developed by AWTG utilises this synchronous feature to enable this functionality.

The White Rabbit solution is handled separately from the ethernet connection and has its own dedicated fiber



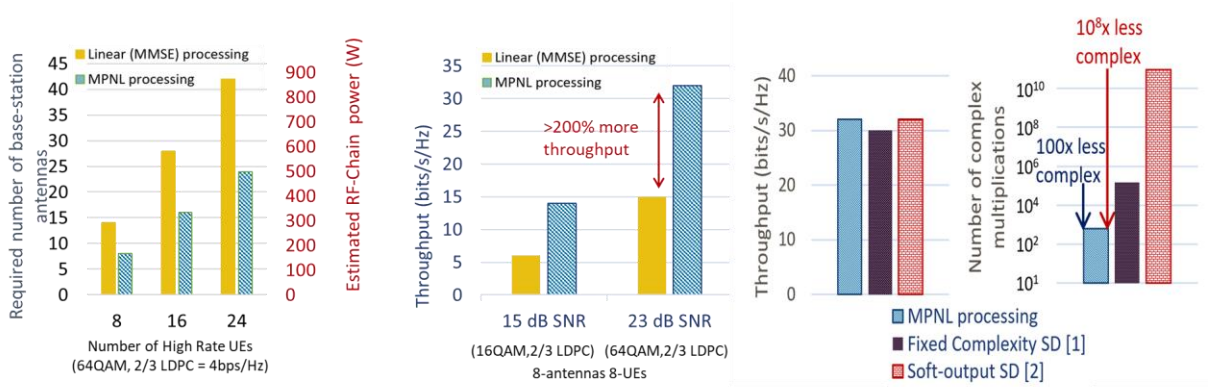
3.4 MU-MIMO ADVANCEMENT

Multi-user Massive MIMO promises increased channel capacity and number of connected users by increasing the number of base-station antennas. However, conventional Massive MIMO obliterates Power efficiency



Through Massively Parallelizable Non-Linear (MPNL) Processing, significant gains can be made against key network metrics

- Achieve same throughput with half the RF power
- Double the throughput on the same power budget
- Orders of magnitude less complex compared to traditional non-linear approaches



MIMO-SoftiPHY: A Software-Based PHY Design and Implementation Framework for Highly-Efficient Open-RAN MIMO

Open RAN designs PHY solutions are envisioned to be heavily based on software, offering advantages such as:

- accelerated product development and release cycles
- inherent upgradability compared to hardware approaches
- opportunities to leverage existing cloud infrastructure

However, there was no existing Open RAN, 5GNR solution able support massive MU-MIMO setups with large numbers of spatial streams!

We developed a world-first, fully standard compliant MU-MIMO PHY solution in software, substantially extending OpenAirInterface(OAI)

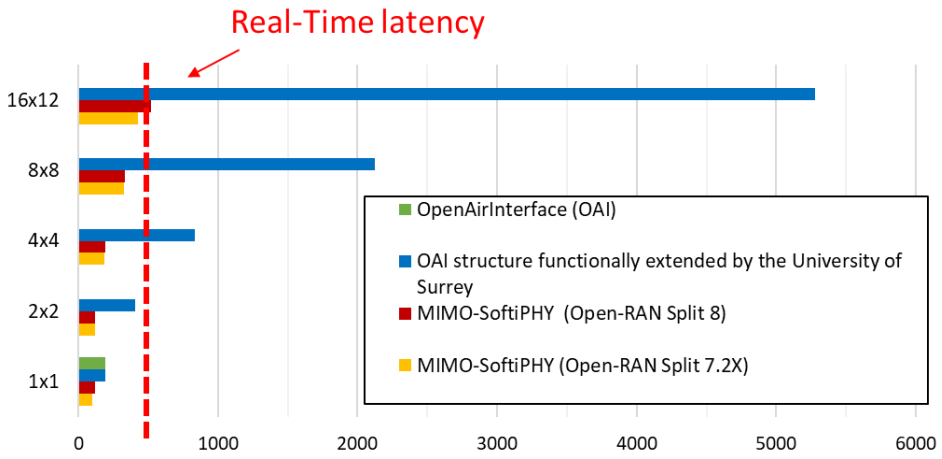
- supporting both, linear and non-linear MIMO processing
- extendable to support Massive-MIMO 64x12 at 100MHz with 260 cores

	Bandwidth (MHz)				
	10	20	40	80	100
SISO	QPSK,16/64-QAM	QPSK,16/64-QAM	QPSK,16/64-QAM	QPSK,16/64-QAM	QPSK,16-QAM
2x2	QPSK,16/64-QAM	QPSK,16/64-QAM	QPSK,16/64-QAM	QPSK	QPSK
4x2	QPSK,16/64-QAM	QPSK,16/64-QAM	QPSK,16/64-QAM	QPSK	QPSK
4x4	QPSK,16/64-QAM	QPSK,16/64-QAM	QPSK,16-QAM	x	x
8x4	QPSK,16/64-QAM	QPSK,16/64-QAM	QPSK	x	x
8x6	QPSK,16/64-QAM	QPSK,16/64-QAM	x	x	x
8x8	QPSK,16/64-QAM	QPSK,16/64-QAM	x	x	x
16x8	QPSK,16/64-QAM	QPSK	x	x	x
16x12	QPSK,16/64-QAM	x	x	x	x

Supported configurations (MMSE) with up to 12 processing cores (Split 7.2x)

To achieve MU-MIMO in software we:

- employ aggressive vectorization (AVX-512), reducing the single core processing latency
- exploit multi-core and NUMA (non-uniform memory access) aware optimizations, including cache and locality optimizations, to minimize memory access bottlenecks



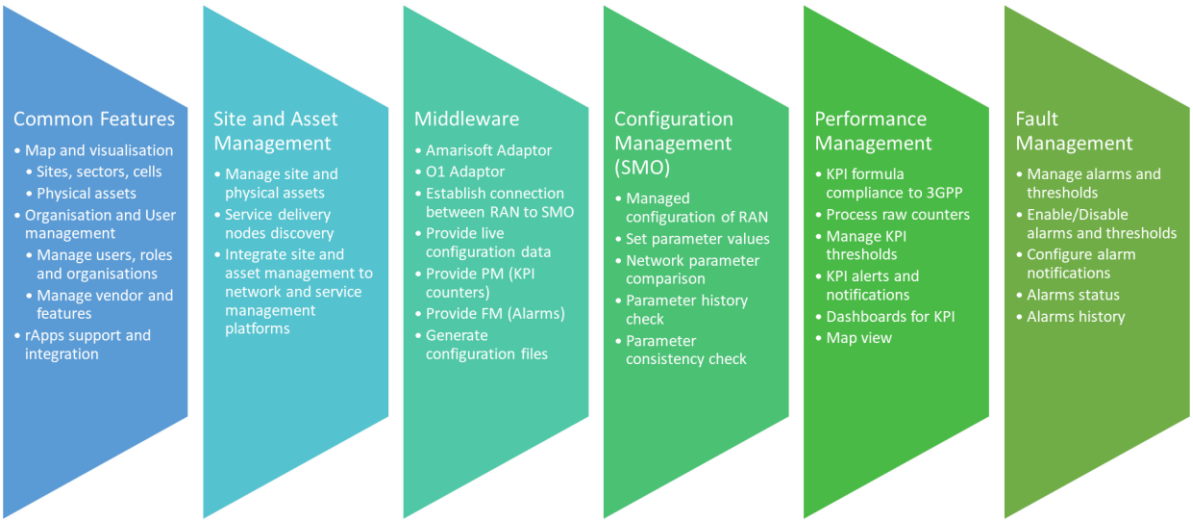
Processing Latency in microseconds with just 12 processing cores (64-QAM,10MHz)

First xApp for interoperable MU-MIMO rate adaptation

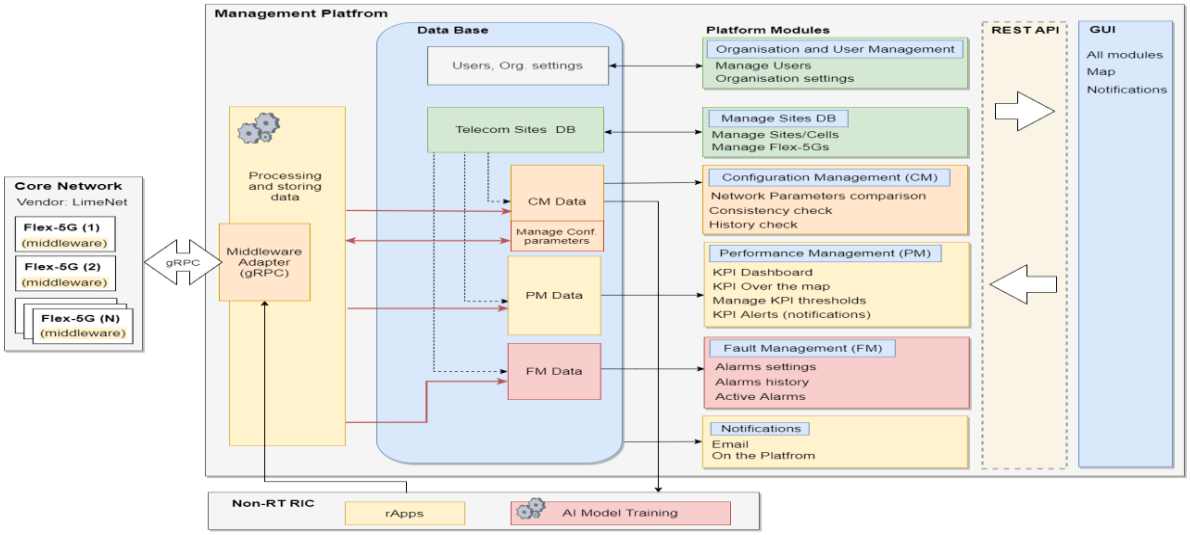
- Future O-RAN system may support a wide range of algorithm solutions
- We developed the first xApp able to perform rate adaptation for different processing approaches, specifically for linear and non-linear
- We use ML-based (neural network) to learn and explore not only the channel condition, but also channel correlation among users to optimize the modulation and coding scheme (MCS) for each user
- The ML model is implemented as xApp deployed as a microservice to control the RAN through near-RT-RIC

3.5 SERVICE MANAGEMENT AND ORCHESTRATION

To extract the performance and flexibility of the Flex5G Solution, a Service Management and Orchestration platform was developed



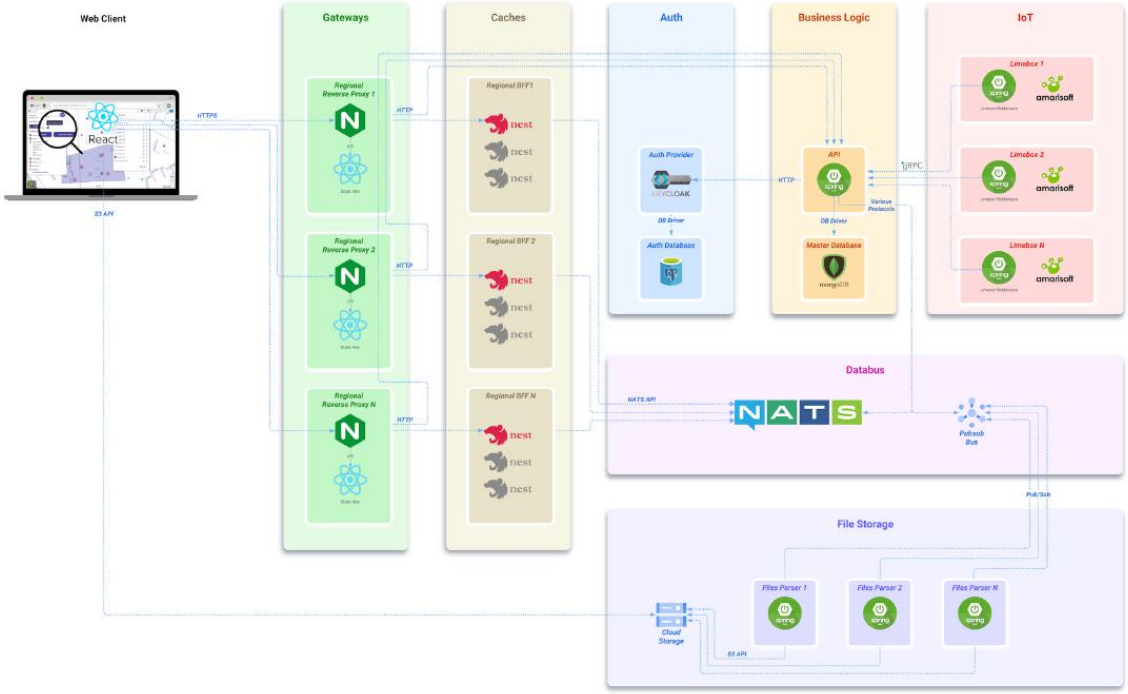
Below illustrates the functional architecture of the Platform



Functionality Highlights

- Middleware developed as a solution to extract data from, and establish configuration control of, Flex5G solution
- Extracting and storing data from the Flex5G solution at 1min intervals, pre-aggregation at 30min intervals to assist in system performance
- KPIs created to 3PP specifications. Fully flexible KPI Trend analysis, from minute up to monthly granularity with seamless transition, trend comparison and threshold based alarms
- CM History and consistency checks, and active CM change with built in protection mechanisms to avoid out of range settings
- Alarm definition and threshold setting, Live monitoring and alarm history
- Resiliency and temporary storage to prevent data loss in the event of an O+M outage
- Demonstrated rApp functionality – Live Radio Resource monitoring triggering a forced handover under certain load conditions

Below illustrates the logical architecture of the Platform



DevOps principles followed

Cloud Resources

- Comprehensive coverage of cloud resources with Terraform

Cross Platform

- Author and support more than 100 scripts for building Java, NodeJS, React, Golang applications and libraries for cross-platform environments with the support for both ARM/AMD chips architectures and various Linux kernels including Debian, RedHat and Amazon Linux

Enhanced Availability

- Near 99% uptime of all WEB-related production systems with enhanced deployment, logging, monitoring and alerting approaches

Secured

- Developed secure on-fly reloading of the runtime configuration sourced from the secret vaults, compatible with containerless, Docker and k8s environments

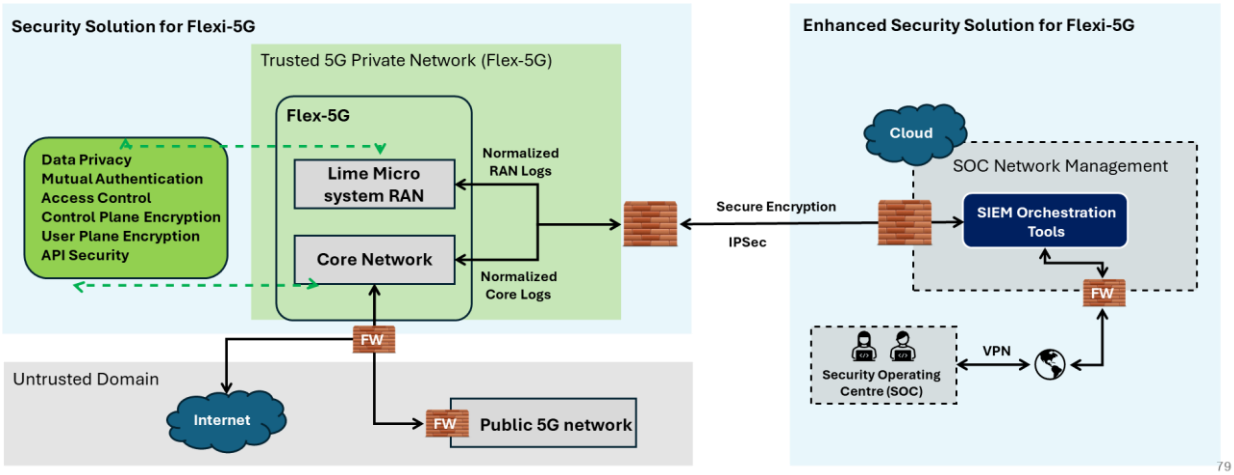
Interoperable

- Provided high availability of the IOT cluster and making the target devices automatically discoverable through the secure reverse tunnels.

Reusable

- Developed a concept of the «golden images» of reusable WEB components within the SCAP ecosystem

Security Strategy Framework implemented on Flex 5G

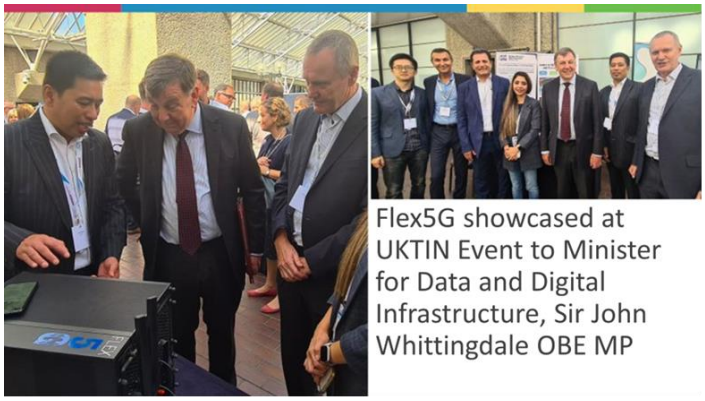


3.5.1 USE CASE TRIALS

3.5.2 INDUSTRY EVENT DEMONSTRATIONS

Flex5G Network-in-a-box was showcased at various Industry Events, highlighting is flexibility in speed and simplicity of 5G services deployment

Users were invited to test the out-of-box functionality (Voice and Video calls, Web connectivity and Video Streaming), and it allowed excellent opportunity to interact with Businesses about use cases and future collaboration



Flex5G showcased at UKTIN Event to Minister for Data and Digital Infrastructure, Sir John Whittingdale OBE MP

Future Net 2023

2 Very busy days at Connected Britain, with lots of interest in the Flex5G product !

- Flex5G (and FlexDAS / RIS) showcased at IoT Tech Expo in December

3.5.3 ZAIN SHOWCASE AND LEAP 2024

A Flex5G solution was shipped to our use case partner Zain KSA, where the solution was tested in their Lab, and rapid deployment capability presented to their Product team

Flex 5G Tower was setup and on-air within 2 mins and 30 secs, and Successfully accomplished 5G services including DL/ UL throughput, Voice/ Video call and other tests

Zain offered testament that Flex 5G is very easy to setup and can be used as a self-contained network, where NodeB and Core functions are implemented in the Flex 5G.

TOL ID	Test	Objective	Test Area	Status	Service	Date of Test
F5G-TOL-S-1	Cell configuration	Show the configuation and ability to configure the cell from the network element management system	Config	Passed	Voice + Data	30-Oct-23
F5G-TOL-S-2	Performance monitoring (including RU, CU, DU)	Show the ability of the management interface to gather and collate statistics from the nodes.	Performance	Passed	Voice + Data	30-Oct-23
F5G-TOL-S-3	Radio Resource Control (RRC) Functionalities	SIB, paging, call setup and release configured and correct	Config	Passed	Voice + Data	30-Oct-23
F5G-TOL-S-4	QoS/5QI support	Management and mapping to data radio bearers	Config	Passed	Voice + Data	30-Oct-23
F5G-TOL-S-5	Admission Control	show the ability to manage connections (rrc rejections, etc) based on available resouces	Config	Passed	Voice + Data	30-Oct-23
F5G-TOL-S-6	Idle Mode Behavior with NR Indicator	Show Idle Mode handling	Config	Passed	Voice + Data	30-Oct-23
F5G-TOL-S-7	UE Attach/Detach	Show UE Attach procedure	Config	Passed	Voice + Data	30-Oct-23
F5G-TOL-S-8	UE Data Transfer with small / large packet sizes	Show successful data transfer at a stable, consistent and repeatable throughput rate that aligns with configuration (theoretical thpt)	Performance	Passed	Data	30-Oct-23
F5G-TOL-S-9	Ookla Speedtest		Performance	Passed	Data	31-Oct-23
F5G-TOL-S-10	Voice Service	Show support for voice services.	Config	Passed	Voice	31-Oct-23
F5G-TOL-S-11	Video Call Service		Performance	Passed	Voice + Data	30-Oct-23
F5G-TOL-S-12	Basic call metric - CSSR (Voice Only)		Performance	Passed	Voice	31-Oct-23
F5G-TOL-S-13	Basic call metric - DCR (Voice Only)		Performance	Passed	Voice	31-Oct-23
F5G-TOL-S-14	All 5QI modes available	Show what available 5QI Modes are available	Config	Passed	Voice + Data	30-Oct-23

Following this confidence, the project worked with Zain to develop an innovation use case to test its capability. A language translation app was embedded within the solution, and taking advantage of the edge processing and 5G stack, demonstrated the low latency use case of “real time” speech to speech translation

So confident were Zain in the potential of Flex5G, they showcased the product as part of their portfolio at LEAP2024, promoting its usecase as a pop-up private network

3.5.4 SOHAM COLLEGE AR EXPERIENCE

In collaboration with Cambridgeshire County Council and Factory42, Flex5G was used to deliver an Interactive AR experience for students at Soham College in Ely

In another demonstration of the solutions possibility and flexibility, the Factory42 AR experience app was loaded onto a server connected locally to Flex5G. And through the high bandwidth low latency capability of the MEC and 5G stack, Students were able to experience an interactive AR experience. The Network solutions ran stably and seamlessly across the full 7 hour event with multiple simultaneous connections

The Event was also an excellent opportunity to engage with 11-16 year olds about the power of 5G Technology – relating to their personal experiences of latency during online gaming, data security, and the future capabilities of an interconnected society

4 LESSONS LEARNED AND NEXT STEPS

4.1.1 CHALLENGES AND LESSONS LEARNED

Hardware

Very early in the project, a Worldwide shortage and procurement problems of semi-conductors was apparent. Lead-times on these chipsets have now reduced, however for the project, alternative chip sources to secure components well ahead of time had to be sought

Software & Integration

Technical challenges cited by all partners related to SW. The lack of maturity and regular iterations of codebases, the openness of interpretation with 3GPP, a lot of focus on debugging crashes was required

Frequent community updates to base SW required rigorous and continuous testing

Due to delays in Final HW, Integration activities were re-forecast, and this is where most SW challenges presented themselves.

Important lessons to learn, when it comes to planning to factor in time for these activities – whilst you don't know what you are going to encounter, the nature of the activity is inevitable issues will arise! Also, that the development is never static. Even during a "short" 12-24 month project, it should be expected to uplift along the journey in line with the latest standard and releases.

Resource planning its important to have an engineering community for support when debugging. Whilst this is a RAN/Telecom focussed project, the technical disciplines involved stretch wider and it is important to ensure skillbase across IT Networking, coding/programming, data management are covered

MIMO

Lack of Open RAN PHY solutions able to support MIMO systems with a large number of transmitted streams

Adaptability

Delays in Hardware however drove innovation and adaptability within the consortium – Use of emulation and alternative data sources to ensure Software development could continue mitigating the impact.

This was essential, had we not worked in parallel we would not have complete the project. Having at least the knowledge of dataflows and structures assisted in troubleshooting during integration

Compatibility issues arose due to absence of Open solutions, common APIs and 3rd party IPs required by O-RAN

Use Cases

Feedback from Events indicates it is all about the Use Cases. We need to evolve beyond providing the Product and Technology, to Solutions. Flex5G, with its open platform, along with SMO, is ideally place to exploit these innovation opportunities

More engagement with Business and Industry, and demonstrating how the technology can solve real world problems

4.1.2 BENEFITS REALISATION

Densification and high-performance coverage enhancement for 5G

The capability of the SDR solution to be integrated with dis-aggregated CU, DU and Core built on COTS servers, provides flexibility for high density deployment, and simplifies operational model

As a result of this easily deployable solution, densification can be carried out with limited time and effort in comparison to traditional deployment methods

The Baseline for this is a relatively closed market eco-system, with vendor proprietary hardware and specialist operational knowledge. The project assured the capability of COTS HW to manage the performance requirement through rigorous testing

The project has lowered the overall cost to deploy by circa 40%, in effect allowing the industry to be able to deploy more equipment over same area for same price, with further cost savings associated with the wider market to operate and maintain standardised IT Infrastructure

Size and Cost Optimisation - X3 SDR Board operates at 2x2, 4 RF paths with the same form factor as original SISO board. X8 Board operates 8x8, 64 paths with same form factor. Alongside X8 Board will be 8xPAs, these will be the same cumulative size as the 2 PAs which supported X3 Board

Efficiency enhancement

Through the optimisation of the radio - Algorithms used in physical implementation of Radio was improved by further optimisation of the FPGA code used in the design - and subsequent reduction in form factor, power dissipation of the overall unit has been reduced by from the start of the project by 20%

This, plus the innovations from University of Surrey in relation to MU-MIMO and controlling xApp proved further efficiencies in power utilisation with improved user experience

Interoperability of Radios

Tier 1 Operator validation of the solution being inter-operable with 2 existing traditional RAN Vendors – In the Vodafone lab, the Flex5G solution was connected directly to Vodafone Core network and successful handovers performed with Huawei and Samsung 4G equipment

SDR successfully integrated into different RAN SW stacks – Amarisoft was the base SW stack used for the solution and product testing, through the life of the project OAI SW was deployed and evolved to integrate with Flex5G

Open RAN integration work acceleration

Awards of further DSIT projects in the ONE and 5GIR portfolios, and SBRI projects, to members of the consortium are testament to knowledge base and experience developed

International Business opportunities are in progress with Finance and Military sectors

Verification/furthering UE emulation capabilities/experience

Keysight RU and UE Sim are in operation in Vodafone lab enabling a number of potential load and tests cases – perennial challenges for Telco operators is performance in localised high demand areas, which solutions like Flex5G targeting. These test solutions are essential to replicate these scenarios and prove capability

Project outputs will be commercially ready not just laboratory ready

Successful Use Case performed at Soham College, Cambridge operating live AR experience for students with seamless user experience

Vodafone Phase 2 Testing completed with integration to their Core Network, and inter-operability with their Macro RAN (Huawei and Samsung) achieving their internal CA milestone

Zain showcased as part of their product portfolio at LEAP 2024

4.1.3 NEXT STEPS

O-RAN SW Development and Maturity

Extensive efforts and collaboration during the project with codebase developers such as OAI – It would be great to continue this collaboration and development to improve stability, expand functions and features of the Open RAN solution, enabling greater diversification in the supply chain

Focus on application and use cases

Exploit the flexibility and programmability of the solution to offer Edge services and workload for 5G Private Networks

Benefits to Private Networks, in particular Small to Medium Enterprise, is the solution simplicity in deployment to provide rapid 5G services attached to their existing IT Infrastructure

IOT can take advantage of low latency and security made possible by local processing using General Purpose Processors. This keeps all architecture onsite allowing greater control in e2e performance

Built on a Linux platform, it is a platform ready for existing apps, and apps developers to collaborate and innovate

Cost is also a key factor. Cost reduction is made possible by virtue of its software-basis and reliance on GPPs along with the associated economies of scale and upgradability

Performance and Configuration flexibility made possible by software defined radio and management platform allowing the system to by dynamically optimised to suit use case requirements

Supply Chain Diversification

SMO Platform base features are agnostic to deploy with other RAN Vendors, and project learnings around data ingestion will make adoption of other RAN Vendors data a more streamlined process

Inter-operability between Open components will enable faster market adoption

Commercialisation

Easy to deploy 5G MPN solution is already being exploited by potential customers such as banking, defence and large enterprises in overseas markets

UoS is one of the winners of the SBRI: Future Telecommunications Challenge, for the further development and commercialisation of the corresponding Non-Linear MIMO processing technology (NL-COMM: Practical, Non-Linear Processing for High Performing Communications

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