Demo: A Campus Scale Private 5G Open RAN Testbed

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Abstract

The next generation of mobile networks are embracing disaggregation, reflected by the industry trend towards Open RAN. Private 5G networks are viewed as particularly suitable contenders for adopting Open RAN, owing to their setting, high degree of control, and opportunity for innovation. Motivated by this, we have recently deployed the first of its kind campus-wide, O-RAN-compliant private 5G testbed across the central campus of the University of Edinburgh. We first present the rationale behind our testbed along with an overview of its make-up. Then, we outline our plan to showcase the coverage, flexibility, and the operational view of the testbed from both network side and user perspectives.

CCS Concepts

• **Networks** → **Mobile networks**; **Network performance evaluation**.

Keywords

Open RAN, Private 5G, Testbeds

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1 Introduction

Mobile networks in the recent past have embraced *disaggregation* at different levels, driven by the need for cost-effective and flexible system architecture that accelerates innovation and enables new services. Complimentarily, they are increasingly leaning towards *data-driven and AI powered operation* to unlock significant energy, operational and spectral efficiency gains. These trends are most prominently evident in the *Open Radio Access Network (RAN) architecture*, being standardized by the O-RAN Alliance, comprised of disaggregated RAN components with open standardized interfaces between them, and RAN Intelligent Controllers (RICs) and Apps to intelligently drive RAN operations [11].

While Open RAN is expected to become an integral part of next generation mobile network system architecture in general, *private 5G mobile networks* [9] in particular are seen as the early adopters. Unlike national scale public mobile networks, private networks are local scale deployments that are attractive for industrial (e.g., manufacturing, mining, warehouses) and enterprise (e.g., business parks, universities, hospitals) settings, transport hubs, venues and such. This is because they not only allow high degree of control and customization but also offer greater opportunity for innovation (e.g., sensing applications that leverage the mobile network communication infrastructure).

University campuses are a representative and compelling setting for Open RAN based private 5G networks. Moreover, as history has shown with software-defined networking (SDN), campus networks can be excellent experimentation grounds for innovative technological solutions and services that have the potential to shape our future connectivity [7].

With the above motivation, we have recently deployed the first of its kind campus-wide, O-RAN-compliant private 5G testbed across the central campus (over 50 acres) of the University of Edinburgh [3]. This testbed is intended to enable a broad ranging experimental research on next generation wireless access networks, including experimentally exploring systems research challenges in the Open RAN context;

developing and validating innovative data-driven solutions for optimized RAN operation and beyond; and investigating issues unique to private 5G networks and their role in the future mobile network system architecture.

In this demonstration, we intend to highlight two key features of our testbed. Firstly, its blanket coverage across the campus, including the impact of our spectrum planning as well as the ability to optimize for both coverage and capacity. Secondly, its flexibility in supporting a wide variety of software stacks at every layer: from the RAN, to the RIC and the apps supported by the RIC, to the 5G Core; providing the capability to realize a diverse set of scenarios and serve as a a springboard to investigate a wide range of research questions. Going beyond this, we plan to demonstrate the testbed from two key perspectives. Firstly, the network side perspective, particularly the operations dashboard with various metrics from across the whole stack running on the network, and the insight that can be drawn from them to inform various network management decisions. Secondly, the user perspective, including running a variety of mobile applications on a connected device, and seamless handoffs between cells on the network.

2 Testbed Overview

At a physical level, our testbed deployment consists of twenty radios (RUs in O-RAN parlance) from two different vendors installed on rooftops of different campus buildings, all operating in the 3.8-4.2 GHz shared access spectrum band in the UK. The maximum possible power level (medium or low) and antenna type (omni or directional) for each radio was carefully chosen not only to yield blanket coverage across campus but also to ensure adequate capacity to provide cutting-edge data rates in high footfall areas on the campus.

In line with the Open RAN architecture, the bulk of the RAN processing for the network operation (corresponding to CU and DU) is consolidated in an edge cloud powered by a set of telco-grade servers. The edge cloud is deployed in one of the campus buildings and is connected to each of the RUs through a high-speed network switch and custom fiber fronthaul. Additional servers for management, GPU based AI compute and storage are integrated into the edge cloud to ease management and enable the deployment of data-driven "Apps" for network monitoring, control and beyond. All the testbed components are synchronized with a PTP grandmaster clock to ensure reliable and performant operation.

Noting that most functionality in a modern 5G network resides in software in the form of various virtualized network functions, we have deliberately aimed to keep our testbed highly flexible with several alternative software options. These include multiple different RAN software stacks (e.g., srsRAN [2], OpenAirInterface (OAI) [8]) and RIC platforms (jbpf [4], EdgeRIC [6], FlexRIC [10], O-RAN SC [1]). We have also integrated various data-driven Apps for RAN and beyond into the testbed, including apps for RAN telemetry data collection, anomaly and interference detection, power saving and device localization.

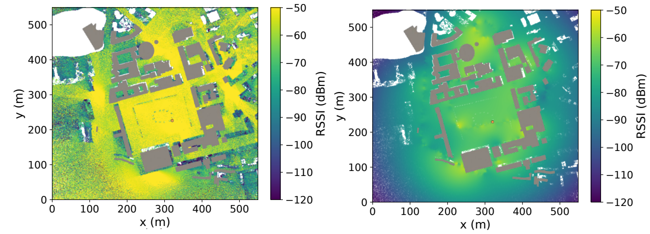

Figure 1: (a) Ray-tracing-based coverage map, (b) Measurement-based coverage map.

3 Demonstration

Coverage. We will demonstrate the *radio signal coverage* from the testbed before and after deployment through *coverage maps.* A coverage map assigns signal quality metrics to each bin on a 2D plane, enabling mobile operators to evaluate signal reception at arbitrary locations. Our demonstration will support diverse signal quality metrics, such as received signal strength indicator (RSSI), reference signal received power (RSRP), reference signal receive quality (RSRQ) and signal-to-interference-plus-noise ratio (SINR). The coverage maps will be obtained at user-defined bin granularities (e.g., 1m×1m or 2m×2m), which offers a trade-off between coverage map resolution and computational complexity.

At the planning (pre-deployment) stage, we constructed a real-world scene model of our campus and use SionnaRT [5] to generate a ray tracing (RT) based coverage map. We will show the SionnaRT-based coverage maps based on diverse signal quality metrics with different cell activation decisions. Post deployment, we have conducted several campus-scale measurement campaigns that resulted in a large dataset. Using this dataset, we will show the measurement based coverage map, obtained through a combination of measurements and interpolation, and compare it with the SionnaRT-based planning stage estimated coverage map. As shown in Figure 1, both estimated and measured maps reflect blanket coverage across the campus area. We will also show a *real-time coverage map* based on the real-time measurement reports sent periodically from the connected UEs to the RAN. In addition, we will show the impact of using different interpolation methods (e.g., inverse distance weighting, kriging, machine learning based methods) as well as the inter-cell interference map.

Flexibility. Our goal has always been to create a testbed that supports the wide variety of software stacks, including commercial alternatives. Such a testbed provides flexibility that is conducive for research, thanks to its ability to use the most appropriate software stack for a given scenario. For example, some software stacks may be mature and stable, therefore suitable for long-term testing and deployment with large numbers of users, while other software stacks may support certain experimental features, enabling novel solutions to be investigated and trialed.

To demonstrate the flexibility offered by our testbed, we will present the use of different software stacks, and the resulting metrics and traces from the testbed. In particular, we intend to show the use of different virtualized RAN (vRAN) stacks (e.g., srsRAN, OAI) paired with different RIC platforms (e.g. O-RAN SC, FlexRIC, jbpf, EdgeRIC). Besides highlighting the flexibility with our testbed, this also demonstrates the unique features supported by the different software components.

Operator Perspective. To demonstrate the network side perspective, we will present several live dashboards. At the lowest layer, information about the hardware platform (CPU load, memory, network, temperatures, etc.) will be presented. Additionally, separate monitoring for the radio units themselves will be showed. At the next layer, information provided by the vRAN software stack will be presented, including the number of connected users, the aggregate throughput (downlink and uplink), and per-UE quality-of-service metrics, including the modulation and coding scheme (MCS) and SNR. All of this RAN-side information will be presented at both a cell-specific level and a more general whole-network level.

Beyond the RAN, we will present information from the various RIC platforms that sit atop the RAN.. The RIC platforms allow for a variety of different apps to run on the network, and we will demonstrate some sample apps such as KPI monitoring.

User Perspective. We will demonstrate the user perspective in two ways. Firstly, via a remote connection to a connected device, we will demonstrate (and enable attendees to interact with) a variety of different applications (instant messaging, web browsing, video streaming, speed tests) all running on a device that is connected to our network. Beyond demonstrating the performance of our network in a variety of use cases, when combined with the metrics available to the operator, this demonstrates how the different end-user applications appear to the network operator.

Secondly, with the assistance of a remote participant, we will demonstrate making calls (voice and video) to a device connected to our network. Unlike the previous device, this device will be mobile and roaming between different cells during the demonstration. This enables us to showcase the performance of our network for roaming users, and how handoffs between cells does not impact the performance of latency-sensitive applications.

Environment and Resources Required. Our demonstration setup is fairly simple, requiring only two tables and two electrical outlets. We will present the demo on four monitors, one each for the four subcategories of our demonstration (coverage, flexibility, operator perspective, and user perspective). Due to our computers and monitors having UK-standard plugs, we will bring the necessary extension leads to ensure sufficient electrical outlets for the computers and monitors.

A good network connection is essential for our demo to run smoothly. We will ensure that all computers are equipped to connect to a WiFi network; wired Ethernet is not required.

Acknowledgments

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