

5G Cloud RAN Architecture Evolution

Cloud RAN Trial Based on Combined CU and DU Architecture

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1. Introduction

Cloud-Radio Access Network (Cloud RAN) technology is dynamically evolving as the next generation of wireless RAN implementation. It provides cloud-native, flexible, and disaggregated architecture providing scalability and streamlining network management through standardized operations [1].

As part of Rogers' wireless network evolution strategy, Rogers has been collaborating with our partner vendor on the Open RAN technology evolution based on a Cloud RAN solution. Rogers Communications successfully trialed 5G Cloud RAN technology based on separated Centralized Unit (CU) and Distributed Unit (DU) architecture over a commercial network at a live event in Canada in 2024 [2, 3]. In February 2025, another milestone was achieved with the 5G Cloud RAN successful trial based on a combined CU and DU architecture in a live network followed by the trial of Next Generation Open Lower Layer Split (NG-OLLS) interface (i.e. Open Fronthaul) in April 2025.

This paper starts with a background on different RAN deployment solutions namely purpose-built, virtualized, cloud and Open RANs. This is followed by a summary of the different Cloud RAN architecture options in section 3. In section 4, a discussion of the open lower layer split options is presented. This is followed by an assessment of the 2024 Canada Day trial and details of the evolution of the solution towards the 2025 version which is currently being evaluated in the Network.

2. RAN Deployment Solutions

Before going into the details of our trials and their results, it is critical to understand the different deployment solutions possible in a Radio Access Network:

- **Purpose-built RAN:** based on purpose-built hardware with very close integration between the hardware and software components. This is the current state of the Radio Access Network in most wireless network deployments worldwide. This solution is highly mature and has evolved over the years to provide high performance tailored to Radio Access Network requirements.
- **Virtualized RAN:** in this setup the software and hardware are separated, and the software can be implemented on any commercial off the shelf (COTS) hardware. Virtualization can be achieved by using virtual machines and hypervisors on standard hardware.
- **Cloud RAN:** a step further where the software is cloud-native and can be deployed on COTS hardware. Cloud-Native means that the system is designed for deployment on a cloud, whether that is a private or public cloud does not really matter. The key is that the implementation is based on container-based microservice architecture and utilizes container orchestration applications [1]. This allows for easier portability and faster deployment and scaling of the solution.
- **Open RAN:** does not necessarily need to be based on Cloud RAN, Hardware and Software disaggregation based on open principles as laid out in O-RAN framework. Open RAN focuses on opening the interfaces between the different RAN components which allows for easier interoperability between components from different vendors as opposed to the proprietary solutions that usually lock operators into a certain vendor's products.

3. Cloud RAN Deployment Options

While the current traditional deployment of the RAN limits the options to the baseband being located at the cell site or near edge due to latency requirements and limitations on the front haul link, cloud RAN allows for more flexible options depending on the architecture choices made. Figure 1 highlights different deployment scenarios under two main architecture choices:

- CU and DU each using dedicated servers which would allow for a hybrid deployment with centralized CU and Distributed DU.
- DU+CU on the same server hardware allows CU+DU to be co-located, like purpose-built RAN, for both distributed and centralized RAN deployments.

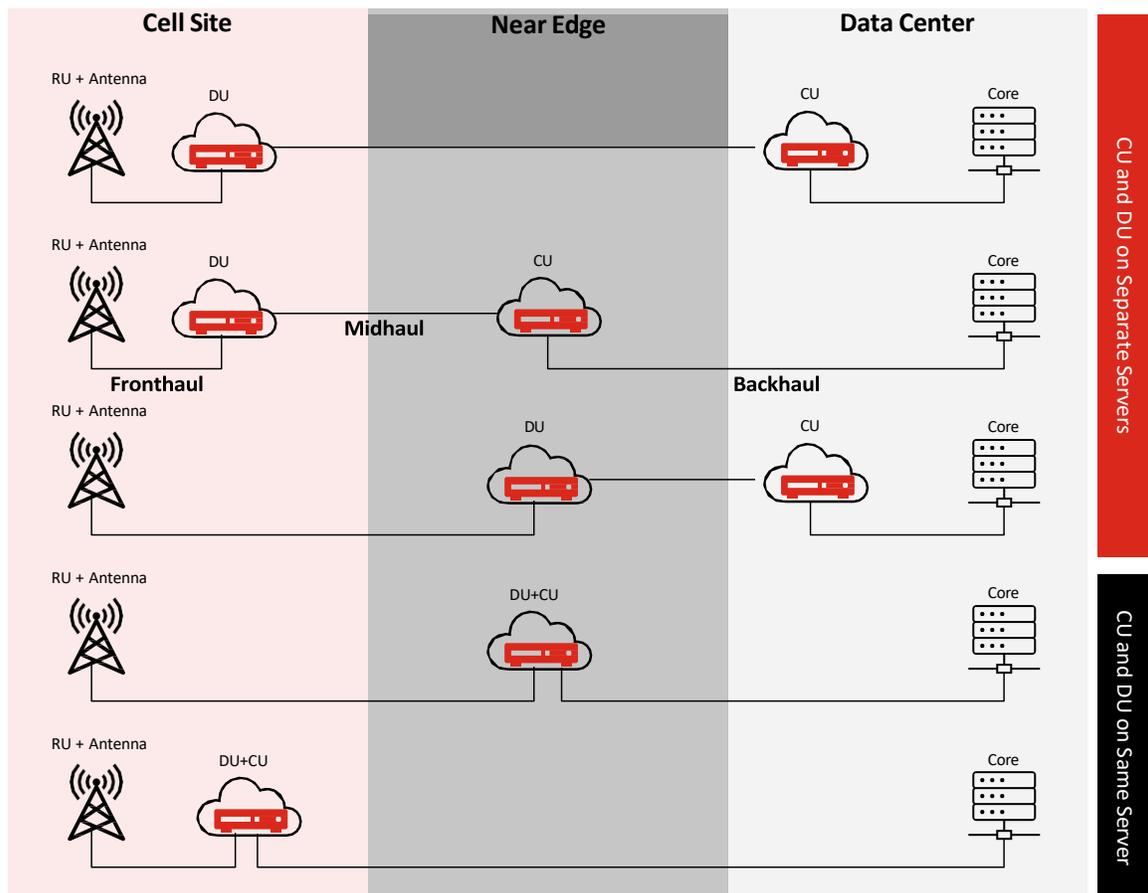


Figure 1: Cloud RAN Architecture Options

3.1. Deploying CU and DU on Separate Servers

With CU and DU on separate servers, the components can be located in different parts of the network. The CU can be located at central data centers with the DU being at the cell site or near the edge, a *centralized CU deployment*. Another option is that the CU can be deployed near the edge with the DU at the cell site.

This deployment flexibility provides several different opportunities. Since processing requirements for the CU are not as high as the DU [1], the CU can control multiple DUs located at different cell sites. Being a cloud-native solution, expanding capacity on the CU is simple if the server has extra capacity availability, it is just a matter of deploying a new pod with the required containers. The CU can also be fully hosted in the cloud, making capacity expansion even simpler. Although operational costs of renting out cloud capacity need to be evaluated to ensure the most efficient operation. In addition, the use of a cloud-native solution and a CaaS platform on COTS hardware can allow the deployment of other network functions on the same server in the future, for example, a UPF instance can be deployed on the CU server near the network edge. This can lead to a more efficient use of resources and can be used in conjunction with slicing to meet service requirements for some applications like latency sensitive applications for example. This flexibility also provides an opportunity in enterprise networks, where the whole network from RAN to core in addition to other functions that require computer processing can all be hosted on common hardware reducing the overall cost and complexity of the solution.

Finally, with specific hardware configurations, the same servers hosting the CU containers can also be used to run AI workloads on network edge [4], with the increased use of generative AI and the current development progress of agentic AI, this could be an interesting prospect for communications service providers in the future. With intelligent management, the server can be used for AI workloads during off peak hours, allowing for higher efficiency in compute resource usage. This is still not a possibility now but could be feasible in the future.

It is important to note, however, that while the deployment of other network functions and AI workloads is possible on any cloud-native architecture, it is relatively easier to implement in centralized deployments.

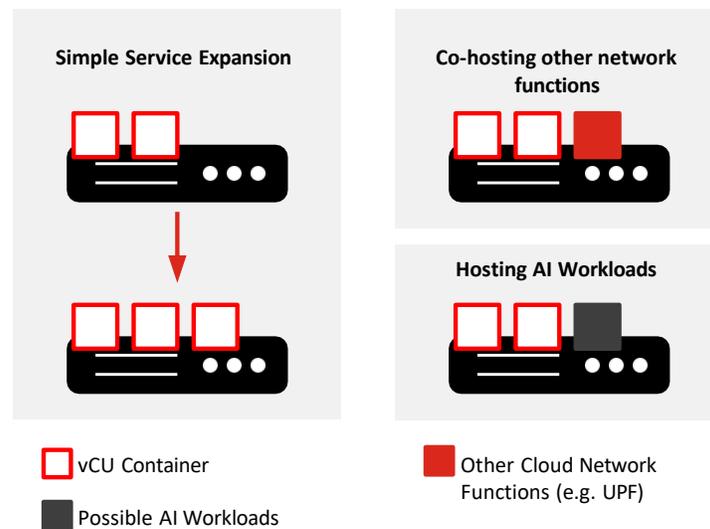


Figure 2: Benefits of a Cloud Native Solution

The DU on the other hand poses two main challenges compared to the CU. First, handling lower layers requires much higher processing capacity, according to Ericsson “layer 1 and 2 combined comprise 90% of processing demands” [1]. This leads to the need to use specialized accelerators to either accelerate the full layer 1 stack or accelerate selected functions, such as high capacity massive MIMO workloads. Second, the stringent front haul latency requirements on the link between the DU and the RU and the different lower layer split options available. Due to these two differences, DU

requires different hardware capabilities and naturally needs to be located either at the cell site or near the edge. With the higher processing capacity requirements for the DU and its location at the site or edge of the network it becomes more difficult to share the compute resources with other network functions.

Centralized deployment, however, also introduces challenges. Requirements for mid-haul transport capacity and low latency in the order of 1 to 2 milliseconds between the centralized CU and distributed DU limit the options for the type of mid-haul transport as well as the maximum distance between the CU and DU [5, 6]. This will influence the deployment strategy and network design, requiring having more data centers closer to the network edge than a legacy distributed RAN network. In addition, having CUs in centralized locations controlling many DUs distributed in the network increases the risks of having a single point of failure which raises a requirement for more georedundancy in the network architecture. Finally, brown-field operators already have a network designed to work with a distributed architecture, utilizing a centralized architecture will require re-designing part of the network to increase the benefits from a centralized RAN approach.

3.2. Deploying CU and DU on Same Server

With the advancement in processor and server performance, it is now also possible to host the CU and DU on the same hardware (i.e. collocated hardware). This option is similar to the current purpose-built architecture utilized in most CSP networks globally. The main difference is in the cloud-native design of the radio node software to allow it to run on COTS hardware.

The main benefit of having both the CU and DU on the same server is the reduced complexity and cost. In addition, this aligns well with the expected deployment scenarios in brown-field operators. While it is possible to deploy a distributed RAN architecture utilizing separate servers for the CU and DU, this would mean having to cover the extra cost of acquiring multiple servers without benefiting from the centralized RAN opportunities discussed in the previous section. Being able to deploy both the CU and DU on the same server reduces the cost of the solution and fits well with a distributed RAN architecture. With future advancement of CPUs, GPUs, and server hardware, it will also be possible in the future to easily host other network functions on the same server as well as eventually being able to run AI workloads. Those future enhancements will allow this solution to provide many of the benefits highlighted for the split architecture solution while eliminating some of its drawbacks like near edge data center acquisition costs, network architecture re-design and increased risk of single point of failure.

Table 1: Collocated/Distributed CU/DU VS Centralized CU Comparison

Impact	Collocated/Distributed CU/DU	Centralized CU
Architecture	Classic architecture similar to traditional RAN	New architecture: DU on site; CU in data/edge center
Scalability	Scaling of CU/DU is done on eNB/gNB level [7]	Independent scaling of the CU from the DU function [7]
Resource Pooling	No pooling gain of CU across multiple DUs [7]	Pooling of resources required for CU across multiple DUs [7]
Core Network	No impact – similar with traditional RAN	Fewer logical eNB/gNB possibly allowing less signaling load from Core [7]
SW Life Cycle Management (LCM)	One SW LCM for CU and DU	Independent SW for CU and DU, allowing independent CU/DU SW upgrades independently but adding more operational complexity

Hardware Investment	Fewer Basebands and Baseband locations required	Additional locations required for centralized CU, and additional COTS servers for centralized CU
Latency	No extra transport latency	Extra mid-haul transport latency, depending on the distance between CU and DU [7]
Transport	No mid-haul - similar with traditional RAN	Impact on transport topology, planning, and design
Operation	One RAN node to operate and manage	Added complications due to separate CU clusters and distributed DU clusters
Reliability	Resiliency is on eNB/gNB level	Risk of single-point failure for the CU, geo-redundancy normally required
Migration	Good for Cloud RAN migration by interleaving with traditional RAN on a site-by-site basis as an intermediate step	Challenging on interleaving due to different architecture

3.3. Layer 1 Acceleration Options

One common aspect for using either a single or multiple server deployment is the requirement for layer 1 (physical layer) acceleration on the DU. Layer 1 acceleration is required to accommodate the high processing requirements of some layer 1 functions that require intensive processing and would benefit from being accelerated on specialized accelerators built specifically for the function. There are two main options for layer 1 acceleration, the first is known as “lookaside” or “Selected Function Hardware Acceleration”, this option utilizes an integrated CPU consisting of the CPU and an accelerator [4, 8]. Most of the processing is done by the CPU while it offloads some of the processing intensive functions to the accelerator. The second is known as “inline” or “Full L1 Acceleration” [4, 8], in this solution, the whole layer 1 is accelerated on special hardware and then the higher layer functions are controlled and implemented by the CPU.

In the trial, a “Selected Function Hardware Accelerator” architecture was used.

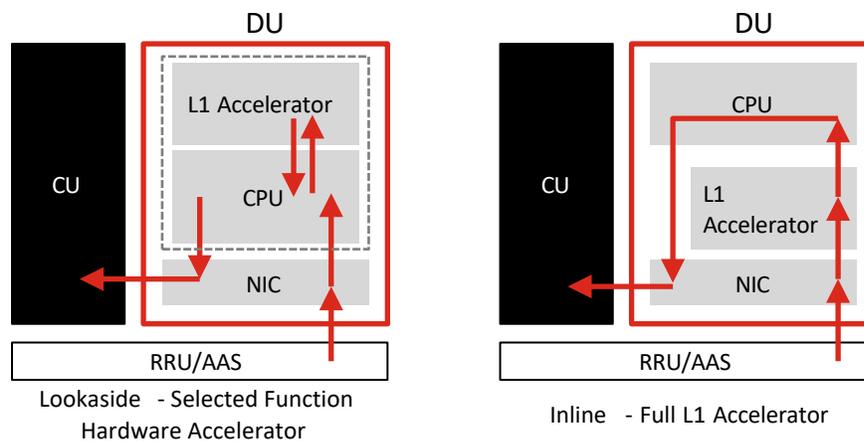


Figure 3: Lookaside VS Inline Acceleration

4. Open RAN Functional Splits

To open the RAN interfaces and facilitate an open RAN ecosystem, there needed to be a clear definition of how the functional layers in the protocol stack are split between the different components of the RAN. Generally, the split between the CU and DU is referred to as the Higher Layer Split (HLS) and the split between the DU and RU is referred to as the Lower Layer Split (LLS). There are multiple ways to achieve this split, but the O-RAN Alliance adopted option 7-2x for the LLS [9, 6, 10], while option 2 is to some extent the only considered option for the HLS [6]. In this paper the focus is mainly on the LLS as this is the more latency stringent and performance limiting link in the RAN architecture.

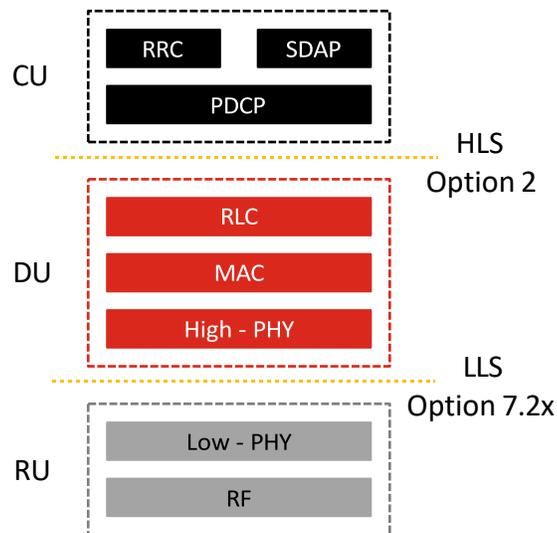


Figure 4: Open RAN Functional Splits Options 2 and 7.2x

Due to the special nature of radio network processing requirements on the physical layer, lower layer split architecture selection has a profound impact on the performance of the radio network, especially when utilizing open fronthaul to comply with open RAN standards [9]. There are two main options adopted by the O-RAN alliance, an option used with Radio Units with eight antenna ports or less, known as Cat-A, and an option used with massive MIMO active antenna systems that have up to 64 antenna ports, known as Cat-B [9, 10]. Cat-A radios are simpler and most of the processing is done in the DU, while for Cat-B there are benefits to moving some of the lower Layer 1 functionality to the RU to reduce the capacity requirements for the fronthaul link. The focus in this paper is on Cat-B as the trial involved a massive MIMO antenna. The original proposed Cat-B solution in the O-RAN Alliance had limitations that degrades uplink performance when compared to proprietary solutions that vendors have developed over the years [9]. As a solution to these limitations, the O-RAN Alliance adopted two options for Uplink Performance Improvement (ULPI) in 2023, namely O-LLS Cat-B ULPI Class A and O-LLS Cat-B ULPI Class B. Class A is officially known as DMRS-BF-EQ and Class B as DMRS-BF-NEQ [9]. In the rest of the paper, we use Class A and Class B terminology for easier reading. While both options move most of the L1 functionality to the RU, there is one main difference. In Class A, the Equalizer is moved to the RU while in Class B the equalizer remains in the DU with beamforming and channel estimation always being located in the RU [9, 10]. Class A enables easier inter-operability between DUs and RUs from different vendors due to the clear split in functionality between the RU and DU and allows the use of lower capacity fronthaul links [9, 10]. With Class B keeping the equalizer in the DU requires that the channel estimation is performed in both the RU and DU which introduces complexity in achieving interoperability

across RUs and DUs from different vendors. The DU will need to support both ULPI Class A and ULPI Class B but the RU needs to support only one architecture. Figure 5 summarizes the differences between Class A and Class B.

The OLLS solution used in our trial utilizes ULPI Class A and we compare its performance to the purpose-built solution and the proprietary LLS in a cloud solution.

	ULPI Class A	ULPI Class B
UL Channel Estimation	RU	RU and DU
UL Beamforming Calculations	RU	RU
UL Equalizer	RU	DU

Figure 5: Differences between ULPI Class A and ULPI Class B

5. Phase 1: CU and DU on Separate Servers

On Canada Day, July 1st, 2024, Rogers and Ericsson conducted the first commercial live event trial of Ericsson’s 5G cloud RAN at Rogers Centre, home of Major League Baseball’s Toronto Blue Jays. This demonstration aimed at validating the performance of the Cloud RAN offering in a high-capacity event to stretch the capabilities to their limit and observe how the technology behaves under high load. [2, 3]

For this proof of concept, the architecture used involved a separate server for the CU and DU, even though they were both collocated in the same server rack. This architecture in deployment enables deploying the CU in a centralized datacenter location while the DU can be located closer to the edge or at the cell site. Figure 6 shows an overview of the solution architecture. For the proof of concept, one of the existing site sectors was rehomed to the cloud RAN solution, basic testing and performance validation were performed and the cloud RAN sector was utilized to carry live network traffic, Figure 7 shows the location of the sector used in the trial.

The solution utilized a proprietary lower layer split. This limits the use of the solution to same vendor active antenna units; however, this is the initial step towards an open fronthaul interface to eventually support third party radios and active antenna units.

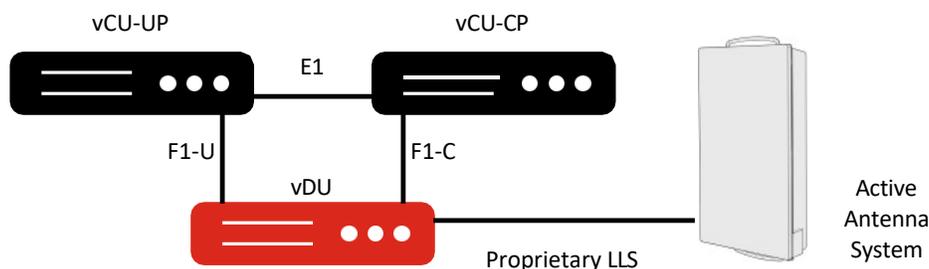


Figure 6: Architecture of Separate Servers Solution

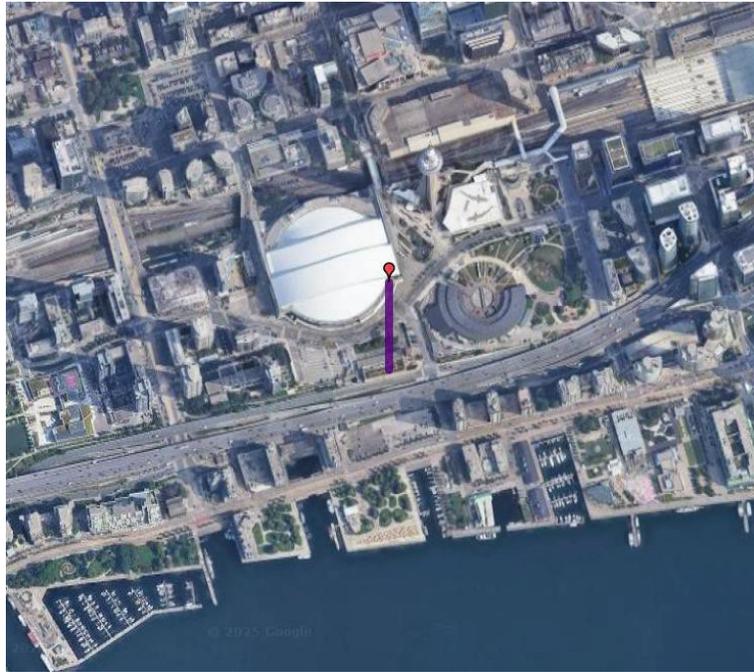


Figure 7: Cloud RAN Trial Sector

The solution only supported NR 3.5 GHz in a non-standalone setup, as a result, an LTE anchor node was required to enable EN-DC connectivity. For this purpose, a legacy purpose-built baseband was used which already existed and hosted the LTE carriers on the node. The focus in this trial was to evaluate the stability of the cloud RAN solution and ensure an acceptable level of service. Service parity between the purpose-built solution and the cloud RAN solution was not the expectation at this stage due to the early stages of development for the cloud RAN solution and the limitations on some feature support in the solution. Nevertheless, the performance of the solution was acceptable and no major stability issues were observed during the trial.

Figure 8 to Figure 11 show some of the main KPIs observed during the trial, the sector was able to carry up to 5GB of hourly traffic during the event with good performance in terms of accessibility, retainability and throughput.

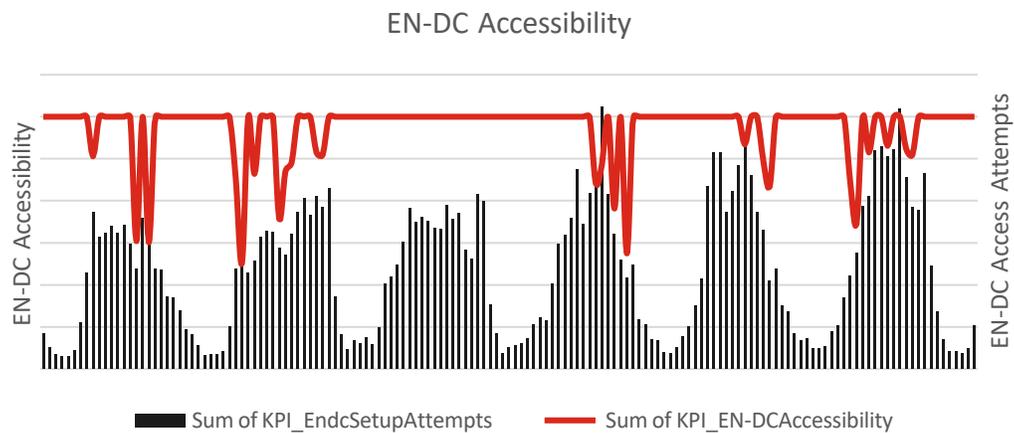


Figure 8: EN-DC Accessibility KPI for Cloud RAN Sector

EN-DC Retainability

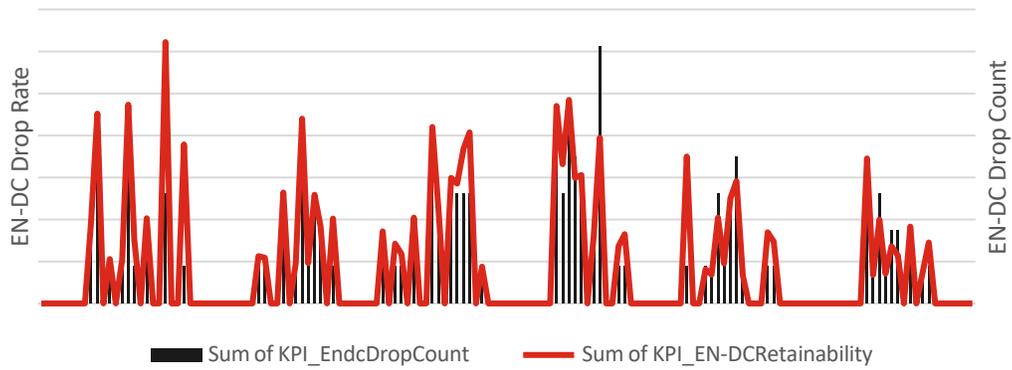


Figure 9: EN-DC Retainability KPI for Cloud RAN Sector

EN-DC DL Throughput and Traffic

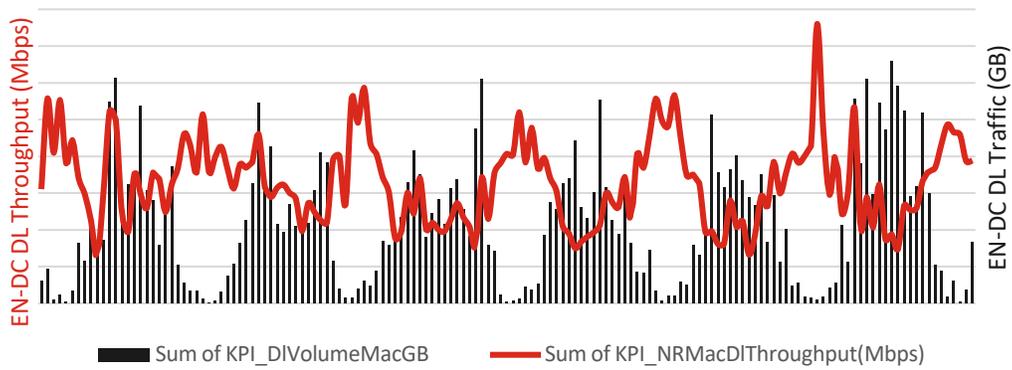


Figure 10: EN-DC DL Throughput for Cloud RAN Sector

EN-DC UL Throughput and Traffic

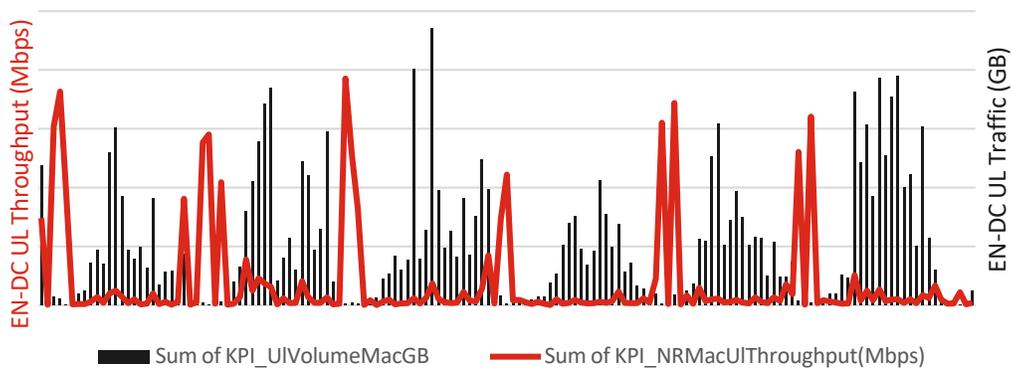


Figure 11: EN-DC UL Throughput for Cloud RAN Sector

6. Phase 2: CU and DU on Same Server

Starting in February 2025, phase 2 of the trial utilizing a single server for both CU and DU was initiated. The solution utilized Sapphire Rapids 4th Gen Intel Xeon Scalable processors with selected function hardware acceleration. This solution has the capacity to host the CU and DU pods on a single server. This makes the solution footprint comparable to the purpose-built deployment mostly utilized in a brown-field network. While the solution under trial is still evolving to achieve full feature parity, the functionalities implemented allowed the performance comparison with the purpose-built solution to be carried out. The trial was implemented in steps to allow visibility into the performance of the proprietary lower layer split and the open lower layer split options. The baseline for the performance was the purpose-built deployment performance. The first step utilized the proprietary lower layer split architecture and the second step utilized the open lower layer split architecture based on Cat-B ULPI Class A. In both steps the same Active Antenna System was used to ensure a fair performance comparison between the two options. The architecture is shown in Figure 12.

A performance comparison in terms of some of the main performance metrics is highlighted in Figure 13. On average, the Cloud RAN solution has comparable performance to the purpose-built RAN although there are still areas of improvement and feature parity that are still in progress and should be resolved in the near future.

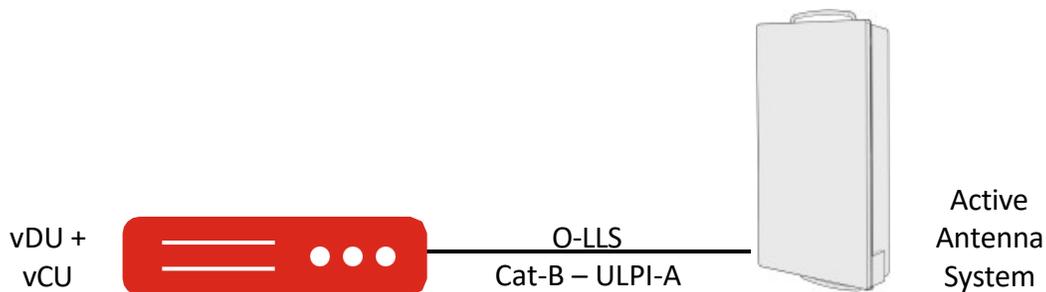


Figure 12: Architecture Using Single Server for vCU and vDU

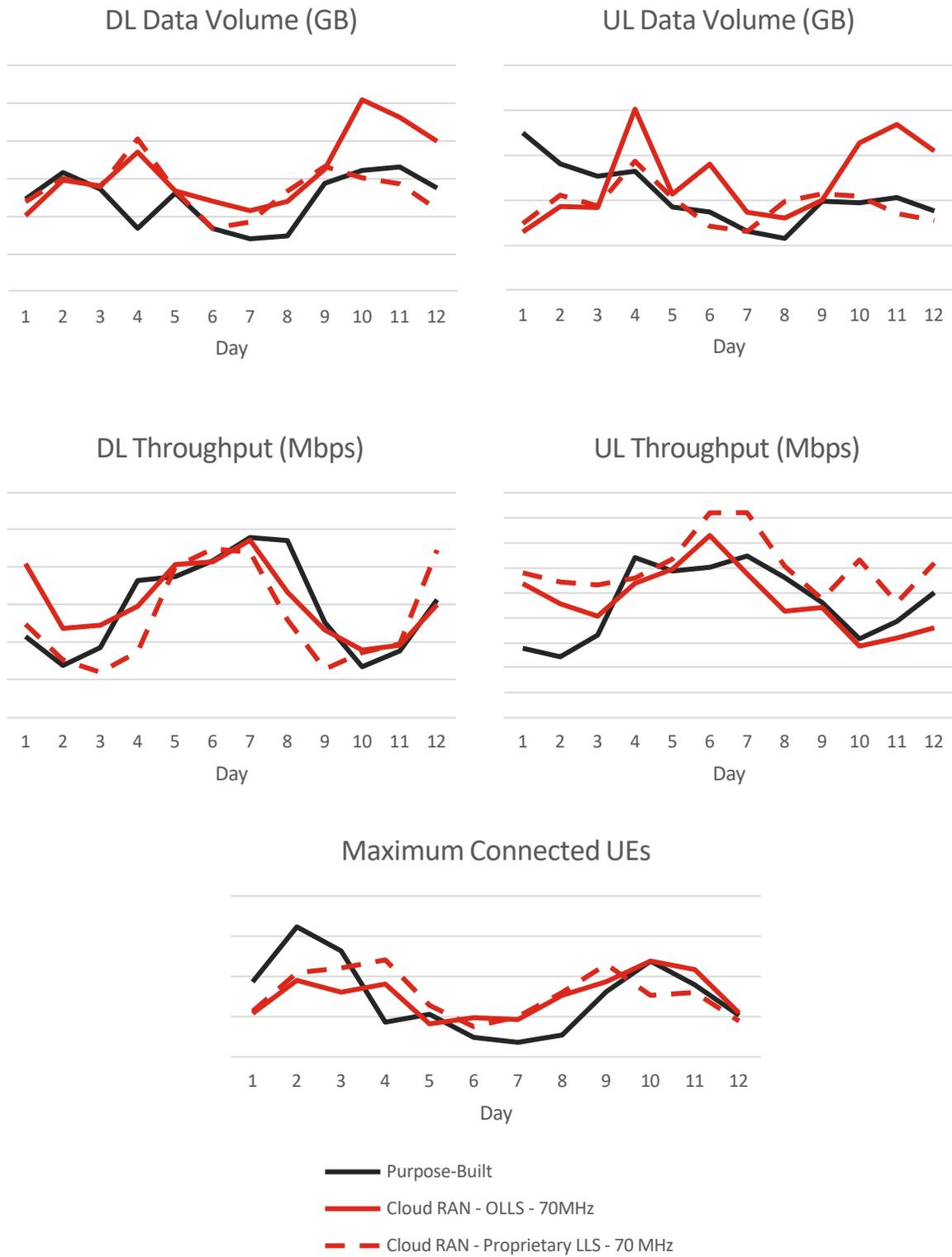


Figure 13: Performance Comparison - Purpose Built VS Cloud RAN with Proprietary LLS VS Cloud RAN with OLLS

7. Conclusion

In this paper we have shown that Cloud RAN has exhibited promising performance comparable to existing purpose-built RAN, however, it is important to highlight that Cloud RAN is still in development and new features and functionalities are constantly being developed to achieve full parity with purpose-built RAN. In addition, automation in life cycle management of Cloud RAN software and CaaS layers has the potential to reduce operating costs. Furthermore, the use of COTS hardware allows for deploying cloud-based core components right at the edge of the network which can reduce end-to-end latency for latency-sensitive services and applications. We also envision a future where AI workloads can be processed right on the edge of the network, which opens the door for future innovations in services and applications. The deployment architecture choice is not a one size fits all, some CSPs will benefit from using a distributed RAN deployment where having the CU and DU on the same server is optimum, this is highly relevant for brown-field CSPs that already adopt a distributed RAN architecture. While other CSPs could prefer a centralized RAN architecture where having the flexibility to deploy the CU and DU on separate servers could be useful, this could be suitable for CSPs that are planning to shift their network architecture to be more centralized.

Abbreviations

AAS	Active Antenna System
AI	Artificial Intelligence
CaaS	Containers as a Service
COTS	Commercial Off the Shelf
CPU	Central Processing Unit
CSP	Communications Service Provider
CU	Centralized Unit
DL	Downlink
DU	Distributed Unit
eNB	Evolved Node B
EN-DC	E-UTRA New Radio dual connectivity
gNB	Next Generation Node B
GPU	Graphics Processing Unit
KPI	Key Performance Indicator
L1	Layer 1
LCM	Lifecycle Management
LLS	Lower Layer Split
MAC	Medium Access Control
MIMO	Multiple Input Multiple Output
NG-OLLS	Next Generation Open Lower Layer Split
OLLS	Open Lower Layer Split
PDCP	Packet Data Convergence Protocol
PHY	Physical Layer
RAN	Radio Access Network
RLC	Radio Link Control
RRC	Radio Resource Control
RRU	Remote Radio Unit
RU	Radio Unit
SW	Software

UL	Uplink
ULPI	Uplink Performance Improvement
UPF	User Plane Function

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