Open RAN Mobile Access: The View of an Operator on an End-To-End Implementation

Carlo Cavazzoni, Marco Caretti, Alessandro Percelsi, Mauro Agus
TIM, Via G. Reiss Romoli 274, 10148 Torino, Italy.
carlo.cavazzoni@telecomitalia.it

Abstract: This paper describes some challenges that an operator must face when setting up the environment to evaluate end-to-end 5G mobile networks, with a specific focus on the RAN segment implemented by disaggregated Open RAN solutions.

1. Introduction

Recent years have witnessed an exponential increase in mobile traffic, which has been accompanied by growing demand for support of always-connected connections and remotely controlled terminals (the so-called Internet of Things). Operators are pushed to make substantial investments to upgrade the network capacity and introduce new features and services quickly, looking for new architectural solutions that can guarantee this goal while making the costs of network expansion and management compatible with the highly competitive scenario.

Towards these goals, operators are investigating interoperable and open software-based solutions especially in the 5G radio access network. One of this initiative is the O-RAN Alliance [1] which aims to build a more open ecosystem in the RAN segment. In this paper we will review the main aspects of the O-RAN architecture the Alliance is working on, the main challenges the operators are facing in testing solutions based on such architecture and some of the gaps towards a commercial adoption.

2. Open RAN architecture and deployment options

Several emerging initiatives are proposing the concept of Open RAN for radio access, with the aim of introducing more competition in the radio segment and encouraging the entry of new players, by means of a multi-vendor environment where devices, equipment, applications, virtualized network functions deployed on appropriate Cloud Native Infrastructure (CNI) can interoperate via open standard interfaces. These initiatives are also considering Artificial Intelligence / Machine Learning (AI/ML) techniques to automate many operations aimed at radio management, configuration and optimization.

The O-RAN Alliance is an operator-led initiative supported by operators such as AT&T, China Mobile, Deutsche Telekom, NTT DOCOMO, Orange, Verizon and TIM. The Alliance pursues the goal of evolving radio access along the paradigms of radio feature disaggregation, virtualization and hardware/software decoupling. Off-the-shelf hardware, automation and standardization of open interfaces to enable true interoperability are considered the pillars to reach such goal. To this end, a reference architecture has been defined (shown in Fig. 1) where different components associated with various radio functionalities are represented.

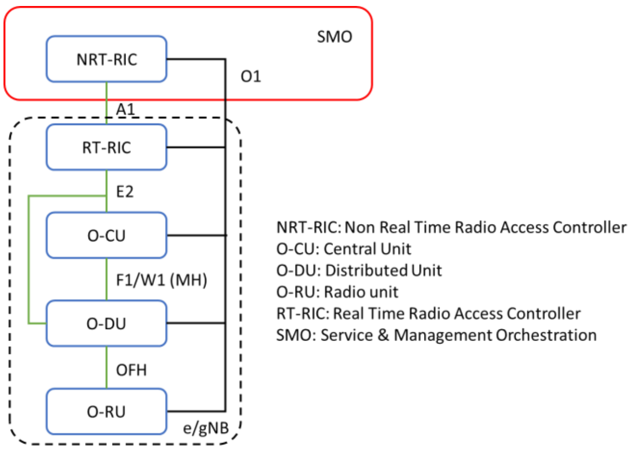

Fig. 1. Open RAN Architecture.

Excluding the O-RU (the component of the radio node connected to the antennas and responsible for converting the signal from digital to analog and RF in transmission and vice versa in reception), it is clear that the O-RAN Alliance proposes the disaggregation of the baseband and management functions into different components (O-CU, O-DU, NRT and RT-RIC) that can be deployed by the operator in different ways, depending on the use case of interest and the right trade-off between cost and performance (See Fig. 2). Looking for example to the O-CU and O-DU components, that contain most of the baseband processing of the signal, a first option is the one in which these functions are centralized (even in different locations as depicted at the bottom of Fig. 2) to serve multiple radio sites. This solution enables radio-level coordination features such as CoMP (Coordinated Multi-Point) and Carrier Aggregation and optimize the sharing of hardware resources. The other option is to implement a fully distributed network (top of Fig. 2), similar to what is done in most legacy networks. Intermediate solutions are possible where, for example, centralization involves only O-CU. In the trials carried out in TIM, an attempt has been made to adopt as much as possible the centralized option even though it entails significant impacts on the transport solutions to be chosen.

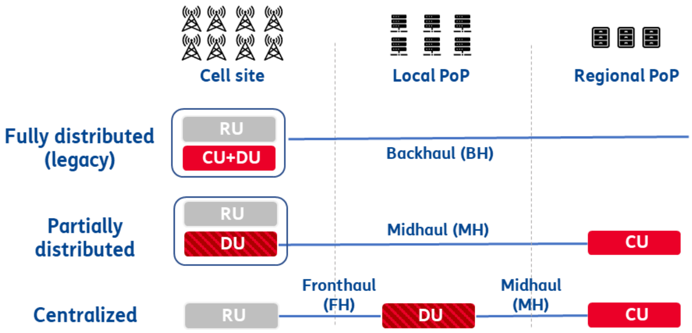

Fig. 2. Open RAN deployment options.

3. Testing an Open RAN solution

Setting up an end-to-end scenario for testing innovative solutions for the 5G RAN is a very difficult task that requires a wide range of expertise in different network segments.

A realistic end-to-end chain has to include many elements: from the mobile terminals to the core network, the Fronthaul (FH), Midhaul (MH) and Backhaul (BH) transport networks, and the virtualization infrastructure (both hardware and software) that not only must host the 5G cloud network functions and their management systems, but also should provide automation to properly manage the life-cycle of the cloud functions and of the CNI itself.

3.1 Cloud Native Infrastructure

3GPP [2] has defined the 5G as a Service-Based Architecture where network functions are implemented as self-contained, independent, and reusable modules that expose functionalities via suitable interfaces. Currently, the preferred way to implement this architecture is provided by the Cloud Native Infrastructure Technology.

CNIs provide a common open platform, (CaaS, Container as a Service) where applications can be deployed worldwide in a similar way (as all CaaS typically are based on the Kubernetes open-source project [3], [4]), offering a modular approach for the deployment, scalability and evolution of software components. For usual IT Cloud applications, the CaaS doesn't require specific hardware for the computing resources: however, in case of Telco Cloud applications such as the O-RAN O-DU and O-CU, requirements represent a big challenge for a CNI because these virtualized functions need high demanding features not common in traditional IT cloud applications. Apart from large amount of CPU, RAM and Storage resources, Telco user-plane applications typically require heavy computing to elaborate complex digital mechanism (such as for example FEC): also, high-speed packets transfer is required to avoid latency as much as possible. Considering these two aspects, servers hosting the O-RAN applications must support several features (such as for example kernel bypass, virtual CPUs pinning, RAM access optimization…), provide at least 25Gb/s bit-rate Network Interface Cards (NICs) and likely support HW acceleration. In particular, for O-DU function, where FEC is managed at very high-speed level, tailored HW is required, in contrast with the "general purpose" HW approach typical for traditional IT cloud.

Using high-speed NICs has also an impact on the network infrastructure of the site: switches must provide ports with bit-rate scaling from 10Gb/s to 100Gb/s. Typically 10 Gigabit Ethernet (GE) and 25 GE ports are required for the Telco Cloud intra-site connectivity. When the Telco Cloud site is only hosting the O-CU (with O-DU being hosted in another site or co-located with O-RU), 25 GE ports can be enough also for MH connectivity. When also O-DU is hosted, the FH link typically requires at least 40 GE or 100 GE ports on the switches.

Last but not least, as explained in next section, switches in the Telco Cloud Site must be also able to act as Boundary Clock to receive and propagate synchronization protocols.

3.2 Transport network

Transport aspects are very challenging in the O-RAN centralized topology, due to the constraints in terms of throughput and latency of the FH segment: according to the functional split 7.2x ([5] par. 4.2), throughput generated by each O-RU for NR easily crosses the threshold of 10Gb/s, and overall latency ([5] par. 4.4) limits the physical distance and affects the choice of the deployment option (architecture and elements positioning). Moreover, any radio site is usually equipped with three sectors and multiple frequency layers for each sector, so a lot of interfaces must be aggregated locally by a Cell Site Gateway (CSGW). The total amount of throughput to be managed requires long-distance/high bit-rate (40/50/100 GE) interfaces on CSGW towards the FH link. Therefore, dark fiber availability in the access segment becomes a must for centralized topology.

A distributed topology can mitigate the need of dark fiber and expensive interfaces, because the MH interface [6] has lower constraints both in terms of latency and throughput, and it can be carried on existing metro/packet aggregation network infrastructure, (e.g., WDM, L2/L3 aggregation network, Packet based Radio Links). Moreover, if servers hosting the O-DU have aggregation capabilities, a further cost optimization could be possible skipping the CSGW.

In order to provide an accurate phase synchronization to O-RU and O-DU, Precision Time Protocol (PTP) must be used and properly distributed in the Transport network ([5] par. 11.2 and 11.3). Among the different options for synchronization distribution, we are initially looking at the configuration where the synchronization source is implemented in the FH network and distributed towards O-DU and O-RU (LLS-C3, Lower Layer Split – Configuration 3) in a centralized topology. In this configuration the CSGW has a central role in the radio site and must be configured as boundary clock. Another interesting option suited for the distributed topology is the LLS-C1 where the O-DU directly synchronizes the O-RU through a point-to-point link. In this case the O-DU server would also implement the aggregation function (to avoid expensive CSGW) and act as boundary clock.

4. Final considerations on Open RAN challenges towards commercial adoption

The approach proposed by the O-RAN Alliance is promising and represents a common target for next generation mobile access network. However, there are several open points that need to be resolved to enable wide-scale adoption of this new technology, some of them are listed below:

- Interoperability: despite a mature specification of open fronthaul interfaces and related interoperability test, still a 'plug & play' approach is not possible and baseband and radio vendors have to perform intensive integration activities to declare full interoperability
- Automation: the deployment of a large number of sites hosting cloud native network functions must be implemented using tools and procedures that reduce or eliminate completely any manual action, besides the physical installation of hardware components.
- Radio intelligence disaggregation: currently the number of baseband solutions capable to support centralized Radio Resource Management via third-party implementation based on AI/ML mechanism is rather small, and obviously this may be a block to the introduction of this important element.
- Feature parity: 4G and 5G networks are very complex in terms of features, especially in mature markets such as Europe. This represents a barrier for new entrants developing O-RAN solutions and if the gap is not filled in the coming months/years, these solutions may be relegated in small deployments. In addition, many operators still have a 2G network (which is not currently envisioned in the O-RAN specification) and it is unclear how to achieve migration to an O-RAN architecture where such systems are present.
- Cost and Power consumption: operators should foster the emergence of new players that can offer cost-competitive interoperable solutions, such as O-RAN, thanks also to economies of scale. On the power consumption front, an evolution of hardware solutions toward architectures with greater efficiency is desirable, since to date x86-based platforms have power consumption figures that are not competitive with legacy solutions.

5. Acknowledgements

This work has been partially supported by the Horizon Europe SEASON (GA 101096120).

6. References

[1] "O-RAN Alliance", https://www.o-ran.org/

[2] "3GPP TS 23.501 - System architecture for the 5G System (5GS)", https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3144.

[3] "Kubernetes Documentation / Concepts / Overview", https://kubernetes.io/docs/concepts/overview/ .

[4] "Kubernetes Documentation / Concepts / Containers", https://kubernetes.io/docs/concepts/containers/.

[5] "O-RAN.WG4.CUS.0-v10.00 - O-RAN Working Group 4 - Control, User and Synchronization Plane Specification", https://orandownloadsweb.azurewebsites.net/specifications.

[6] "3GPP TS 38.401 - NG-RAN; Architecture description", https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3219.