Capgemini engineering

OPENRAN'S 2ND MILE

Considerations for an efficient 5G fronthaul

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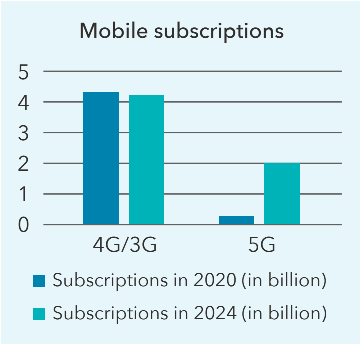
Executive summary

Since the first commercial launch of 5G services in 2018, 5G's momentum has ramped up. By the end of September 2020, there were over 100 commercial 5G networks launched worldwide (source: GSMA) with several mobile communication service providers (CSPs) achieving nationwide status. With all these milestones, 5G will still have to coexist with 4G for several more years, as the figures below show:

	Subscriptions (in billion)	
	2020	2024
4G / 3G	4.5	4.4
5G	0.2	2

	Data traffic per month (EB)	
	2020	2024
4G / 3G	40	80
5G	2	50



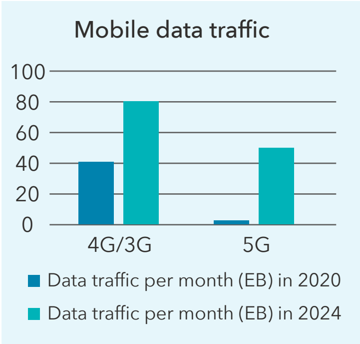


Figure 1: expected mobile data traffic and subscribers growth
Source: Ericsson Mobility Report

According to GSMA, 4G accounted for 52% of mobile connections in 2019 and will increase to 56% by 2025. Meanwhile, 5G will roughly take a 20% share.

Unlike the moderate pace in the access side, radio access network (RAN) architecture migration is accelerating and driven by a total cost of ownership (TCO) benefit. In general, 65% total cost of ownership of a network is in the RAN[1]. RANs are rapidly migrating (or have already migrated) from D-RAN (distributed RAN) architecture to C-RAN (centralized RAN) architecture. The OpenRAN initiative promises to fuel innovation and growth by the transformation from closed elements and protocols to open, plug-and-play, fully interoperable elements using standardized protocols.

In this paper, we examine a crucial element of the RAN that is not currently addressed by OpenRAN standardization efforts – the fronthaul network. Current OpenRAN definitions mention and standardize the fronthaul interface between the radio and baseband unit (BBU) but do not address the fronthaul network in detail, especially the various brownfield and converged network scenarios that every operator must deal with. We bring out the need to consider efficient fronthaul solutions to mitigate specific challenges in RAN evolution.

Capgemini Engineering and UfiSpace are collaborating to bring the right solutions to address these challenges by using open, disaggregated, modular, and programmable components to support OpenRAN (O-RAN) to fuel initiatives and hasten RAN evolutions for 5G deployments.

1. Source: O-RAN Alliance

Introduction

To optimize cost, the first major step was to split radio functions from the baseband unit and connect them through fiber in order to provide better flexibility. C-RAN adoption was then introduced by bringing distributed BBUs into a central location. Then came the virtualization of RAN functions, which consisted of disaggregating hardware from software in building vRAN solutions. And now comes the ultimate step – the creation of O-RAN, which relies on and achieves full interoperability between multiple remote radio units (RRUs) and BBU as defined by the OpenRAN Alliance. OpenRAN enables strong TCO savings: 34.5% over a five year period as opposed to legacy RAN (source: Strategy Analytics and Mavenir). As a result, many parties are working in the OpenRAN ecosystem right now with a focus on:

1. Hardware and software disaggregation of RAN components including RU, DU, and CU

2. Open interfaces between RAN components

3. Intelligent RAN control mechanism to automate management process of RAN components

There is still a part missing to complete the future RAN architecture – fronthaul transport.

4G is still using legacy common public radio interface (CPRI) or open base station architecture initiative (OBSAI) as the fronthaul transport protocol. They are point-to-point, semi-proprietary, and inefficient. For example, in order for a 20Mhz channel using a 2x2 antenna configuration to deliver a downlink of 150Mbps, it will require a much higher CPRI data rate of 2.5Gbps due to the analog to digital conversion process. So CPRI's inherent inefficiencies in data transport do not meet the requirements needed within a 5G network. Although new standards such as enhanced common public radio interface (eCPRI), radio over Ethernet (RoE), and time-sensitive networking (TSN) are defined, the details of the fronthaul element design are not addressed. This leaves many uncertainties on the convergence of 4G.

Challenges in deployment

CPRI limitations

The OpenRAN project from the Telecom Infra Project (TIP) depicted a vision of the future RAN with vendor-neutral hardware and software solutions. It is still more suitable for greenfield implementations. The real challenge is brownfield.

The transition to C-RAN and eventually to an O-RAN architecture will face certain limitations set forth by CPRI. In the current architecture, dedicated CPRI links are used to connect RRUs and BBUs. In the case of C-RAN, where the RRUs and BBUs are separated over a vast distance, the one-to-one CPRI link also needs to be extended. For example, upgrading a single band with three antennas to C-RAN will need three long haul CPRI links. To support two different bands, the CPRI links will be doubled and large amounts of long haul CPRI links will be required. Also, the transmission distance of CPRI is limited to 15 km to 20 km on a point-to-point basis. This reduces the benefits of C-RAN, such as cost savings and deployment flexibility.

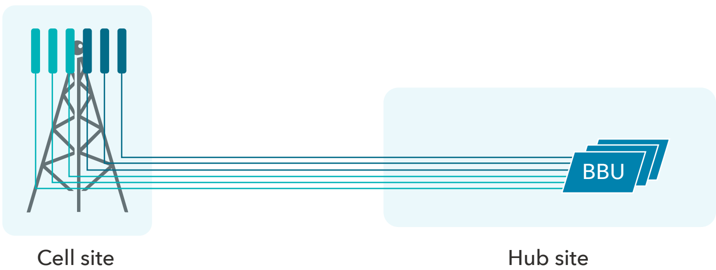


Figure 2: separated radio unit (RU) at cell site and baseband unit (BBU) at different location

Interoperability issues

The OpenRAN concept realizes multi-vendors participation in the infrastructure but multi-vendor interoperability is always a concern, especially for existing equipment. Traditional 4G RAN is provided by a single vendor with semi proprietary CPRI, which makes it difficult to converge 4G CPRI from various vendors into an open infrastructure.

Timing requirements

Accurate time synchronization is the foundation of the mobile network. Historically, BBUs are the timing source for 4G RRUs and time information is carried through the CPRI link. The distance between BBUs and 4G RRUs in the C-RAN architecture introduces some inaccuracies, but the real problem is in the Ethernet-based fronthaul. Ethernet was not designed for time-critical applications. The focus was on reliable data transmission, and the delay due to retransmission was acceptable. A precise time solution for Ethernet-based fronthaul would be necessary to enable time-critical applications in 5G.

Manageability

As the number of devices in the network grows, management complexity grows exponentially, especially in a multi-vendor scenario. Devices may support different management methods, and even when they support the same management method, they may use different objects and object models. This can result in substantial recurring costs of operations if efficient and uniform management methods are not applied.

Diverse and mixed deployments

As we have seen earlier, networks will go through a prolonged phase of 4G and 5G co-existence. This necessarily creates multiple deployment situations such as:

- CPRI radio units and CPRI baseband units
- CPRI radio units and eCPRI baseband units
- eCPRI radio units and CPRI baseband units
- eCPRI radio units and eCPRI baseband units

It is impossible to migrate everything at both ends within a short time window. Each of these combinations requires different interworking and/or multiplexing in the fronthaul. So, this is a fascinating puzzle that operators must solve in the network.

Solutions

Overcoming CPRI limitations

UfiSpace's fronthaul gateway enables flexible configuration to converge 4G and 5G networks, no matter if it is in greenfield or brownfield.

In the scenario where an existing 4G network is upgraded to a C-RAN architecture to optimize the network efficiency and costs, the CPRI link can be replaced by an Ethernet transport.

Radio over Ethernet (RoE) conversion is used to encapsulate and map radio data into Ethernet frames that are transported over Ethernet. In such a configuration, 4G RRUs and BBUs are not aware of the changes in the transport network. Two fronthaul gateways are used in both the cell site and hub site to process the signals. A converged access switch (CAS) is used to aggregate the traffic from the fronthaul gateways located at the cell sites.

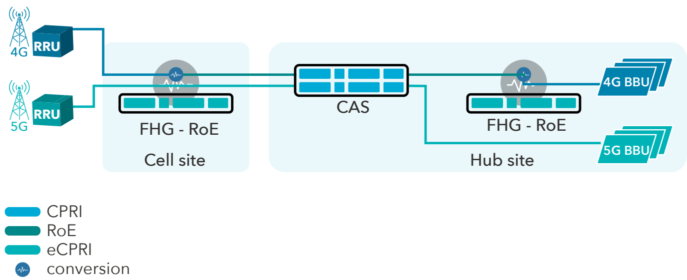


Figure 3: fronthaul network with 4G and 5G RUs as well as 4G and 5G BBUs

As the network evolves, BBUs will be further split into distributed units (DUs) and centralized units (CUs) to not only facilitate RAN virtualization but also to enable deployment flexibility. The eCPRI is used to reduce fronthaul capacity and optimize transport efficiency. A low PHY enabled fronthaul gateway is able to convert legacy CPRI signals into frequency domain eCPRI packets, allowing 4G RRU signals to be included in the more efficient 5G transport network.

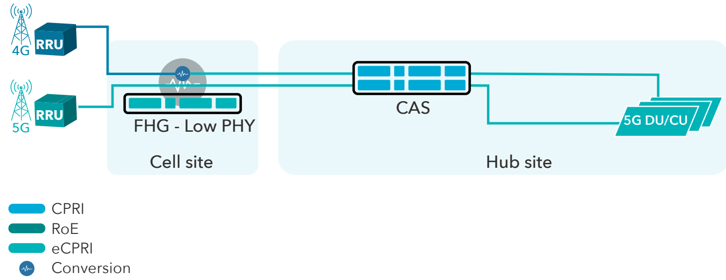


Figure 4: fronthaul network with 4G and 5G RUs and 5G DU/CU only (requiring CPRI to eCPRI conversion)

Addressing interoperability issues

To fit into any deployment scenario, UfiSpace designed our fronthaul gateway's service ports to be modularized. It is built with powerful field-programmable gate arrays (FPGA) that can be customized to support different pluggable standards, ports count, and new features. System integrators, software partners, and even RAN vendors can customize the module to make our fronthaul gateway interoperable with their protocols.

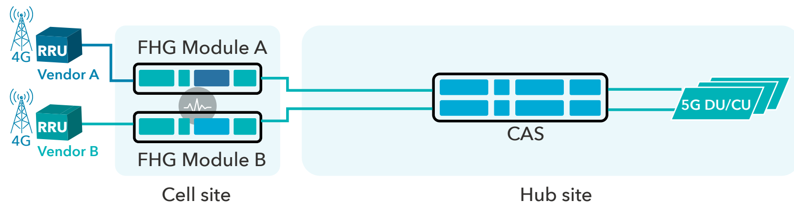


Figure 5: modular and flexible fronthaul gateway unifies and simplifies connectivity to multiple 4G RUs

Addressing timing and latency requirements

UfiSpace's in-house network timing module provides ITU-T Class C precision to guarantee the time error within 10 ns, and we are even targeting to meet the Class D requirement (5 ns). It also supports telecom profiles such as G8265.2, G8275.1, and G8275.2, as well as SyncE synchronization. This allows the fronthaul gateway to be capable of functioning as a telecom grandmaster clock (T-GM), telecom boundary clock (T-BC), and telecom transparent clock (T-TC) in any hierarchy to optimize network synchronization deployment.

Capgemini Engineering's software solution fully leverages hardware platform capabilities by integrating the required control and management plane for PTP/IEEE 1588 v2, SyncE, and the various telecom profiles. It satisfies the requirements specified in the IEEE 802.1CM specification for TSN in the fronthaul, along with support for different TSN requirements such as time- aware scheduling (802.1Qbv), frame preemption (802.1Qbu), and interspersing express traffic (802.3br).

Together, this hardware-software combination meets the most stringent latency demands and timing requirements in the fronthaul.

Efficient management

The Capgemini Engineering software supports both legacy management methods such as CLI/SNMP and modern management methods such as NETCONF and REST. Management information bases (MIBs) and YANG models are comprehensive to support 100% manageability through either scheme.

Support for standardized MIBs and NETCONF/YANG models enable easy management using existing systems without requiring additional investment in new management systems. Comprehensive NETCONF/YANG support also allows automation of management tasks, thus creating enormous efficiencies and eliminating unnecessary recurring operational costs. The system is therefore ready for networks migrating to (or already migrated to) a full software-defined networking (SDN) architecture.

The OpenRAN working group (ORAN-WG) identifies a RAN intelligent controller (RIC) for efficient management of the RAN. The Capgemini Engineering software uses the management models defined by the ORANWG, thus enabling any management system to manage it easily.

Handling diverse and mixed deployment scenarios

As described earlier in this paper, the UfiSpace platform is built with powerful FPGAs. The Capgemini Engineering software harnesses this capability by adding the flexibility to set up the FPGA according to different situations. This allows the same gateway in different deployments to support various interworking methods such as tunneling mode, line code aware mode, structure-aware mode, and low-PHY mode. This brings two powerful advantages for the operator – (a) the same device can be deployed in different positions in the network, thus reducing management complexity; (b) as the network changes to increase the 5G percentage, the same device can be reused, thus avoiding costly capex expenses.

Conclusion

A good fronthaul strategy mitigates RAN inefficiencies and enables operators to exploit the movement's benefits to a centralized, virtualized, and OpenRAN architecture.

Capgemini Engineering, an industry leader in product engineering services, together with UfiSpace, a pioneer in hardware 5G networking solutions, has established a collaboration with Capgemini Engineering's proven network operating system (NOS) software running on UfiSpace's white box platform for fronthaul gateways and access switches. This offers the advantage of disaggregated, open networking along with proven reliability to rapidly develop and deploy converged RANs in the shortest time, thereby dynamically improving return on investment on the network.

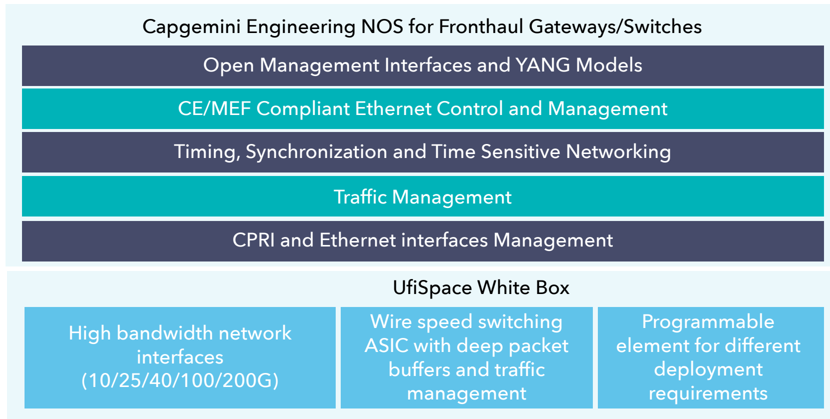


Figure 6: Capgemini Engineering and UfiSpace's joint solution for efficient fronthaul

About Capgemini Engineering

Capgemini Engineering combines, under one brand, a unique set of strengths from across the Capgemini Group: the world leading engineering and R&D services of Altran – acquired by Capgemini in 2020 – and Capgemini's digital manufacturing expertise. With broad industry knowledge and cutting-edge technologies in digital and software, Capgemini Engineering supports the convergence of the physical and digital worlds. Combined with the capabilities of the rest of the Group, it helps clients to accelerate their journey towards Intelligent Industry. Capgemini Engineering has more than 52,000 engineer and scientist team members in over 30 countries across sectors including aeronautics, automotive, railways, communications, energy, life sciences, semiconductors, software & internet, space & defence, and consumer products.

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