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FRONTHAUL TO 5G NEEDS A STRONG OPTICAL NETWORK

FROM C-RAN TO CLOUD-RAN BY YVON ROUAULT, TECHNOLOGY ADVISOR IN CTO OFFICE, EXFO

Accurate predictions for some technologies are difficult, but the ongoing standardization of 5G by 3GPP is providing the industry with precise requirements for future radio access network (RAN) architecture. 5G networks will be based on a radical change like the network functions virtualization (NFV), the new functional split of the 5G-New-Radio (5G-NR) based on an evolution of the centralized RAN (C-RAN) to a Cloud based RAN.

Widespread deployments of 5G are scheduled for 2020. In the meantime, mobile operators can stretch their LTE-A network to address some 5G use cases with accurate performance figures, with a mounting pressure to adopt the C-RAN architecture.

LTE-Advanced Pro (3GPP Release 13), as well as for 5G-NR (release 15), will affect the RAN and fronthaul parts of the network particularly. Hence the optical distribution network will be a key to the C-RAN/Cloud-RAN architecture, as it is hard to reach each cell site and small cells with the appropriate optical network: 5G-PPP has said the lack of access to optical networks will be the biggest obstacle to deployment of 5G.

OPERATORS MUST SPEED TOWARDS 5G

Mobile operators have limited spectrum with which to provide more subscribers with faster connectivity for bandwidth-hungry applications on smart devices. They are also looking for new sources of revenue, such as from the IoT.

5G will address these needs through apparently contradictory features: 10-100 x throughput, 10 x lower latency, and 10-100 x more connected devices. Tier 1 operators are accelerating trials of 5G radio technologies and evaluating new bands, like 3.5 GHz or 28 GHz radio bands with 200 MHz basebands, which are 10 x wider than is used in LTE.

3GPP Release 15 is set to standardize the first phase of 5G requirements by mid-2018, but already 5G is hailed as a game changer. 5G-PPP identified three classes (known as verticals) with specific radio access requirements:

- **Extreme mobile broadband** (eMBB), for example, offers 4K video. Increasing backhaul throughput will raise the bit rate of the fronthaul as well. (for the FWA – fixed wireless access – use case the data rate of the Fronthaul could be 40Gb/s, up to 100Gb/s).
- **Massive machine communication** (MMC), for example, offers connectivity to billions of IoT devices. Some applications will need deep analytics for data from sensors and other devices. More processing will happen in the RAN at the baseband unit (BBU), based on mobile edge computing (MEC) technology.
- **Critical machine communication** (CMC) will feature in many industries, from production (remote robot control) to delivery (piloting drones), which need ultra-low latency (1 ms) and reliability. Fronthaul performance will be critical.

NETWORK SLICING, VIRTUALIZATION AND C-RAN

The 5G network will be based on network slicing, a concept that still needs to be refined. Each slice supports a certain service level (latency, accuracy, data rate, coverage, etc.) for a class of end-users. All slices must run on the NFV infrastructure, including the radio network. Coordinating radio resources in real time is the only way to meet the diverse performance parameters – and this can only be achieved using a centralized RAN architecture– see Figure 1 below.

Also, before mass 5G deployment, mobile operators will improve LTE's performance with new standards. They will use new techniques – like coordinated multipoint (CoMP) – to

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reach 1 Gbit/s throughput, but this needs a shorter, faster path between RRHs, which is difficult without centralized RAN architecture.

C-RAN TECHNICAL REQUIREMENTS

C-RAN architecture (see Figure 2) has specific requirements, in addition to the maximum distance between the BBU and the RRHs:

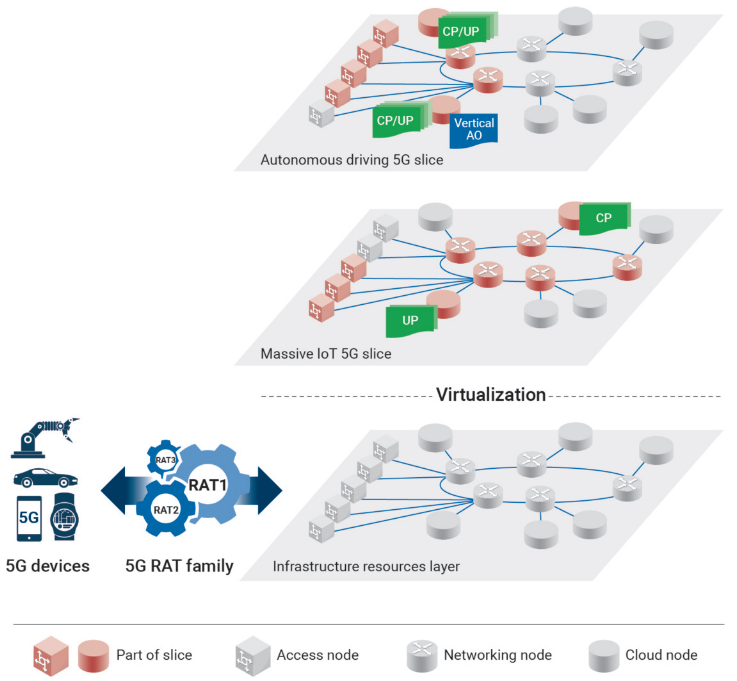
- The round-trip time of the packet handshaking protocol must be less than 3 milliseconds.
- Power budget is important, especially in passive optical networks (typical budget is 15-20 dB) which are affected by wavelength-division multiplexing etc.
- Latency asymmetry – the difference between the speed of the downlink and uplink fronthaul connections.

Virtualization of the mobile network is in progress with virtualized IP multimedia subsystem (vIMS) and virtualized evolved packed core (vEPC) networks. The next phase will be the RAN and virtualizing BBU functions.

NEW DEFINITION OF FRONTHAUL ON THE WAY

With the growing data rate to the end users, the Fronthaul will need a faster bit rate across the common radio public interface (CPRI) as well. Considering that the CPRI rate is 12x to 16x the data rate on the backhaul, bit rates would exceed 25 Gbit/s to support 2 Gbit/s FWA service throughput, for instance. To support higher data rate a new split of the BBU functions is required: a new split between the physical layer and the layers 2&3 would reduce the bit rate on the fronthaul interface significantly. IEEE (c.f. IEEE P.1914) and 3GPP RAN are working several split options. however, at the end, the inevitable increase of the data rates by a full magnitude for eMBB services will require much faster Fronthaul speeds anyway.

FIGURE 1: NEXT GENERATION MOBILE NETWORKS (NGMN) DESCRIPTION OF 5G NETWORK SLICING



C-RAN TESTING CONSIDERATIONS

Fronthaul, with the CPRI transport layer, was designed for short distances between the BBU cabinet and the RRH, on top of a tower or roof. In such a topology, the fronthaul parameters (RTT, jitter, etc.) are easy to meet. Most operators and contractors associate fiber to the antenna (FTTA) in a distributed RAN architecture as plug and play, where the latency of the fiber will never exceed 1 μs and the optical power loss is typically below 3 dB.

This is not so with C-RAN, as the insertion of optical network elements between the BBU hotel and the cell site – and the distance between the two ranging from 15 to 25 km (10 to 16 mi) – make a huge difference. Testing cell sites (RRH) should be separate from the tests at the BBU hotel – they are deployed at different times, by different teams so, in most cases, one of these two points is not active.

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RISK OF CD AND PMD DISPERSIONS

In with FTTx optical networks, dispersion issues start when the bandwidth reaches 10Gbaud and the span exceeds 10 km. As C-RAN topologies proliferate, fronthaul optical networks will find themselves in this dangerous zone.

Chromatic dispersion (CD) and polarization mode dispersion (PMD) attenuate the optical signal and increase the bit error rate (BER), especially in unpredictable environmental conditions, such as vibrations, wind and rain. EXFO recommends performing a systematic test of the dispersion above CPRI option 7 (9.83 Gbit/s), with a distance greater than 10 km.

Loss budget varies widely between vendors and network topologies. For example, when comparing SFP+ vendors on the market for a 20-km reach, their power budget will range from 10 dB to 18 dB.

Some disregard this because newer SFP modules have a much better dynamic and are more powerful, making it easier to compensate for a higher signal attenuation end-to-end. This is not an optimal approach, as powerful SFPs are much more expensive for the CWDM and DWDM (colored SFPs). Typically, there will be 12 to 15 SFPs per cell site and the incremental cost per site could exceed $1,000.

EXFO's recommendation is that the most cost-effective SFP/SFP+ modules should be carefully selected, based on the qualification of the power budget between the BBU hotel and the RRHs in each case. Specification sheets usually provide the minimum and maximum transmission power (launch power). Loss budget is calculated as the difference between the minimum launch power and receiver sensitivity.

CONCLUSION

To support the LTE-Advanced Pro evolution, and 5G New Radio, the optical links between the cell sites and the CRAN central offices or Cloud RAN Data Centers (or the virtual BBU data centers) will be a critical component of the new RAN architectures.

Requirements like latency, power loss and CPRI bit error rate, which are not critical for 3G and LTE Release 8, will become major concerns as operators migrate to LTE-Advanced Pro and 5G-NR. Even for the longer-term evolution of fronthaul technology to an Ethernet-based transport layer, the optical infrastructure will remain the same. Today's transformation investments by mobile operators in the RAN will have to support the future evolution of fronthaul technologies.

The transformation starts with FTTA and replacing copper cables with fiber to the RRH on a tower or roof. This is followed by the concentration of the BBUs in a central location, up to 25 km away from the cell sites. The evolution of radio access to C-RAN and Cloud-RAN is driven by the densification of radio access technologies, such as small and indoor cells, the multiplication of frequency bands and their aggregation to form larger basebands.

This growing complexity demands better coordination of the radio resources, requires a better Optical network foundation. Testing the optical distribution network and the CPRI transport protocol today will support network transformation to make 5G feasible and sustainable, and thus protect future investment.

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FIGURE 2: C-RAN ARCHITECTURE