Things You Should Know About Fronthaul

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Abstract *After introducing fronthaul requirements in Centralized Radio Access Network architecture, different fronthaul solutions are presented. Perspectives for medium term evolution including fronthaul supervision are hinted as well as challenges for future mobile evolution towards 5G.*

Fronthaul is a new network segment that appears in C-Radio Access Network (RAN) architecture, where the C can have different meanings following different implementation phases.

Traditional Base Stations (BS) are composed of two elements: a Digital Unit (DU), performing digital signal processing, and a Radio Unit (RU), that contains the Radio Frequency (RF) transmit and receive components and is connected to the antenna as shown in Figure 1. Since more than ten years now, the internal interface between RU and DU has been defined as the result of the digitization of the radio signal according to Common Public Radio Interface (CPRI)[1], or Open Base Station Architecture Initiative (OBSAI)[2] specifications. CPRI is currently the most used by RAN vendors.

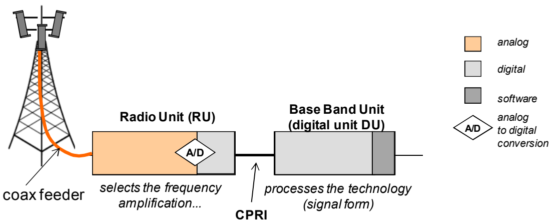

Fig. 1: Traditional Base Station with RU and DU.

In C-RAN phase 1, C stays for Centralized and takes advantage from stretching the CPRI interface and co-locating the DUs corresponding to a number of cell sites in a common location, i.e. the DU hotel that is typically in a Central Office (CO). This is represented in Figure 2, where the Fronthaul is defined as the segment between the cell site (RU location) and the DU hotel. Generally, there is one DU per radio access technology (2G, 3G, Long Term Evolution, LTE and LTE-Advanced) and site.

In C-RAN phase 2, bigger centralized DU's serving cell clusters will provide bigger opportunities for DU resource pooling gain[3].

C-RAN is gaining great interest and some network operators have started its deployment because of its potential to bring reduced costs, improved performance and fixed/mobile convergence. Cost benefits come from the fact that leaving on site only RUs with compact power supply, cell site engineering is simplified, footprint is reduced, time to install and to repair are shorter and renting cost is lower. This is especially true in dense urban areas where operational people face more and more roll out difficulties. Additional economies will come from significant reduction of power consumption and are expected with DU pooling (lower DU capacity to support same number of sites). Radio performance gains and better performance in mobility are enabled by Coordinated Multi-Point (CoMP) implementation thanks to the very low latency between DUs in the same CO (or DU pool).

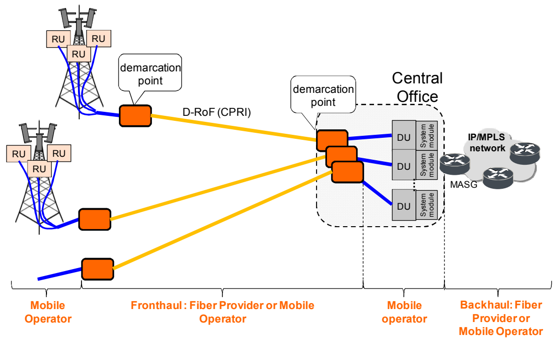

Fig. 2: C-RAN architecture with fronthaul and backhaul.

In spite of such advantages, C-RAN introduces also some stakes that are mainly related to the fronthaul segment.

For building a fronthaul solution it is mandatory to keep into account for some interdependent requirement types: technical aspects, business aspects and, under an operator point of view, regulation and operation administration and management (OAM) constraints. After shortly recalling them, this paper will present some technical solutions and perspectives for medium term evolution. Finally, open challenges for mobile evolution towards 5G will be hinted.

Fronthaul requirements

Fronthaul technical requirements include[4]:

- **Data-rate**: CPRI data rates go from 614.4Mbit/s up to 10.137Gbit/s depending on radio access technology (RAT), carrier bandwidth and Multiple Input Multiple Output (MIMO) implementation. For one LTE sector with 20MHz carrier and 2x2 MIMO the CPRI rate is 2.457Gbit/s. LTE-A with 4x4 MIMO leads to 4.915Gbit/s CPRI rate per sector.

- **Cell site configuration**: typical configurations in urban areas with 3 sectors for each RAT can yield up to 15 RUs per cell site. This leads to the need of multiplexing (in time or wavelength) to reduce the number of required fibers up to the CO.
- **Latency:** the maximum tolerated latency on the fronthaul depends on the considered RAT. The most stringent requirement is imposed by LTE-A with a maximum round trip propagation time in the order of 400-500µs, including both time delays for the fibers and equipments that could be placed on the link. This value is still under clarification at standardization level.
- **Synchronization and jitter**: the RU clock for frequency generation is synchronized to the bit clock of the received CPRI signal. As a consequence, if some jitter affects the CPRI signal, it will impact also the precision of the clock frequency generation. For LTE, the frequency accuracy requirement on the air interface is ±50ppb (parts per billion). Inside this overall value, the CPRI link contribution is limited to ±2ppb[1,5]. Phase and time synchronization will impose further requirements on the fronthaul link.

In regulated countries (Europe) the fronthaul solution, could be provided to the mobile operator by a fiber provider in the form of a wholesale offer. In order to clarify responsibility limits, the definition of network demarcation points is proposed in Figure 2. Different levels of Service Level Agreement (SLA) can be envisaged depending on the chosen fronthaul solution, but the basic and necessary one is the capability to monitor the optical link and detect if there are failures. To reach this purpose the fiber provider must be able to distinguish problems due to the optical link from problems connected to the mobile network.

Finally, business requirements aim of course at low cost implementation. This dictates the choice of the technical fronthaul solution, but concerns also cell site engineering aspects. Under this point of view, the demarcation point at the cell site will be preferred passive (no power consumption) and compact. On top of this, the cell site demarcation point will be most of times deployed outdoor and consequently subjected to industrial temperature range requirements (-40 to +85 °C). Finally, on the cell site, some local alarms are used for basic but essential indications as for instance, battery charge, fire, or intrusion. The fronthaul solution should also be able to transport such signals for a centralized management.

Fronthaul technical solutions

Fronthaul solutions can be classified in active and passive ones[4]. An active solution means that the CPRI traffic is encapsulated for example by means of OTN (Optical Transport Network) or other protocols and multiplexed on the fronthaul. In this case, the demarcation point at the radio site needs power supply.

A passive solution is based on passive multiplexing and demultiplexing of the CPRI links. Monitoring can be implemented with active equipment at the CO demarcation point. In this case the cell site demarcation point does not need any power supply.

For short term fronthaul deployments based on 2.5 or 5 Gbit/s CPRI interfaces, passive Coarse WDM (CWDM) plus monitoring appears as a good option because it is simple and cost effective as well as perfectly adapted to outdoor deployment, highly reliable and with reduced footprint. CWDM Small Form Pluggables (SFP) are used in each RU-DU pair. Additionally, one channel can be devoted to transport on site local alarms. However, some issues can be raised:

- CWDM ITU grid includes 18 channels, thus imposing the need of two fibers (one for uplink + one for downlink) for large cell sites that have 15 or more RUs.
- Inventory management is required to align optics color with RU-DU link, potentially burdening the mobile network administration.
- It is not possible to leverage on existing FTTH deployment (in terms of fiber infrastructure reuse).

Some kind of “CWDM-like” bidirectional transceivers could enable single fiber ODN fronthaul solutions and facilitate migration in case of already deployed CWDM filters.

A first transceiver option is to use the same CWDM wavelength for transmission and reception. Unfortunately, this transceiver is strongly affected by reflections and has poor performance.

Signal reflection impact can be reduced by single wavelength single fiber SFP with reflection immune operation that recognizes and cancels reflected signals[6].

A third option consists in dividing each 20nm CWDM channel in two sub-channels that are used for transmission and reception[7]. This solution provides performances equivalent to standard dual fiber SFP, is compatible with industrial temperature range and scalable up 10Gbit/s CPRI.

Such kind of “CWDM-like” bidirectional transceivers could then be used in single fiber dedicated ODN or shared ODN (FTTx).

On a longer term horizon, the inventory issue could be solved by low cost colorless transceivers. DWDM based on self seeded

Reflective Semiconductor Optical Amplifier is a promising solution for fronthaul because it brings the advantage of assigning automatically and passively the wavelength[4,8]. Existing work is based on Bit Error Ratio measurements, but real CPRI transmission and impact on the radio link should be also considered.

Previous considerations are based on a pure wavelength selective ODN that is completely dedicated to fronthaul application. Structural convergence scenarios (with FTTH) would bring to consider also power splitter and/or hybrid ODN cases.

Besides finding solutions to implement fronthaul on a single fiber ODN, it is also important to underline that currently available monitoring solutions for the fronthaul link are not compatible with a single fiber ODN. In NGPON2 framework point-to-point WDM for fronthaul implementation could use only Point to point framing or Auxiliary Management and Control Channel (AMCC) or both of them.

Open challenges towards 5G

A lot of work is currently ongoing to lay the foundation of 5G, the next generation mobile and wireless communications system, that according 3GPP could be implemented by 2020. With respect to 4G, 5G should support[9]:

- 1000 times higher mobile data volume per area;
- 10 to 100 times higher number of connected devices;
- 10 to 100 times higher typical user data rate;
- 10 times longer battery life;
- 5 times reduced End-to-End latency.

Such goals could be reached by the joint action of three factors: 10 times performance improvement by acting on spectrum efficiency, 10 times more available radio spectrum and 10 times more BS. All these aspects will have a direct impact on fronthaul and pose some questions on CPRI interface.

As introduced before, CPRI was originally intended as a BS internal interface that has been subsequently stretched in C-RAN. The consequence is that CPRI might not be the optimal interface, in particular because of the high bit-rates. Moreover, CPRI is not a real and open standard. Some existing works already deal with CPRI compression or with proposals of different functional splits between RU and DU. ETSI Open Radio Initiative is also trying to go towards an open interface. 5G preparation could provide the opportunity to fill these gaps and define properly an optimized fronthaul interface.

A possible C-RAN scenario with network densification is represented in Fig. 3. A switch fabric would affect dynamically DU resources according to traffic requirements. Some studies show that dynamic resources allocation following tidal effect can bring up to 50% pooling gain. However, the implementation of such switch fabric is still unclear. Should it be CPRI based or would it be possible to leverage on Ethernet switch? Is CPRI over Ethernet feasible?

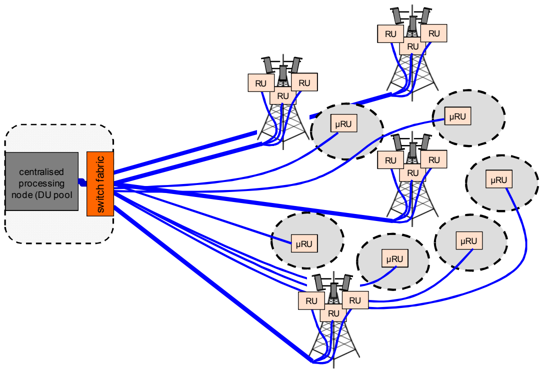

Fig. 3: C-RAN in Heterogeneous Network. μRU: micro RU for small cells.

Conclusion

On a mid term horizon, a good candidate for fronthaul over single fiber ODN is given by CWDM like bidirectional solutions. Self seeded could solve inventory issues. In both cases OAM aspects need still to be addressed.

On a longer term horizon, 5G preparation appears as a good opportunity to define an optimized fronthaul interface.

Acknowledgements

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