

Things You Should Know About Fronthaul

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(Invited Paper)

Abstract—This paper provides a review of the new fronthaul network segment that appears in centralized radio access network (C-RAN) architecture. C-RAN drivers are presented under an operational, economic, and radio point of view. The different fronthaul interfaces are briefly described as they have to be taken into account to build a fronthaul transport solution. Then, fronthaul requirements are detailed going from the technical ones to the business ones. Finally, different fronthaul solutions are presented. Perspectives for medium term evolution including fronthaul supervision are hinted as well as challenges for future mobile evolution toward 5G.

Index Terms—Fronthaul, next generation passive optical network (NGPON), optical access network, radio access network.

I. INTRODUCTION

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) or BaseBand Unit, 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. 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.

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 Fig. 1, 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 (RAT) (2G, 3G, long term evolution, LTE and LTE-Advanced) and site. It has to be noted that the RU is also called remote radio head or remote radio unit.

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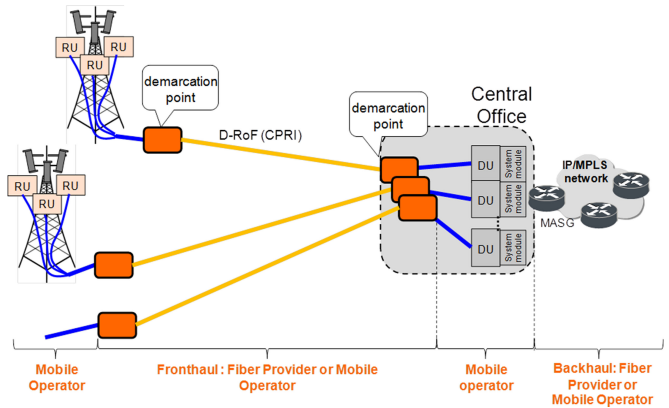


Fig. 1. Centralized RAN architecture with fronthaul and backhaul definition.

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

In this paper, after introducing C-RAN drivers, we will define fronthaul interfaces and then list all the requirements to be kept into account for building a fronthaul transport solution. On the basis of these requirements we will present some technical solutions and perspectives for medium term evolution including fronthaul inclusion in next generation passive optical network (NGPON2). Finally, open challenges for mobile evolution towards 5G will be hinted.

II. C-RAN DRIVERS

C-RAN is gaining great interest and some network operators have started its deployment because of its potentials.

A first driver comes from network operational teams who see centralized RAN as a site engineering solution due to increased rollout difficulties especially in dense urban areas. Indeed, as the DU is moved to a CO and only the RUs with compact power supply plus battery are left on site, the antenna site installation is simplified and footprint is reduced. These aspects as well as shorter time to install and to repair are expected to bring cost benefits. Moreover, adding new radio access technologies (RAT) on existing sites with very limited space becomes feasible.

A second driver is connected to the reduction of energy consumption made possible by C-RAN. A detailed analysis is provided in [4] based on existing infrastructures with already available RAN equipment, and shows that 40–50% energy savings can be achieved with respect to traditional macro-cell installation with backhaul. The biggest gains come to RU installation close to the antenna that avoids power dissipation on coaxial feeders and from the fact that cooling or air conditioning is no longer needed on the antenna site. Even higher power savings

should come with C-RAN phase 2 where DU pools will be capable to dynamically allocate processing resources according to traffic load.

A third driver is related to radio performances. Indeed, very low latency between DUs enables better performance in mobility and improved uplink coverage. Furthermore, C-RAN architecture enables the implementation of coordinated multipoint an LTE-A feature that is expected to provide higher capacity and improved cell-edge performance thanks to coordination between adjacent cells. Finally, in case of heterogeneous networks including macro and small cells, the fact that a same DU is shared between small cells and parent macro cell (same coverage area) will allow to better manage interferences.

The last driver comes from securitization. In traditional LTE deployments it is necessary to secure the backhaul link by implementing a secured protocol as IPSec that adds some overhead. In C-RAN, the DUs are located in a physically secured locations, thus IPSec is no longer needed.

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

III. FRONTHAUL INTERFACE

The fronthaul interface, i.e. the interface between RU and DU, has been defined by CPRI and OBSAI specifications for more than ten years, now.

The first version of CPRI specification [1] was released at the end of 2003 as the result of the cooperation between five radio equipment vendors. Further versions have been published until version six in 2013. CPRI initiative aims at defining a publicly available specification of the protocol interface between DU and RU. It deals with the physical layer and with layer 2, defining a frame that contains I and Q samples resulting of radio signal digitization, synchronization information and some control and management information.

The physical layer is typically optical fiber based on small form pluggable (SFP) connectivity. Moreover, CPRI is a serial constant bit rate interface. Currently CPRI is, by far, the most adopted specification for fronthaul interface implementation. However, some parts are left vendor proprietary, thus interoperability of equipment from different vendors is not possible.

The OBSAI is another industry initiative joining BS vendors, module and component manufacturers [2]. OBSAI aims at creating an open market for cellular BSs and hence substantially reducing the development effort and costs associated with creating new BS product ranges. OBSAI specifications cover the areas of Transport, Clock/Control, Radio and Base Band, as well as interfaces and conformance test specifications. OBSAI was first established in 2002 and, as for CPRI, successive versions have been released in the last years.

Finally, in May 2010, the European Telecommunications Standards Institute (ETSI) has initiated a new Industry Specification Group (ISG) called open radio interface (ORI) [5]. ORI goal is to develop an interface specification envisioning interoperability between elements of BSs of cellular mobile network equipment; release four is currently close to approval. The interface defined by the ORI ISG is built on top of the CPRI with

the removal of some options and the addition of other functions so to reach the full interoperability. A main difference between CPRI and OBSAI on one side, and ORI on the other side, is that the first two groups are composed only by equipment makers, whereas ORI members include also several network operators.

In spite of a few differences between CPRI, OBSAI and ORI, some key common aspects are the following:

- All BSs are split in two parts connected with fronthaul interface.
- The fronthaul most adapted physical layer is optical fiber.
- Fronthaul interface is implemented in SFPs that constitute the “de facto” connectivity in all RUs and DUs.
- Fronthaul interface presents a constant bit rate in uplink and downlink.

In the following we will make reference only to CPRI interface as it is the most common one.

IV. FRONTHAUL REQUIREMENTS

For building a fronthaul transport 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.

A. Radio Site Configuration

Radio sites can be classified in macro cells and micro or small cells.

Macro cells have in general three to six sectors. Additionally, for each sector, several RAT on different bands can be present e.g. 2G, 3G at 1800 MHz and/or 2100 MHz, LTE at 800 MHz and/or 2600 MHz. 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.

In case of micro/small cells the antennas are omnidirectional, thus having only one RU for each RAT and frequency band.

B. Data-Rate

CPRI is a constant bit-rate interface, whose data rates go from 614.4 Mbit/s up to 10.137 Gbit/s depending on RAT, carrier bandwidth and multiple input multiple output (MIMO) implementation [1], [6]. The CPRI data-rate results from the following calculation:

$$\text{Data rate} = M \times S_r \times N \times 2(I/Q) \times C_w \times C$$

where M is the number of antennas per sector, S_r is the sampling rate used for digitization (sample/s/carrier), N is the sample width (bits/sample), $2(I/Q)$ is a multiplication factor for in-phase (I) and quadrature-phase (Q) data, C_w represents the factor of CPRI control word and C is a coding factor (either 10/8 for 8B/10B coding or 66/64 for 64B/66B coding). CPRI specification provides sampling rates values corresponding to different RAT and channel bandwidths, as well as minimum and maximum values for uplink and downlink IQ sample width.

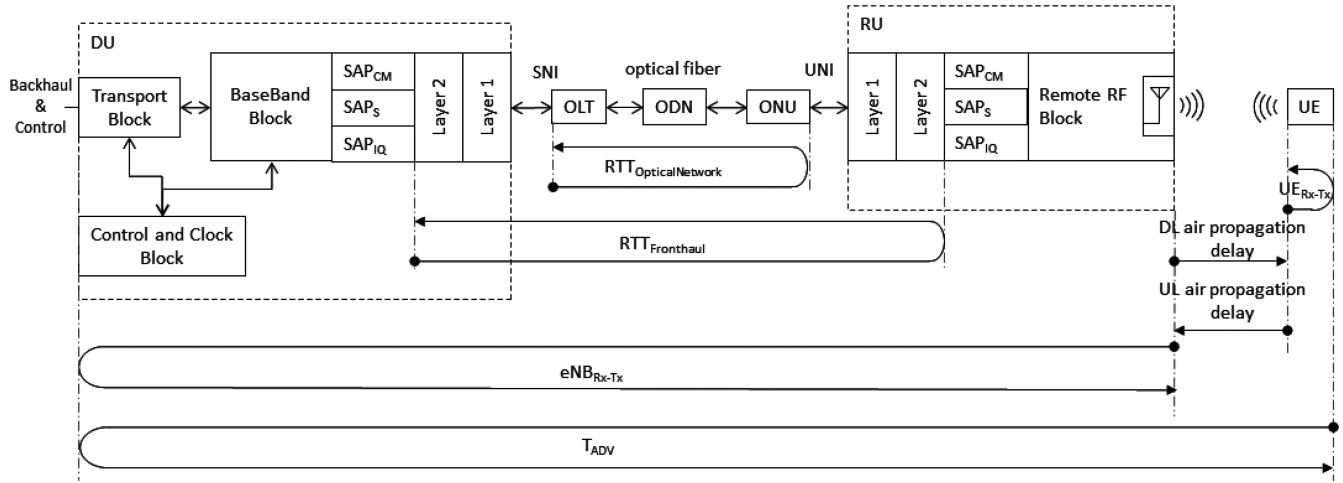


Fig. 2. Illustration of basic time definitions.

For one LTE sector with 20 MHz carrier and 2×2 MIMO $M = 2$, $S_r = 30.72$ MHz, $N = 15$, $C_w = 16/15$ and $C = 10/8$, thus leading to 2.4576 Gbit/s. LTE-A with 4×4 MIMO leads to 4.9152 Gbit/s CPRI rate per sector.

C. Data-Rate Performance

According to CPRI specification the bit error ratio (BER) on the fronthaul link must be lower than 10^{-12} . Under a global point of view, the fronthaul segment must not degrade the radio performance that is typically quantified in terms of error vector magnitude at the RU output [7]. For instance, for LTE radio signals, the maximum EVM shall not exceed 17.5% for QPSK modulation and 9% for 64 QAM.

D. Latency and Other Timing Parameters

The calculation of latency dedicated to fronthaul is not defined by RAN standards because this network segment is included inside an implementation dependent block which is the Evolved Universal Terrestrial Radio Access Network NodeB (eNB). We propose here a discussion about latency based on RAN requirements.

Before describing RAN timing requirements, we propose in Fig. 2, to define DU and RU functional split based on OBSAI and CPRI architecture overviews:

- DU is constituted of a transport block, a control and clock block, a baseband block and a fronthaul block. The last one is based on several Service Access Points (for Control&Management (CM), Synchronisation(S) and IQ data) plus two protocol layers for physical layer (Layer1) and the digital data link layer (layer2).
- RU is made up by the same fronthaul blocks and a remote RF block.

Specifically, the ETSI specifications for LTE and Evolved Universal Terrestrial Radio Access [8], [9] define several time differences:

- The UE_{Rx-Tx} (UE: User Equipment) time difference which is defined as the difference of the UE received timing of

downlink radio frame #i, defined by the first detected path in time and the UE transmit time of uplink radio frame #i. The reference point for the UE_{Rx-Tx} time difference measurement shall be the UE antenna connector.

- The eNB_{Rx-Tx} time difference which is defined as the difference of the eNB received timing of uplink radio frame #i, defined by the first detected path in time and the eNB transmit time of downlink radio frame #i. The reference points for the eNB_{Rx-Tx} time difference measurement shall be the Rx and Tx antenna connector.
- The timing Advance (T_{ADV}) should be defined as the time difference based on the sum eNB_{Rx-Tx} , UE_{Rx-Tx} , and Down-Link (DL) and UpLink (UL) propagation delay.

For UE_{Rx-Tx} , the timing measurement requirements [8] are:

- A resolution of 2 T_s (T_s is the basic time unit = $1/(15\,000 \times 2048)$ seconds ≈ 32.552 ns [10]), for a time difference less than 4096 and 8 T_s for a time difference equal to or greater than 4096 T_s up to 20 472 T_s ,
- An accuracy of ± 20 and ± 10 T_s for a downlink bandwidth ≤ 3 MHz and ≥ 5 MHz, respectively.

For eNB_{Rx-Tx} , no requirements exist due to the fact that this block is implementation dependent. Nevertheless, the T_{ADV} is defined with a resolution of 2 T_s for a time difference less than 4096 and 8 T_s for a time difference equal to greater than 4096 T_s and up to 49,232 T_s . The accuracy of T_{ADV} is not defined but the UE shall adjust the timing of its transmission (T_{ADV} adjustment delay) with a relative accuracy better than or equal to ± 4 T_s to the signaled T_{ADV} value compared to the timing of the preceding uplink transmission. The T_{ADV} command is expressed in multiple of 16 T_s . It is also defined that the UE shall adjust the timing of its uplink transmission timing at sub-frame $n + 6$ of a T_{ADV} command received in sub-frame n [8].

After this description of timing specification coming from RAN standards, we propose to discuss the Round Trip Time dedicated to fronthaul ($RTT_{Fronthaul}$) and to the optical network segment ($RTT_{OpticalNetwork}$). The optical network segment is natively considered by fronthaul interface (CPRI,

OBSAI and ETSI ORI) as a symmetrical passive optical fibers cable (one fiber uplink, one fiber downlink). Presently several investigations are considering the feasibility to transport this fronthaul interface by using traffic encapsulation (with or without compression) coming from optical transport network (OTN), Ethernet and PON. We propose in Fig. 2, a description of this optical network segment based on optical access architecture with an optical line terminal (OLT), a passive optical distribution network (ODN), and an optical network unit (ONU). The introduction of such transport method of fronthaul interfaces need to fix timing parameters.

We propose to first discuss the maximum latency including fiber cable for $RTT_{\text{Fronthaul}}$ and $RTT_{\text{OpticalNetwork}}$. This value must be strictly under the difference between the maximum value of T_{ADV} ($49\,232\,Ts \approx 1.6\,ms$) and the DU and RU processing time and air propagation delays. This value is still under clarification at standardization level and could reach $500\,\mu s$ including fiber propagation delay and equipment (OLT and ONU) delay as the maximum value for $RTT_{\text{Fronthaul}}$ and $RTT_{\text{OpticalNetwork}}$. A more stringent delay requirement could be preferred when fronthauling legacy BS equipment is used with typically $200\,\mu s$.

A second part of the discussion considers the $RTT_{\text{Fronthaul}}$ accuracy. We are not considering the $RTT_{\text{OpticalNetwork}}$ because only $RTT_{\text{Fronthaul}}$ value is reported to the DU (in the case that $RTT_{\text{Fronthaul}}$ calculation is based on the report by OLT of $RTT_{\text{OpticalNetwork}}$, we must have the same accuracy). This $RTT_{\text{Fronthaul}}$ accuracy must be strictly below the $\pm 4\,Ts$ accuracy that UE shall adjust the timing of its transmission (T_{ADV} adjustment delay). CPRI specification (requirement n°21) proposes accuracy of $\pm Ts/2$ which corresponds to $\pm 16.276\,ns$. In CPRI specification, this calculation introduces the T_{ADV} resolutions which are $2\,Ts$ or $8\,Ts$ in function of time duration. The links between T_{ADV} resolution and $RTT_{\text{Fronthaul}}$ accuracy require further work for consolidation of this value.

A third part of the discussion concerns the potential time asymmetry of the fronthaul segment between downlink and uplink. This time asymmetry is characterized by:

- optical fiber cable length difference when two fibers cable are used to achieve Up and Down link (7 m of standard single mode fiber corresponds approximatively to 34 ns),
- the difference of wavelength propagation delays when a bidirectional transmission is used (typically $1.3\,\mu m$ and $1.55\,\mu m$ wavelength duplex provide $\sim 33\,ns$ time difference over 20 km of standard single mode fiber),
- the difference of processing time (including functions as time multiplexing, encapsulation, compression, other...) at OLT and ONT,
- the difference of processing time of Layer 1 and 2 of fronthaul at DU and RU.

All time differences coming from processing time could be solved with adequate buffer and bandwidth allocation to provide symmetric traffic flow. The fiber cable difference and wavelength delays could also be compensated by either OLT and ONU or fronthaul Layer2 with specific measurement and management methods. In order to fix a value for this asymmetry, we

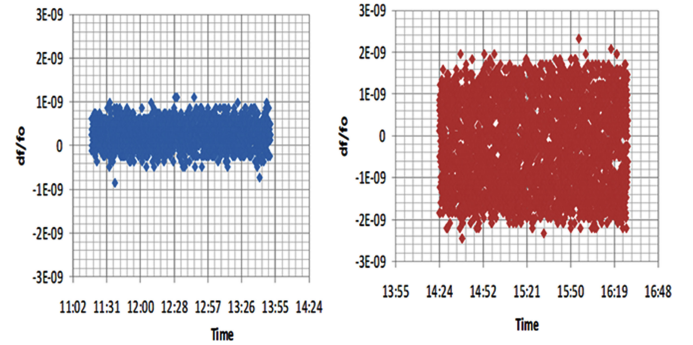


Fig. 3. On the left: frequency deviation measured on RU radio output for reference fronthaul. On the right: frequency deviation measured on RU radio output with sinusoidal jitter @ 1 MHz 0.5 UI and random jitter 0.49 UI added on the fronthaul.

propose that fronthaul time asymmetry must not affect the UE positioning error (localization) which is based on the time report of reference signal time difference measurements (RSTD) with a resolution of Ts for an absolute value of RSTD under 4096 and 5 Ts for absolute value of RSTD greater than 4096 Ts [8] and an accuracy from ± 5 to $\pm 21\,Ts$ in function of positioning reference signals bandwidth and intra- or inter-frequency mode. We propose to consider that time difference between up and down-link for fronthaul and optical network must be strictly under the minimum accuracy of 5 Ts . A value of $Ts/2$ could be discussed in future works.

The last part of the fronthaul latency discussion concerns the longer term time variation (wander) of this time delay due for instance to temperature variation on optical fiber cable length. A time interval error should be defined for the fronthaul and optical network segment. CPRI specification proposes to fit the specification of IEEE 802.3. For high speed time variation (jitter), the next sub-section covers this issue.

E. Synchronisation and Jitter

The clock is generally provided to the DUs either by global positioning system or by the backhaul link e.g. using Synchronous Ethernet. Then, the RU clock for frequency generation is synchronized to the bit clock of the received CPRI signal, thus behaving as a slave of the DU. 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 $\pm 50\,ppb$ (parts per billion). Inside this overall value, the CPRI link contribution is limited to $\pm 2\,ppb$ [1], [11]. Phase and time synchronization will impose further requirements on the fronthaul link.

Moreover, maximum values for tolerated deterministic, random and sinusoidal jitter at the transmitter and at the receiver are specified in [1].

Fig. 3 shows an example of jitter impact on frequency deviation. The figure on the left reports frequency deviation measured at the output of a commercial LTE RU at $f_0 = 2.6\,GHz$ for a reference configuration with dark fiber between RU and DU. The figure on the right shows the same measurement when sinusoidal and random jitter are introduced on the fronthaul using

the setup presented in [11]. The jitter measured at receiver respects CPRI specification, thus we would have expected that also CPRI frequency deviation was respected, but the effect on frequency deviation is considerable and the maximum value tolerated by CPRI specification is attained.

F. Fronthaul Monitoring

When building a fronthaul transport solution, it is important to consider also that it must include natively OAM aspects. In other terms, the fronthaul must be monitored in order to detect any problem on the link. This requirement is even stronger in regulated countries where 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 Fig. 1. Different levels of service level agreement 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.

The fronthaul traffic encapsulation over transport framing, discussed in Section D, could natively offer the OAM in parallel of fronthaul transport. Other solutions could be proposed based for example on pilot tones to achieve an OAM channel over native fronthaul transmission.

G. Business and Local Requirements

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.

V. FRONTHAUL TRANSPORT SOLUTIONS

Fronthaul solutions can be classified in active and passive ones [7]. An active solution means that the CPRI traffic is encapsulated for example by means of OTN or other protocols and multiplexed on the fronthaul. In this case, the demarcation point at the cell 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.

A. Dual Fiber Coarse Wavelength Division Multiplexing (CWDM)

For short term fronthaul deployments based on 2.5 or 5 Gbit/s CPRI interfaces, passive CWDM plus monitoring appears as a good option because it is simple and cost effective as well as

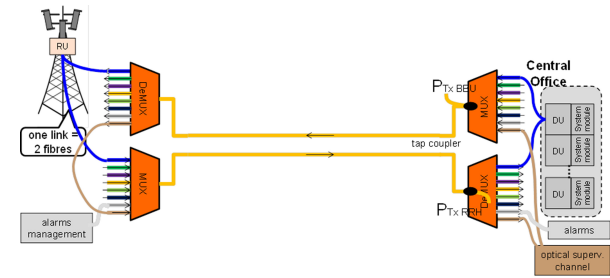


Fig. 4. Fronthaul based on CWDM with two fibers including monitoring and remote management of on-site alarms.

perfectly adapted to outdoor deployment, highly reliable and with reduced footprint. Eighteen CWDM channels with 20 nm channel spacing are defined by ITU-T. An example of implementation is shown in Fig. 4. CWDM SFPs are used in each RU-DU pair.

One channel is devoted to link supervision by measuring the received optical power at the CO after having inserted a loop back in the cell site demarcation point. 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 fiber to the home (FTTH) deployment, in terms of fiber infrastructure reuse. Indeed FTTH is based on single fiber ODN.

B. CWDM-Like Solutions for Single Fiber ODN

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 called single wavelength single fiber (SWSF) and uses the same CWDM wavelength for transmission and reception thanks to an optical splitter. An isolator is placed after the laser diode and a CWDM filter is placed before the photodiode. However, this transceiver is strongly affected by reflections and has poor performance.

Signal reflection impact can be reduced by using APC connector on the SWSF SFP, but this is not practically feasible.

Another way to reduce reflection impact is by SWSF SFP with Reflection Immune Operation that recognizes and cancels reflected signals [12].

A third option consists in dividing each 20 nm CWDM channel in two sub-channels that are used for transmission and reception [13]. This solution is called cooled single channel (CSC) and provides performances equivalent to standard dual fiber SFP. Moreover, it is compatible with industrial temperature range and scalable up to 10 Gbit/s CPRI.

Fig. 5 shows BER measurements performed on 20 km fronthaul links as a function of the received power for different types of SFP. As expected, it can be observed that SWSF has the worst

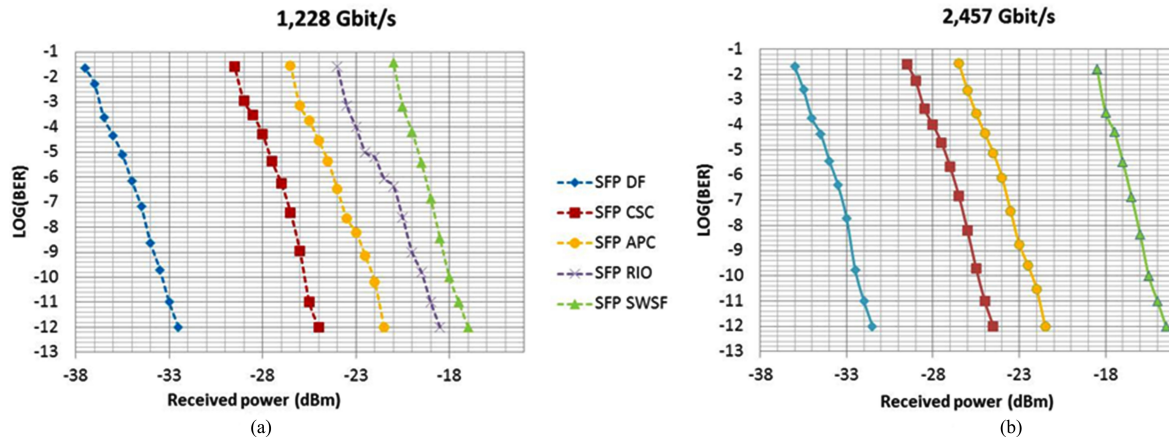


Fig. 5. Measured BER as a function of received power over a 20 km fronthaul link for different SFP types. (a) for CPRI 2 at 1.228 Gbit/s, (b) for CPRI 3 at 2.457 Gbit/s. DF: reference dual fiber SFP. CSC: cooled single channel. APC: SFP SWSF with angled connector. RIO: SFP with reflection immune operation.

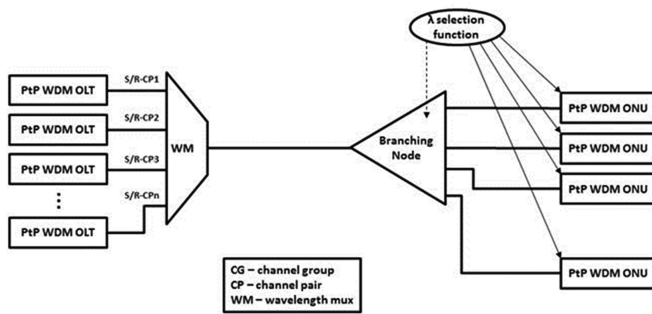


Fig. 6. Point to point WDM PON implementation (source [15]).

behavior with link budget limited to 10 dB (at BER 10^{-12} with Tx power -7 dBm) due to reflection issues. With RIO and with angled connector, the effect of reflections is reduced, but the link budget is still limited. Only SFP CSC is completely unaffected by reflections and can achieve a 24 dB link budget.

Besides finding solutions to implement fronthaul on a single fiber ODN, it is also important to underline that currently available out of band monitoring solutions for the fronthaul link are not compatible with a single fiber ODN.

C. Dense WDM (DWDM) Solutions

DWDM offers better spectral efficiency than CWDM with typically 100 GHz (0.8 nm) or 200 GHz (1.6 nm) channel spacing. Moreover, it is possible to insert DWDM channels in a CWDM infrastructure thus allowing for a smooth migration in case of higher density antenna sites.

Alternatively, a pure DWDM fronthaul network could be an option, but the need for low cost transmitters and the industrial temperature requirement still need to be assessed.

The cost of DWDM transmitters could be reduced by implementing an identical transmitter in each network termination whatever the targeted wavelength, as in this case mass production could be achieved. This colorless transmitter will also solve the inventory management problem to associate RU-DU links. Several colorless systems have been studied [6]. Some

of them have reached industrial maturity at 1.25 Gbit/s but are not easily scalable to higher bit-rates, others for example based on tunable lasers can achieve 10 Gbit/s transmission, but control and management of the wavelength can be costly and complex especially in case of outdoor temperature variation.

Another option could be also DWDM based on self-seeded reflective semiconductor optical amplifier [14]. However existing work is based only on Bit Error Ratio measurements, 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.

D. Fronthaul in NGPON2

Fronthaul has been identified by full service access networks as one of the drivers for Next Generation access optical networks.

NGPON2 will be mainly based on a time wavelength division multiplexing passive optical network. Annex A in [15] describes as an option a point to point WDM PON implementation with wavelength tunability including natively fronthaul applications as represented in Fig. 6.

In NGPON2 framework point-to-point WDM for fronthaul implementation could use only Point to point framing or auxiliary management and control channel or both of them.

TWDM NGPON2 could also support fronthaul, but with a big challenge to meet the latency requirement: a fixed bandwidth allocation could be a solution.

VI. OPEN CHALLENGES TOWARDS 5G

A lot of work is currently ongoing to lay the foundation of 5G, the next generation mobile and wireless communication system that according to 3GPP, could be implemented by 2020. With respect to 4G, 5G should support [16]:

- thousand times higher mobile data volume per area;
- ten to 100 times higher number of connected devices;
- 10 to 100 times higher typical user data rate;

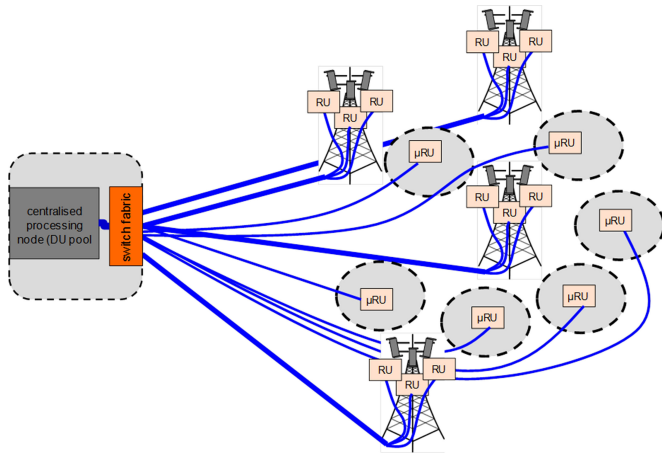


Fig. 7. Example of wide C-RAN for heterogeneous networks including a switch fabric at DU pool level.

- ten times longer battery life;
- five times reduced End-to-End latency.

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

Indeed, 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. 7. 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. Research is ongoing to understand if such a switch can be CPRI based or if it could be possible to leverage on existing Ethernet switch. This opens the way also to studies on the feasibility of CPRI over Ethernet and on the compromises that this would require especially to meet fronthaul latency and synchronization requirements.

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