Rethink Fronthaul for Soft RAN

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ABSTRACT

In this article we discuss the design of a new fronthaul interface for future 5G networks. The major shortcomings of current fronthaul solutions are first analyzed, and then a new fronthaul interface called next-generation fronthaul interface (NGFI) is proposed. The design principles for NGFI are presented, including decoupling the fronthaul bandwidth from the number of antennas, decoupling cell and user equipment processing, and focusing on high-performance-gain collaborative technologies. NGFI aims to better support key 5G technologies, in particular cloud RAN, network functions virtualization, and large-scale antenna systems. NGFI claims the advantages of reduced bandwidth as well as improved transmission efficiency by exploiting the tidal wave effect on mobile network traffic. The transmission of NGFI is based on Ethernet to enjoy the benefits of flexibility and reliability. The major impact, challenges, and potential solutions of Ethernet-based fronthaul networks are also analyzed. Jitter, latency, and time and frequency synchronization are the major issues to overcome.

INTRODUCTION

With the maturity and wider deployment of fourth generation (4G) networks, future 5G technologies have become a research focus. As industrial progress accelerates, some achievements have been presented [1, 5]. Several white papers have been published by various organizations such as Next Generation Mobile Networks (NGMN), IMT-2020, Mobile and Wireless Communications Enablers for 2020 Information Society (METIS), 5G Infrastructure Public-Private Partnership (5G PPP), and others, while some proofs of concepts (PoCs) have been developed to allow people to have a quick grasp on 5G. Although the understanding of 5G may still differ among different people, there is a wide consensus that 5G should be a software defined network with the benefits of flexibility, quicker time to market, unified management, and flourishing applications [1]. Network functions virtualization (NFV) [2] is a strong technology candidate toward this end, and cloud radio access network (C-RAN) [3, 4] is an NFV instance on the RAN side to achieve soft RAN. First proposed by China Mobile [3], C-RAN centralizes baseband processing units and virtualizes them into a resource pool. C-RAN has been viewed as a promising 5G RAN architecture. In addition to softness, C-RAN could also bring operators such benefits as quicker network deployment, system performance improvement, and energy savings.

On the road of C-RAN realization, the fronthaul (FH) issue has been one of the biggest challenges. An FH connection is a link between a baseband unit (BBU) and a remote radio head (RRH). Typical FH interfaces include the common public radio interface (CPRI), open base station architecture initiative (OBSAI), and open radio interface (ORI). The data rate of the FH connection for Long Term Evolution (LTE) is on the order of gigabits per second. The common FH solution in C-RAN is to use dark fiber. Due to the high FH data rate, centralization requires consumption of a number of fiber cores, which are scarce and not easy to afford. Although other transport technologies such as wavelength-division multiplexing (WDM) and optical transport network (OTN) could save fiber consumption, the cost of the introduction of additional transport equipment makes economic viability a concern of operators. Because of the concern regarding FH cost, some operators are still not very convinced of the merits of C-RAN deployment. Therefore, enabling large-scale C-RAN deployment in 5G requires reducing the FH bandwidth.

Current FH interfaces could also raise new issues for C-RAN in an NFV environment. C-RAN is supposed to run on general-purpose platforms (GPPs) consisting of standard IT servers, storage, and switches. However, the GPP platform does not provide an FH interface for telecom applications. To support FH, either a new interface should be created on the GPP platform or an adapter card is needed, both complicating the system and introducing additional cost. It would be desirable for the 5G FH interface to be based on existing GPP interfaces to maximize efficiency and save cost.

In addition, scalability issues exist for today's FH technology to support widely discussed 5G technologies, including large-scale antenna systems (LSASs), coordinated multipoint (CoMP)

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processing, and so on. Take LSAS as an example. It is possible that a 5G RRH could be equipped with 64 or even 128 antennas. With LTE, the FH bandwidth will rise to 100 Gb/s, at which point it is unaffordable. It is clear that the impact of the number of antennas on FH should be minimized to the greatest extent possible.

The industry is gradually realizing the deficiencies of current FH solutions as well as their importance to 5G, and making efforts on improvements. In NGMN, schemes of the BBU-RRH function split are analyzed, aiming to reduce the FH bandwidth to facilitate C-RAN deployment [5]. ORI is studying compression technology to reduce the CPRI data rate. The CPRI Forum has begun the discussion on radio over Ethernet, the idea of which is to use Ethernet to transport the CPRI stream, while in the IEEE, the IEEE 1904.3 Task Force was founded recently, targeting the design of CPRI encapsulation on Ethernet packets [6, 7]. In addition, IEEE 802.1 TSN decided very recently to initiate the development of a potential new work item on time-sensitive networking for FH. The IEEE 1588 Working Group is also considering adding optional specialized solutions to the next edition of IEEE 1588 to enable enhanced synchronization accuracy for FH.

Despite these continuous efforts, from China Mobile's perspective we think that much more effort is required. The current improvements have not touched the root of the FH itself. A new FH interface is required to better support C-RAN large-scale deployment, NFV realization in baseband virtualization, as well as serving other 5G key technologies.

In this article, we share our ideas on the future FH, the called next-generation FH interface (NGFI). From CMCC's perspective, a desirable NGFI should have dynamic bandwidth with traffic variation, be antenna-independent and packet-based, and support collaborative technologies. We describe the shortcomings of CPRI and the definition of NGFI. We elaborate on the design principles of NGFI, while the major impact and challenges of FH transport networks are presented, followed by conclusions.

DEFINITION OF NGFI

In this section, we describe our view on what the NGFI should look like and the major advantages we expect from such an interface redesign. In this and the remaining sections, we use CPRI as an example of traditional FH protocols since it is the most widely used and the basis for other FH interfaces such as ORI.

Figure 1 shows a C-RAN network architecture combining the ideas of software defined network (SDN) and NFV, which consists of a radio cloud center (RCC), an NGFI-based FH network, and new types of RRHs. An RCC provides a cloud platform consisting of standard IT servers, storage, and switches. In an RCC all the radio access network functions appear as software applications running in virtual machines (VMs). Furthermore, in an RCC, the control plane and user plane can be separated based on the wireless performance requirements. Under this network architecture, an NGFI is proposed to connect an RCC and new RRHs. Compared to traditional RRHs, a new RRH contains not only radio processing but also partial baseband processing. What kind of baseband processing should be included in an RRH is discussed later.

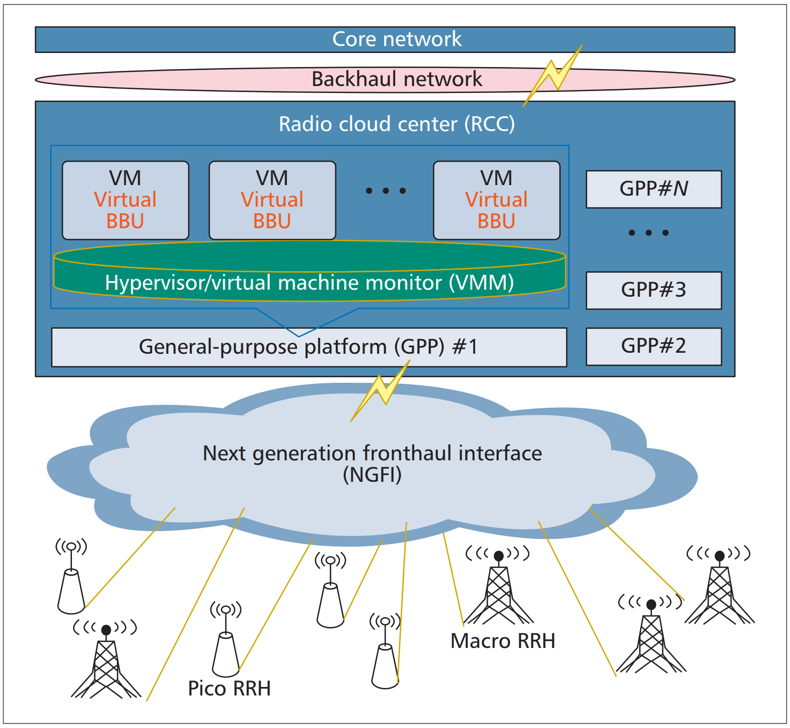

Figure 1. C-RAN network architecture with NGFI.

REVISITING CPRI

The CPRI helps separate the BBU and RRH to enable the deployment of distributed base stations. Although in traditional networks the CPRI is mainly deployed with short distances, usually on the order of several meters or several hundred meters, it can support up to 40 km between the BBU and RRH. CPRI has been working well for traditional mobile networks including 2G, 3G and 4G. With networks evolving to 5G, the following three factors make CPRI more and more unsuitable to accommodate such an evolution:

- Constant data rate due to synchronous digital hierarchy-based (SDH-based) transmission mode [6]
- Fixed one-to-one correspondence between RRH and BBU
- Sampling I/Q data rate dependent on the number of antennas

First, mobile traffic varies in the temporal dimension. For example, the data traffic in an office area is high in the daytime but plummets at midnight. For dense urban areas, the tidal wave effect is noticeable. However, the CPRI data stream is SDH-like [6], which means that it is constant regardless of the change of traffic even when there is no traffic at all. This then leads to low utilization efficiency.

Second, with CPRI an RRH has a one-to-one correspondence to a BBU. The relationship is configured offline. It may cause concern in the context of C-RAN. In C-RAN, the BBUs are

Site 1	Peak			Valley		
	RB (%)	BH (Mb/s)	Duration	RB (%)	BH (Mb/s)	Duration
DL	83.54	175	15: 30~ 16: 00	0.72	0.96	0: 30~ 6: 00
UL	20.19	12.5	15: 00~ 15: 15	3.02	0.23	1: 30~ 6: 30

Table 1. Statistical data of traffic load of site 1.

centralized and virtualized in a pool. Reliability becomes extremely important as each pool takes care of thousands of users. Therefore, for the sake of protection, it would be desirable if in C-RAN, one RRH could be automatically switched to another BBU pool. Current CPRI, however, does not support such flexible and automatic rerouting.

Finally, the CPRI bandwidth is dependent on the number of antennas. As the number of antennas increases, the CPRI data rate increases in proportion. This could become a major hindrance for CPRI's applicability in 5G as far as multiple-antenna technologies are concerned.

Based on the analysis above, we believe that a new FH interface is required to better support the 5G evolution.

NEXT-GENERATION FRONTHAUL INTERFACE

The purpose of designing a new FH interface is to facilitate C-RAN deployment, to make it compatible with GPP platforms and scalable enough to support the evolution to 5G.

We define the new FH as the NGFI between the BBU and RRH with the following four features:

- Its data rate should be traffic-dependent and therefore support statistical multiplexing.
- The mapping between BBU and RRH should be one-to-many and flexible.
- It should be independent of the number of antennas.
- It should be packet-based, that is, the FH data could be packetized and transported via packet-switched networks.

A traffic-aware FH interface could fully leverage the tidal wave effect of mobile networks so that the FH data rate is variable with traffic change. This way the FH transmission efficiency is improved. With a reduced average data rate, it will increase the likelihood of FH transport networks to deploy C-RAN. The antenna-independent feature ensures that the NGFI can support 5G antenna technologies. The packet-based feature makes it possible to use Ethernet to transport FH data. The benefits would be manifold. First, an Ethernet interface is the most common interface on standard IT servers, and the use of Ethernet makes C-RAN virtualization easier and cheaper. Then Ethernet can fully make use of the dynamic nature of NGFI to realize statistical multiplexing. The flexible routing capability could also be used to realize multiple paths between a BBU pool and an RRH.

With the novelty of NGFI, it is clear that it will have a great impact on the FH transport network. In the following sections, we elaborate on our design principles for NGFI, and analyze the impact and challenges confronting FH transport network design.

RETHINKING THE BBU-RRH FUNCTION SPLIT

Traditionally, the baseband-related functions are processed by the BBU while the RRH processes radio frequency related functions. It is this simple partitioning that leads to the shortcomings of CPRI, as mentioned above. Therefore, the NGFI design should start with a paradigm shift by rethinking and redesigning the function split between BBU and RRH. Moreover, the function split between BBU and RRH may be different according to the bandwidth and latency of FH, which is adaptive to different scenarios.

DECOUPLING THE FH BANDWIDTH FROM THE NUMBER OF ANTENNAS

The air interface bandwidth per carrier on 2G, time-division synchronous code-division multiple access (TD-SCDMA) and time-division LTE (TD-LTE) are 0.2 MHz, 1.6 MHz, and 20 MHz, respectively. Correspondingly, FH transport bandwidth per carrier is 30 Mb/s, 400 Mb/s, and 10 Gb/s [8], respectively. At the same time, FH is facing a bandwidth explosion, considering the rapid traffic growth in 5G (potentially 1000× by 2020). Compared to the air interface bandwidth, the existing FH interface transportation efficiency is low. One of the most important reasons is that FH bandwidth is proportional to the number of antennas. In order to increase transport efficiency, a BBU/RRH function split scheme should enable NGFI to decouple FH bandwidth and the antenna number.

Taking TD-LTE and a large-scale antenna system (LSAS) as an example, an 8-antenna TD-LTE carrier FH bandwidth is 10 Gb/s based on the current BBU/RRH function split. If it is a 128-antenna LSAS system, a TD-LTE carrier FH bandwidth will increase to 160 Gb/s. Thus, the existing FH faces a big challenge with the increase of the number of antennas. In order to reduce the bandwidth, one potential idea is to redesign the BBU/RRH function split, that is, the antenna related functions should be moved to the RRH and the non-antenna related functions should remain on the BBU. In particular, in order to phase out the effect of the number of antennas, it is proposed that antenna related functions (e.g., downlink antenna mapping, fast Fourier transform [FFT], channel estimation, equalization) should be moved from the BBU to the RRH. It is shown that an LTE carrier FH bandwidth may decrease on the order of 100 Mb/s no matter how many antennas are used [9]. Therefore, FH bandwidth will decrease significantly if the BBU/RRH function split can decouple non-antenna-related processing and antenna-related processing.

DECOUPLING CELL/UE PROCESSING

Dynamic variation is a major feature of wireless traffic. The tidal wave effect is obvious in many wireless deployment scenarios such as residential, office, and commercial districts. Moreover, the traffic load of most areas is usually in the valley between late night and early morning.

In order to quantify wireless traffic features, a TD-LTE traffic investigation on a commercial LTE network was done via network monitoring systems. There were six base station sites in the investigation, each having at least three carriers. Two of them are indoor distributed systems while the others are outdoor macro base station sites. The investigation period was 7 days during which the traffic load was sampled and collected by network monitoring systems every 15 minutes.

In Table 1, Table 2, and Table 3, the statistical traffic load of two TD-LTE base station sites is shown where DL means downlink and UL means uplink. Site 1 is an indoor site and site 2 is an outdoor site. In the table, RB means resource block utilization, which is expressed as a percentage. BH means backhaul transportation bandwidth, which is in the unit of megabits per second. The duration of peak/valley is the absolute time in 24 hours. The duration of average load is the time length during which traffic load distributes in [average load–1%, average load+1%]. Based on the statistical data, several traffic load features were observed:

- The tidal wave effect is obvious in the test districts, where the traffic load is almost zero for 12 hours.
- Even when the site is at peak status the RB usage is not high. The duration of a site at peak status is short, usually not exceeding 30 minutes.
- The probability that different sites are simultaneously in peak status is almost zero.
- When the site is at valley status the RB usage is low and the duration is long, usually exceeding two hours.
- Different sites are frequently in valley status at the same time. Moreover, the overlapping time is long among different sites.
- Most of the time the traffic load stays at the average level, which is low.

Based on the above observations, it is clear that constant-rate FH transport does not match the mobile traffic features, which results in a waste of resources. To address this issue, we first observe that the existing baseband processing can be divided into cell processing and user equipment (UE) processing. Cell processing is irrelevant to traffic load and is fixed no matter how many UEs are active. Some examples of such processing units in LTE include inverse FFT (iFFT)/FFT, cyclic prefix (CP) addition/removal, cell-specific reference signal/primary synchronization signal/secondary synchronization signal (CRS/PSS/SSS) generation, and physical broadcast channel (PBCH) processing. It is therefore proposed to move these cell processing functions from the BBU to the RRH, that is, decoupling the cell and UE processing.

If cell processing is moved from the BBU to the RRH, the FH bandwidth will be lower and load-dependent. The load-dependent feature gives an opportunity to exploit the statistical multiplexing gain when it comes to FH transport network design for C-RAN deployment. Thanks to statistical multiplexing, the bandwidth needed for transport of a number of FH links in C-RAN could be greatly reduced, thereby diminishing the cost.

Site 2	Peak			Valley		
	RB (%)	BH (Mb/s)	Duration	RB (%)	BH (Mb/s)	Duration
DL	20.38	144	13: 30~ 13: 45	0.70	0	21.00~ 8.15
UL	47.06	34.2	14: 00~ 14: 15	3.00	0	21.00~ 8.15

Table 2. Statistical data of traffic load of site 2.

	Site1			Site2		
	RB (%)	BH (Mb/s)	Duration (hours)	RB (%)	BH (Mb/s)	Duration (hours)
DL	3.29	3.95	4.3	1.27	2.20	22
UL	4.22	0.31	15	4.00	0.40	22

Table 3. Average load distribution.

Cell/UE processing decoupling can further help reduce power consumption and enhance network reliability. This is because cell basic coverage signal processing is a kind of cell processing. Therefore, cell basic coverage will be provided by the RRH if cell processing functions are moved from the BBU to the RRH. On one hand, BBU software can be switched to a dormant state to save power when there is no active UE. On the other hand, RRH is able to provide continuous air interface coverage, even when a BBU breaks down. This way, it provides sufficient time for BBU fault processing.

FOCUSING ON HIGH-PERFORMANCE-GAIN COLLABORATIVE TECHNOLOGIES

CoMP has been viewed as one of the important 5G technology candidates to improve system performance, which can be divided into two classes: medium access control (MAC) layer coordination and physical layer coordination. For example, collaborative scheduling is one of the MAC layer coordinated mechanisms. Joint reception (JR) and joint transmission (JT) are physical layer coordinated technologies. The design of NGFI should take into account support for CoMP. The above two principles lead to a low-bandwidth traffic-dependent FH. In the meantime, some physical-layer-coordinated technologies are difficult to implement since some collaborative information has be processed and terminated by an RRH. Fortunately, it is found that the performance gain of JR/JT decreases significantly as the number of antennas increases

Network load	JT/CoMP	CS/CoMP	CoMP/Total
20%	20.04%	79.96%	42.02%
50%	18.09%	81.91%	34.43%
70%	20.89%	79.11%	54.33%
100%	24.89%	75.11%	47.31%

Table 4. Utilization factor of JT and CS.

[10]. Moreover, it is also found that MAC-level collaborative technologies can bring comparable performance gains with lower complexity, easier implementation, and fewer constraints.

In order to verify this, a CoMP field trial was conducted in 2014 in which two CoMP schemes including JT and CS were examined and compared. The testing zone was a central business district including around 7000 active user equipments (UEs), which is a typical CoMP test scenario. It was covered by 35 base stations with different antenna heights in which inter-cell interference is serious because of the high-ratio overlapping area.

Test results show that cell edge UE throughput increased by 127.45~173.65 percent when the serving cell reference signal received power varied from –88 dBm to –106 dBm. Table 4 shows the utilization factor of JT, CS, and the CoMP application. In Table 4, CoMP/Total means the utilization factor of CoMP, which is defined as the ratio of the number of CoMP transmission time intervals (TTIs) to the total number of test TTIs. Similarly, JT/CoMP and CS/CoMP are defined as the ratio of the number of JT and CS TTIs to that of CoMP TTIs, respectively.

From Table 4, it is found that the network load growth results in a small reduction of CS usage. For example, when the network load increases to 100 percent, the usage ratio of CS is still around 75 percent, similar to other cases. The usage of JT is only around 25 percent, much lower than CS. It is therefore fair to say that most of the performance gain is contributed by CS. Compared to JT, CS does not need complex matrix computing. It is easier to implement CS with current base station equipment. On the contrary, JT performance is influenced by antenna calibration accuracy, channel estimation accuracy, and channel variation speed, all requiring high FH bandwidth.

The test results demonstrated that MAC-level collaborative technologies could solve most network interference. Therefore, NGFI design should focus on high-performance gain collaborative technologies rather than all the collaborative technologies. This principle provides guidance on how to make a trade-off between wireless and FH performance.

RETHINKING FH TRANSPORT

Earlier, it was pointed out that a desirable FH interface should be packet-based, which makes it easy to transmit by packet-switched networks, especially Ethernet. This could make full use of the advantages of Ethernet to achieve multipoint-to-multipoint connection, statistical multiplexing, flexible routing, and so on. However, the adoption of Ethernet also introduces new challenges. In this section, we analyze such challenges and propose potential solutions.

RELIABLE SYNCHRONIZATION ON PACKETIZED NETWORKS

Time-division multiplexing (TDM) systems require strict synchronization that includes two aspects: frequency and time (or phase). For TD-SDMA and TD-LTE, the accuracy of frequency synchronization should be in the range of ±0.05 ppm, while the accuracy of time synchronization should be in the range of ±1.5 μs [11].

In CPRI three types of data including wireless protocol data, synchronization data, and control and management data are packaged together and transmitted in TDM mode. Upon receiving the CPRI frames, the clock and data recovery (CDR) circuit of an RRH can extract the frequency information to achieve frequency synchronization. Meanwhile, the CPRI transport time is nearly constant and can be measured by the BBU. Based on the measurement, the timing between the BBU and RRH can be configured in advance. With the timing information extracted from CPRI frames, time synchronization at the RRH can be achieved.

For Ethernet–based NGFI, as opposed to CPRI, the transport time of FH data is no longer constant due to the packet-switched nature of Ethernet. As a result, frequency and time synchronization between the BBU and the RRH potentially becomes difficult. To address this issue, one potential solution is to use a synchronous Ethernet (SYNC-E)/1588v2 hybrid network. The working principle of SYNC-E is similar to CPRI as both use 8B/10B encoders in the physical layer. Therefore, high-accuracy frequency synchronization can still be achieved [12].

To achieve time synchronization, a potential solution is to use 1588v2, which is a high-accuracy time synchronization protocol based on packetized networks. In order to meet the high time synchronization requirement, a 1588v2 module should be added in both the BBU and RRH. At present, the accuracy of 1588v2 is on a magnitude order of 100 ns for one hop [13]. The major issue of 1588v2 when adopted in RRHs is the time hopping issue since an RRH only obtains time offset information between it and the BBU. Time hopping could result in discontinuous transmission on RRHs, which is intolerable for mobile communications. One potential solution is to use a frequency adjustable oscillator to calibrate time in the RRH, which can adjust the oscillator frequency gradually to ensure a continuous time variation.

When it comes to support for MIMO or TX diversity transmission technologies, the time synchronization requirement is stricter, and should be in the range of ±65 ns [14]. This imposes a big challenge for Ethernet-based NGFI even when 1588v2 is leveraged. More efforts are needed to figure out how to meet the ±65 ns time synchronization requirement such as deploying a GPS antenna on the BBU, improving the accuracy of timestamps, increasing clock frequency, and optimizing the deviation adjusting algorithms.

RELIABLE DATA TRANSPORT ON PACKETIZED NETWORKS

In Fig. 2, an example of FH topology of a C-RAN system is shown. All the RRHs are connected to a BBU pool through a ring Ethernet network. There are multiple routes between the BBU and RRH to help to enhance network reliability. When one of the routes fails, FH packets can be transported through another route.

FH downlink data is encapsulated with the Ethernet header in the BBU and de-encapsulated from the Ethernet header in the RRH and vice versa for the uplink. In Fig. 2, the structure of NGFI-supporting Ethernet packet is proposed. It includes the traditional Ethernet header, the NGFI header, and the payload. The source MAC address, destination MAC address, and packet type are filled in the traditional Ethernet header. The packet type here is the new NGFI type to distinguish NGFI packets from other packets. The NGFI header consists of the NGFI packet sub-type, the packet length, and the reserved field for protocol extension. There could be at least two NGFI packet sub-types, one for wireless data, and the other for control and management data. For the control and management types, it may include the link delay test, link status monitoring, RRH configuration, and RRH status report.

In CPRI jitter is negligible, while it is common and unavoidable in Ethernet-based NGFI since all the packets are processed in every network node based on the store-and-forward pattern. Therefore, transport latency fluctuates over a range. In order to meet RRH air interface timing, an appropriate circular buffering may be needed in the RRH. On one hand, data packets can be sorted in order. On the other hand, data is continuously sent to the air interface because the transport jitter can be isolated by the buffer.

The maximum transport latency is another big factor influencing FH transport performance. Take China Mobile's current packet transport network (PTN) as an example. For PTN equipment, the processing time of one hop is 50 μs [15]. A typical PTN ring consists of 6 nodes (hops) and has 20 km length. The transmission time of fiber for 20 km is 100 μs. In the case of 6 hops, the total delay is 100 + 50*6 = 400 μs. However, a RAN has strict timing requirements. For example, it is specified by the Third Geeration Partnership Project (3GPP) that in LTE from the instant a RRH receives a frame from UE, within 3 ms it must respond by beginning to transmit the responding DL frame. The 3 ms time budget is consumed by BBU processing, RRH processing, and FH transportation, which includes the transmission latency on fiber and processing latency by FH nodes. The more time the BBU and RRH processing takes, the less budget can be allocated to FH transport. As a result, the maximum allowable transport latency for FH networks requires co-design from both the wireless and transport perspectives.

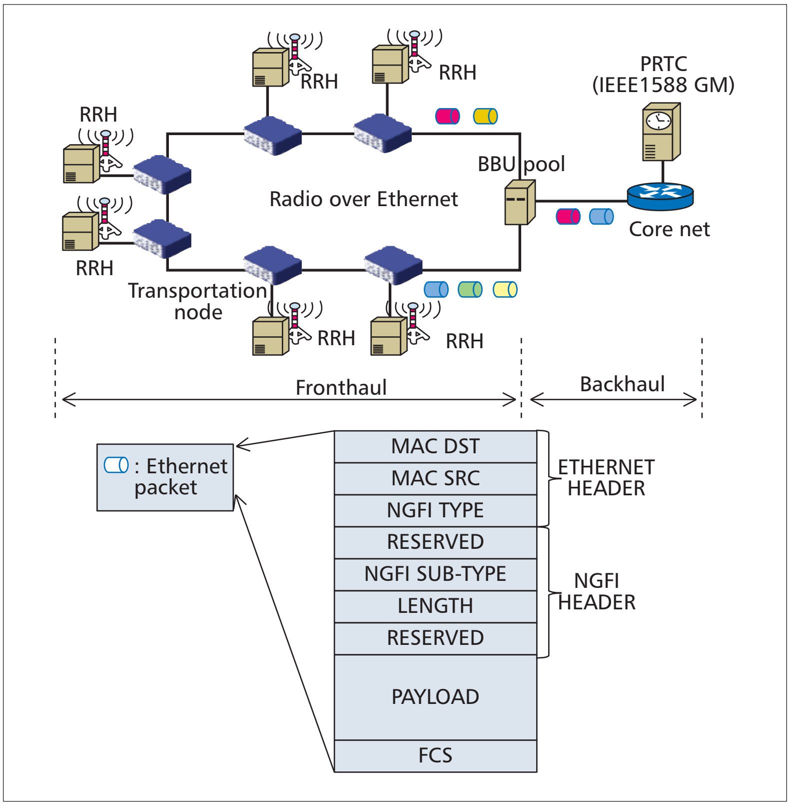

Figure 2. An FH topology example and illustrative Ethernet packet format to support NGFI.

CONCLUSIONS

Traditional FH interfaces are not suitable for 5G technologies such as C-RAN, NFV, and LSAS due to the features of SDH-based transmission, point-to-point connection, and low transmission efficiency. In this article, a new FH interface called the next-generation fronthaul interface is proposed. The design principles are described, and the major impact, challenges, and potential solutions of and for FH transport networks are analyzed. NGFI requires redesign of the BBU-RRH function split and packetization of FH data. By decoupling the FH bandwidth from the antenna number, NGFI can better support large antenna technologies. With decoupling of cell and UE processing, the NGFI data rate varies with traffic change, which enables exploiting the statistical multiplexing gain to improve efficiency. The use of Ethernet for NGFI transmission brings the benefits of improved reliability and flexibility due to the packet switching nature of Ethernet. While SYNC-E and 1588v2 could be introduced to address the time and frequency synchronization issues, they still need careful design in order to support CoMP technologies. In the meantime, jitter and latency remain the other key difficulties to overcome to finally realize NGFI.

In addition to the challenges analyzed in this article, in the future there remains a lot of work to do to deeply understand NGFI. For example, the analysis of traffic performance with NGFI in 5G networks is necessary to evaluate the performance gain of NGFI. In addition, the control, data, and management channels that are transported via NGFI should be analyzed and carefully designed to make NGFI a better fit in different 5G architectures.

While SYNC-E and 1588v2 could be introduced to address the time and frequency synchronization issues, they still need careful design in order to support CoMP technologies. In the meantime, jitter and latency remain the other key difficulties to overcome to finally realize NGFI.

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BIOGRAPHIES

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