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Latency and bit-error-rate evaluation for radio-over-ethernet in optical fiber front-haul networks

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ABSTRACT

Nowadays several research projects are under progress to manage a soft migration toward the 5th generation networks. Radio over Ethernet (RoE) is one of recent topics that try to have a cost efficient and independent front-haul network. In this paper, we discuss the requirements of the 5G networks and analyze the conditions for the implementation of a RoE protocol. For this purpose we digitalize radio frames that are taken from BBU or RRH and create RoE basic frames considering all the requirements of protocol. We then encapsulate RoE basic frames into an Ethernet packet and finally experimentally evaluate this Ethernet packet as a case of study for RoE applications. The packet is transmitted through different fiber spans, measuring the BER and latency on each case. The system achieves BER values below the FEC limit and a manageable latency. These results serve as a guideline and proof of concept for applications on RoE, showing the viability of its implementation as part of the next generation of front-haul networks.

1. Introduction

Mobile data transmission is foreseen to grow 13-fold in 2017 in comparison to its volume in 2012 [1]. Also it is easily forecasted that 5th generation networks [2] will operate in a completely heterogeneous environment including different types of access technology, devices and user applications [3]. Facing with this challenge has resulted in several research works and experiments.

Cloud Radio Access Networks (C-RAN) [4–6] is one of recent evolutions in cellular networks to address all these challenges related to increasing the number of users and network traffic [1]. The C-RAN proposes to centralize the processing of the mobile networks, moving the base band units (BBU) from the radio access unites (RAU) to the central office. This change will simplify the RAUs, allowing the network to be more scalable [7], cost and energy efficient [8] and increase the throughput [9], but will bring new challenges with its implementation. One example is the asymmetric architecture of C-RAN in allocating functions between BBU and RRH. As Fig. 1 shows, there is only one functional layer in RRH side (Physical layer) whiles there are three functional layers in BBU side (Physical, MAC and Network layers). This asymmetric architecture creates a dependency between front-haul network and the radio access technology and increases the network burden on front-haul. This problem creates challenges is interconnecting and cooperating Base Band Units (BBU). As a way to address this problem, Radio-over-Ethernet (RoE) has been proposed to achieve a cost efficient and green solution for C-RAN challenges.

In this paper, we present a general overview on Radio over Ethernet (RoE) requirements and specifications to implement in future radio access networks. This overview later is summarized by a case of study for an experimental implementation of RoE protocol, where we evaluate the transmission of the RoE packet in terms of BER performance and latency of the process. The remainder of the paper is structured as follows: Section 2 describes the architecture of RoE, Section 3 describes the implementation of the RoE protocol and Section 4 the experimental setup. Section 4 discusses the experimental results and finally Section 5 summarizes and discusses the results.

2. Radio over Ethernet

Radio over Ethernet is a platform that has been standardized as IEEE 1904.3 [10]. This platform is located between RRH side and BBU side and tries to address the main challenges in C-RAN. The heart of RoE is the mapper.

As Fig. 2 shows the mapper receives radio data from RRHs or BBUs

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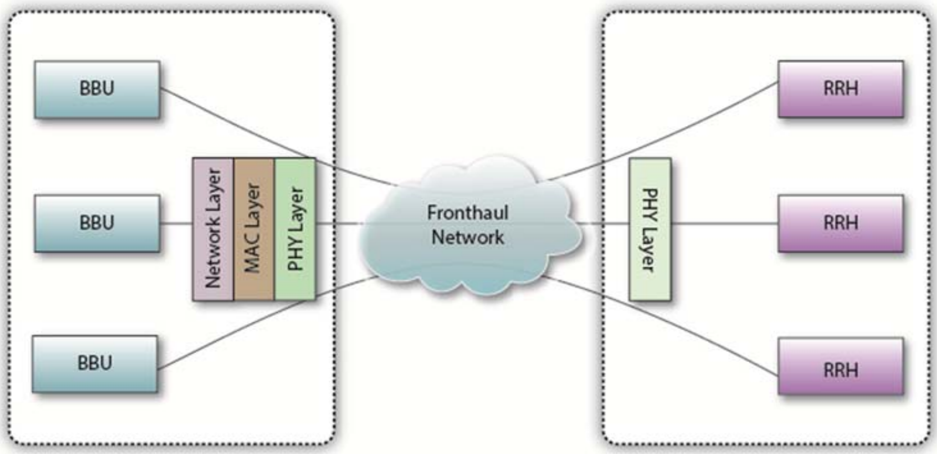

Fig. 1. Asymmetric architecture of C-RAN.

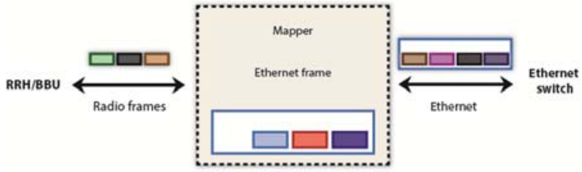

Fig. 2. Mapper of RoE and the description of its basic operation.

and encapsulate them into an Ethernet frame and then transmit it over an Ethernet based network. At the other side the mapper extract radio data from the received Ethernet frame and deliver them to their destinations.

As it was explained before, currently there is only PHY layer at RRH side and each RRH-BBU pair should use a dedicated front-haul network depend on the access technology this pair is using.

By using the RoE architecture, the mapper encapsulates all radio data types in similar Ethernet frames and the only data type is sent on front-haul network is the Ethernet frame. As the first achievement of RoE, the front-haul network becomes independent from the radio access technology and several RRHs with different radio access technologies will be able to transfer their data over the same front-haul network.

Coordination of BBUs and cooperation between them is the other advantage of RoE, because the mapper works as an adaptor and different BBUs can easily understand each other (Shown in Fig. 3).

3. Implemented RoE protocol

The structure we have used for this implementation is shown in Fig. 4. In this structure, the mapper at the source side receives the radio data and put it into an Ethernet frame. By using an Ethernet switch, the Ethernet frame including the radio data is sent over the front-haul network. At the destination, the mapper gets the Ethernet frame from the switch, extract the radio data and deliver it to the final destination.

In the Ethernet frame, there is a field named Ether_Type that shows the type of data in payload. According to the values reserved for this field, we use 'E001' which is free now and can be used for RoE application. In this situation payload should be exactly 1500 Bytes because Ether_type is used for the type of data in payload and there is not any other field for the length of payload. Fig. 5 shows an Ethernet frame.

The data that is received in the mapper is modulated radio signals and we are trying to encapsulate different radio data into one Ethernet frame. To manage this process we need to have a RoE sub-frame to identify and recognize each radio data from others. To simplify and optimize the protocol, this sub-frame is 20 Bytes and used for all radio data. As Fig. 6 shows, RoE sub-frame includes 16 Bytes of radio data and 4 bytes for header. This means that we can encapsulate 75 RoE sub-frames in one Ethernet frame.

The header in RoE sub-frame has some fields to support different radio data types and approaching the goal we are targeting. The media connecting the mappers in both source and destination sides carries only Ethernet frames which are including different radio data.

Frame_ID is a 12 bits field to identify radio frames. Starting with 0 and when it reaches 4095, then it will be set by 0. Each radio frame gets one Frame_ID. If we have frame larger than 16 Bytes, it has to be fragmented and all fragments get similar Frame_ID. These fragments will be differentiated by Seq_No.

Since the largest frame in CPRI is 324 Bytes long so Seq_no should be 5 bits long. When fragmentation is taken place, this field helps to recognize pieces of a radio frame. To manage the fragmentation and defragmentation process a 2-bit field named Fr_Flag has been used. This field shows that whole a radio data is within the payload or current frame is the first, the last or a middle part of a fragmented radio data.

Frame_Type shows the type of frame. The system is able to support

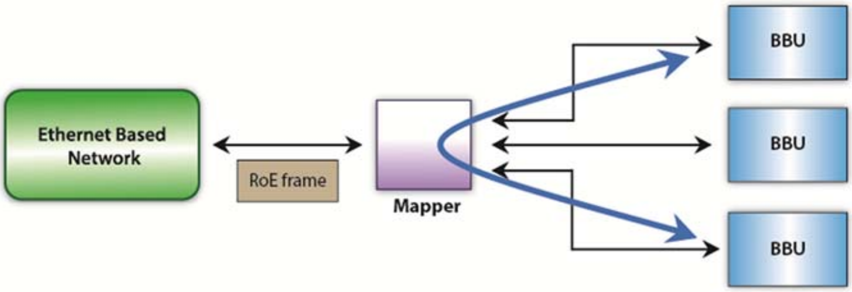

Fig. 3. Cooperating BBUs via the mapper.