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Performance Evaluation of Ethernet Network for Mobile Fronthual Networks

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Abstract

Increasing mobile data traffic due to the rise of both smartphones and tablets has led to high-capacity demand of mobile data network. To meet the ever-growing capacity demand and reduce the cost of mobile network components, Cloud Radio Access Network (C-RAN) has emerged as a promising solution. In such network, the mobile operator's Remote Radio Head (RRH) and Base Band Unit (BBU) are often separated and the connection between them has very tight timing and latency requirements imposed by Common Public Radio Interface (CPRI) and 3rd Generation Partnership Project (3GPP). This fronthaul connection is not yet provided by packet based network. To employ packet-based network for C-RAN fronthaul, the carried fronthaul traffic are needed to achieve the requirements of fronthaul streams. For this reason, the aim of this paper is focused on investigating and evaluating the feasibility of Ethernet networks for mobile fronthaul. The fronthaul requirements used to evaluate and investigate this network are maximum End to End (E2E) latency, Packet Loss Ratio (PLR) and Packet Delay Variation (PDV). The simulated results and numerical analysis confirm that the PDV and PLR of High Priority (HP) traffic in Ethernet network meet the requirements of mobile fronthaul using CPRI. However, the PDV of HP traffic meets the fronthaul network when the number of nodes in the Ethernet network is at most four. For Ethernet network, the number of nodes in the network limits the maximum separation distance between BBU and RRH (link length); for increasing the number of nodes, the link length decreases. Consequently, Radio over Ethernet (RoE) traffic should receive the priority and Quality of Service (QoS) HP can provide. On the other hand, Low Priority (LP) classes are not sensitive to QoS metrics and should be used for transporting time insensitive applications and services.

Keywords*: C-RAN, Fronthaul, CPRI, BBU, RRH*

1. Introduction

Mobile network architectures are usually split into three parts: Radio Access Network (RAN), backhaul network and core network [1]. The RAN consists of systems and technologies performing radio-access related functions such as managing radio transmission and reception to/from mobile devices. There is a standard called Radio Access Technology (RAT) that defines the interfaces, protocols, the architecture and specific functions. An example of RAT includes Wideband Code Division Multiple Access (WCDMA)/High Speed Packet Access (HSPA), Long Term Evolution (LTE), Worldwide Interoperability for Microwave Access (WiMAX)… etc. Traffic aggregation and transport between the core network and the RAN is performed by the backhaul network. Since the architecture and implementation of the backhaul networks are almost agnostic with respect to RAN and core architectures, they are not defined by RAT standards. Eventually, the core network performs all non-radio access related functions and used as the gateway towards all fixed and mobile networks, mainly towards Internet. In most cases, functions and interfaces of core networks are standardized according to the adopted RAT. The User Equipment (UE) is directly connected to the BS of RAN via the radio link, and evolution of this BS undergoes several changes and leads to the new RAN network, C-RAN.

In 1G and 2G cellular networks, the BTSs were equipped with its own cooling system, battery backup, monitoring system, and so on. It implies that the BTS had an all-in-one architecture, an architecture where all power, analog, and digital functions are housed in a single container as large as a refrigerator and is commonly found in large cell deployments. Since each BTS is working on its own, it doesn't reduce the interference with other BTSs by

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using collaboration algorithms such as genetic algorithm [2]. In addition, it is hard to upgrade and repair because of the all-in-one BS architecture.

Later, in Third Generation (3G) deployment, a distributed BS was introduced where the RRHs and BBUs are separated using fiber links with digital baseband interfaces, such as CPRI and Open Base Station Architecture Initiative (OBSAI). At this stage, the concept of fronthaul was introduced. Unlike traditional cellular networks that are built with many all-in-one BS architectures, C-RAN can be viewed as an architecture evolution based on distributed BSs. To enable flexible deployment, C-RAN or C-RAN architecture divide the BS into BBU and RRHs. Figure 1 illustrates the segment where fronthaul and backhaul are located in the overall mobile network. Fronthaul is a segment that connects RRH and BBU, whereas backhaul accounts for the segment between the core network and the edge of the entire telecommunication network, and the physical medium can be fiber, copper, and microwave. As it is depicted by Figure 1 C-RAN is a fronthaul architecture that addresses capacity and coverage issues while supporting mobile xHaul (x can be Fronthaul or Backhaul) solutions. It also provides great benefits in controlling ongoing operational costs, improving network security, network controllability, network agility and flexibility [3, 4].

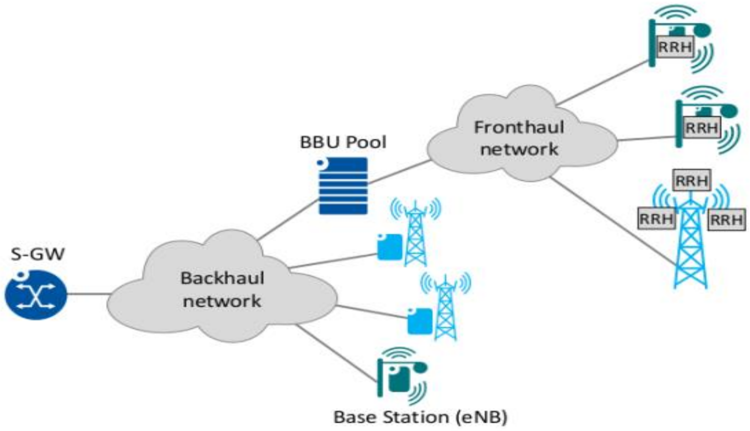


Figure 1. Mobile backhaul and fronthaul network architecture in LTE, extracted from [5]

In fronthaul network, fronthaul flows have a very high bitrate in the order of gigabits per second; For instance, for an LTE sector configured as 2x2 Multiple Input Multiple Output (MIMO) with 20 MHz carrier bandwidth requires about 2.5Gb/s, which gives a total of 7.5Gb/s for a typical 3-sector cell sites. Such fronthaul capacity doesn't not scale with time-varying traffic load condition of the cell (i.e. it leads to fully non-elastic traffic). These features constitute a relevant problem to the traditional RAN infrastructure that is designed to carry much lower bitrate. As a result, the common fronthaul solution in C-RAN is the use of an optical access networks. But this transport solution requires consumption of a number optical fiber links, which are scarce and needs huge investment by operators. For example, in areas where there is dynamic user expectation like clients are engaged in mobile-savvy activities-from texting to video phone calls such as in ultra-modern stadium and dense population area (like China), requires a new emerging technology, the C-RAN. In such scenarios, using fiber as full fronthaul network may not be economically available to the rooftop where the RRH needs to be deployed [6]. In other cases, installing fiber in existing tower may be a challenging problem. And also deploying traditional small cell sites in suburban and road areas (where more capacity is needed to meet the fast growing traffic demand) are not realistic solutions for areas that form a high percentage of an operator's footprint. As a complement to both the traditional small cell and fiber, a new fronthaul network that can extend the existing traditional small sites and enable quick deployment of cell site with much lower TCO is needed. Another technology such as WDM and OTN could save fiber consumption, however, the cost of introducing these additional transport equipment makes economically not viable for operators. Hence, the current Mobile

Fronthaul (MFH) solutions are rather short-term approaches and needs improvement in both the topology and technology. As an attempt to address this issue, recently many researchers are focusing on Ethernet-based fronthaul transport network pushed by their lower costs, ability to employ statistical multiplexing, and improved performance.

Using Ethernet in the fronthaul [7] has been proposed to take some advantages: lower cost equipment, shared use of lower-cost infrastructure with fixed access networks, obtaining statistical multiplexing, and optimized performance. Despite of their attractive advantages, Ethernet also comes with their own challenges: achieving low latency and jitter to meet delay requirements, and ultra high bit rate requirements for transporting radio streams for multiple antennas in increased bandwidth [7]. For the above reasons, the current fronthaul networks are increasingly integrating more cost-effective packet switched technology, especially Ethernet/Internet technologies. The former disadvantage will be explored in this study, while the latter is studied in detailed in [7].

With packet-based C-RAN realization, the MFH issue has been one of the biggest challenges. As a result, several continuous studies/efforts towards an MFH have been made even though they haven't touched the root of the MFH itself. Institute of Electrical and Electronics Engineers (IEEE) 802.1CM [1] has begun the development of a potential new work item on Time-Sensitive Networking (TSN) for MFH. ORI [8] is studying how to reduce the CPRI data rate using compression technology. In addition, the use of Ethernet to transport the CPRI data traffic is under discussion by the CPRI Forum, while the design of CPRI encapsulation on Ethernet packets has begun by the IEEE 1904.3 Task Force [9].

2. Fronthaul Network Requirements

As a consequence of decoupling the traditional BS functions into a centralized BS that will be shared among multiple RRHs, strict timing conditions between BS and RRH have been specified by RAT standards. Delay contributions due to the transportation of fronthaul signals along RAN network, "fronthaul latency", is one of the main significant challenges for the BBU RRH design and has a relevant impact on the total latency in the BS.

In general, given that the total latency is fixed by standard, as shown in the Table 1 and the internal processing delays of both BBU and RRH depends on the specific software and hardware implementation, there is a standard upper limit on the latency of fronthaul network. The latency can be further categorized into two parts: namely 1) latency due to the adaptation of fronthaul signals into the RAN infrastructure services, which can be caused by the technology used such as CPRI and OBSAI transmission/reception interfaces, and other functions required by optional layer transport technologies (i.e. multiplexing/demultiplexing, buffering, reframing and error correction), and 2) latency due to the contribution of signal propagation along the RAN. The second contribution imposes a limitation on the maximum geographical distance between BBU hostel and the controlled cell sites.

Table 1. Latency, PDV, PLR, and synchronization requirements for Ethernet Fronthaul with symmetry assumption

Properties	Values	Sources
Latency budget(BBU to RRH, in cluding fiber length, PDV, bridged delays)	50 μs (for data rate 1–10 Gbit/s)	[10]
Latency budget(excl. cable, BBU to RRH)	5 μs(for data rate 1–10 Gbit/s)	[10]
Maximum Frequency Error contribution	2 ppb	[11]
Maximum Bit Error Ratio	10^{-12}	[10] [12]
Maximum End to End Latency /RTT(including fiber length, PDV, bridged delays)	100 μs- 400 μs (250 μs for optical networks)	[7] [10]
Maximum PDV	5 μ or 10 % of E2E latency	[1]
Geographical distance between RRH and BBU	Less than 20 Km (current working assumption) and 25 km for optical networks	[13] [14]
PLR caused by bit error, congestion...etc	10^{-6} - 10^{-9}	[1]

PDV is defined as 2-point packet delay variation. As per ITU Y.1540 "delay variation of an individual packet is naturally defined as the difference between the actual delay experienced by that packet and a nominal or reference delay. ITU Y.1540 6.4.2.1 and RFC 5481 using the minimum delay as a reference (Use of the average delay as the delay variation reference is depreciated.)".

To achieve the objective of this paper, the programming language chosen to construct the simulation model for the fronthaul network is **Simula** based on Discrete Event Modelling on Simula (DEMOS) software, a context class for discrete event simulation. Moreover, **Matlab** has been used for post processing of raw data's from the simulator and plotting the data's with error bars. The simulations were run 10 times by varying simulation seeds for each data points, and the results were reported with **95**% confidence interval.

3. Simulation Parameters

Table 2 and Table 3 presents the set of parameters which have been used during the simulation and the list of notations used for different traffic loads on different interfaces respectively.

Table 2. Simulation parameters used in the analysis of performance metrics of LP and HP packets

Parameters	Value
Seed values	907 234 326 104 711 523 883 113 417 656
Output link capacity	10 Gb/sec
Minimum LP length	40 Bytes
Length of HP packet	1200 Bytes
Maximum LP length	1500 Bytes
Load of HP traffic	Varies
Load of LP traffic	Varies
Buffer size	16 MByte
Number of packets	40,000

Table 3. Notation of parameters used in the simulation result analysis

Description	Notations
The load of LP traffic on 1 Gb/s interface	L_{10GE}^{LP}
The load of HP traffic on 10Gb/s interface	L_{10GE}^{HP}
The load of HP and LP traffic on 10 Gb/s interface	L_{10GE}^{T}

4. Results and Analysis

We considered PDV, PLR, and average latency as a performance metrics to evaluate performance of Ethernet switch. With analysis of each metrics, an identification of parameter that restricts the overall performance is conducted. The evaluation Ethernet network in mobile fronthaul is also conducted. From this evaluation, we find how such networks can be dimensioned with respect to: fiber link length, number of nodes, · · · etc.

4.1. Ethernet Switch Performance

To study the performance of non-preemptive Ethernet switch while transporting HP and LP traffic, the diagram shown in Figure 2 were implemented in the simulation program. In this scenario, the Ethernet switch transmits LP packet only if no packets with higher priority (HP packets) is available at the input queue. When HP packet arrives while LP packets are being served, the packet will be queued till the lower priority packet has finished.

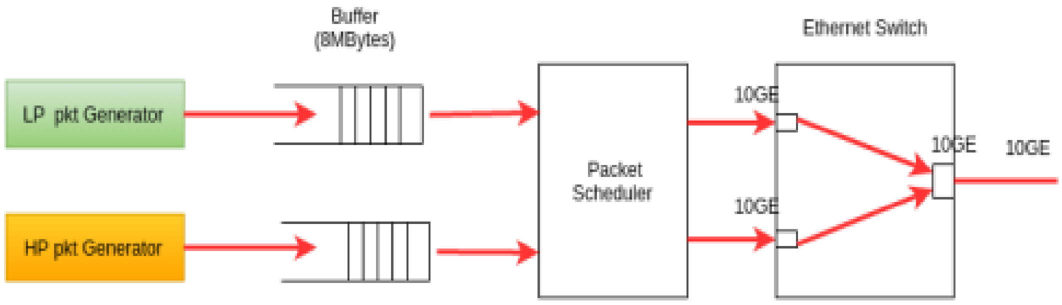


Figure 2. Ilustration of Ethernet Switch for measuring the performance of HP and LP traffic

For Ethernet switch, average latency, PLR, and PDV of LP and HP traffic with respect to HP load are illustrated in Table 4 The values are obtained by keeping LP load fixed, L_{10GE}^{LP}=0.4.

Table 4. Average latency and PDV of LP and HP traffics as function of HP load for HP load=0.4

	L_{10GE}^{LP}	L_{10GE}^{HP}	Average HP la tency (μsec)	Average LP latency(μsec)	PDV of HP(μsec)	PDV of LP (μsec)
1	0.4	0.10	$0.076 \pm 7.16 \times 10^{-9}$	4.33	1.19977	35.16
2	0.4	0.20	$0.15 \pm 1.67 \times 10^{-8}$	11.67	1.19988	66.16
3	0.4	0.30	$0.22 \pm 1.43 \times 10^{-8}$	505.90	1.19991	10.49
4	0.4	0.40	$0.30 \pm 1.41 \times 10^{-8}$	2857.33	1.19990	993.04
5	0.4	0.50	$0.37 \pm 2.21 \times 10^{-8}$	5002.60	1.19995	10097.20
6	0.4	0.57	$0.47 \pm 2.76 \times 10^{-8}$	63529.00	1.19997	10608.52

4.1.1 HP Traffic Performance

In this part, the performance of HP traffic is presented with respect to: average latency, PLR, and PDV.

1. Average Latency

Figure 3 presents the average latency of HP traffic with respect to HP load for L_{1GE}^{LP}=0.4 and 0.45. Form Figure 3 we see that the average latency is increasing with increasing value of HP load. This is because HP packets have to wait in a queue when they arrive while the LP packets are serving. When the system load increases, the probability of getting the output wavelength free is low. As a result, the latency of HP packet increases. The maximum latency experienced by HP packet was 1.2μsec.

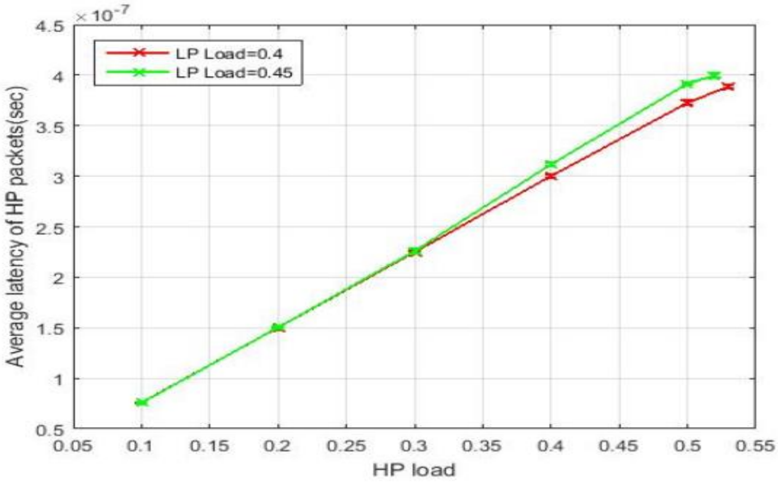


Figure 3. Average latency of HP traffic as function of HP load for LP load 0.4 and 0.45

2. Packet Delay Variation

Figure 4 indicates that the packet delay variation of LP traffic as a function of HP load for different values of LP load. As we can see from the figure, the PDV is increased for increasing HP load. However, the increment interval is not noticeable. It varies between 1.1997μsec and 1.1999μsec. This is due to the fact that the interpacket gap for both high priority (HP traffic) and low priority (LP traffic) is not preserved which leads to the observation of this measured value. And also, the non-preemptive scheduling algorithm in Ethernet switch introduces synchronization problem, jitter [7].

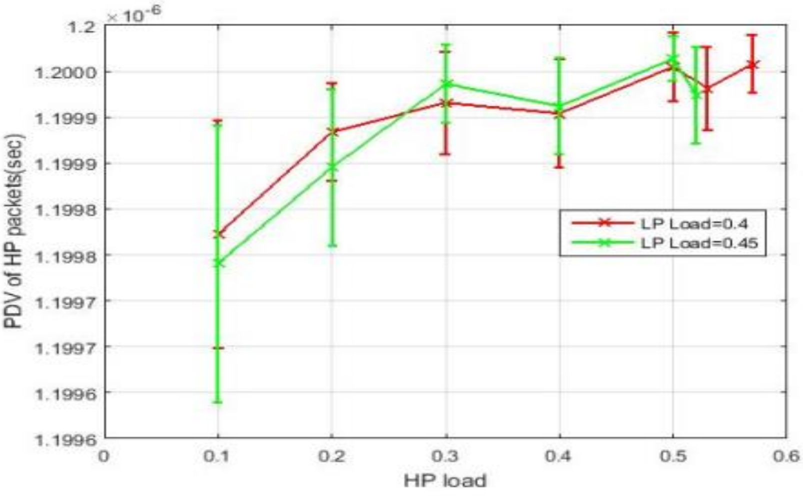


Figure 4. PDV of HP traffic as function of HP load for HP load=0.4 and 0.45

As discussed in Section 4.1, in Ethernet switch, packets from higher priority class are always scheduled first. If the queue of this class is empty, packets from the lower priority class are transmitted. The higher priority packet experiences delay equal to the service time of the maximum length of LP packet when it arrives while the maximum LP packet is serving. Whereas, the minimum delay experienced by HP packet is zero when the HP packets are served freely. Consequently, Ethernet switch introduces PDV equals to the duration of maximum length of LP packet to HP traffic. The measured PDV value was approximately 1.2μsec.

3. Packet Loss Ratio

The measured PLR of HP traffic was zero, i.e. all HP packet generated in the source were received at the output port of the Ethernet switch. This shows that the HP traffic is given higher priority than LP packets.

4.1.2 LP Traffic Performance

The performance of LP traffics in Ethernet switch is described below.

1. Average Latency

As shown in Figure 5, the LP packet latency increases slowly as the 10GE HP load increases. The average Latency increases exponentially from 1 msec to 8 msec for L_{1GE}^{LP}=0.4 and 0.45. This is because packets with low priority are transmitted only if the higher priority input queue has no available packet to transmit. As the HP load increases, the low priority queue begins to fill up due to the arriving LP traffic while the output wavelength is not free. As a result, the amount of latency the LP packet experiences in the queue increases.

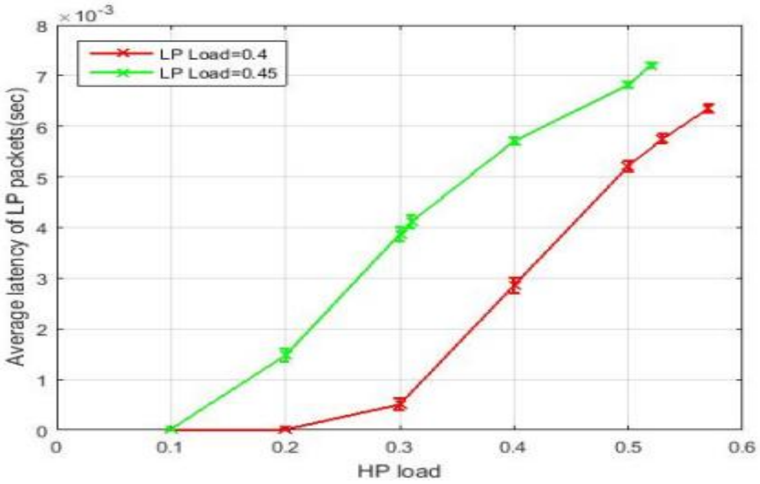


Figure 5. Average latency of LP traffic as function of HP load for LP load=0.4 and 0.45

The maximum latency the LP packets experience in queue is proportional to buffer size. The longer the line of LP packets in a queue waiting to be transmitted, the longer the average waiting time is.

2. Packet Delay Variation

Figure 6 presents the PDV of LP traffic as function of HP load for L_{10GE}^{LP}=0.4 and 0.45. Form the figure we see that the PDV increases for increasing values of L_{10GE}^{HP}. Here, the important observation is that the PDV for LP load L_{10GE}^{LP}=0.45 is higher than the PDV for LP load L_{10GE}^{LP}=0.4. Since LP traffic is treated as a best effort traffic, the minimum and maximum latency value of LP packet is higher than the min. and max. latency value of HP packet.

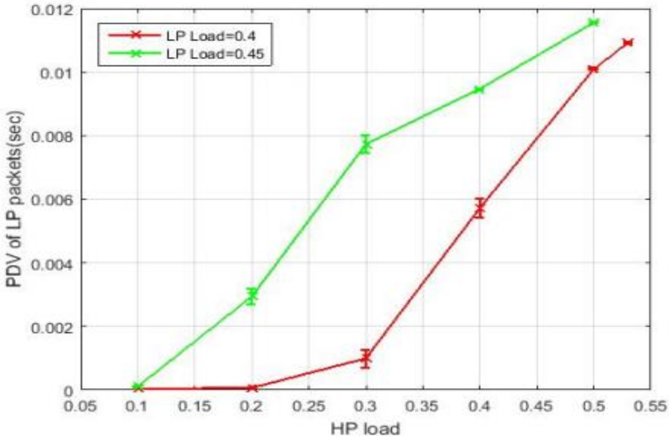
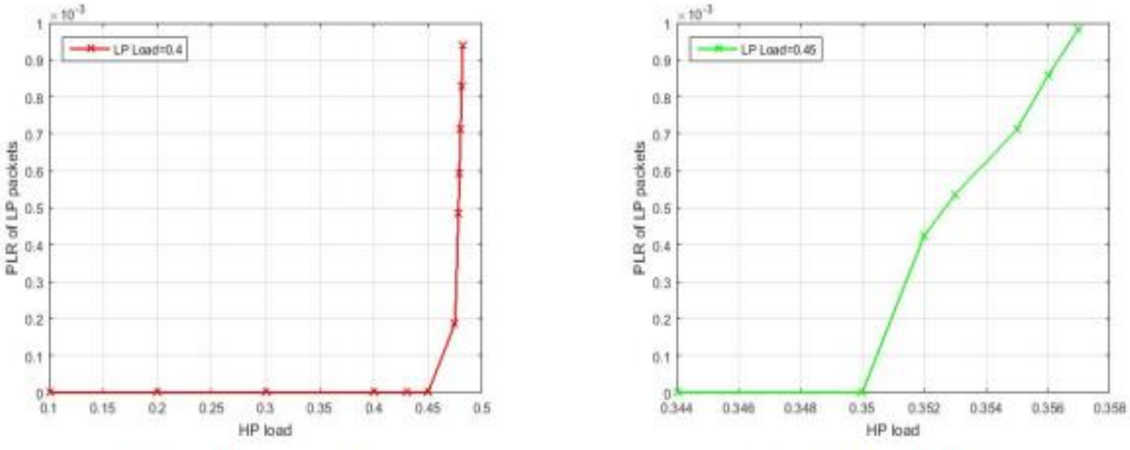


Figure 6. Packet delay variation of LP traffic as function of HP load for LP load=0.4 and 0.45

3. Packet Loss Ratio

Figure 7a shows there wasn't packet losses for the range from L_{10GE}^{HP}=0.1 to L_{10GE}^{HP}=0.45 i.e. every single LP packet sent was transmitted via the output wavelength. However, when L_{10GE}^{HP} is 0.45, there was a PLR of 0.0001. Afterwards, the PLR has sharply increased when the system load is increased. Since the low priority queue has a finite buffer size, at high system load the LP queue receives packets while HP traffic is serving. The increasing HP load causes the LP traffic to stay longer time at the queue. As a result, the queue of LP becomes full in short time. In this case, the LP packets arriving after the queue is full are discarded and the number of discarded LP packet increases for increasing HP load. The results for L_{10GE}^{LP}=0.4 and 0.45 are presented in Figure 7, Figure 7a and Figure 7b. It is worth mentioning that increasing more traffic while the buffer size of HP and LP packets is fixed will causes buffer overflow which in turn increases the number of packets lost exponentially. The observed result proved that packets getting dropped after the buffer of the packet is full.



(a) LP load=0.4 (b) LP load=0.45

Figure 7. PLR of LP traffic as function of HP load for LP load=0.4 and 0.45

4.2. Mobile Fronthaul Networks

To evaluate Ethernet network for fronthaul C-RAN network, we have gone through the fronthaul network requirement given by IEEE 802.1CM and the RoE standards for transporting radio signals over a packet switched network given by IEEE 1904.3. To evaluate the performance of these networks, we have considered more than two nodes in a network scenario as shown in Figure 8.

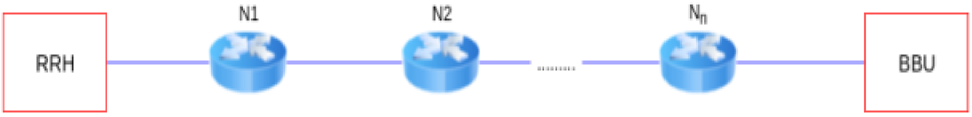


Figure 8. Mobile fronthaul network under study

In the following subsections, the different parameters of the Ethernet switches in a mobile fronthaul setting are evaluted. Our aim is to find how such a network can be dimensioned with respect to fiber length and number of nodes. It is important to note that the latency results described below represent only the queuing and transmission delays; but the nodal delay, which depends entirely on the implementation of the node, has not been taken into account.

4.2.1. Evaluation of Ethernet Network for Mobile Fronthaul Network

This section evaluates the performance of Ethernet network for mobile fronthaul network in terms the above mentioned performance metrics. Based on the observations from Figure 3, Figure 4, Figure 5, and Figure 7; and the data from Table 4, the average latency, PDV, and PLR required for transporting the HP and LP in Ethernet switch have been studied. To evaluate the performance of Ethernet network for fronthaul network, consider a scenario when LP load is 0.4 (assumed threshold value) and the HP load varies in the interval [0.1, 0.59].

1. Average Latency

As previously described, the maximum End to End (E2E) latency between BBU and RRH in mobile fronthaul network is 50 μsec (including fiber length, PDV, bridged delays). And the latency requirement when cable propagation excluded is 5μsec.

Table 5 presents the average latency of HP and LP packets with respect to the HP loads for values of LP load, L_{10GE}^{LP}=0.4. From the table, we see that the average latency of HP traffic is lower than the latency fronthaul requirement in MFH. It also shows that the average latency of both HP and LP traffic varies with the system Load.

Since the average latency of HP packets in Ethernet switch varies with system load, its maximum latency was used for evaluating the Ethernet network. From the simulation, we found that the maximum latency of HP packets in an Ethernet switch is 1.2μsec. Using this value, the maximum link length as a function of number of nodes is calculated using (1).

Maximum E2E latency (L_{total}):

$$L_{total} = N \times (D_{node} + Delay\_PDV_{node}) + D_T \times Link_{length} \qquad (1)$$

where, N = Number of nodes.
D_{node}= Latency in a single node, 1.2μsec (obtained from the simulation).
$Delay\_P\ DV_{node}$=PDV in a single node, 1.2μsec (obtained from the simulation).
D_T =Transmission latency, 5μsec/km.
L_{total}= Maximum E2E latency, 50μsec.
$Link_{length}$= Maximum link length.

Table 5. Average latency comparison between LP and HP traffics of Ethernet switch and fronthaul requirements for LP load=0.4

SN.	Average Latency				
	L_{10GE}^{LP}	**L_{10GE}^{HP}**	HP_latency(μsec)	LP_latency(sec)	Fronthaul requirement
1	0.4	0.1	$0.07 \pm 7.1 \times 10^{-10}$	$4.33\times10^{-6}\pm1.44\times10^{-7}$	5μsec (excluding cable length)
2		0.2	$0.15 \pm 1.7 \times 10^{-9}$	$11.6\times10^{-6}\pm1.13\times10^{-6}$	
3		0.3	$0.22 \pm 1.4 \times 10^{-9}$	$0.51\times10^{-3}\pm0.12\times10^{-3}$	
4		0.4	$0.30 \pm 1.4 \times 10^{-9}$	$2.85\times10^{-3}\pm0.14\times10^{-3}$	
5		0.5	$0.37 \pm 2.2 \times 10^{-9}$	$5.32\times10^{-3}\pm0.11\times10^{-3}$	

In this work, the Ethernet switch implemented was a cut-through switch in which a packet is forwarded as soon as it arrives. As a result, the HP packet's latency is very low. HP packets can be transmitted via Ethernet fronthual network provided that the relationship between maximum separation distance and a number of nodes in the network is as presented in Table 6. For instance, for Ethernet network with 3 nodes require 8.56 Km fiber link length. Similarly, for Ethernet network with 2 nodes require 9.04 Km fiber link length.

Table 6. Maximum link length and number of nodes in Ethernet network to meet the fronthaul requirements for HP traffic where L_{total}=50μsec, D_T =5μsec/km, and D_{node}=1.2μsec

N	Total (D_{node} + $Delay\_P\ DV_{node}$)(μsec)	$Link_{length}$(Km)
2	4.8 μsec	9.04
3	7.2 μsec	8.56
4	9.6 μsec	8.08
5	12.0 μsec	7.60
6	14.4 μsec	7.12

2. Packet Delay Variation

In Table 4, the maximum PDV specified for fronthaul network is 5μsec or 10% of E2E latency. For HP traffic, the PDV of a single node was approximately 1.2μsec regardless of the system load. To evaluate Ethernet network for fronthaul with regard to PDV, the following equation has been used:

Maximum PDV (PDV_{total}):

$$PDV_{total} = N \times PDV_{node} \qquad (2)$$

Where, N = Number of nodes.
PDV_{node}=PDV in a single node, 1.2μsec (obtained from our simulation).
PDV_{total}= Maximum PDV, 5μsec.

Table 7. The Number of nodes in Ethernet network to meet the PDV fronthaul requirements for HP traffic where *PDVtotal*=5μsec and *PDVnode*=1.2μsec

N	PDV_{node}(μsec)	PDV_{total}(μsec)
2	1.2	2.4
3		3.6
4		4.8

As shown in Table 7, the HP traffic in Ethernet network meets the PDV fronthaul requirement as long as the number of nodes in the Ethernet network is at most 4. This implies that HP packets can be transmitted via Ethernet fronthual network when the number of nodes in the network is at most 4.

3. Packet Loss Ratio

As shown in Table 8, HP packet loss wasn't observed at any system load. Table 8 depicts that the PLR of HP and LP packets with respect to the HP loads for LP load=0.4. The table shows that the observed PLR of HP is lower than the PLR requirement in mobile fronthaul requirements.

Table 8. PLR comparison between LP and HP traffics of Ethernet switch and Fronthaul requirements for LP load=0.4

SN.	Packet Loss Ratio				
	L_{10GE}^{LP}	L_{10GE}^{HP}	HP_PLR(μsec)	LP_PLR(μsec)	Fronthaul requirement
1	0.4	0.1	0.0	0.0000	10^{-6}-10^{-9}
2		0.2	0.0	0.0000	
3		0.3	0.0	0.0000	
4		0.4	0.0	0.0000	
5		0.5	0.0	0.0061	

The results for HP traffic shown in Table 8 confirm that the Ethernet network meets the PLR requirement for fornthaul C-RAN requirements; the PLR of HP traffic was zero. This implies that HP packets can be transmitted via Ethernet fronthual network without any packet loss.

5. Conclusion

In this work, the overall performance of standard Ethernet switch and Ethernet network for mobile network were analyzed. The high quality of service was reflected on HP traffic while Low Priority (LP) traffics are not sensitive to QoS metrics and should be used for transporting time insensitive applications and services. The maximum separation distance between BBU and RRH (link length) in the fronthaul network is limited and depends on the number of nodes given that the maximum E2E fronthaul latency is as presented in Table 1. Moreover, the measured PDV of HP traffic in Ethernet switch limits the Ethernet fronthaul network to have a maximum of four nodes in order to achieve the PDV fronthaul requirement. The measured PLR of HP traffic in Ethernet switch was zero. Comparing this value with fronthaul requirement, Ethernet network performs better than what is recommended in IEEE 802.1CM standards. Hence, the performance of Ethernet switch fits into C-RAN fronthaul requirement in PLR comparison. As a result, the HP classes can be used for transporting RoE traffic.

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