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Virtualized eNB Latency Limits

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ABSTRACT
In flexible functional split, functions of a virtualized evolved NodeB (eNB) can be disaggregated in distributed computational resources. One of the main constraints for their placement is the latency experienced by the communication between the Virtual Machines (VM) hosting the functions. This paper evaluates experimentally the latency limits for different functional splits providing insights on flexible functional split implementation.
Keywords: fronthaul, 5G, control plane, functional split.

1. INTRODUCTION

To address the demanding requirements in terms of expected throughput, latency and scalability, 5G networks are expected to be massively deployed and offer an unprecedented capacity[1][2]. A solution combining increased performance with limited cost increase is to deploy a novel architecture of the Radio Access Network (RAN) in which the evolved NodeB (eNB) functions are split by centralizing the base-band processing in the so-called Base Band Units (BBUs) (or in the New Radio architecture specified in TR38.801 referred to as Central Unit – CU) and leaving the RF processing at the edge of RAN in the Remote Radio Head (RRHs) (in the NR referred to as Distributed Unit – DU)[3]. Furthermore new solutions are based on virtualizing the split functions paving the way to the concept of Virtualized RAN (V-RAN) and Virtualized EPC (V-EPC) [4]. In addition more than one eNB functional split is foreseen (i.e., the so called cascaded functional split) and the functional split must be capable of flexibly adapting to transport network characteristics and application requirements (i.e., flexible functional split) [5].

So far the Common Public Radio Interface (CPRI) has been used to connect BBU and RRH. CPRI is based on carrying time domain baseband IQ samples between RRH and BBU. However CPRI needs a high capacity and low latency fronthaul, low delay variation and fine synchronization. For these reasons, new upper layer functional splits have been proposed by 3GPP in TR38.801 and a Next Generation Fronthaul Interface (NGFI) is under definition [6]. However, different functional splits have got different requirements in terms of capacity and latency [7]. This paper evaluates experimentally the latency limits and the fronthaul bandwidths requirements in a NGFI network architecture.

2. SYSTEM MODEL

To perform the experimental evaluation of the fronthaul performance required by different functional splits the testbed depicted in Fig. 1 has been setup.

Figure 1. C-RAN testbed.

The deployment of the RAN and EPC functions on the testbed is shown in Fig. 2 and it is based on Open Air Interface (OAI) software.

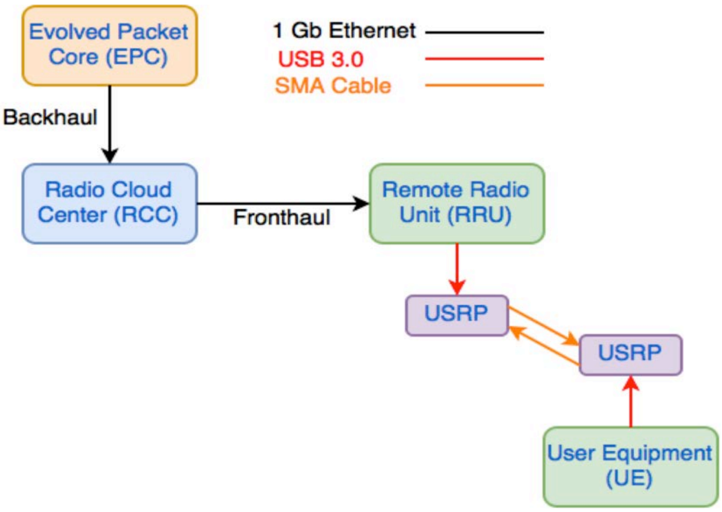

Figure 2. C-RAN configuration.

The EPC and the functional elements belonging to it (i.e., the Serving Gateway (S-GW), the PDN Gateway (PDN GW), the Mobile Management Entity (MME) and the Home Subscriber Server (HSS)) are deployed on a mini-pc (Up-board) featuring an Intel Atom x5-Z8350 Quad Core Processor and hosting Ubuntu 14.04 LTS with a 4.7 kernel (directly precompiled by OAI team). The radio cloud center (RCC) (i.e. the CU) is deployed on a desktop server with Intel Xeon E5620 and hosting Ubuntu 14.04 with 3.19 low-latency kernel, also known as a soft real-time kernel. It is connected by a 1 Gigabit Ethernet link to the EPC. The remote radio unit (RRU) (i.e., the DU) is deployed on a second desktop server with Intel Xeon E5620 and hosting Ubuntu 14.04 with 3.19 low-latency kernel. This machine is connected to the RCC by a 1 Gigabit Ethernet link as well. The RRU is also connected through a USB 3.0 link to an Ettus B210 USRP. This device is a fully integrated, single-board, Universal Software Radio Peripheral (USRP) platform and acts as radio front-end performing Digital to Analog and Analog to Digital Conversion (DAC/ADC). The UE is deployed by means of the Mini-ITX featuring an Intel I7 7700 and hosting Ubuntu 14.04 with 3.19 low-latency kernel. The functional splits implemented by the OAI emulation platform are the IF5 and IF4.5 also known as Option 8 and Option 7 (referred to as IF4p5) in the 3GPP terminology. In our study we consider a signal bandwidth equal to 5 MHz and 10 MHz, corresponding to 25 and 50 Physical Resource Blocks (PRBs).

3. EVALUATION SCENARIO

Without losing in generality, a single DU and a single UE are considered. Option 7-1 functional split (or intra-PHY split) (referred to as IF4p5 in OAI) is considered, as defined by 3GPP, where in the in the UL, FFT, CP removal and possibly PRACH filtering functions reside in the DU, the rest of PHY functions reside in the CU. In the DL, iFFT and CP addition functions reside in the DU, the rest of PHY functions reside in the CU. In other word the Option 7-1 functional split is made before/after the resource mapping/demapping respectively. The UE is static and connected to the DU through coaxial cables. The experiment duration is set to 100 s and all the other experiment parameters are shown in Table 1.

Table 1. Simulation parameters.

Parameter	Value
Experiment Duration	100000 TTIs
Frame Duration	10 ms
Duplexing Mode	FDD
PHY Layer Abstraction	NO
#RRUs	1
#UEs	1
IDT	1 ms
Carrier Bandwidth	5 MHz, 10 MHz

4. RESULTS

Figure 3 and Fig. 4 show the occupancy in terms Mb/s of the fronthaul link. The experimental evaluation of the fronthaul bandwidth occupation, is carried out in three different scenarios. In the first scenario no UEs are attached. In the second scenario a UE is attached but only control plane data are sent. In the third scenario, when the UE is attached, the offered traffic in the uplink is gradually increased. In particular, from the UE, a ping tests with a fixed packet size, equal to 512 bits, and an incremental inter-departure time are performed. With the *-i* ping option, the waiting time between sending each packet is set. In our experiment the waiting time varies from 0.1 second to 10^{-5} second, with steps of 0.1 second. In this way the offered traffic, calculated by means of Eq. (1), varies from 5.12 kb/s to 5.12 Mb/s respectively.

$$Offered\,Traffic[b/s] = \frac{ping\_packet\_size}{ping\_packet\_waiting\_time} \quad (1)$$

As shown by Fig. 3 and Fig. 4, as expected, the fronthaul bandwidth occupation is fixed and not sensible at the UE traffic. It only depends on the signal bandwidth and on the applied functional split.

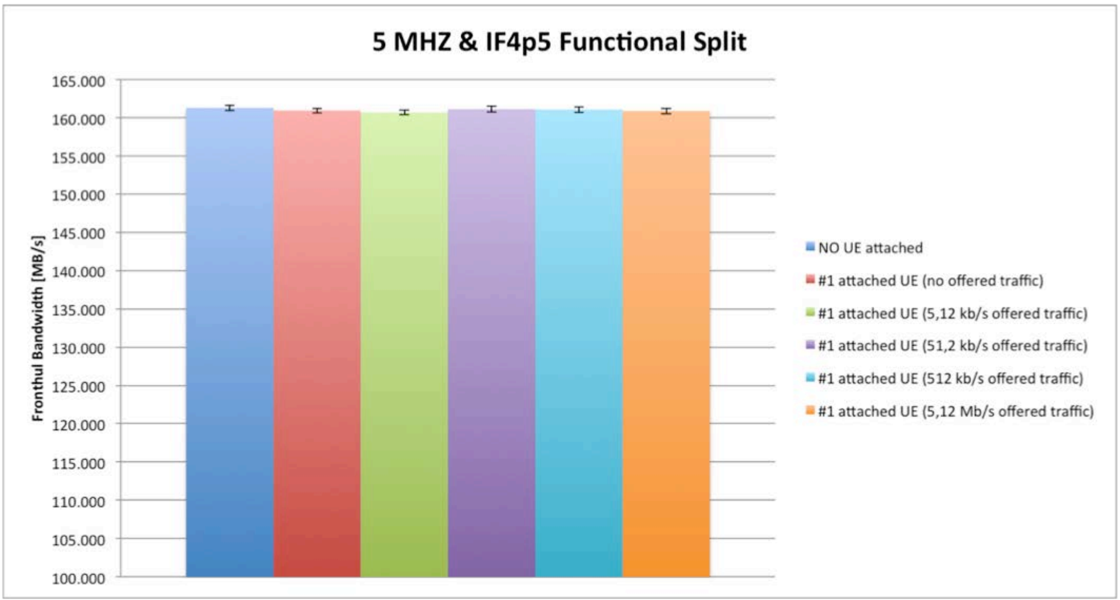

Figure 3. Fronthaul bandwidth (5 MHz signal bandwidth).

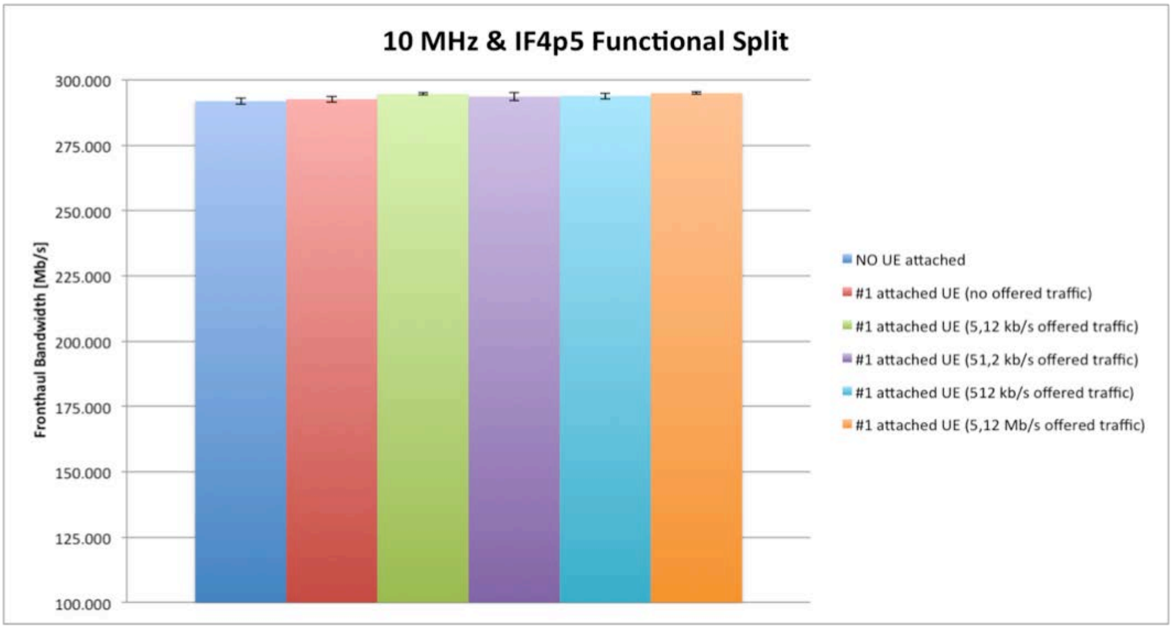

Figure 4. Fronthaul bandwidth (10 MHz signal bandwidth).

The latency experienced along the fronthaul link connecting DU and CU is emulated by means of the Linux utility traffic control tc. The tc utility is capable of increasing the delay experienced on a link by a packet by storing it in the output interface for a specified amount of time before its transmission on the link. A delay d0 is applied to the eth1 Ethernet interface of the PC in which the DU is deployed and a delay d1 is applied to the eth0 Ethernet interface of the PC in which the CU is deployed. In this way a one-way latency is inserted in the fronthaul link. d0 and d1 vary from 0 ms to 3.0 ms, with steps of 0.1 ms. The fronthaul latency limit as a function of the different functional split options and signal bandwidth is considered. As depicted by Fig. 5 when the delay overcomes a certain delay threshold DU and CU are not capable of communicating. The threshold at about 200 µs for the 10 MHz bandwidth and about 250 µs for the 5 MHz bandwidth. The emulated delay causes loss of synchronisation between the DU and the CU. The module that performs the FFT/IFFT, implemented by the USRP Ettus B210 at the DU, receives samples from the CU through the fronthaul, not in the expected order. For these reasons a mismatch occurs and the connectivity between the CU and the DU is lost. It must be noted that the delay fronthaul threshold does not change significantly with the LTE Signal Bandwidth. Figure 5 show the status of the fronthaul connection between DU and CU as a function of the link latency and of the signal bandwidth.

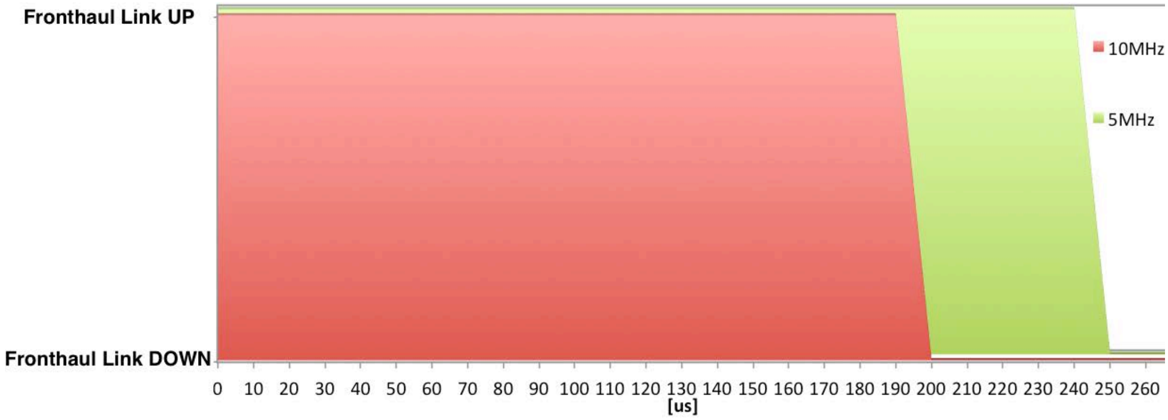

Figure 5. Fronthaul latency limit.

5. CONCLUSIONS

This paper experimentally evaluated the capacity and the latency requirements of the fronthaul network when the Option 7 (intra-PHY) functional split of the New Radio is implemented. As expected, the capacity requirement is independent of the traffic generated by the UE because the fronthaul is carrying cell-level information. Moreover, the maximum one-way latency that can be tolerated along the fronthaul is about 250 µs as specified by 3GPP.

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