Performance Analysis of 5G NR vRAN Platform and its Implications on Edge Computing

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***Abstract*—To date, the performance challenges of the emerging 5G virtual Radio Access Network (vRAN) are still unexplored though 5G is projected to be the predominant commnication technology. In this paper, we provide a thorough architectural characterization for the 5G vRAN and the Multi-access Edge Computing (MEC) system in 5G era. The implications of the vRAN system and the performance analysis of the co-running vRAN and MEC system will provide beneficial guidelines for future access network design.**

I. INTRODUCTION

The emerging 5G New Radio (NR) standard promises an explosion in the network bandwidth and the extremely low latency for the network system. These attributes enable consolidated services to be provided which cannot be achieved by the traditional LTE network, such as AI, VR and autonomous driving, etc. In order to efficiently use the evolving network features and profoundly support the various user service requirements, the 5G network exploits Network Function Virtualization (NFV) [1] to enhance the Radio Access Network (RAN) architectural viability. Characterazing architectural characteristics of the emerging 5G NR virtual RAN will benefit the future system and architecture design for vRAN. In this paper, we perform a thorough characterization for the emerging network. We utilize the OpenAirInterface5g-nr [2] platform for both 5G next generation NodeB (gNB) base station and User Equipment (UE). Besides, we select PARSEC [3] as our edge deployment to mimic edge-based video processing workloads. We choose Intel Xeon machine (Xeon w-2194 @ 2.30GHz) for gNB and Intel Core machine (i9-9900X @ 3.50GHz) for UE. The Operating system used for both machines is Ubuntu 16.04. Both testbeds are implemented with a real RF front-end (Ettus X310 USRP).We profile the architectural characteristics of the 5G RAN system and MEC applications deployed on Commercial Off-The-Shelf (COTS) servers. Figure 1 demonstrates our experimental setup for the 5G NR and MEC co-running platform. Our experiments demonstrate the following: (1) The 5G vRAN system utilizes more threads when processing the packets compared to the LTE vRAN system. (2) The thread which handles zero copy reception mechanism consumes the majority of the CPU resource. (3) The main bottleneck of the current 5G vRAN functions is Backend Bound, the optimization for Backend Bound is necessary to get better vRAN performance. (4) The co-running of vRAN system and MEC application will slow down the MEC processing time. However, the vRAN system itself is not affected when co-running with our chosen MEC applications.

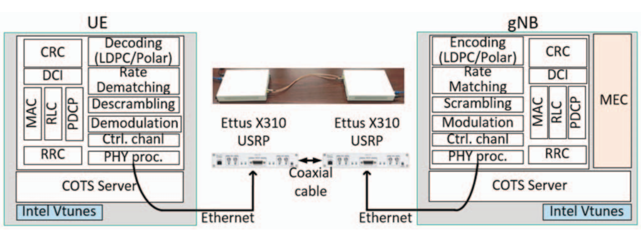

Figure 1. 5G NR Architecture with MEC applications

II. 5G RAN AND UE CPU DOMINANT THREADS

We first report the CPU times of dominant threads of OpenAirInterface5g-nr gNB and UE processes. As shown in Figure 2 and 3, we observe that the dominant threads for OpenAirInterface5g-nr gNB are zero_copy_recv, thread_FH and nr-softmodem, while the dominant threads for OpenAirInterface5g-nr UE are zero_copy_recv, UEthread, Tpool_-1 and nr-softmodem. The zero_copy_recv, UEthread, Tpool_-1 threads are developed to mitigate the burden of the copy actions when transmitting data from Network Interface Card (NIC) to user space. These threads enable the direct transmission from NIC to user space instead of the two copy actions: from NIC to kernel space and from kernel space to user space. With the theoretical traffic burst for 5G, the traditional copy procedure will exhaust the device resource. We observe the CPU consumption of current zero copy reception is high whether there is traffic or not. To decrease the CPU consumption of the zero copy reception procedure would be a future direction for improving performance.

III. CPU AND MEMORY USAGE OF gNB AND UE

We profile the CPU utilization of the OpenAirInterface5g-nr gNB and UE in two stages - before the traffic incoming and after the traffic incoming. As shown in Figure 4, we observe that for OpenAirInterface5g-nr gNB, the CPU utilization does not make a large difference during the two stages. The gNB's CPU utilization is around 160%, note that the

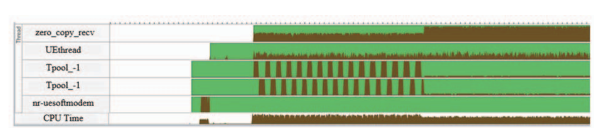

Figure 2. CPU time for 5G UE threads

Figure 3. CPU time for 5G gNB threads

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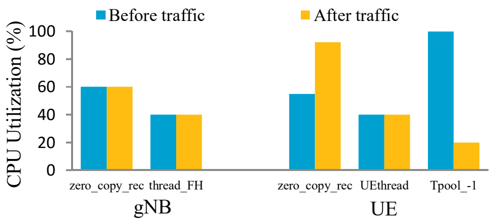

Figure 4. CPU usage before and after traffic income

OpenAirInterface5g-nr is a multi-core system, which means the total CPU time value of all threads will be more than 100%. However, the UE's CPU utilization has an obvious change between the two stages. Before traffic coming in, the UE's CPU utilization is around 180%. After the traffic coming in, the UE's CPU utilization decreases to 160%. The reason for the phenomenon is that the UE utilizes the thread Tpool_-1 to do signal synchronization and detection before the traffic's incoming. After the traffic's incoming, the signal synchronization and detection functionalities are abandoned and this release the majority of CPU resource occupied by the Tpool_-1 threads. With respect to memory usage, both gNB and UE consume 1.70GB memory throughout the two stages, which demonstates that the OpenAirInterface-nr is a computation-intensive application.

IV. ARCHITECTURAL CHARACTERIZATION OF 5G FUNCTIONS

Figure 5 and Figure 6 show the cycle breakdown for the dominant functions of OpenAirInterface5g-nr gNB and UE. Frontend Bound denotes that instruction-fetch stall will prevent core from making forward progress due to lack of instructions. Bad Speculation reflects slots wasted due to incorrect speculations. Backend Bound illustrates that no micro-ops are being delivered at the issue pipeline, due to lack of required resources in the Backend. We can see that across all the functions, the Frontend Bound and Bad Speculation overheads are negligible. The main stall of OpenAirInterface5g-nr functions is concentrated on the Backend Bound, which means the optimization for Backend part is necessary for OpenAirInterface5g-nr application. The methods such as avoiding dependent arithmetic operations in a sequence; or better vectorization of OpenAirInterface5g-nr system may alleviate the severe Backend Bound performance limitation for OpenAirInterface5g system.

V. 5G NR AND MEC APPLICATIONS CO-LOCATION

We choose video processing related applications vips and x264 from PARSEC3.0 as our benchmarks since most of today's edge computing applications are concentrated on video provisioning. Figure 7 shows the normalized runtime of MEC applications. With the co-running with OpenAirInterface5g-nr, the edge computing applications require more time on completing the same-volume workload. The prolonged time for MEC applications range from 1.4X to 3.5X.

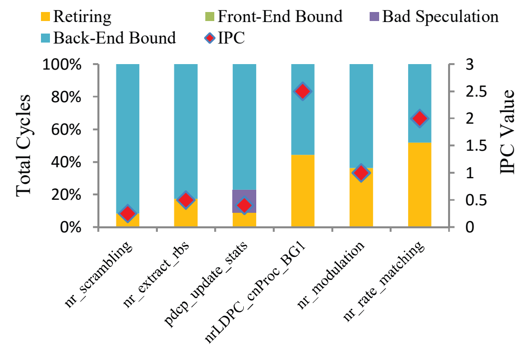

Figure 5. Microarchitecture value for gNB main functions

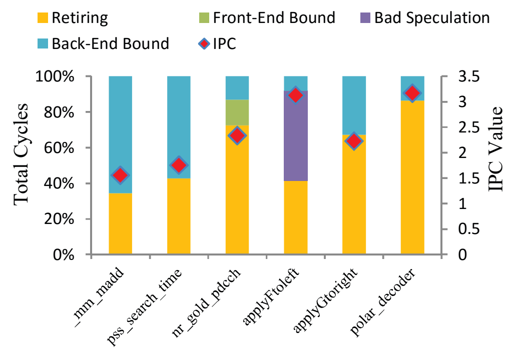

Figure 6. Microarchitecture value for UE main functions

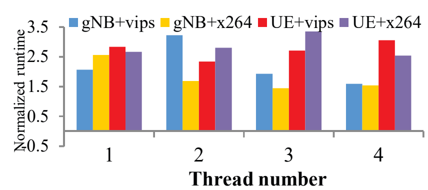

Figure 7. The MEC applications runtime when co-running with 5G NR

Furthermore, we evaluate the OpenAirInterface5g-nr gNB and UE performance when it is co-running with edge computing applications. We observe that the performance of the OpenAirInterface5g-nr application does not degrade even though it is sharing the same core with the edge computing applications. The reason is that the threads created by OpenAirInterface-nr get the real time priority (OAI_PRIORITY_RT), which provides the OpenAirInterface5g-nr high priority during the scheduling when co-running with edge PARSEC applications. This high priority schedule is essential for the 5G NR system when co-running with MEC applications since it contains a strict time stamp requirement, the violation of the constraint time stamp will cause the breakdown of the whole 5G NR system. The prolonged processing time of MEC application is less harmful compared to the breakdown of the 5G NR system.

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