Benchmarking of Elastic Cellular Core

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ABSTRACT
Current cellular networks have dedicated middleboxes that provides the necessary network functionality to sustain the demands of the network. It has been proposed to shift these functions currently implemented by individual specialized hardware into software functions in the shape of Network Function Virtualization. The Evolved Packet Core of the network which comprises of the MME (Mobility Management Unit), S-GW and P-GW (Serving and Packet Gateways) is being advocated to be converted into virtualized network functions running as virtual machines in generic hardware in data centers. SoftEPC [2] and KLIEN [1] have studied the effects of this change in network architecture under some conditions. However we believe that there is still room for more extensive analysis to be done on EPC functions running under NFV. The analysis especially concerning how this design will scale in the future. Mobile networks are poised to grow by large scale in a short time, especially with the prolifferation of IoT devices. We review the proposed architecture present some results. We have tested under load conditions to conclude on benefits and drawbacks of this approach.

Categories and Subject Descriptors
C.2.0 [**Computer Communication Networks**]; C.2.1 [**Network Architecture and Design**]: Centralized Networks; C.2.3 [**Network Operations**]: Network Management

General Terms
Measurement, Documentation, Performance, Design, Reliability, Experimentation, Theory

Keywords
Software defined networking, network function virtualization, mobile packet core, evolved packet core, future mobile networking, 5G networking, network slicing, software defined networking.

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1. Introduction
Mobile networks are facing an explosive growth in the number of connected devices and this trend is likely to continue [3]. The proliferation of smartphones, tablets and other devices has placed a severe burden on existing base stations and backhaul infrastructure. Moreover due to the quality assurance requirements of telecom providers, there is a need to over provision on top of the base traffic requirements. This is a capital intensive task that vastly increases operational and capital expenditure of the network providers. It is not considered feasible to provide for increase in capacity, especially in light of the low return on investment coupled with future load forecasts. [2]

1.1 Network Function Virtualization
In conjecture with Software Defined Networking (SDN), there is a rapid change undergoing in communication networks with the development of NFV. The flexibility and cost-effectiveness it provides makes the migrations to software attractive. Moreover NFVs based on NetVM [5] principles has enabled network functions to remain flexible while at the same time run at near line speeds. This design allows dynamic scaling and reprogamming.

1.2 Evolved Packet Core
Existing cellular networks comprise of two major components. This includes the LTE Radio Access Network (RAN) and the Evolved Packet Core (EPC). A generic mobile network has been given in Figure 1.

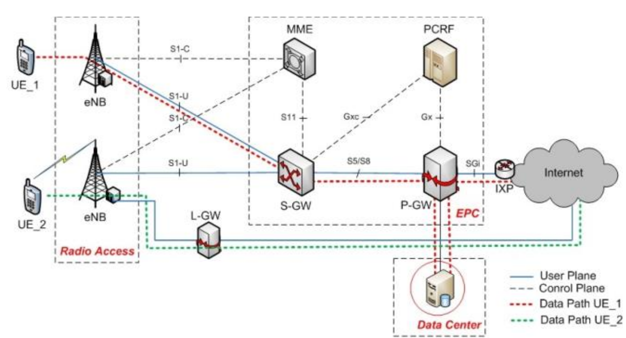

Figure 1: Generic EPC Mobile Infrastructure [2]

The RAN consists of the eNodeB (i.e a base station) which communicated with the User Equipment (UE, i.e the mobile device) through a radio link and forwards packets to the required destination via the EPC.

The EPC is comprised of several important entities. These include the MME (mobility management unit), S-GW and P-GW (serving and packet gateways) and any other function specific middleboxes such as NATs or firewalls. The MME deals with the control plane functionality i.e user authentication, session establishment, and mobility management. The S-GW and P-GW provide the data plane functions, i.e packet forwarding, traffic management, and policy enforcement.

The existing EPC are based on a mission specific, specialized network nodes that are interconnected via standardized interfaces in a static manner, each providing a specific service.

The concept of an Elastic Cellular Core in which hardware functions of the EPC are implemented as virtual network functions leverages the technology concept of Infrastructure as a Service (IaaS). It's main benefits include on demand and load-aware dynamic instantiation of network functions and services at appropriate locations in response to traffic demand. It helps in increasing utilization of network resources by increasing flexibility. The benefits and gains of this technique have been demonstrated by Yousaf et al [2].

We have set up the EPC and RAN as virtual functions on different workstations and interfaced them together with the help of OpenAirInterface [4]. After running a number of number of tests to evaluate the performance of the proposed futuristic ECC network, we have gathered results which provide us a good overview of the ability of this architecture to scale to future traffic demands.

2. BACKGROUND AND MOTIVATION

The subject of an Elastic Cellular Core is quite new and hence there is limited literature on the subject. Some popular works in this field are KLIEN and SoftEPC.

KLIEN [1] studied the performance of a proposed cellular core built with limited changes to existing infrastructure and compared it to a clean slate solution. It found that the intermediate solution that required no changes to the 3GPP compliant routing mechanism performed well under the load conditions. It had vastly greater performance than the existing EPC implementation while being close to the optimal performance provided by a clean slate solution.

In SoftEPC [2], Yousaf et al first proposed moving the EPC to network functions. Their results show that compared to today's static and fixed deployment of mobile core functions, the SoftEPC method can achieve significant saving in network bandwidth and processing load. By enabling the placement of SoftEPC functions in an intelligent manner, there is 25% saving of network resources. Moreover if this is coupled with a strategy to decentralize the service access points, the potential savings shoot up to 48%.

3. PERFORMANCE ANALYSIS

To continue forth with the approach of shifting EPC functions to NFV architecture. We ran a number of tests, mainly focusing on the scaling of throughput and latency (RTT) with changes in load conditions. We present our results in 3.2 and give the relevant analysis in 3.3.

3.1 Emulation Environment

The workstation running our RAN is an intel i5 machine running Ubuntu 14.04 Kernel 3.19.0-56-lowlatency. The workstation running our EUTRAN (i.e emulated network functions of the EPC) is also on a separate intel i5 machine running Ubuntu 14.04 Kernel 4.70-RC7. Both machines are connected to the LUMS network that has 1 Gbps capacity.

Using analysis tools provided by EUTRAN we can get a deep look into the state of connections between the user equipment and eNodeB.

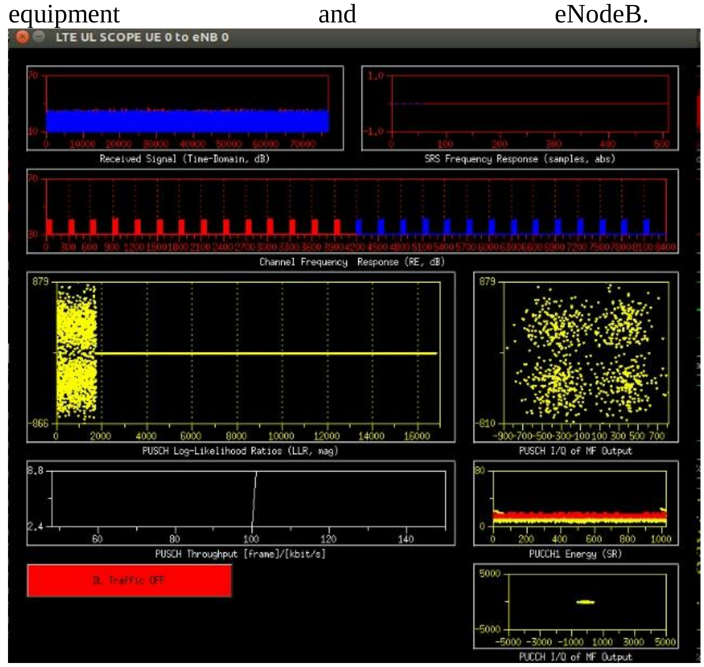

Figure 2: Scope on connection from UE to eNodeB

As shows in the scope in Figure 2, we can get plots of the received signal, the received symbol, the frequency response of the channel and several other parameters.

Similarly, the connection between the eNodeB to UE can also be studied in detail. The scope on this connection gives us plots of the received signal, both in time and frequency. We're also provided with the channel impulse response and log likelihood ratios.

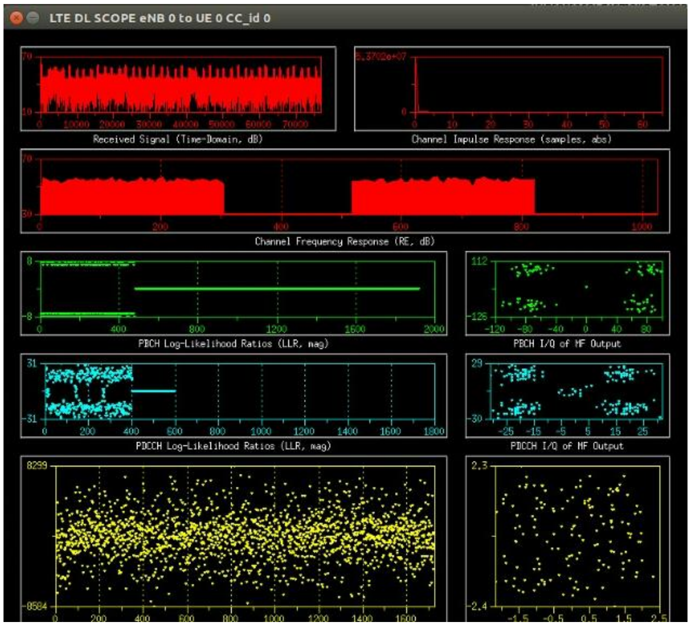

Figure 3: Scope on Connection from eNodeB to UE

3.2 Results

The tools we used for our analysis were iperf and speedtest-cli [7] that enabled us to measure throughput and latency.

We measured the relevant metrics while increasing our number of connections to the server. The final results were averaged.

In Figure 4, the line graph of our RTT measurements to some chosen servers across the world our displayed.

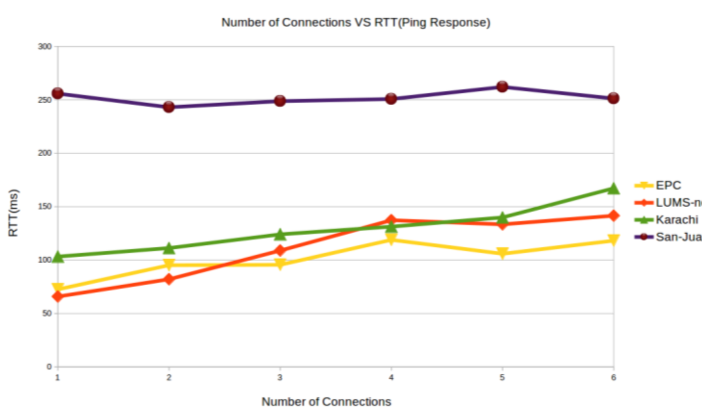

Figure 4: RTT Latency Measurements

In Figure 5, we present the results of our throughput measurements extracted from speedtest-cli [7].

We tested on two different servers provided by speedtest.net and could see a marked decrease in average throughput of each process as their number increased.

3.3 Analysis

Under conditions of increasing load placed on an EPC through increase in mobile connections from a single UE, we have gathered significant results to conclude that there is apparent service degradation. This aspect needs to be looked at further to reach a proper thesis. However it can be seen that throughput suffers at much greater level than the latency.

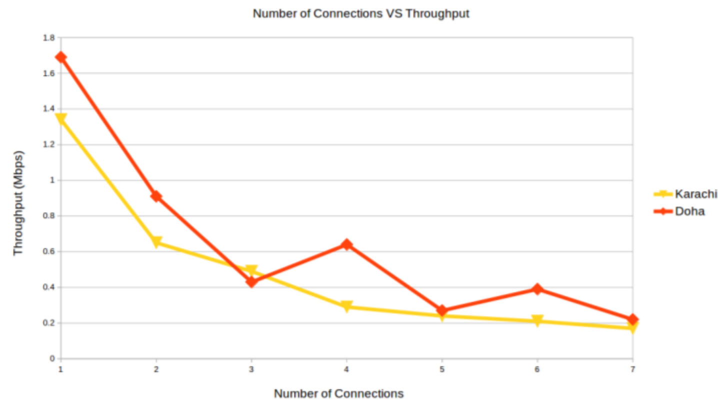

Figure 5: Throughput Measurements

4. DISCUSSION AND FUTURE WORK

Due to the novelty of NFV and ECC, there exist several opportunities for research in this domain to further knowledge and utility.

1. Combining P-GW/S-GW with MME. While this would reduce flexibility in the network, it is possible that the consolidation of EPC functions can reduce signaling traffic. This would allow the network to scale better.

2. Wireless microwave backhaul links between eNodeBs (Base stations) for load balancing and backup links.

3. Further experiments can be run for varying load conditions to study their impact of mobile networks.

4. Using multiple UEs, that we were not able to explore due to constraints of the emulation environment. This also leads us to the conclusion that OAISim is at its present stage not suitable for research due to significant efforts and time required on configuration. An emulation system that it at once both powerful in analysis and easy to configure and use can fill a major shortcoming.

5. SUMMARY

With our extensive testing and results we have shown that the scaling of network functions happens as expected. Studying both throughput and latency observed at the UE connecting to backhaul network. We can conclude that there is significant service degradation occurring at the EPC on increasing load placed on it by the access network. This presents a shortcoming of the proposed elastic approach. There is still a need for more extensive testing under different conditions.

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