# An Emulation Framework for End-to-End 5G Systems

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***Abstract*—5G system is designed to meet the requirements of various network services such as eMBB (enhanced Mobile Broadband), URLLC (Ultra Reliable Low Latency Communications), and mMTC (massive Machine Type Communication) by making use of the technologies such as Software Defined Networking (SDN) and Network Function Virtualization (NFV). Service Based Architectures (SBA) have been in use in the software industry to improve the modularity of products. A service can be broken down into micro-services, making packet exchange lightweight. The core network of the 5G system is built using the Service Based Architecture (SBA). In this demonstration, we will show the capabilities of our SBA based 5G Core (5GC) for an end-to-end complete flow with an always on PDU session with eMBB service using HTTP streaming. Also, the deployment of the 5GC will be demonstrated in a complete dockerized environment with the network functions of 5GC and the application.**

## I. INTRODUCTION

The 5G system architecture consists of two important parts namely Access Network and Core Network (CN). 3GPP has defined the 5G Core (5GC) with a Service Based Architecture (SBA) [1] to provide support for three different generic services namely enhanced Mobile Broadband (eMBB), massive Machine-Type Communications (mMTC), and ultra-Reliable Low-Latency Communications (uRLLC), each offering different Quality of Services (QoS) to the users subscribed to those services. Hence this is a paradigm shift from the existing 4G Evolved Packet Core (EPC), replacing the monolithic network entities running on proprietary hardware with the software modules called Network Functions (NFs). The NFs are capable of running on cloud servers or commodity hardware by making use of Software Defined Networking (SDN) and Network Function Virtualisation (NFV) like technologies, supporting flexible network deployment.

There are efforts across the globe to build a complete end-to-end 5G system for prototyping 5G system network and applications. Free5GC [2] is being leveraged to explore the softwarization in the 5G system composed of the Radio Access Network (RAN) and the core components [3]. Kube5G [4] provides an open source platform to deploy 5G and beyond services in cloud native environment with a set of OAI [5] CN and Radio Network Cloud Native Function (CNF)s. Authors in [6] have presented a gRPC [7] based model for the realization of SBI for 5GC and evaluated it with respect to the control plane latency and resource utilization. Our focus here is to enable a 3GPP compliant, network slice supportive platform to meet the varied needs of diverse applications arising from primary categories of slice services such as eMBB, URLLC, and mMTC. The following are the key features of our 5GC that would be demonstrated.

- A complete sliceable 5GC which can facilitate primary network slicing.
- Emulated 5G test-bed showcasing an end-to-end eMBB service using HTTP video streaming.
- Deployment of the 5GC in a dockerized environment showcasing the flexible 5GC deployment.

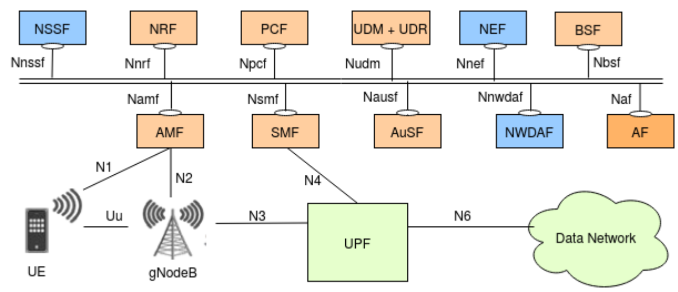


Fig. 1: 5G System Architecture.

## II. 5G CORE NETWORK PROTOTYPE

The developed 5GC prototype is based on 3GPP Release 15 specifications [1, 8] emulating the functions of various entities and call flow procedures between them as shown in Fig. 1. Our 5GC comprises of 5GC control plane Network Function (NF)s listed as Access and Mobility Management Function with co-located Security Anchor Function (SEAF), Network Repository Function (NRF), Authentication Server Function (AUSF), Unified Data Management (UDM) with co-located Authentication Repository and Processing Function (APRF) along with Subscriber Identity De-concealing Function (SIDF), Session Management Function (SMF). The framework leverages Service Based Interaction (SBI) between Control Plane (CP) NFs. Service Based Interfaces (SBIs) are realized and implemented with REST APIs using HTTP/2 library from nghttp2 [9]. NRF provides service registration and discovery services to other network functions in the framework. UPF in the 5GC participates in data plane path with Application Server (AS) enabling GPRS Tunneling Protocol User plane (GTP-U) on $N3$ with RAN and $N6$ interface AS. Here, AS represents Data Network (DN) connectivity point on $N6$ interface with UPF.

While UE can be provisioned with static policies for its PDU session's Quality of Service (QoS) flows by SMF, we support Dynamic Policy provisioning for QoS flows with Policy and Charging Function (PCF). Further Binding Support Function (BSF) is also developed to support external traffic influencing Application Function like Multi-access Edge Computing (MEC).

For emulating the end-to-end UE slice services, we have developed a light weight RAN + UE emulator on control plane with Next Generation Application Protocol (NGAP) and embedded User Equipment (UE) with Non Access Stratum (NAS) to support $N2$ and $N1$ interface functionalities with AMF. All these network functions including RAN + UE Emulator are developed as virtualized docker containers [10] each intended to provide micro service functionalities running in a single or a multi-host dockerized container networking environment.

Key features and functionalities of our 5GC are

- Supports UE registration and de-registration.
- User Id protection with Elliptic Curve Integrated Encryption Scheme (ECIES)-B profile using SIDF.
- 5G Authentication and Key Agreement using ARPF, AuSF, and SEAF.
- Always on PDU session for UEs.
- Dynamic policy provisioning for QoS flows using PCF.
- Data transfer between two endpoints on the data plane through GTP-U.

The following endpoint applications are supported in this end-to-end solution consisting of UE App, RAN + UE Emulator, UPF, and AS on the data plane.

- HTTP video streaming through VLC player.
- Performance benchmarking using iperf utility.
- Real-time Video Caching Application with MEC.

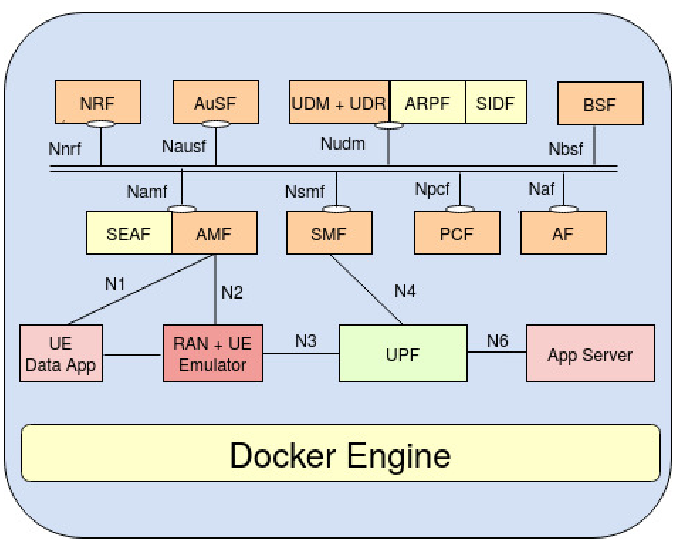


Fig. 2: 5G Emulation Framework for end-to-end application using 5GC.

## III. 5G Emulation Framework Demonstration

The Fig. 2 shows the complete deployed demonstration framework in a dockerized environment with primary set of NFs along with PCF and BSF to support dynamic policy provisioning and external traffic influencing in 5GC along with RAN + UE emulator to demonstrate UE registration, in Mobile Subscriber Identification Number (MSIN) protected mode, PDU session establishment, and UE deregistration on the control plane. On the data plane the external IP based UE Application, RAN + UE Emulator, UPF, and AS on N6 facilitate data path in UL and DL directions for a specific UE. We enable VLC media player in both UE application and AS docker containers to showcase the HTTP streaming in the data path.

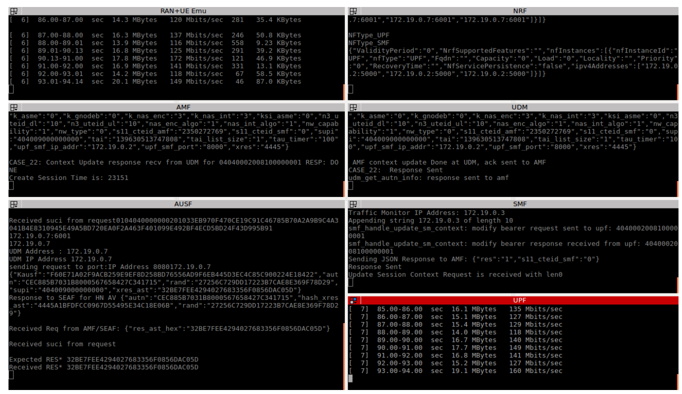

Fig. 3: End-to-end data exchange using 5GC.

In the demo execution, NRF is first brought up and activated, after which each NF in the 5GC is instantiated and activated. Each of these NFs in 5GC register its service at NRF. Each NF upon activation is now ready to serve the traffic of 5GC control plane and data plane. Once the RAN + UE emulator function gets active, it emulates the UE activities, requesting for a specific slice service first by registering to 5GC. RAN emulator then allows for data exchange in UL and DL directions (as shown in Fig. 3) for a specified run time configurable duration. During this, we demonstrate the HTTP streaming on the end-to-end data plane, before the timer kicks off at RAN + UE emulator to automatically deregister the UE.

## IV. Conclusion and Future Work

In this demo, we demonstrate a fully virtualised, sliceable 5G core, which can support a variety of applications and industries with network slicing, in an agile way, to help revolutionize an operator's 5G business opportunity. In future, we plan to extend this framework to make it a highly scalable and resilient network slicing platform.

## Acknowledgment

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