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







### **5G System Architecture**



- $\succ$ A 5G system consists of two main parts:
  - Access Network (AN): Formed by RAN and respective cells.
  - Core Network (5GC)
- Service Based Architecture (SBA) with CUPS Framework >
  - Logical Nodes called Network Functions (NF)
  - Each NF provides a set of functions or services

- $\succ$ **AF:** Application Function
- **AMF:** Access and Management  $\succ$ Function
- AuSF: Authentication Server >Function
- $\succ$ **BSF:** Binding Support Function
- **NEF:** Network Exposure Function  $\succ$
- **NRF:** Network Repository Function  $\succ$
- **NSSF:** Network Slice Selection  $\succ$ Function
- $\succ$ **NWDAF:** Network Data Analytic Function
- $\succ$ **PCF:** Policy Control Function
- **RAN:** Radio Access Network  $\succ$
- **SMF:** Session Management  $\succ$ Function
- **UDM + UDR:** Unified Data >Management, Repository
- **UPF:** User Plane Function >
- **UE:** User Equipment  $\succ$

Ref: 3GPP, "System Architecture for the 5G System", Tech. Rep. TS 23.501, 3GPP,

### **5G System Architecture: Core Network**



#### Control Plane

- Service Based Interactions (SBI) between NFs
- Supports Capability Exposure
- REST API Interactions for all SBIs
- Reference Point Interface
  - PFCP emulation between SMF and UPF
  - NGAP interface (N2) between RAN and AMF
  - NAS based N1 interface between UE and AMF
- Ref: 3GPP, "System Architecture for the 5G System", Tech. Rep. TS 23.501, 3GPP,

#### Data Plane/User Plane

- Reference Point (Point to Point) Interface
- GTP-U based N3 Interface between RAN and UPF.
- ✓ N6 between UPF and Date Network (DN).
- Supports concurrent access to local and centralized services (E.g., MEC deployments)

### Key Features of Our 5G Core

- UE Registration and Deregistration
- Always on PDU session establishment
- User Id Protection
- 5G Authentication and Key Agreement
- GTP-U data plane between RAN + UE emulator and UPF
- Uplink and Downlink data transfer
- End point applications with UE App, RAN Emulator, UPF, Application Server /Sink on data plane
  - HTTP video streaming through VLC player
  - Performance benchmarking with iperf utility
- Multi-access Edge Computing (MEC) Support

## End-to-End 5G Emulation Framework



- Docker Environment
  - Single or Multi-Host
  - Standalone
  - Orchestration
- Control Plane

>

- Core: NRF, AMF, SMF, AuSF, UDM+UDR, PCF, BSF
- RAN+UE Emulator
- Data Plane
  - VPF
  - RAN Emulator
- Inbuilt UE application for performance benchmarking
- External UE with docker container for data applications
  - / HTTP Streaming
  - MEC Services

### **5G Core NF Functionalities**

#### > AMF:

- Mobility and Connection Management
- / N1 + N2 Interface with UE and RAN
- / Security Anchor Function
- SBI with SMF, AusF, UDM

#### SMF:

- PDU Session Establishment, Management for UE
- IP Address Assignment to UE, N4 Interface with UPF,
- SBI with AMF, UDM, PCF.

#### > AuSF:

- 5G Authentication and Key Agreement for UE
- SBI with AMF, UDM

#### UDM+UDR :

- Subscriber Information,
- Policy Database,
- Authentication Repository Processing Function
- Subscriber Identity Deconcealing Function

#### > NRF:

- Repository of network functions and associated services.
- SBI for Network Function Service Registration and Discovery

#### UPF:

- Control Plane for PDU Session management on N4,
- Data Plane on N3 with GTP-U and N6

#### > PCF:

- UE PDU Session Management Policy Decisions.
- Supports traffic QoS Flow influence by SBI with SMF, BSF, AF (MEC) .
- BSF:
  - Traffic Influence for trusted / untrusted AF (MEC) towards PCF.

### **RAN+UE** Emulator

- NGAP Functions for N2 Interface:
  - NG Setup.
  - UE Context Setup & Management.
  - NAS Transport
  - UE Context Release.
- NAS Functions from UE for N1 Interface:
  - ✓ UE Registration.
  - User Id Protection.
  - ✓ 5G Authentication and Key Agreement.
  - ✓ UE Deregistration.
  - PDU Session Establishment.
  - Data path with UPF using GTP-U for N3 Interface

СР Арр	DP App
NAS	GTP-U
NGAP	
SCTP	UDP

## **5G Emulated Framework: Flexible Configuration**

#### Basic 5G Core



NRF, AMF, SMF, AuSF, UDM+UDR, UPF
 Static policy for UE from SMF

#### 5G Core with Security



- Basic 5G Core + SEAF, ARPF, SIDF
- User Id Protection with SUPI Concealment + De-concealment using ECIES-B, 5G AKA Procedure

## 5G Emulated Framework for External Traffic Influence

- External Traffic Influence Core
  - Dynamic Policy with PCF
  - / BSF
  - Trusted AF : MEC AF
- AF registers at BSF
- UE Registers and establishes PDU Session
  - SMF fetches dynamic policy from PCF
  - ✓ AF arrives
    - Influences traffic rules at PCF using BSF
  - PCF notifies SMF
  - SMF installs the changed rules at UPF



## **5G Emulated Framework Demonstration**



- 5G Core Bring Up
  - Service Registration with NRF
- RAN+UE Emulator Bring Up
  - NG Setup
  - UE Registration
    - Service Discovery
    - UE Context Setup with User ID Protection
    - **5**G AKA
  - PDU Session Establishment
  - UL and DL Data Exchange
  - UE Deregistration

### End to End UE Registration with Data Plane Establishment



### Integration with Commercial/Testbed RAN



- Supports integration with gNodeB and UE
- N1 + N2 Interface functions on Control Plane at AMF
- N3 Interface GTP-U Tunnel Data Path at UPF

### MEC with 5G Core



- Supports concurrent access to local and centralized services.
- Real-time Video Caching Application with MEC

### **Support for Orchestration**

- Deployment in virtualized platform
- Orchestration Support
  - NFV MANO using Open Source MANO (OSM)
  - Container level with
    Kubernetes for Network
    Functions.



### Work in Progress

- Support for large scale simulation/emulation of 5G system
- Enabling core analytics with NWDAF
- Support for network slicing
  - Management
    - NSMF
  - Orchestration
    - NFV MANO
- Edge application deployment and orchestration

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