Note on open source initiatives for the 5GCore Network

The promise of 5G

The innovation of mobile network is measured by the number before G. The last innovation, 5G, is expected to take off ground in 2020 horizon. Unlike the previous generation of mobile network, 5G supports at least three vertical services. Each service has unique characteristics. Those three services are Enhanced Mobile Broadband(eMBB), Massive Machine Type Communication, and Ultra-reliable and low-latency communication. 5G delivers multi-Gpbs peak rates, ultra-low latency, and massive capacity. This empowers 5G to interconnects not only humans, but also objects, machines and devices.

Market size of 5G

Qualcomm estimates that more than 340 operators are investing in 5G and at least one billion 5G devices will be connected by 2023. The total number of 5G connections will also nearly triple to 2.8 billion by 2025.

The main system components of 5G

The mobile network has radio access network and core network. In 5G, access network uses 5G New Radio technology and core network is referred as 5GCore.

Design principal of 5GCore

5GCore is completely different architecture compared to the previous generation of mobile core network. New design of 5Gcore is centered around SDN, and Service Based Architecture (SBA) principals, driven by IT technologies. The New core intends to be a single core that supports different types of access network.

Control and User Plane split

Software Defined Network (SDN) is the separation of the control and data plane in a standard manner. This enables single control plane entity to manages many data plane entities. Second benefits is that control and data plane entity can be developed and scaled independently. SDN is mentioned as Control and User Plane Separation (CUPS) in 3GPP core network.

3GPP reviews this principals and validates the need in the core network. It started separating control and data plane in SGW/PGW of 4G network with a new protocol, Packet Forwarding Control Protocol(PFCP).

The PFCP is adopted in 5GCore with required modification/evolution. 5GCore uses PFCP between SMF (i.e. control plane) and UPF (i.e. data plane).

A single Core network for any type of Radio Access Technologies (RAT)

5GCore is designed in a manner that different RATs can be easily integrated into a single core network.

Service Based Architecture (SBA)

5GCore proposes network functions, unlike the network nodes in pre-5G network. These functions interact with others with well-defined APIs that can be Request/response, and pub/sub methods. Those APIs are based on HTTP/2.

Stateless
Stemmed from the cloud concept, stateless is promised to keeping the processing and storage as a separate entity. Therefore, NF becomes highly scalable and available in the case of failure.

Cloud-native
IT technologies such as NFV and cloud transform the way of creating, deploying, operating and manging the network application. The network application becomes cloud native applications when it follows the micro service architecture.

Micro-service architecture separates the individual task of the application that intends to do into separate services. Those services can developed and managed independently, with their ownAPI, rollout, scaling and quota management. Micro-services are independent, modular, dynamic, and ephemeral. They can be distributed across many hosts, clusters, or even clouds.

Cloud native architecture based on micro-service and containers is a key technology to enable automatic network function life cycle management. Micro service architecture is adopted for 5Gcore network functions when deploying in cloud environment.

5G Architecture

I prefer to use architecture diagram for 5G network from Samsung 5G common core portfolio, which divides all 5G core network functions into four groups based on feature set: 5G Business Enablement, Mobility& Connection Control solution, 5G service support solution, and session and Data Processing solution.

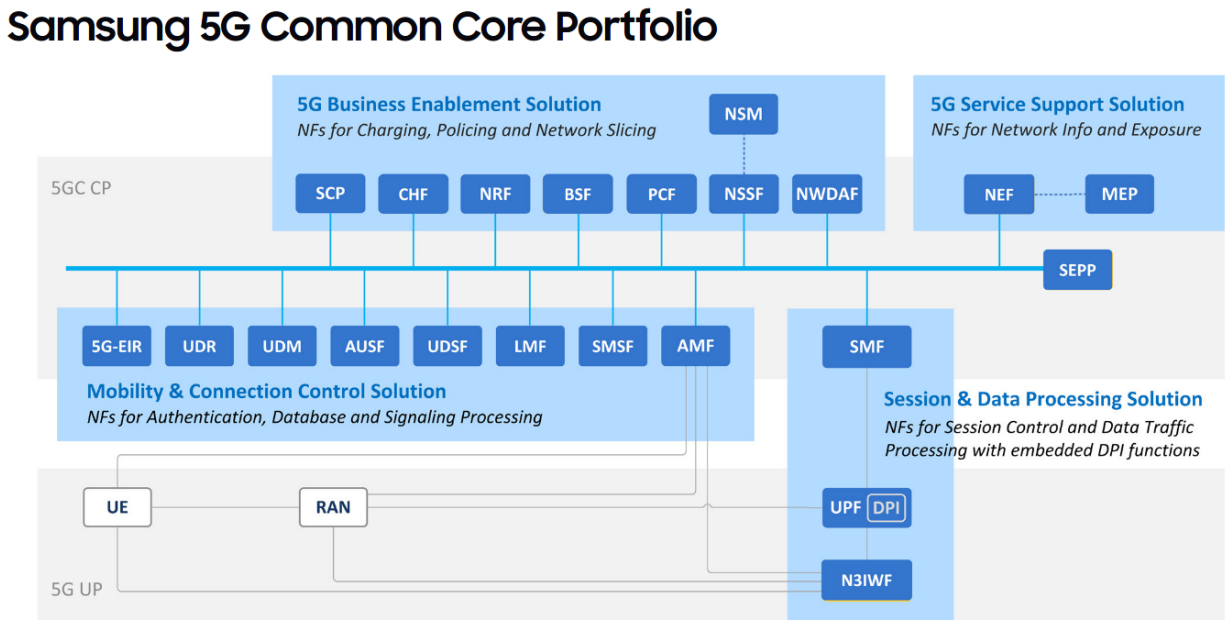


Figure 3-3. Samsung 5G Common Core Portfolio

Photo Courtesy: https://image-us.samsung.com/SamsungUS/samsungbusiness/pdfs/5G_Core_Vision_Technical_Whitepaper.pdf

In the diagram, each function is mentioned with abbreviation. Those abbreviations are described here:

AMF: Access and Mobility Management Function
SMSF: Short Message Service Function
LMF: Location Management Function

UDSF: *Unstructured Data Storage Function*
AUSF: Authentication Server Function
UDM: Unified Data Management.
UDR: Unified Data Repository
5G-EIR: 5G Equipment Identity Register

NWDAF: Network Data Analytics Function
NSSF: Network Service Selection Function
NSM: Network Slice Manager
PCF: Policy Control Function
BSF: Binding Support Function
NRF: Network Resource Function
CHF: Charging Function
SCP: Service Communication Proxy

NEF: Network Exposure Function
MEP: MultiAccess Edge Platform
SEPP: Security Edge Protection Proxy

SMF: Session Management Function
UPF: User Plane Function
N3IWF: Non-3GPP Interworking Function

I leave the readers get understand each network function of 5GCore themselves. Those features are described in 3GPP 23.501 and 23.502 technical specification. However, I list a few functional details at a higher level:

1. Mobility& Connection Control solution
    A. Connection management
    B. Registration management
    C. User profile
2. session and Data Processing solution.
    A. Session Management (service request and different types of PDU Sessions)
        - network resource usage reporting
        - QoS enforcement
        - Local Area Data Network
    B. Handover in 3GPP Access. Handover of UE from NG-RAN to another is possible over Xn or N2 reference points.
3. 5G Business Enablement,
    A. charging, policy and network slices
4. 5G service support solution
    A. Network Exposure and Info

Session management involving with SMF and UPF are interest of my analysis in this note.

Opensource Initiatives
When it comes into mobile core network, well-known open-source initiative is OpenAirInterface Software Alliance (OSA) which released base station and core network software for 4G network. They are continuing their work on 5G also. However, when it comes to 5GCore network, more appealing work comes from Free5GC than OSA. This analysis is completely based on publicly

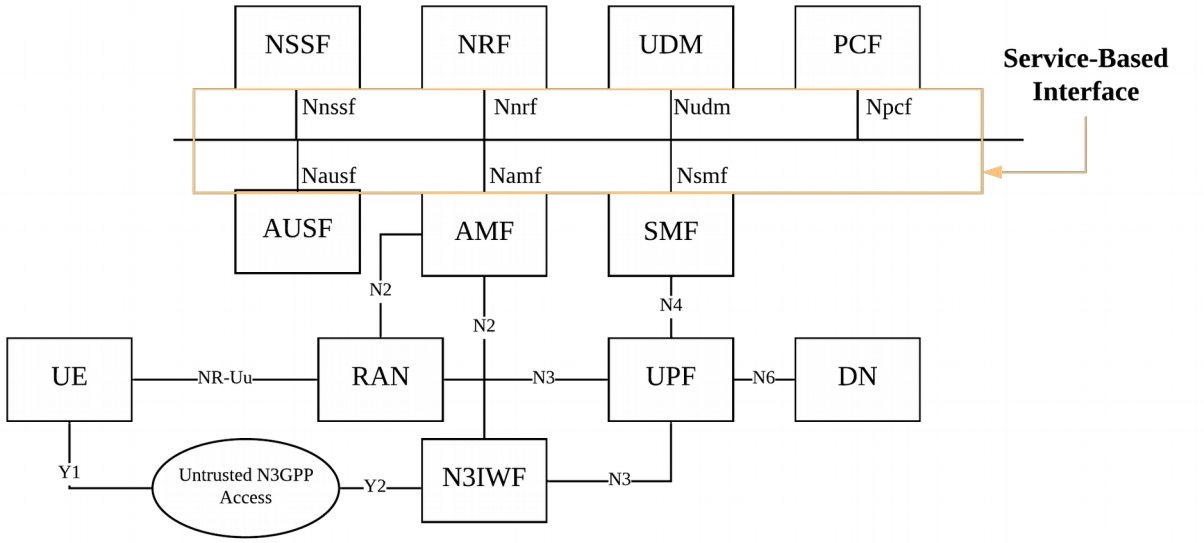
available source code for 5GCore network functions. Another interesting open source network function is UPF which is built using Vector Packet Processing(VPP) by TravelPing. In this note, I will cover Free5GC and VPP based UPF development with implemented features.

Free5GC

On December, 2019, Free5GC, open-source project, released the stage 2 of their development on 5GCore network accommodating the service based interface of 5GCore network functions. Their reference design is given below and includes the following network functions: UPF, SMF, AMF, PCF, UDM, NRF, NSSF, AUSF and N3IWF. 3GPP Release 15 and Release 16 is basis of Free5GC development.

The each function has full set of SBI that is automatically generated from the 3GPP defined yaml files.

RAN and UE shown part of architecture, however, need to get from outside of Free5GC.



Free5GC supports Registration, Session management (Service request, PDU Session release request), handover(Xn/N2 handover), Paging and De-registeration .

The main shortcoming with Free5GC is that all network functions are not developed as micro-services. For examples, SMF is developed as a single monolithic application, rather separating the individual tasks into separate services. This feature is not a blocking point, but it is desired for higher scalability, availability and make it cloud native applications.

VPP based UPF

UPF manages PDU session between access network and data network, based on the information received from SMF. UPF performs UP link classifier/branching point and session anchor.

VPP technology is open-source technology, provided by Cisco to build the higher performance data plane on commodity CPUs. Because of modularity and flexibility, new protocol can be implemented as a VPP plugin. VPP is a good candidate for building the UPF that has proven performance and production quality.

UPF from TravelPing is one derivation of VPP. It supports 3GPP TS 23.214 and TS29.244 version 14.1. Many parts of PFCP protocol is implemented. It means that many PFCP messages are implemented. PFCP has defined five types of rules such as Packet Detection Rule (PDR), Forward Action Rules (FAR), Usage Reporting Rules (URR), Buffer Action Rules(BAR) and QoS Enforcement Rule (QER). The first three rules are implemented.

Note: UPF based on Berkeley Extensible Software Switch(BESS) framework is released part of Open Mobile Evolved Core (OMEC) project. That will be discussed later.

Conclusion:
5GCore network can be built as a Test bed to understand, to validate practical experiments, to extend new features and to demonstrate the 5G network capability in a realistic testbed environment by researcher, engineers from operators and academia, with available open source. Free5GC based network can deliver only eMBB services. Protocols for MassiveIoT and URLLC services are not implemented in Free5GC.

I help design, develop, and deploy 5GCore network to interested parties who work on private network, public network or 5G network services such as Mobile Edge Computing (MEC), Vehicular Edge Computing(VEC), and IoT. At the same, I worked on own implementation of PFCP library which can help implementing of some missing feature in the Free5GC PFCP stack. During my testing in Free5GC and VPP based UPF, I discovered many mismatch features in PFCP at the UPF end, and SMF end. That will be added into the respective repos soon.
How telecom industry is going to chant carrier grade features in the new era? I do analysis of carrier grade features with SMF and UPF. I will provide more details in near future.

ref
[1]https://bitbucket.org/free5GC/free5gc-stage-2/src/master/
[2]https://github.com/travelping/vpp/tree/feature/1908/upf
[3]https://bitbucket.org/sothy5/n4-go/src/master/