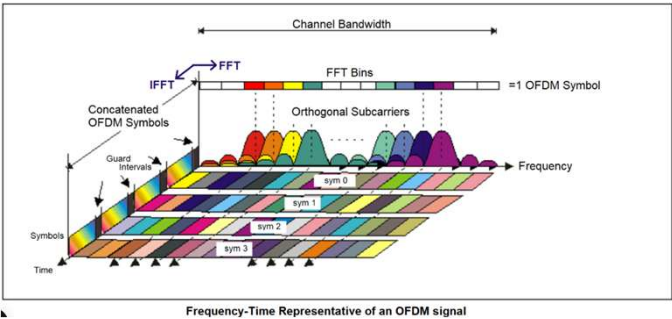
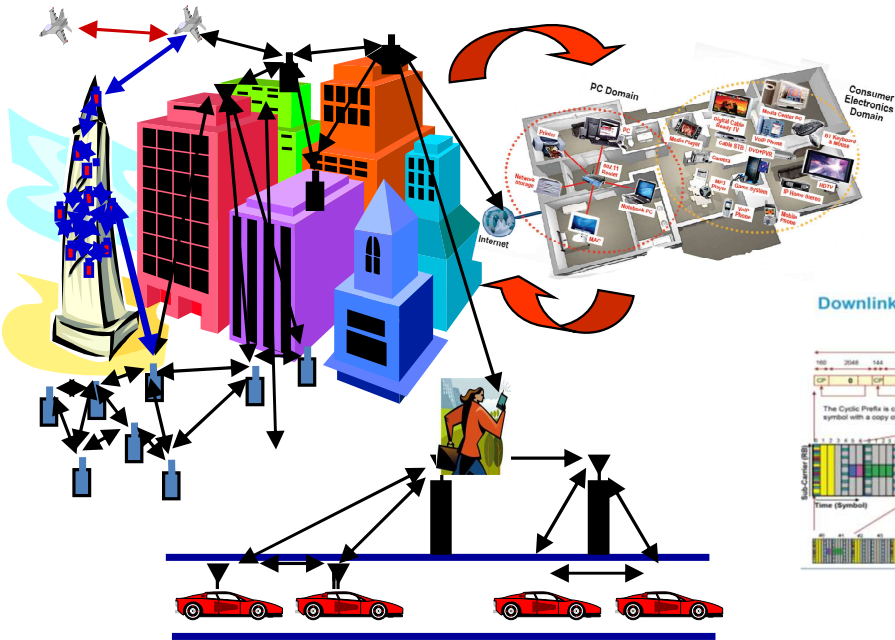
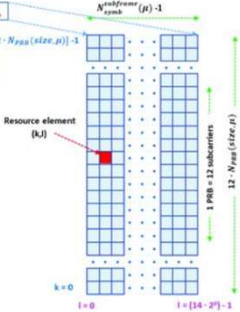
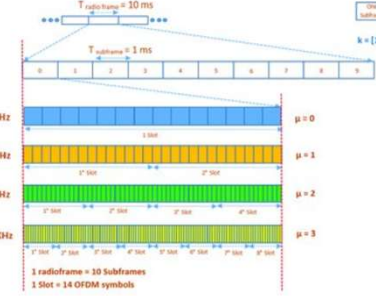
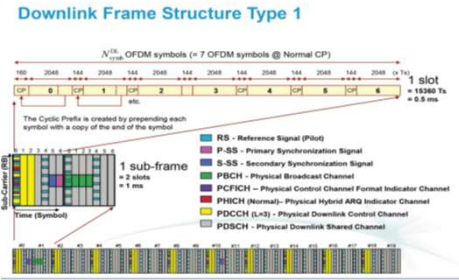


IEE2650: Cellular Communication Technologies

Muhammad Mahtab Alam, Professor



Frequency-Time Representative of an OFDM signal



What do I get from NR ?

Native support for **Low Latency and Ultra Reliability**

Flexible and modular RAN architecture: split fronthaul,
split control- and user-planes

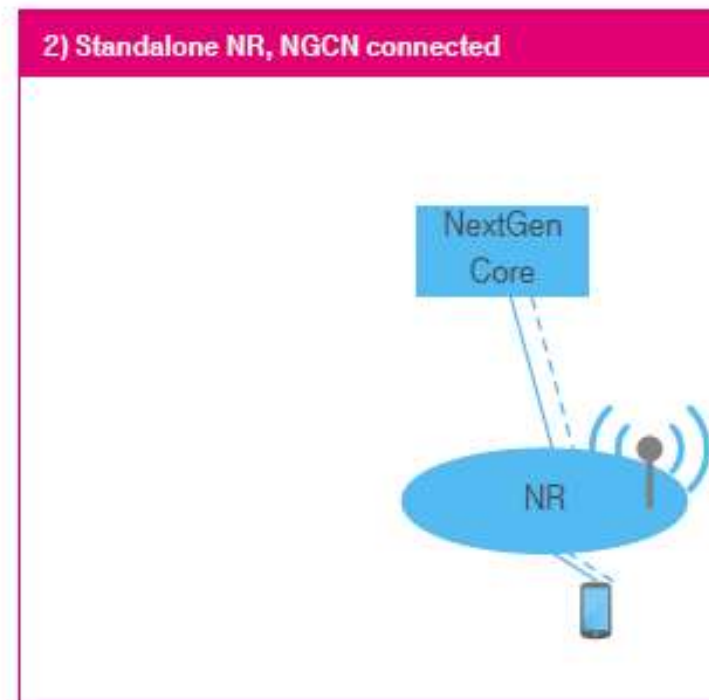
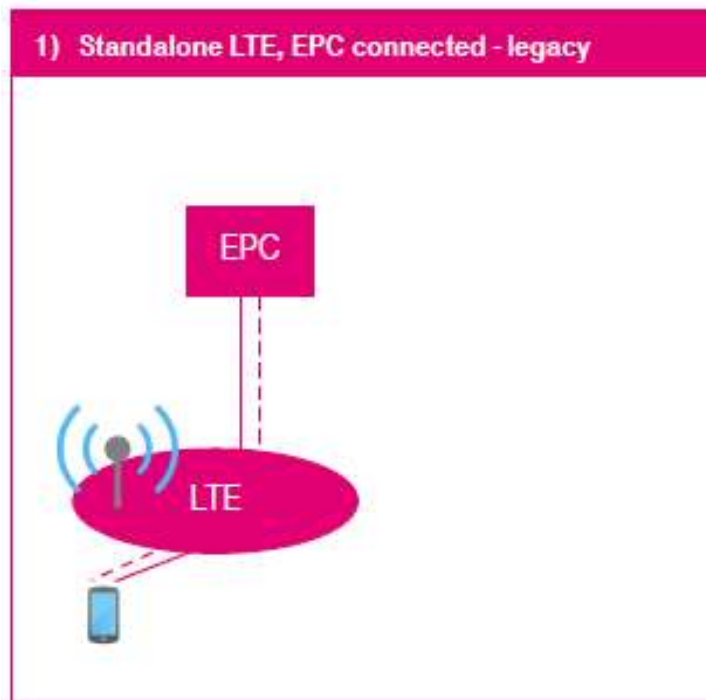
Native end-to-end support for **Network Slicing**

Is 5G just NR ?

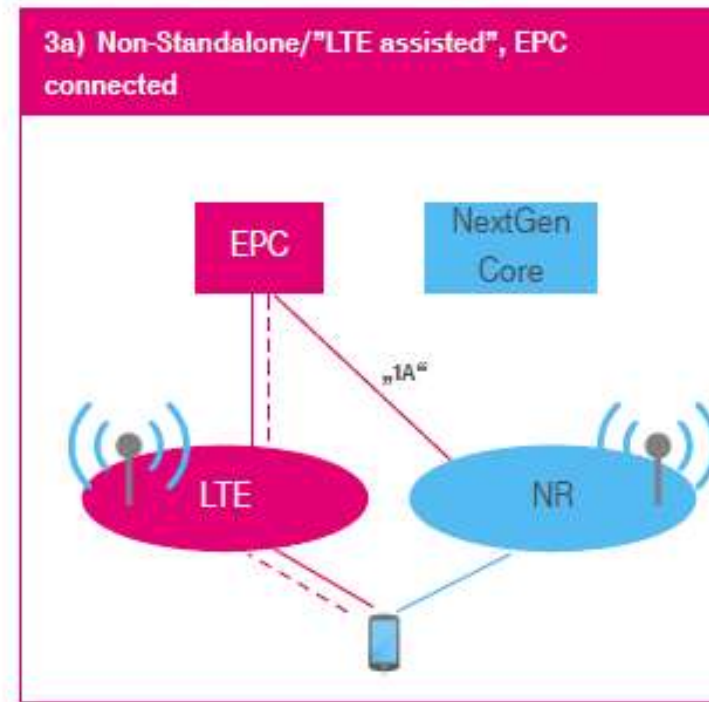
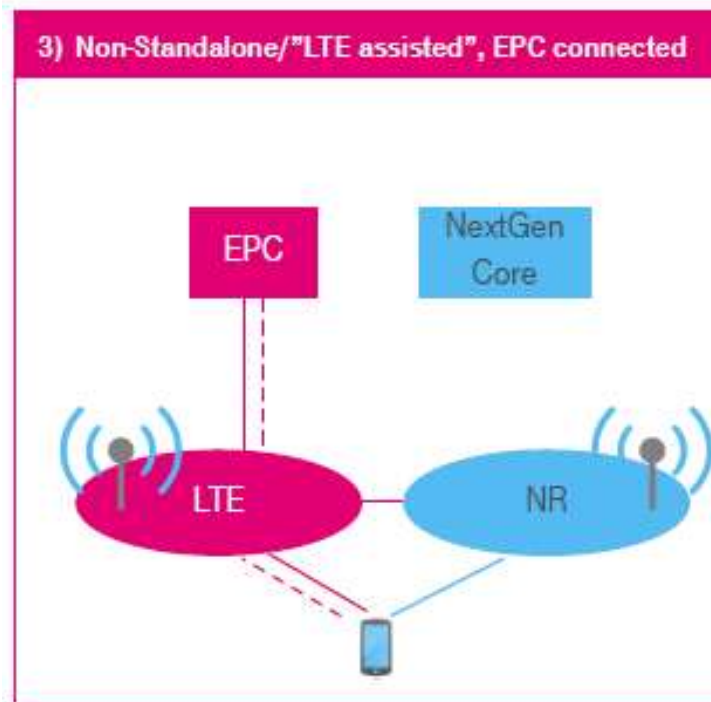
No. To realize the full potential of what NR can offer, the core network needs to evolve from the Enhanced Packet Core (EPS) of 4G to the Next Generation Core Network (NGCN) of 5G.

 So what does the (simplified)  architecture look like?

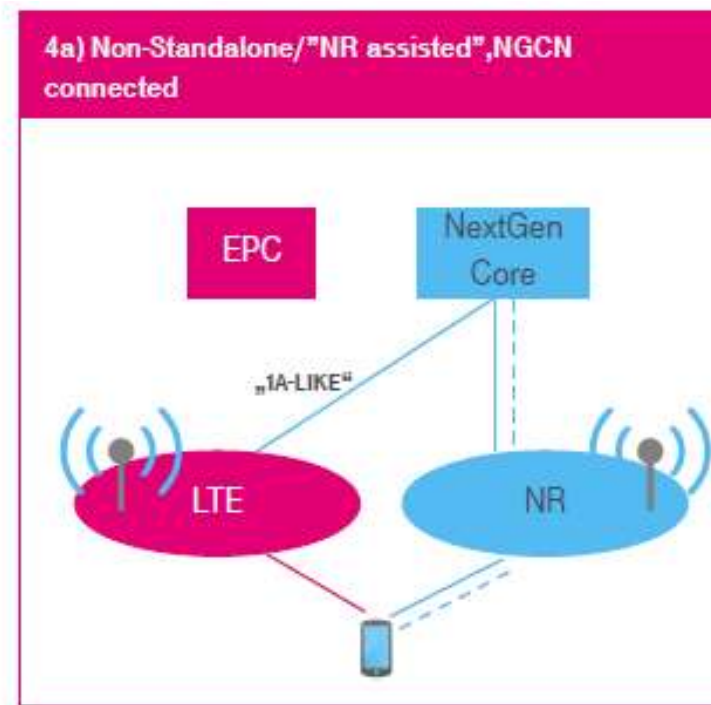
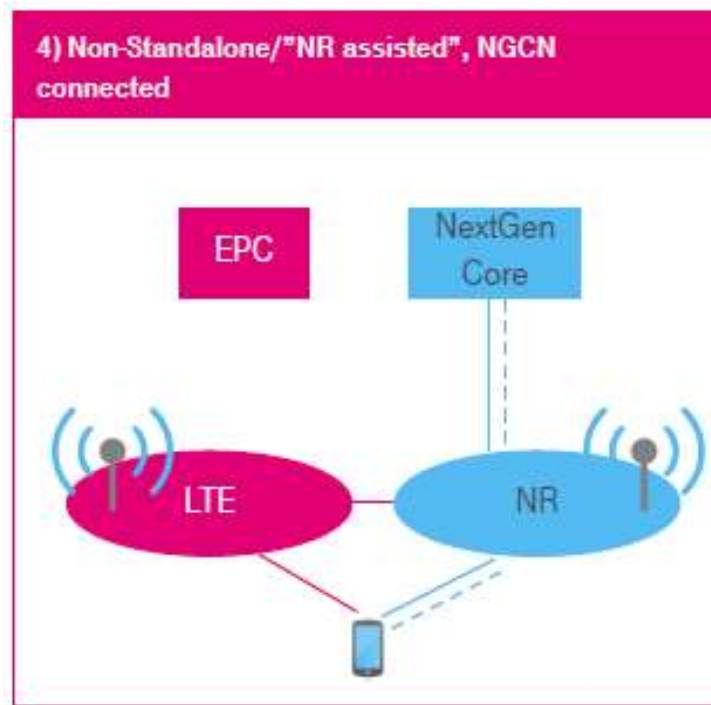
5G system architecture



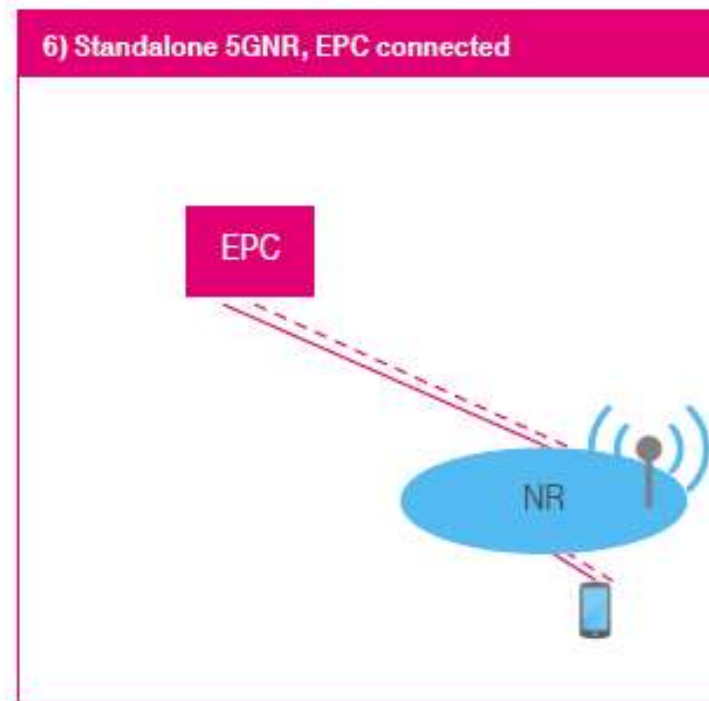
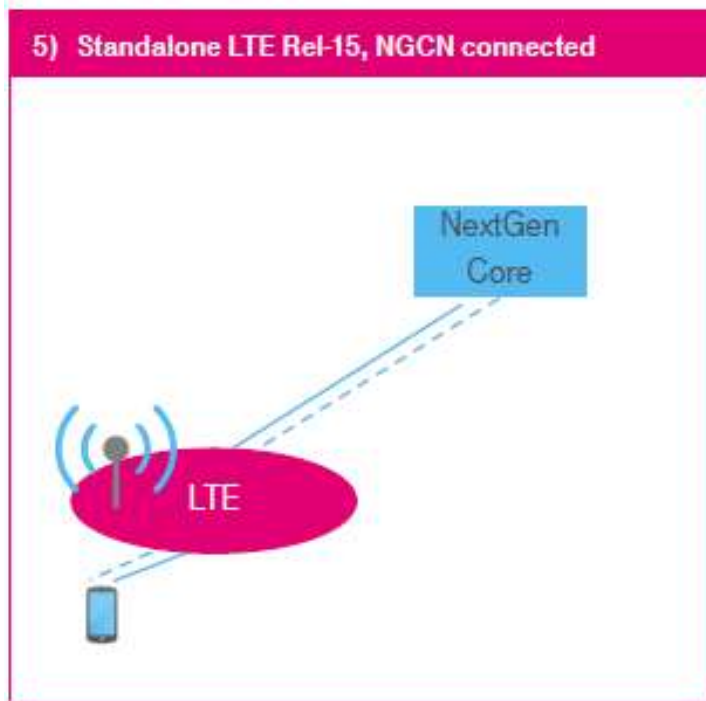
5G system architecture



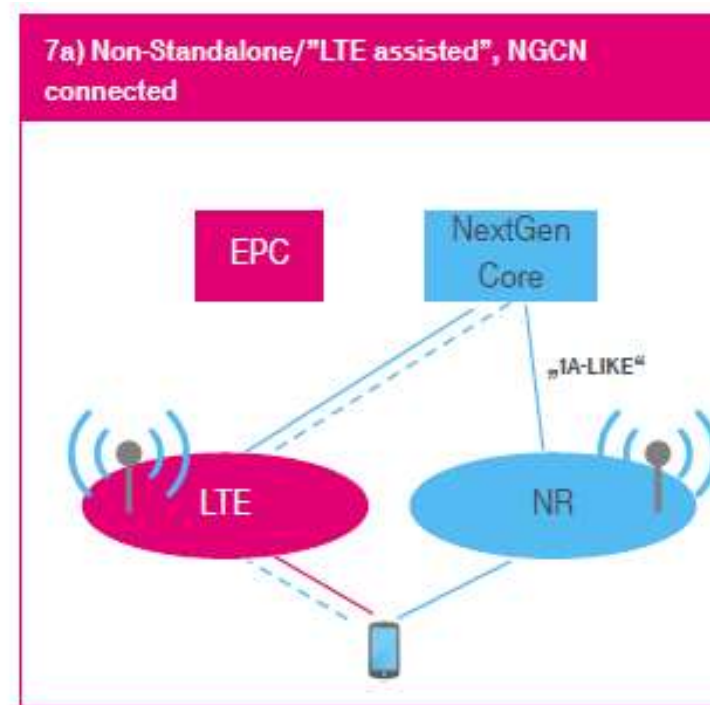
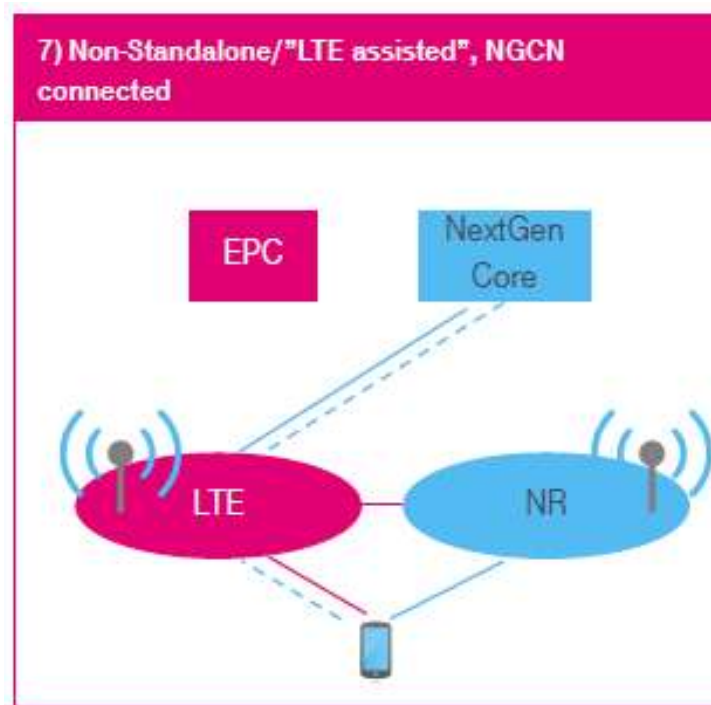
5G system architecture



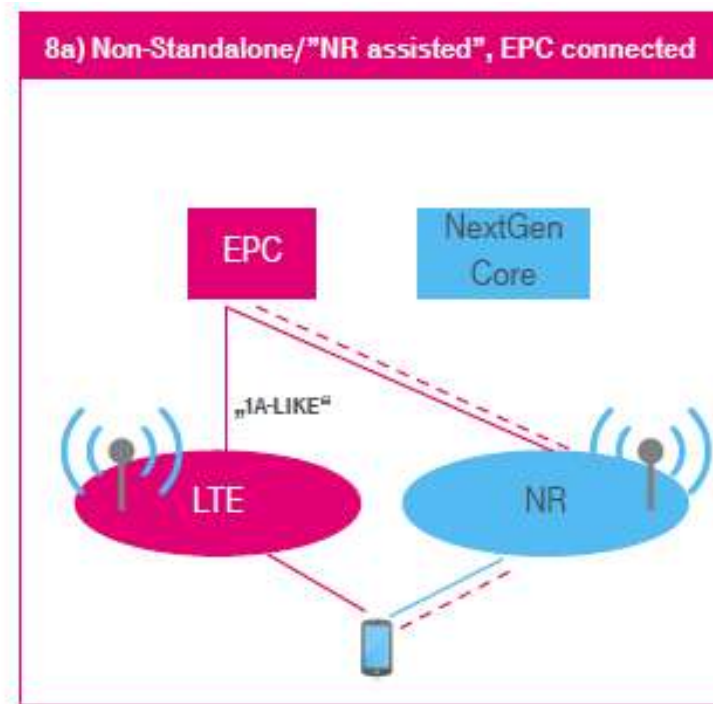
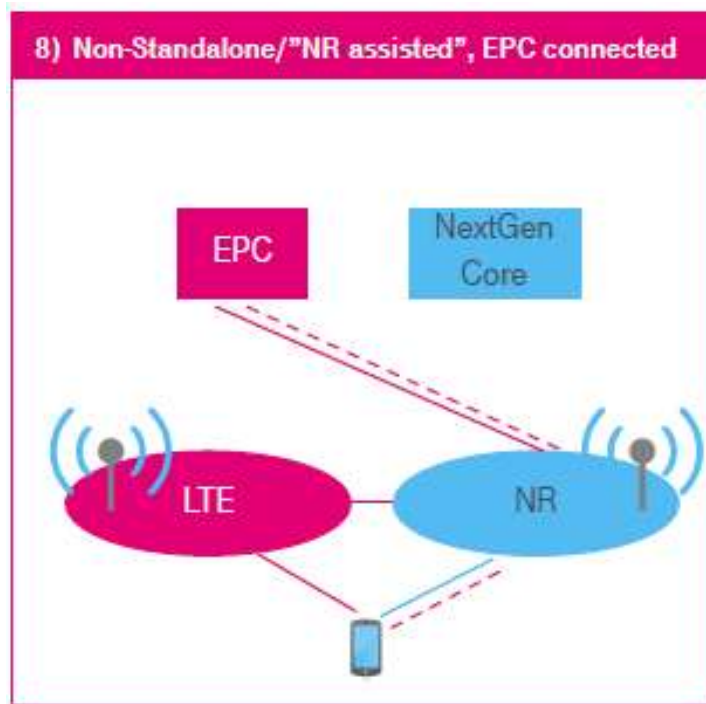
5G system architecture



5G system architecture



5G system architecture

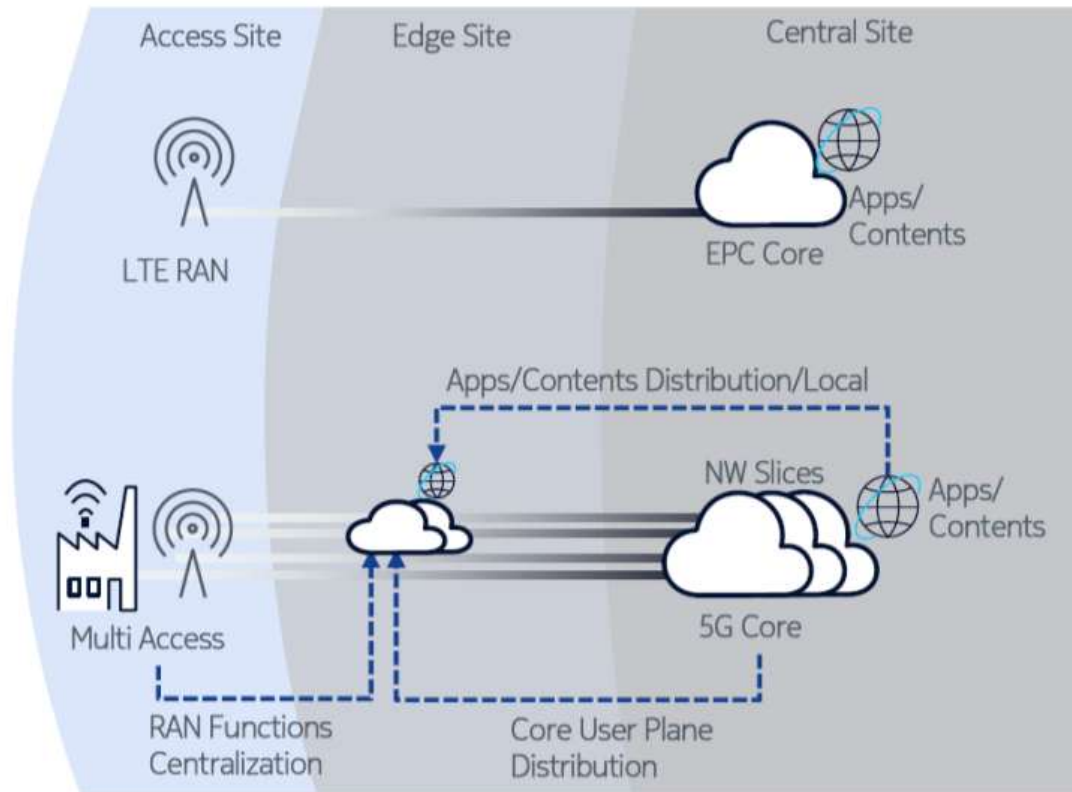


Evolution from 4G to 5G

4G Networks

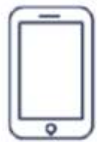


5G Networks

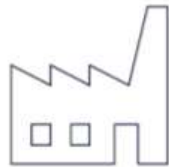


- Centralized Architectures
- VNF/SDN/MANO Adoption
- NW Slices emerge(IoT)

- Functional Decomposition
- RAN/Core/Apps move to Edge
- VNF/SDN/MANO as a foundation
- NW Slicing enabling new use cases
- Multi Access(NR/eLTE, Non 3GPP, Unlicensed, Fixed)



Devices
1.5 GB/day



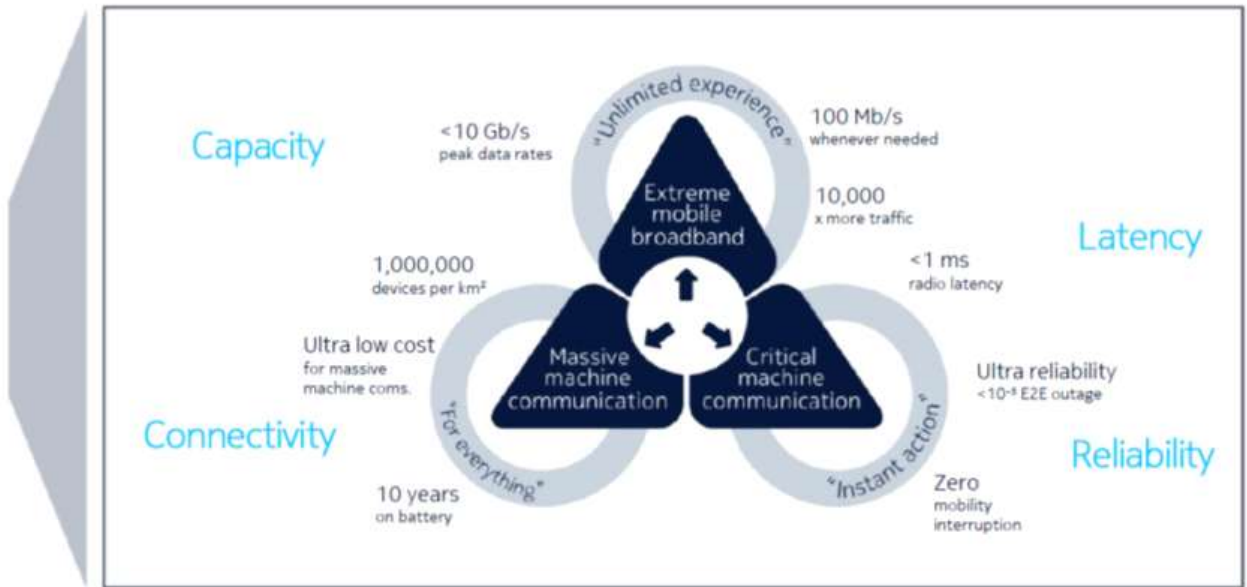
Smart
factories
1 PB/day
 $P = \text{peta} = 10^{15}$



Billions of
sensors
connected



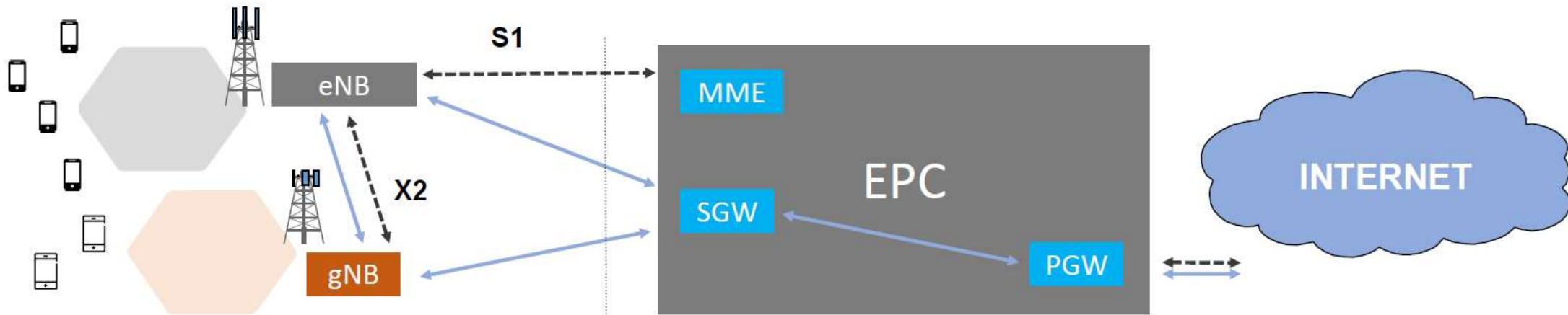
Autonomous
driving
1ms latency



Design and architecture principles:
flexible | scalable | automated | cloud native
software centric | dynamic network slicing

5G Core Network

5G Non Standalone mobile network



Specialized Nodes / Purpose Built

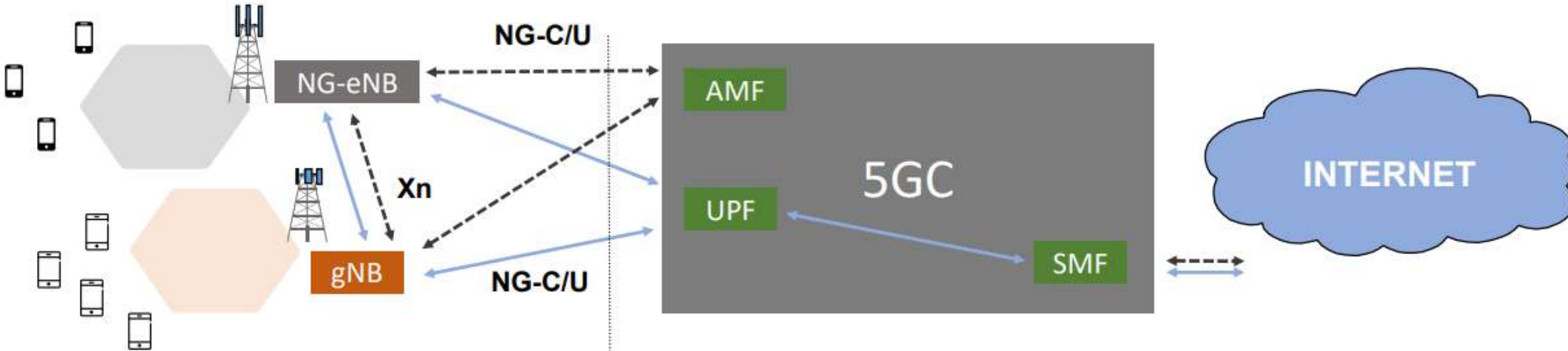
E-UTRAN

Evolved Universal Terrestrial Radio Access Network

Evolved Packet Core (EPC)

MME - Mobility Management Entity
PGW - Packet Data Network Gateway
SGW - Serving Gateway

5G Standalone mobile network



NFV – Network Function Virtualization

NG-RAN

5G Core

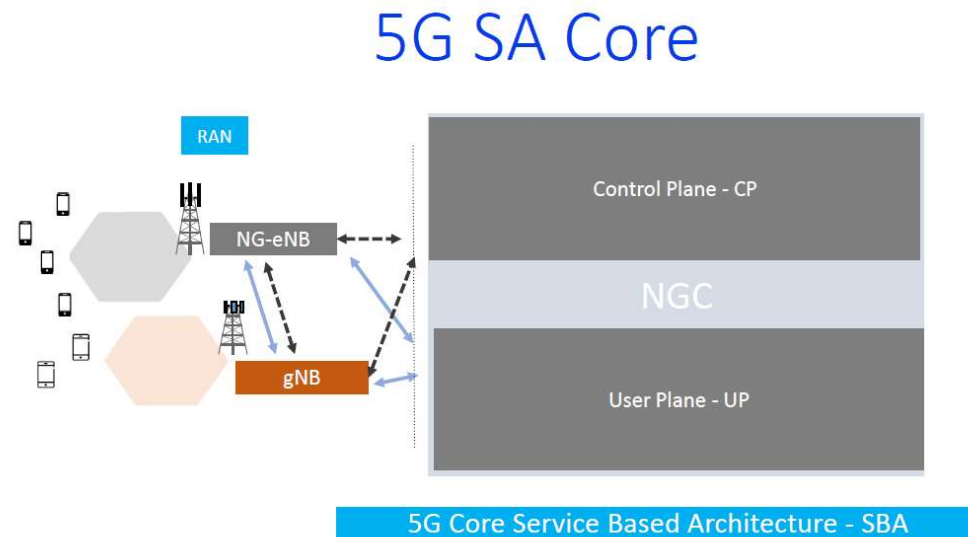
NG – Next Generation
 C - Control
 U - User

AMF - Access and Mobility Management Function
 SMF - Session Management Function
 UPF - User Plane Function



Service-based Architecture

- The 3GPP defines a Service-Based Architecture (SBA) in which the control plane functionality and common data repositories of a 5G network are delivered through a set of interconnected Network Functions (NFs), with each *NF authorized to access the services of other NFs*.
- If an instance or a physical node fails, monitoring systems can detect this and spin multiple instances.
- SBA's design enables network slicing. **Multiple logical networks can run on a single physical network**. Network functions in SBA are exposed via well-defined Service based Interfaces.

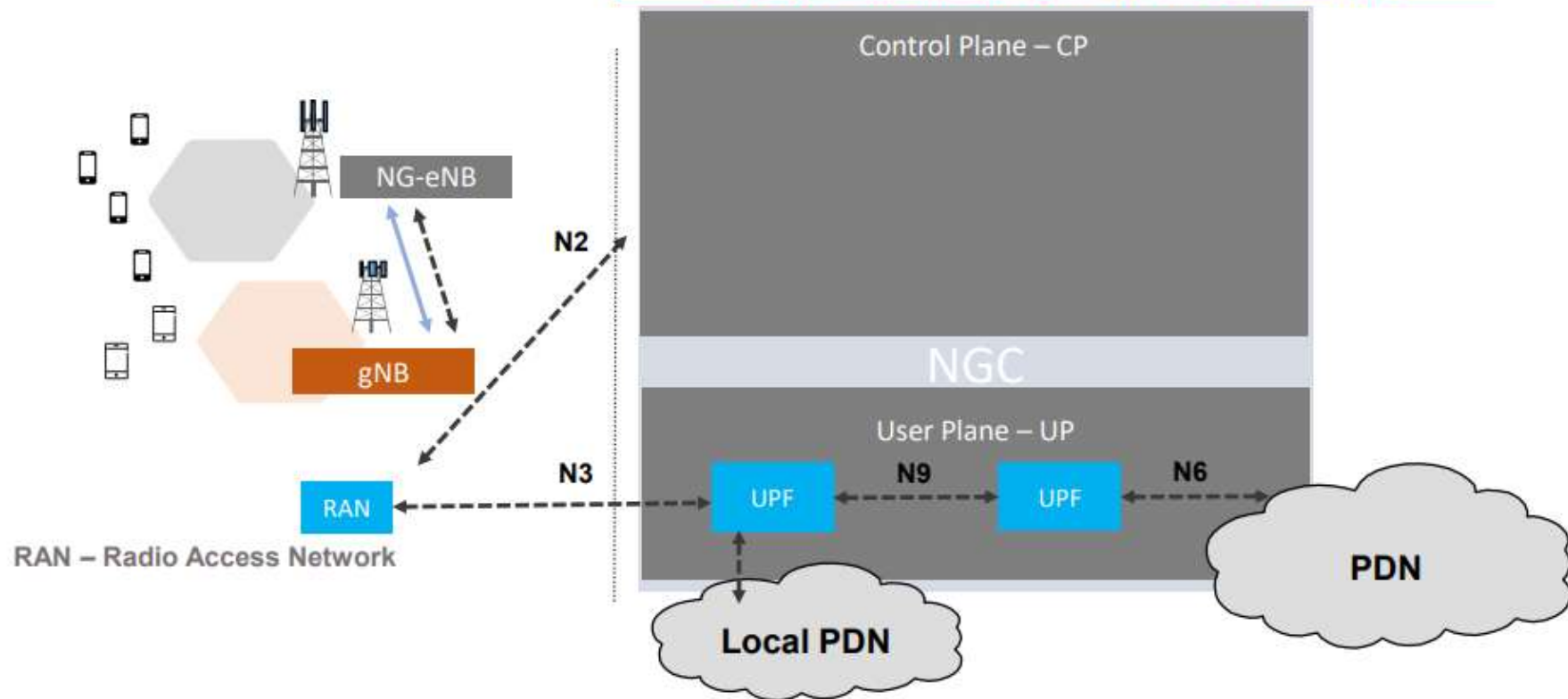


Easy Capacity Scale Up / Down

VMs as Building Blocks

5G SA Core

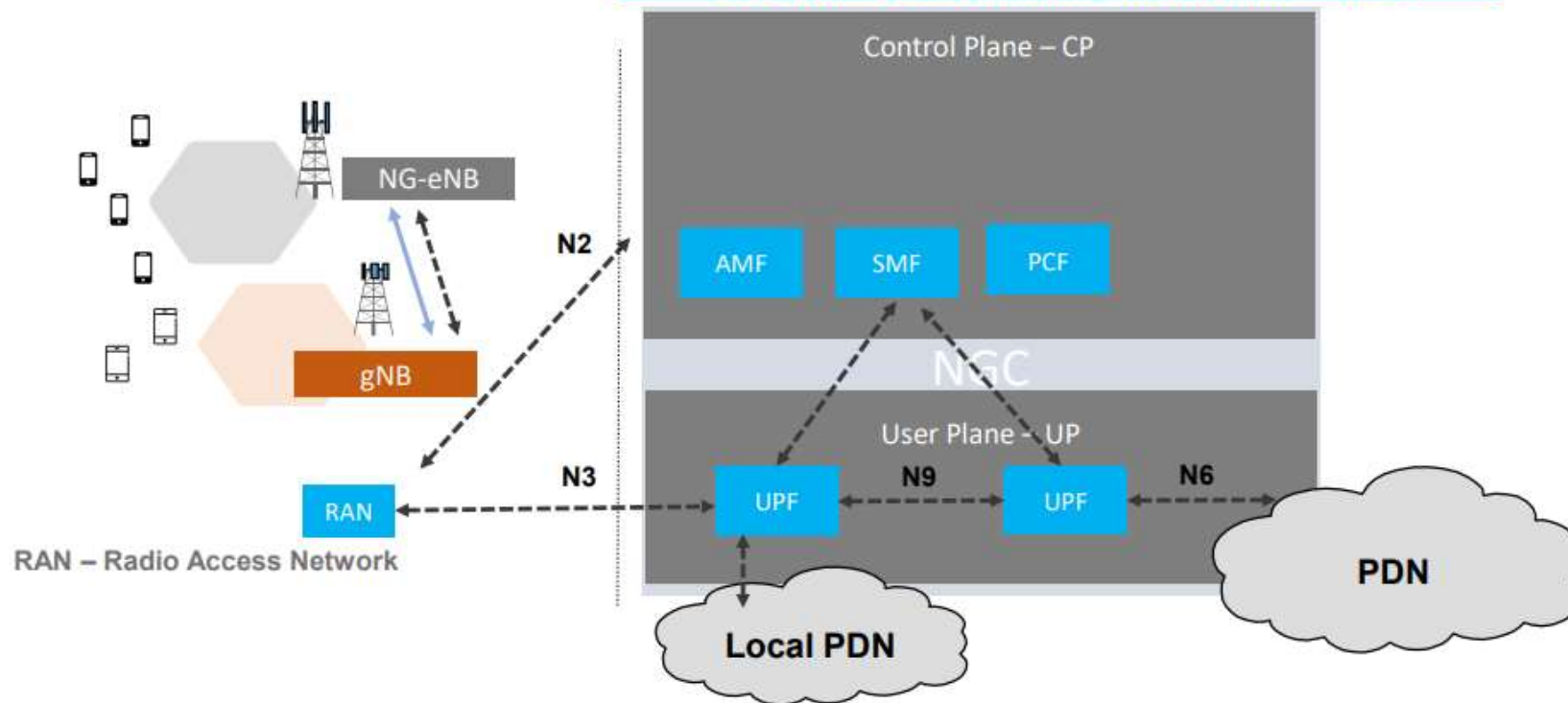
5G Core Service Based Architecture - SBA



UPF – User Plane Function
PDN – Packet Data Network

5G SA Core

5G Core Service Based Architecture - SBA



UPF – User Plane Function

PDN – Packet Data Network

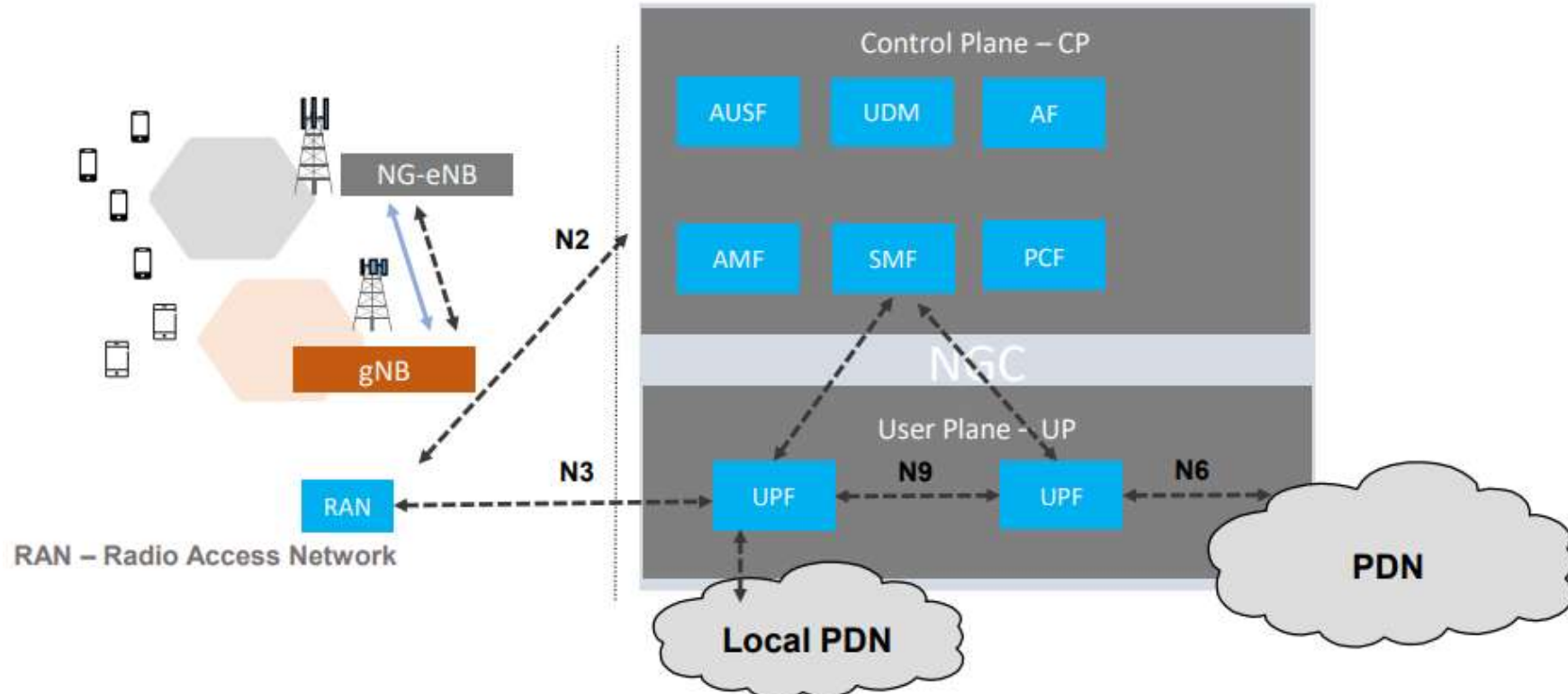
AMF – Access and Mobility Management Function

SMF – Session Management Function

PCF – Policy Control Function

5G SA Core

5G Core Service Based Architecture - SBA



UPF – User Plane Function

PDN – Packet Data Network

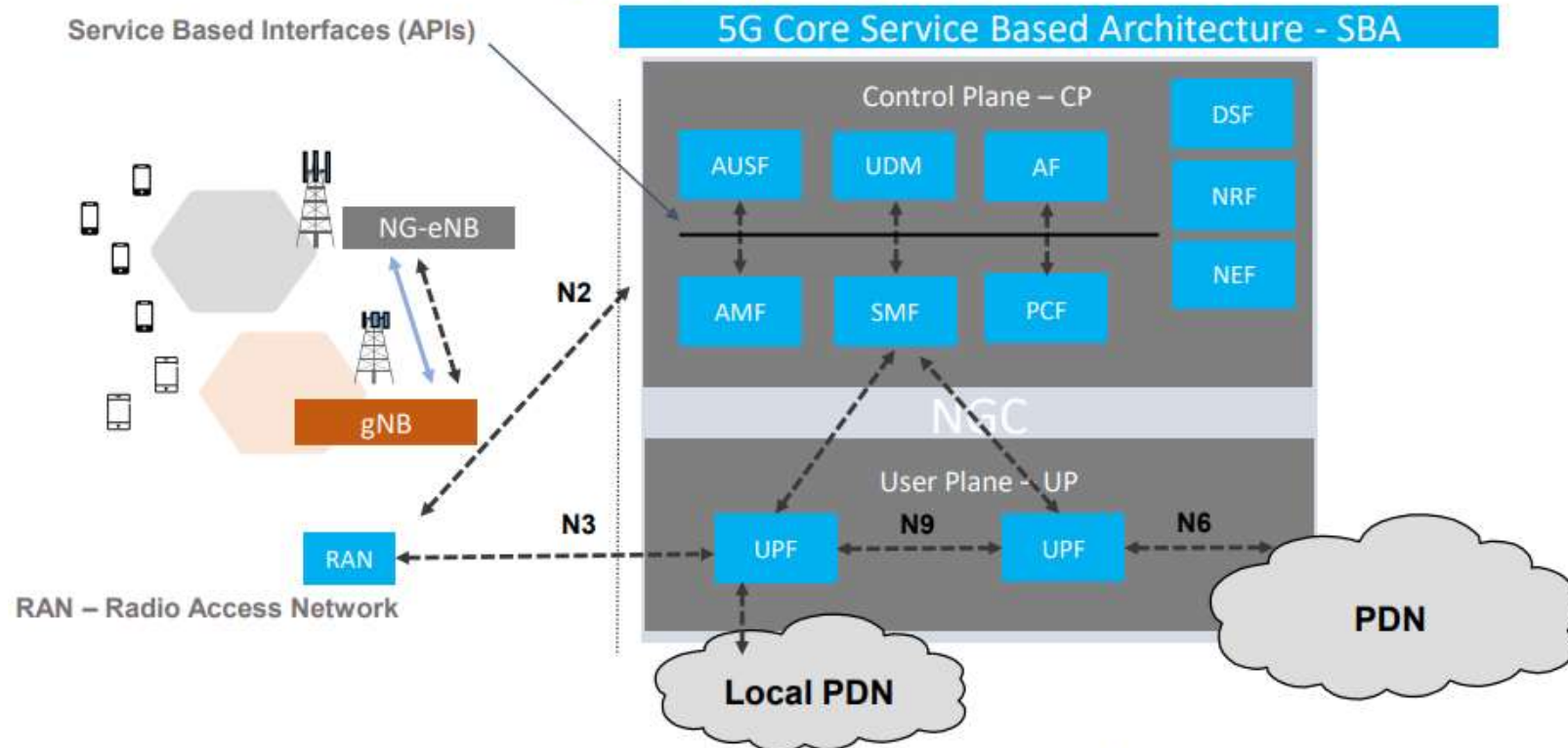
AMF – Access and Mobility Management Function

SMF – Session Management Function

PCF – Policy Control Function

AUSF – Authentication Server Function
UDM – Unified (User) Data Management
AF – Application Function

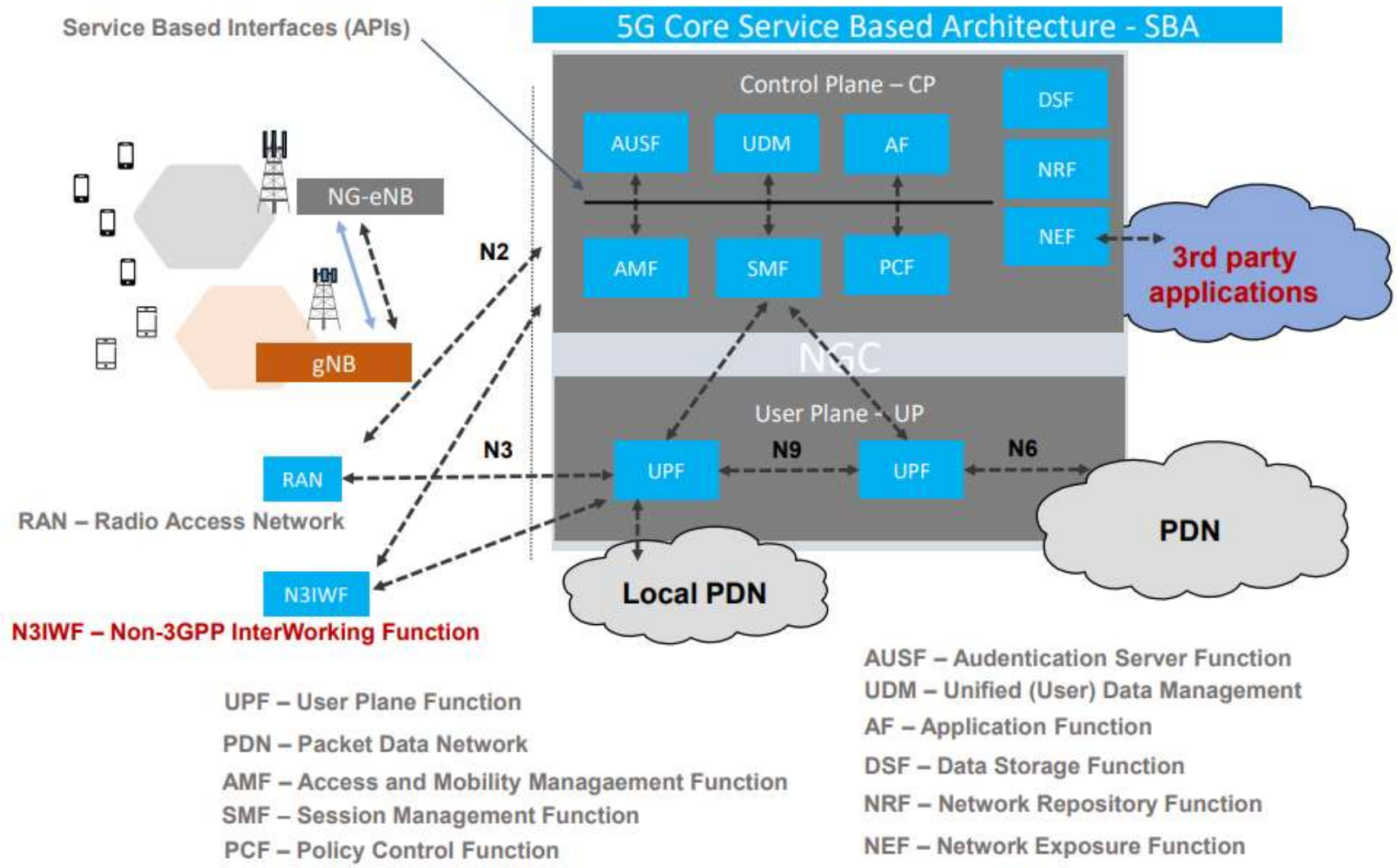
5G SA Core



UPF – User Plane Function
 PDN – Packet Data Network
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 PCF – Policy Control Function

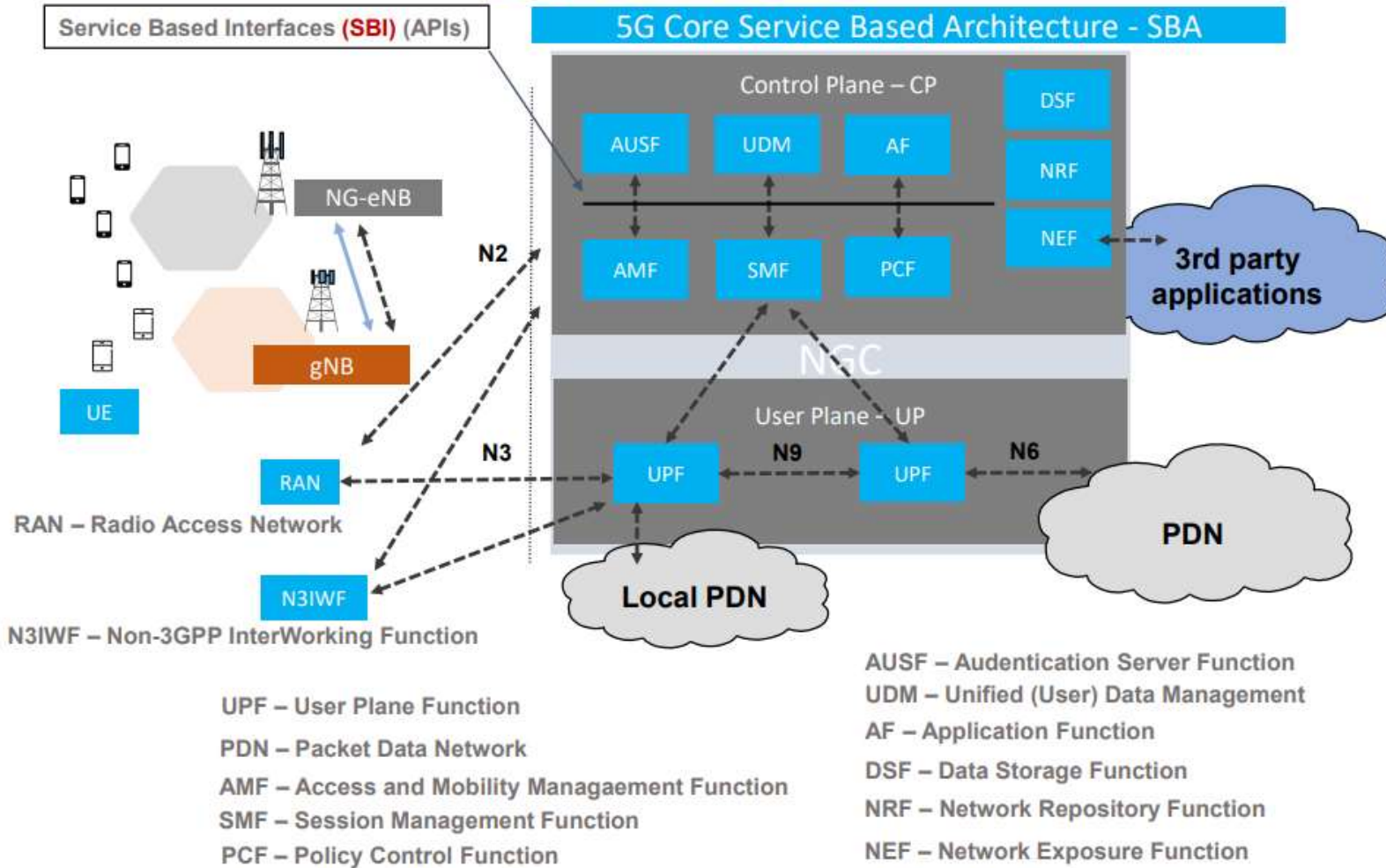
AUSF – Authentication Server Function
 UDM – Unified (User) Data Management
 AF – Application Function
DSF – Data Storage Function
NRF – Network Repository Function
NEF – Network Exposure Function

5G SA Core



5G SA Core

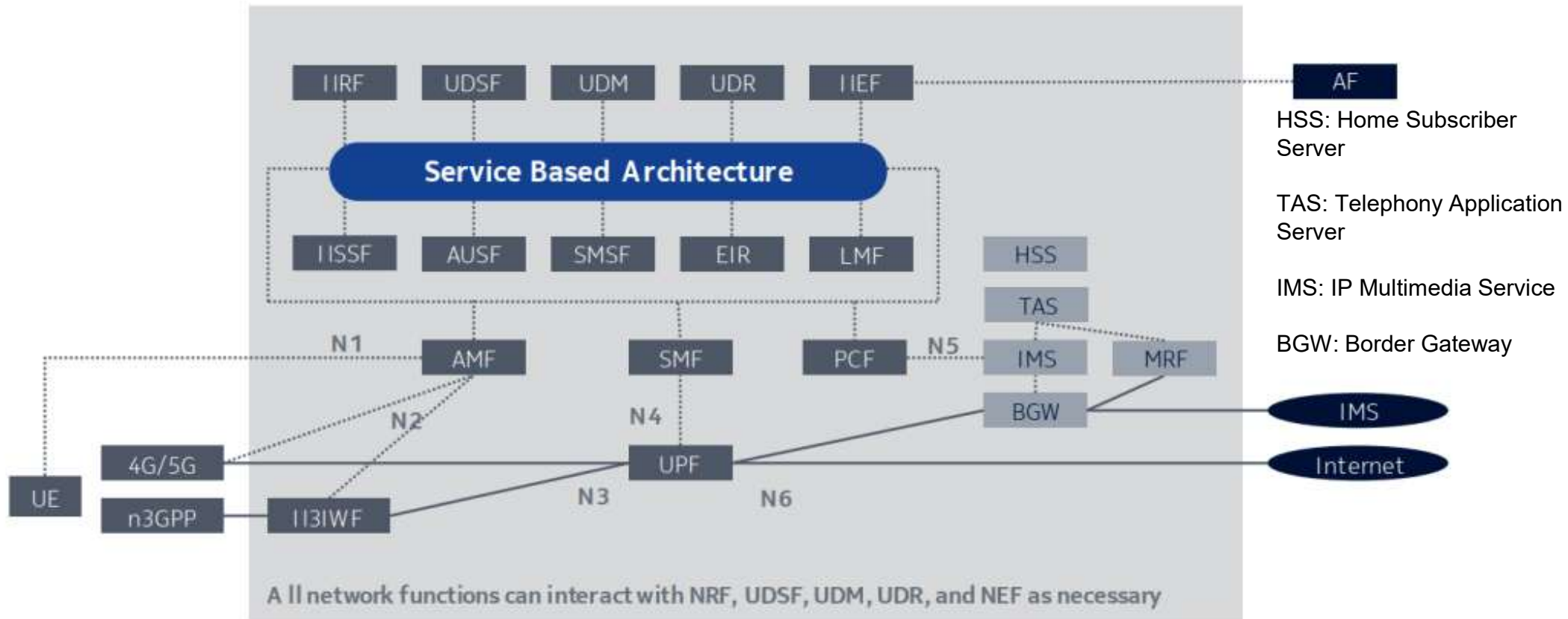
NF services are self-contained, reusable and independent management schemes



UPF – User Plane Function
 PDN – Packet Data Network
 AMF – Access and Mobility Management Function
 SMF – Session Management Function
 PCF – Policy Control Function

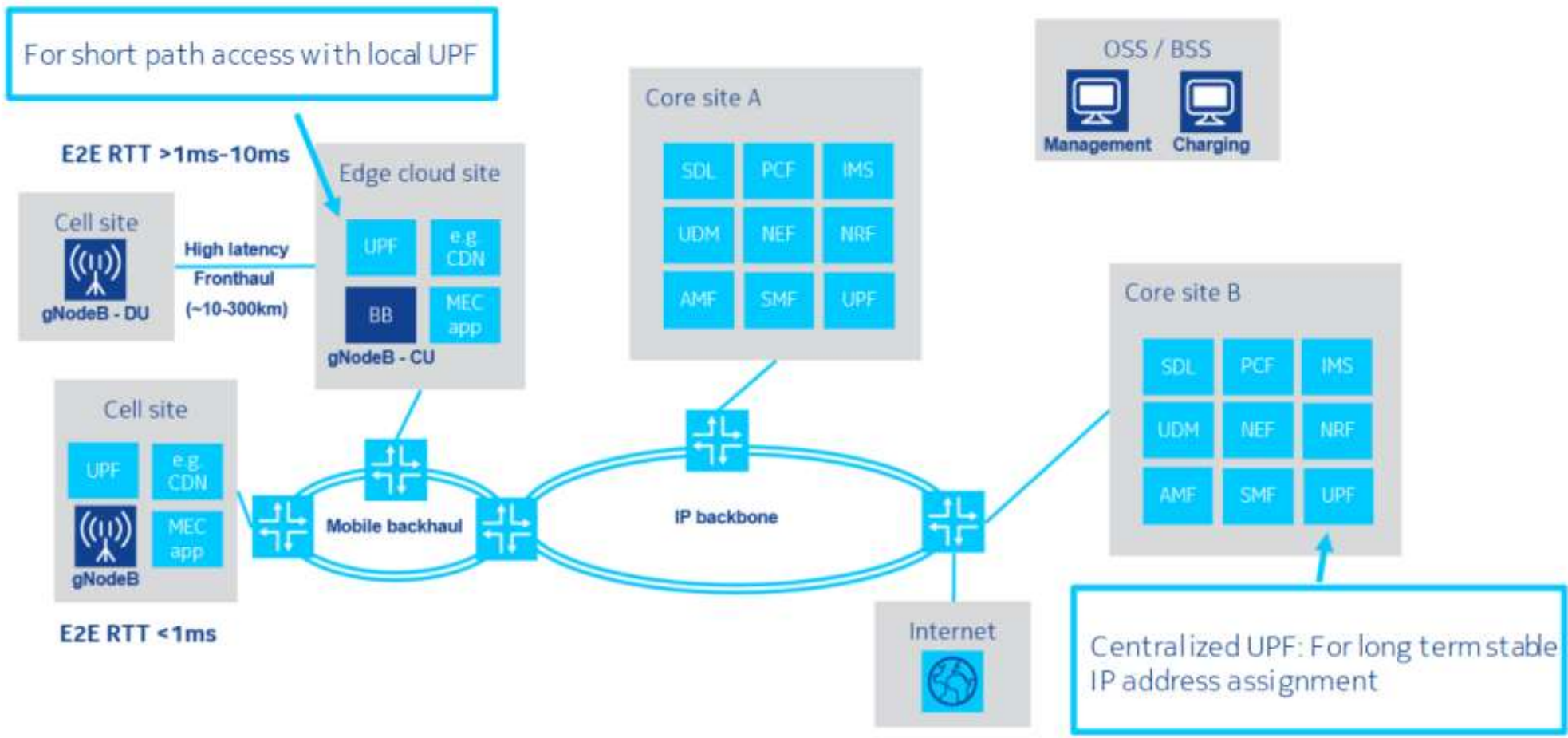
AUSF – Authentication Server Function
 UDM – Unified (User) Data Management
 AF – Application Function
 DSF – Data Storage Function
 NRF – Network Repository Function
 NEF – Network Exposure Function

5G Service based Architecture



This offers Communications Service Providers greater flexibility and more efficiency by decoupling the service consumer from the service producer

5G Distributed User Plane (UP)



CDN – Content Delivery Network (Nokia)

5G SA Core deployment and Tests

TTU Provides Ericsson's 5G Core including:

- Multi-PLMN feature to execute inter-PLMN handover
- Technologies (Slicing, Positioning ..)

AMF:

```
Subscriber Data
-----
IMSI : 248270000000003
Mobile Subscriber ISDN No. : 863305041249940
IMEI : 863305041249940
Radio Access Technology :
Mobility Management State :
UE Time Zone :
time offset : GMT + 3 hour(s) 0 minute(s)
daylight saving time : 1 hour(s) adjustments
Time of Registration in AMF : 2023-10-03 14:26:51.352+03:00
Time released :
RAT restrictions : [WLAN]
Forbidden areas : []
Core network type restrictions : Information not available
RFSP Index in Use : 1
Service area restriction :
Restriction type : NOT_ALLOWED_AREAS
TACS : []
Max num. of TAs : Information not available
Subscribed UE Usage Type : 0
AMF UE NGAP Id : 6394620680
RAN UE NGAP Id : 16799637
NAS Uplink Count : 10
NAS Downlink Count : 12
Security Context State : Security Context with Secure exchange
UE Security Capability :
NFS Encryption Algorithms : nea0, nea1_128, nea2_128, nea3_128
NFS Integrity Algorithms : nia1_128, nia2_128, nia3_128
EPS Encryption Algorithms :
EPS Integrity Algorithms :
S-GMM Capability :
In MICO Mode : No
CN Assistance Info RRC INACTIVE to NG-RAN : false
Faging Proceed Flag :
Last Visited Tracking Area [TAI] : 248-27-5000
Tracking Area List : 248-27-5000
Latest NG-RAN Node List (MCC-MNC-Size-gNBID) : 248-27-22-1
IMS VoPS :
SMS over NAS Allowed : false
S-MSF Instance ID : Information not available
Subscribed S-NSSAIs :
Default S-NSSAIs : 1,2
Non Default S-NSSAIs :
Registered S-NSSAIs : 1,2
Requested S-NSSAIs : 1,2
Rejected S-NSSAIs :
5G-GUTI :
PLMN Id : 248-27
AMF Region Id : 255
AMF Set Id : 2
AMF Pointer : 13
SG-TMSI : 4026583370 (#F000C94A)
```

UE is registered and connected

RM-REGISTERED CM-CONNECTED

Registered in the network

Registered slices

SMF:

```
Smf Selection Subscription Data
-----
S-NSSAI 1 : internet1.taltech.ee
DNN : true
Default DNN Indicator : true
S-NSSAI 2 : internet2.taltech.ee
DNN : true
Default DNN Indicator : true
Subscribed DNN Configuration
-----
Associated PDU Session IDs : 1
DNN : internet1.taltech.ee
Subscribed DNN Configuration
-----
Associated PDU Session IDs : 2
DNN : internet2.taltech.ee
Active PDU Session
-----
Id : 1
S-NSSAI : 1
DNN requested :
DNN in use : internet1.taltech.ee
Active EPS Bearer IDs :
SMF in use :
Instance ID : d67766fc-210f-4ecf-858f-cc42a60fc00e
IPv4 : 172.22.200.96
IPv6 :
FQDN : Information not available
Active PDU Session
-----
Id : 2
S-NSSAI : 2
DNN requested : internet2.taltech.ee
DNN in use : internet2.taltech.ee
Active EPS Bearer IDs :
SMF in use :
Instance ID : d67766fc-210f-4ecf-858f-cc42a60fc00e
IPv4 : 172.22.200.96
IPv6 :
FQDN : Information not available
```

UE has been created in two slices

internet1.taltech.ee : true
internet2.taltech.ee : true

This is active slice

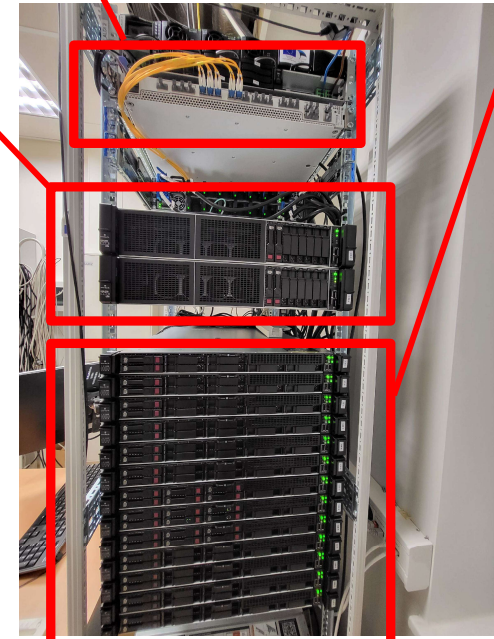
RAN RRU



Positioning ENL platform

RAN BBU

5G SA Core

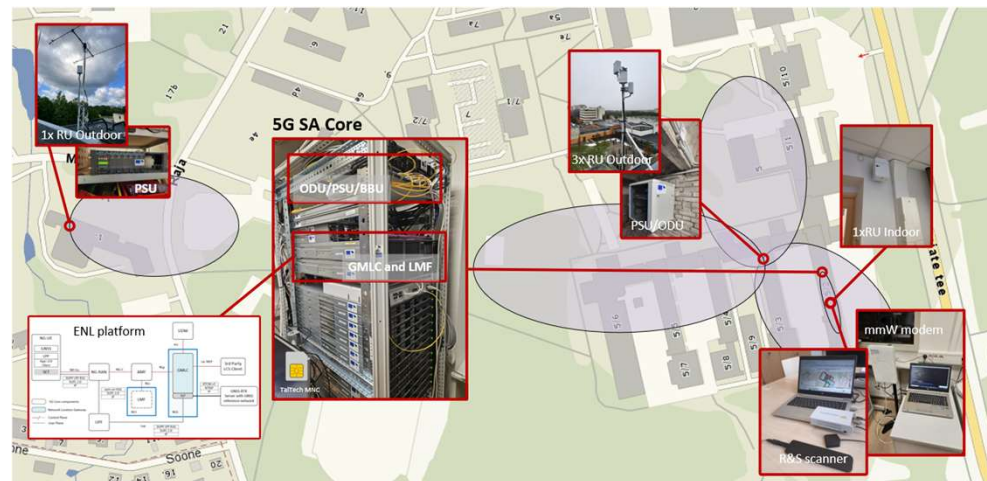


5G AND BEYOND TESTBED (1/2)

To provide 5G advanced network with **unique features supporting verticals** i.e., Smart Cities, Education and Health sectors

Objective is to provide full (end to end) 5G advanced infrastructure **unique feature based which is the novelty of the proposed testbed:**

- 1) We have a frequency license from the Estonian regulatory authority to operate mmWave network in n258 band (24 GHz)..
- 2) 5G Stand-Alone (SA) Core deployment is based on Ericsson's Small Size Target Solution (SSTS). 5G Core is operational
- 3) Our mmWave Radio network is operational. We have installed 4 outdoor radio units and 1 indoor radio unit all connected to a single baseband unit and configured.
- 4) Precise positioning is based on Ericsson Network Location (ENL) platform, and slicing will be offered from the network side as specific features.
- 5) Co-located virtualised service orchestration platform for application integration (via N6 interface)

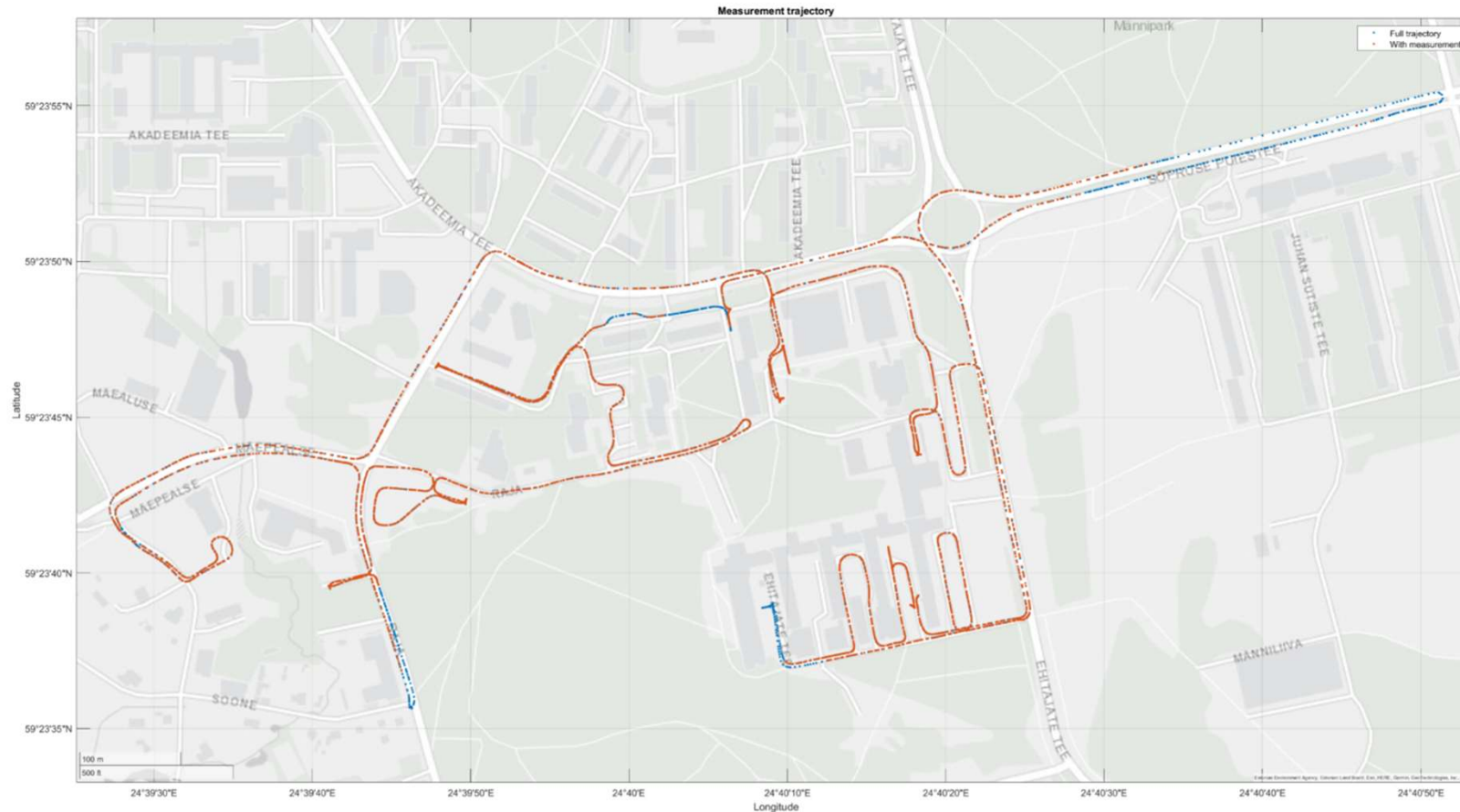


5G Advanced operational infrastructure at TalTech illustrating mmWave radio network (outdoor and indoor radio units and a baseband unit), 5G SA core network including Ericsson network location platform, and terminal including mmWave Quectel modem, radio scanner.

5G AND BEYOND TESTBED (2/2)

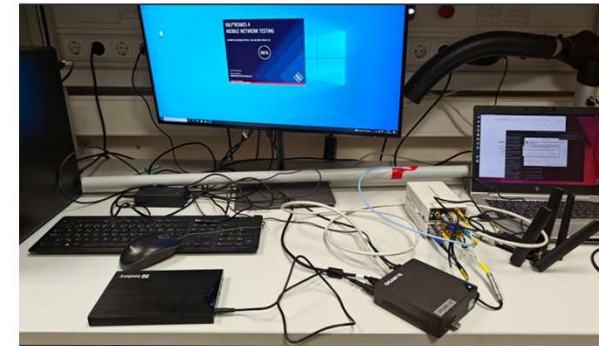
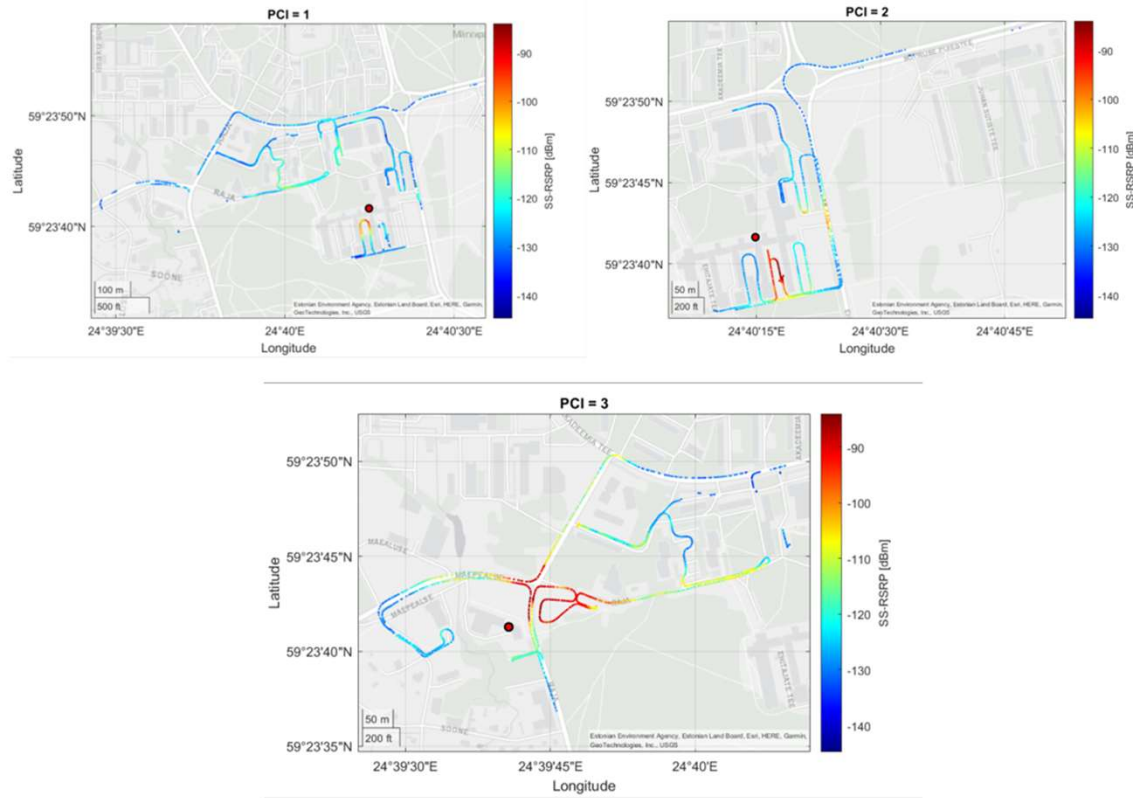
- i) To **provide demonstration** of the **following unique KPIs** from the proposed network:
- a. very high throughput - up to 1.2 Gbps (DL) and up to 120 (UL) - [mmWave]
 - b. very low latency (5-6 ms) – [mmWave]
 - c. High-speed mobility handover (intra-network and inter-network)
 - d. Fully integrated and end-to-end hybrid precise positioning through Ericsson Network Location platform (2-5 cm)

mmWave coverage around TalTech (1/2)



Measurement trajectory (initial measurement campaign performed in October 2024)

mmWave coverage around TalTech (2/2)



Initial measurement results of n256 band with 3 mmWave outdoor RUs. Corresponding RUs of the PCI1 and PCI2 are on the same mast with different pointing direction and PCI3 is on the different building location

Test Flights with UAVs

