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# Modern Wireless Systems - 5G and Beyond

## Mobile core networks

STEFAN HÖST



# Contents

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## Network infrastructure

- Fixed and mobile networks

- Mobile transport

## C-RAN and O-RAN

- CPRI and eCPRI

- Functional splits

## Mobile core, EPC and 5GC

- Data plane

- Control plane

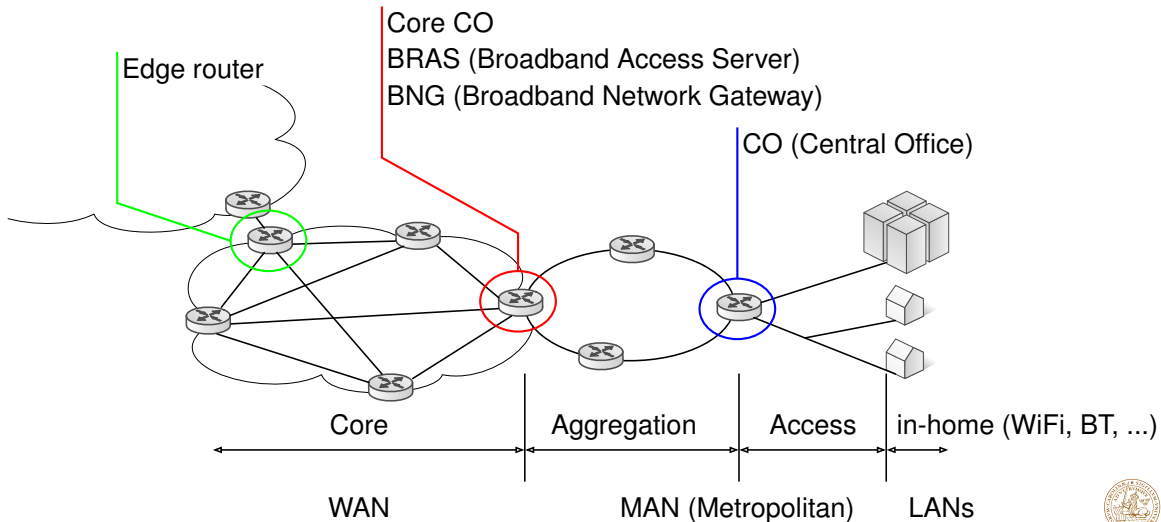
- SIM card

# Network infrastructure

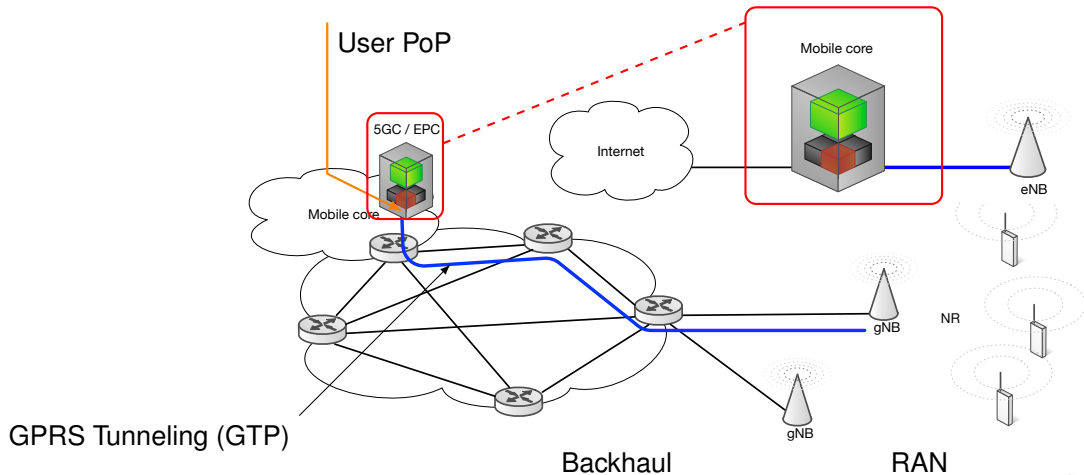
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# Network topology – Fixed network



# Network topology – Mobile network



GPRS Tunneling (GTP)

# Protocol stack – OSI and TCP/IP

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Application		Application
Presentation		
Session		
Transport		Transport
Network		Internet
Data link		Network access
Physical		

Application specific. User interaction

Communication between processes at units

Routing between end units

Framing. Error control. Local addressing

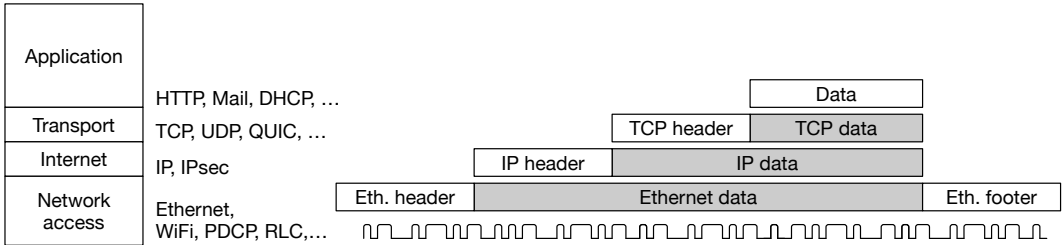
Access to media. Signal propagation

OSI  
(ISO)

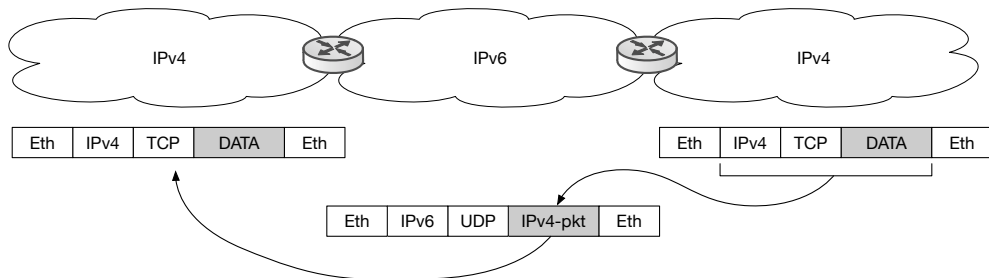
TCP/IP  
(IETF)

# Protocol stack – Layered traffic and framing

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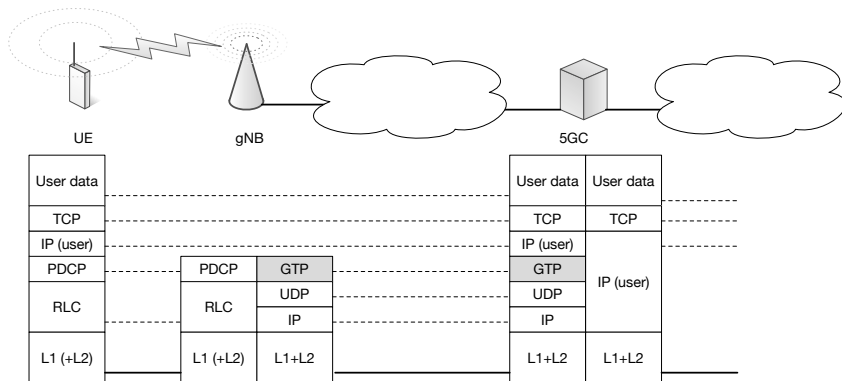


# Tunneling IPv4 over IPv6

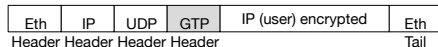




# Tunneling in mobile network



- GTP: GPRS Tunneling Protocol
- PDCP: Packet Data Convergence Protocol
- RLC: Radio Link Control



# C-RAN and O-RAN

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# eNB equipment

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## BBU (Baseband unit)

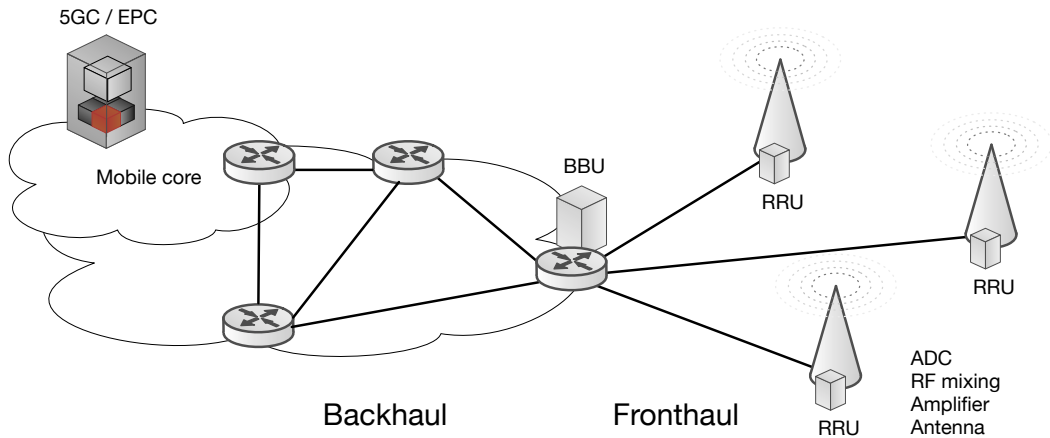
- Coding
- Scheduling
- Modulation
- Beam forming
- Equalization
- IFFT
- Cyclic prefix

## RU (Radio unit)

- DA / AD
- Frequency mix
- Analog front-end (amplifiers)
- Antenna connection

Communication between BBU and RU over fibre using CPRI/eCPRI or sometimes OBSAI

# Mobile network and C-RAN (Cloud RAN)



# CPRI

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CPRI: Common Public Radio Interface

Defined by: Ericsson, Huawei, NEC and Nokia

A protocol intended for transport of mobile digital baseband samples.

- Frames are containers for radio frames
- Supports GSM/EDGE (2G), UTRA (3G), E-UTRA/LTE (4G), 5G, WiMAX
- Normally point-to-point connection
- Can operate over at least 10 km
- At most 5  $\mu$ s delay (excl. propagation delay) and at most  $10^{-12}$  BER

# CPRI framing

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## Hierarchical framing structure

- Basic frame: samples for 260.416 ns radio signal
- Hyper frame: 256 basic frames  $\Rightarrow$  66.7  $\mu$ s
- CPRI frame: 150 hyper frames  $\Rightarrow$  10 ms (one LTE frame)

Line coding: 8B/10B or 64B/66B

Sampling 8-20 b/real sample. Normally 15 b/real sample ( $\Rightarrow$  30 b/sample)

$\Rightarrow$  data expansion by a factor of about 10-14

# CPRI

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## Problems with CPRI

- Point-to-point connection, not routable
- Very high traffic load (Major problems for 5G)
- Not load dependent
- Not settings dependent, e.g. number of bits / carrier
- Very high demands on clock synchronisation
- Up- and down-link must have the same latency (max diff 8 ns)

# Packet based fronthaul and eCPRI

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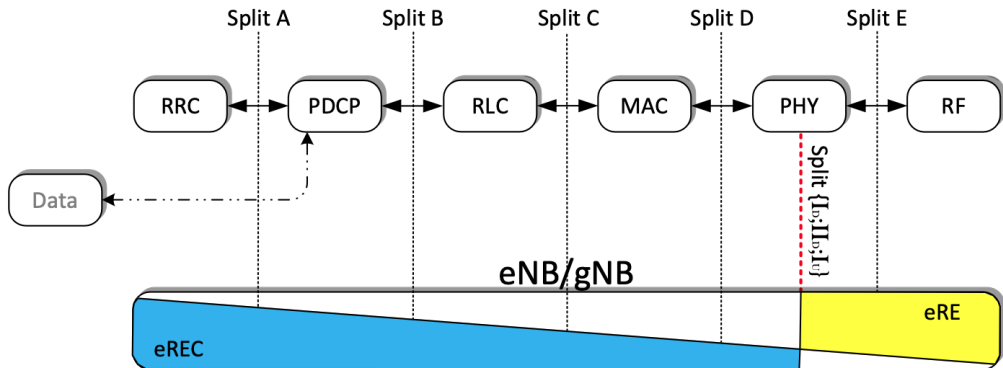
## eCPRI: Evolved CPRI (V1.1 2018-01-10)

- Main alternative for future C-RAN
- New functional splits
- Required data rate scales with user data
- Physical layer from IEEE 802.3 Ethernet
- Layer 2: Ethernet, MPLS (IP address routing on L2)



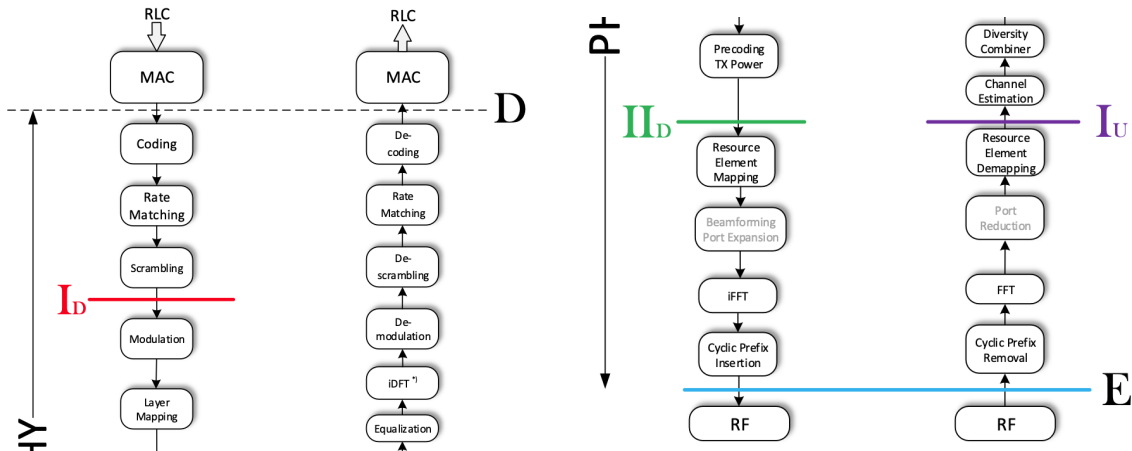
# eCPRI – Functional splits

From documentation V2.0



# eCPRI – Phy layer splits (I)

From documentation V2.0



# Example – Split rates

From documentation V2.0

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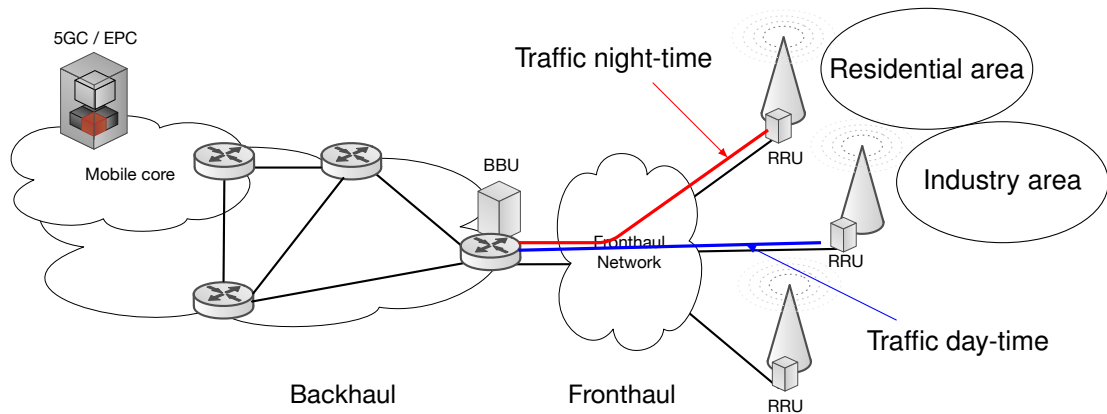
- Utilisation 3/1.5 Gbps at 100 MHz
- DL MIMO layers: 8, UL MIMO layers: 4
- Beam forming i eREC
- Code rate: 0.8
- Modulation: 256 QAM
- Sub-carrier spacing: 15 kHz
- IQ sampling frequency: 122.88 Msps
- IQ-quantisation: 30 bits per IQ-sample

# eCPRI – Phy layer split rates

From documentation V2.0

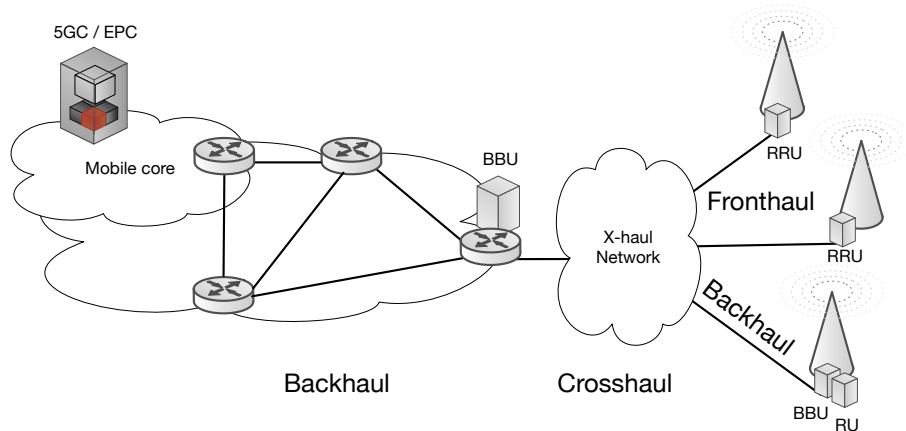
	Split D		Split I <sub>D</sub>		Split II <sub>D</sub>		Split E
	User Data [Gbps]	Control [Gbps]	User Data [Gbps]	Control [Gbps]	User Data [Gbps]	Control [Gbps]	User Data [Gbps]
eREC → eRE	3 (assumption)	<< 1	< 4	< 10	~ 20	< 10	236
			Split I <sub>u</sub>				
eRE → eREC	1.5 (assumption)	<< 1	~ 20	< 10	~ 20	< 10	236

# Packet switched fronthaul



# X-haul

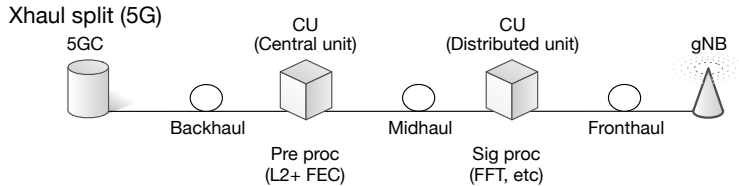
A Crosshaul is a network that transports both backhaul and fronthaul traffic.



# X-haul splits

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Split traffic in backhaul, midhaul and fronthaul at diferent functional splits, e.g.,



# Mobile core, EPC and 5GC

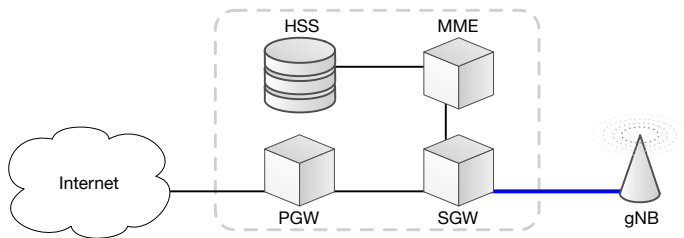
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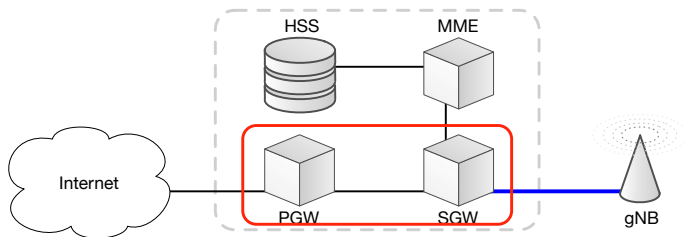
# EPC – Evolved Packet Core (4G)

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- SGW: Serving Gateway
- PGW: Packet Gateway
- MME: Mobility Management Entity
- HSS: Home Subscriber Server

# EPC – Data plane



## Packet GW

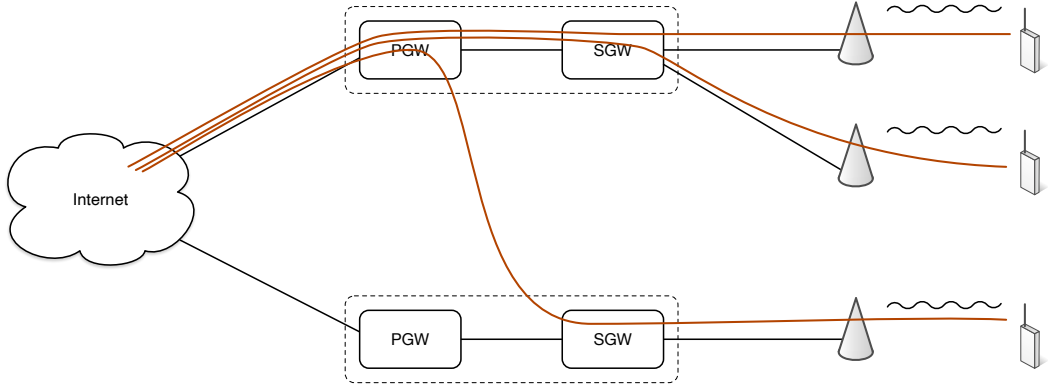
- IP address allocation to UE
- User IP edge
- QoS filtering
- Mobility anchor  
Preserves IP address

## Serving GW

- Collect charging information
- Local anchor towards eNB/gNB  
Can change during session

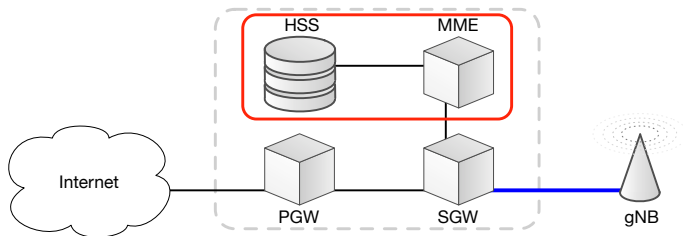
# User mobility

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# EPC – Control plane

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## MME (Mobility Management Entity)

- Communicates with eNB and SGW
- Manages tunnels and encryption

## HSS (Home Subscriber Server)

- Subscriber database
- SIM card key exchange
- AAA  
(Authentication, Authorisation, Accounting)

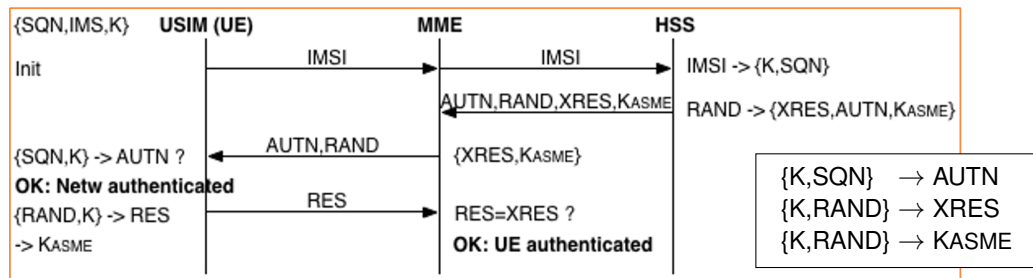
# SIM card

## UMTS Subscriber Identity Module

The (U)SIM card is an application on a smart card and contains:

- IMSI (International mobile subscriber identity) 15 digits
- Authentication key  $K$  and sequence number SQN

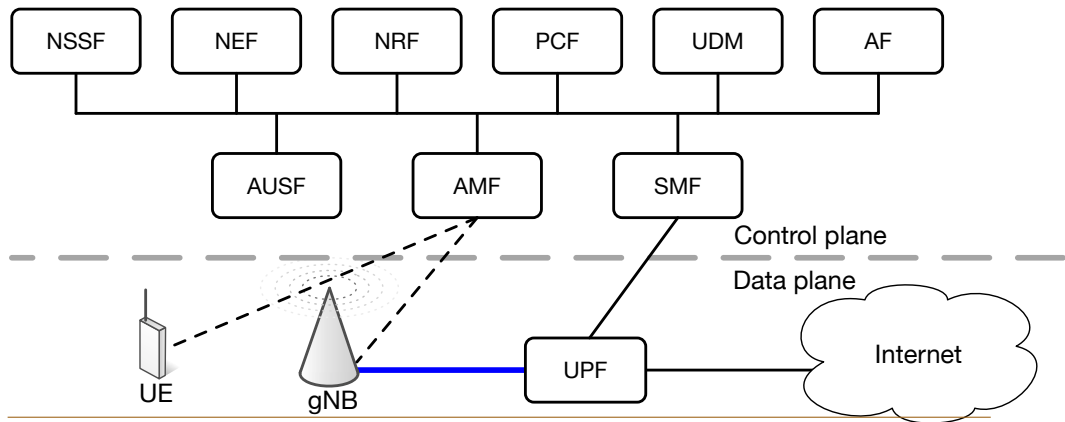
Authentication process:



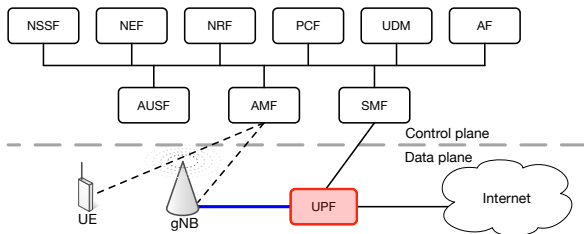
$K_{ASME}$  is used for encryption of messages

# 5G core

The 5GC is by design service oriented and software based  
Implementation on general purpose servers, in a data center environment, e.g.,



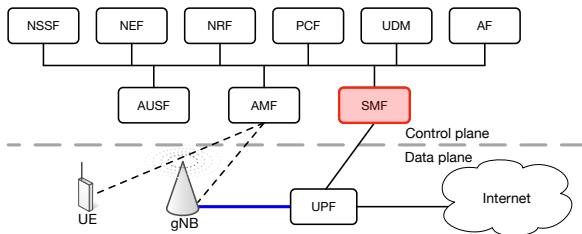
# 5GC – UPF



## UPF User Plane Function

- Data plane in core (replaces PGW and SGW data plane)
- Anchor for mobility
- IP point of presence
- Handles all network traffic, e.g. Data, ARP, QoS enforcing, ...

# 5GC – SMF

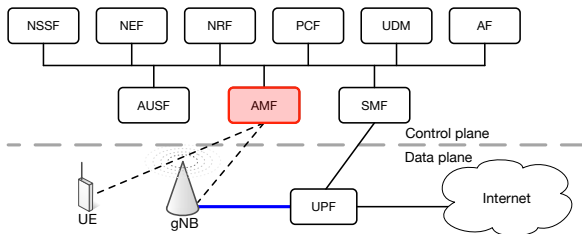


SMF Session Management Function (corresponds to PGW control plane)

- Session management, establish, modify and terminate
- IP address allocation
- Serves as manager for UPF, and controller for policy and QoS enforcement



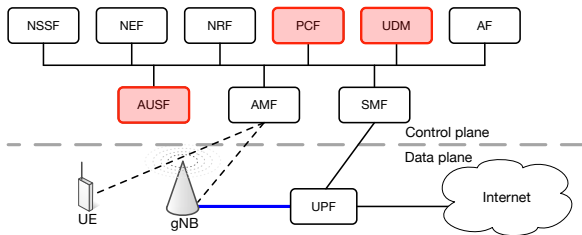
# 5GC – AMF



## AMF Access and Mobility Function

- The 4G MME is split in SMF (session) and AMF (Mobility)
- Handles security control
- Handles 5G-4G handover
- Support of network slicing

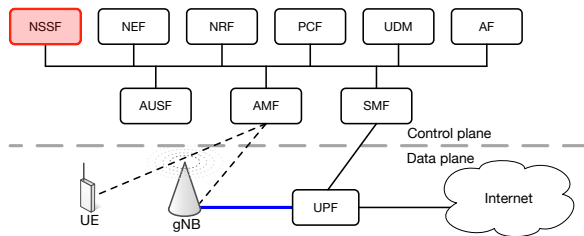
# 5GC – AAA



Corresponds to HSS

- PCF, Policy Control Function
- AUSF, Authentication Server Function  
Stores keys for security and integrity protection
- UDM, Unified Data Management  
Subscriber database  
Communicates with SIM-card

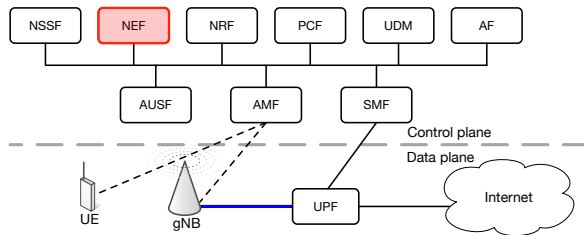
# 5GC – NSSF



## NSSF, Network Slice Selection Function

- Slicing: Different services have different QoS requirements (e.g. IoT, Voice, Video). Create virtual networks over the physical infrastructure.
- Selection of slice serving UE

# 5GC – NEF



## Network Exposure Function

- “Middle box” with APIs for third party applications, like data, voice, subscriber data.
- Makes it possible for third party service provider to access the core functionality.



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