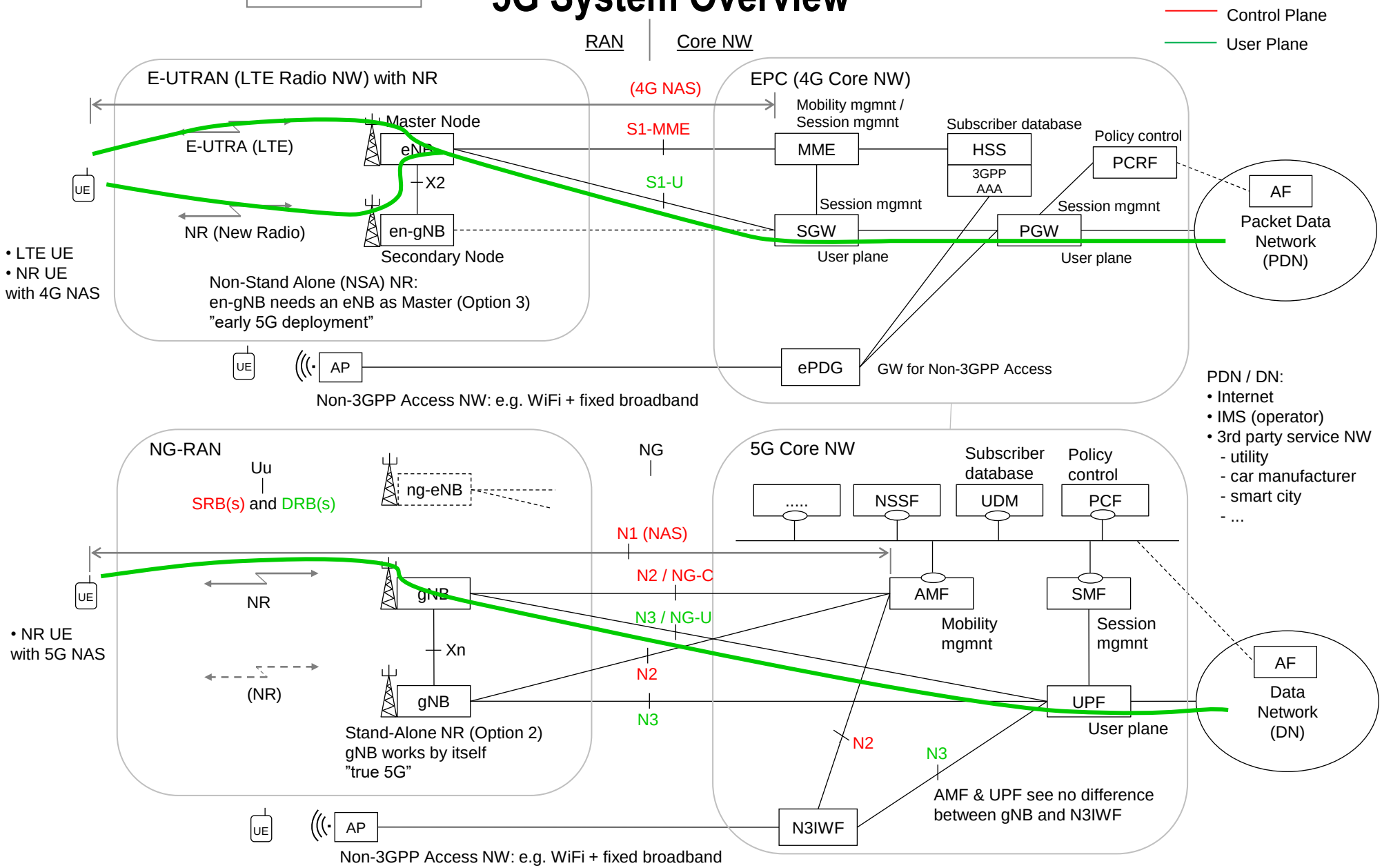
TS 23.501, 38.300

5G System Overview



5GC	5G Core Network	ePDG	evolved Packet Data Gateway	NSSF	Network Slice Selection Function	SMF	Session Management Function
5GS	5G System	IMS	IP Multimedia Subsystem	PCF	Policy Control Function	SRB	Signalling Radio Bearer
AF	Application Function	MME	Mobility Management Entity	PCRF	Policy and Charging Rules Function	UDM	Unified Data Management
AMF	Access and Mobility Management Function	N3IWF	Non-3GPP Interworking Function	PDN	Packet Data Network	UP	User Plane
CP	Control Plane	NAS	Non-Access Stratum	PGW	PDN Gateway	UPF	User Plane Function
DN	Data Network	NG-RAN	Next Generation RAN	(R)AN	(Radio) Access Network		
DRB	Data Radio Bearer	NR	New Radio	SA	Stand-Alone		
EPC	Evolved Packet Core	NSA	Non-Stand Alone	SGW	Serving Gateway		

5G Core Overview

Service Based Architecture

TS 23.501, 23.502, 29.500

Control Plane

User Plane

NF

Service Based Interface

Network Function (NF):
Provides NF Services to other authorized NFs
Can be implemented :
• on dedicated hardware (PNF)
• as a virtualized function on COTS HW (VNF)

Provides policies e.g.
• Access / Mobility policies (to AMF)
• Session policies (to SMF)

Allows NFs to:
• register themselves
• find other NFs
"look-up function"

Subscriber data
UE Context (info about UE)

Data storage
• Backend to e.g. UDM, PCF...

Blocking blacklisted
PEIs/ IMEIs

Application Server
• Operator
• 3rd party

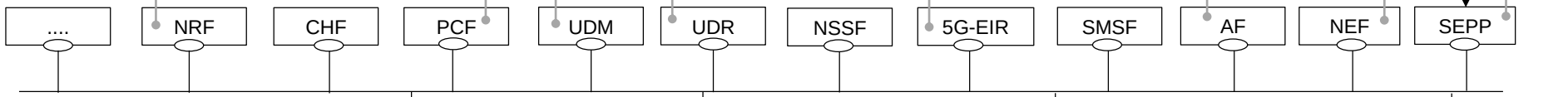
Edge Proxy
to / from
other networks

Exposes services
and capabilities
to 3rd party

For MO and
MT SMS

Charging

Slice selection



"Bus architecture" / IP Network
Protocol: HTTP/2 (JSON format content)

AMF

Registration
Mobility mgmnt
• Registration Area
- e.g.Tracking Area
Reachability Mgmnt

AUSF

UE Authentication
& generation of keys

SMF

Session Authorization
UE IP address allocation
Selects and controls UPF(s)

UE Identities:
• SUPI (IMSI)
• PEI (IMEI)
• GPSI (e.g. MSISDN)
• 5G-GUTI
• various RNTIs
• IP address

N1 (NAS)

N2 (NGAP)

N4
(PFCP)

SRB(s)

DRB(s)

UE

NG-RAN
• gNB
• ng-eNB

N3 (GTP-U)

GTP-U Tunnel (one per PDU Session)

UPF

N6

N9

AF

Data
Network
(DN)

PDU Session

Packet data connection between a UE and a Data Network (DN)

UP Traffic handling
• forwarding
• QoS / policy enforcement
Several UPFs can be linked over N9

• Internet
• IMS (operator)
• 3rd party intranet

Packet Data Unit (PDU):
• IPv4 or IPv6 Packet
• Ethernet frame
• "Unstructured" (something else)

Note 1: DRB(s) and GTP-U Tunnel released for UE in Idle mode
Note 2: Registration without PDU Session is possible (e.g. for IoT UEs)
Note 3: Small amounts of User Data can be sent in CP

5GC	5G Core Network	HTTP	Hypertext Transfer Protocol	(R)AN	(Radio) Access Network
5GS	5G System	IMS	IP Multimedia Subsystem	RNTI	Radio Network Temporary Identity
AF	Application Function	JSON	JavaScript Object Notation	SEPP	Security Edge Protection Proxy
AMF	Access and Mobility Management Function	MO	Mobile Originated	SMF	Session Management Function
AS	Application Server	MT	Mobile Terminated	SMSF	SMS Function
AUSF	Authentication Server Function	NEF	Network Exposure Function	SRB	Signalling Radio Bearer
CHF	Charging Function	NG-RAN	Next Generation RAN	SUPI	Subscription Permanent Identifier
CP	Control Plane	NRF	Network Repository Function	UDM	Unified Data Management
DRB	Data Radio Bearer	NSSF	Network Slice Selection Function	UDR	Unified Data Repository
EIR	Equipment Identity Register	PFCP	Packet Forwarding Control Protocol	UP	User Plane
GPSI	Generic Public Subscription Identifier	PCF	Policy Control Function	UPF	User Plane Function
GTP-U	GPRS Tunneling Protocol - User Plane	PDU	Packet Data Unit		
GUTI	Globally Unique Temporary Identifier	PEI	Permanent Equipment Identity		

TS 23.501

PDU Session Types

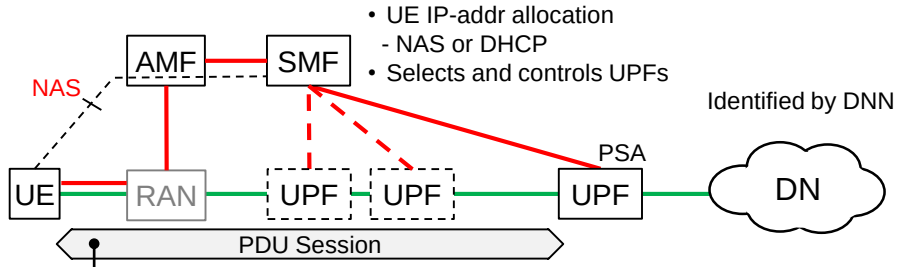
Control Plane

User Plane

IPv4 , IPv6 or IPv4v6

UE gets IPv4 address / IPv6 Prefix from SMF via:
- NAS signalling
- DHCPv4, DHCPv6
- UE's static IP-address stored in UDM

UE indicates to 5GC what method it wants to use.



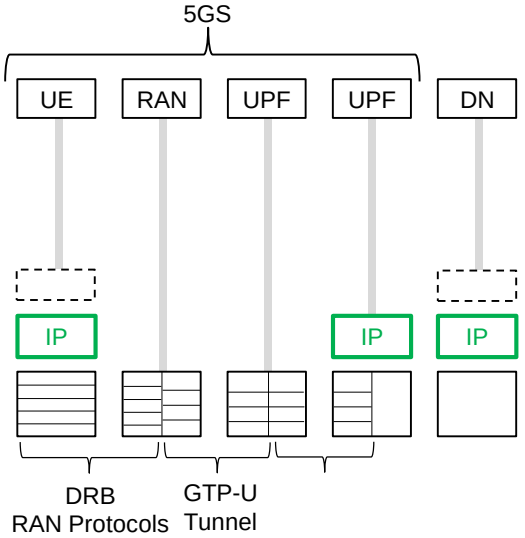
- UE IP-addr allocation - NAS or DHCP
- Selects and controls UPFs

Identified by DNN

- UPF is a Router
- Forwards PDUs based on IP-addresses

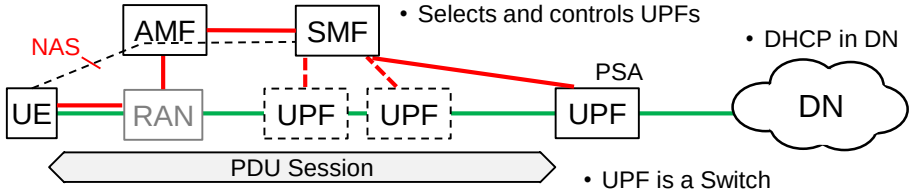
PDU Session Attributes:
- PDU Session ID
- DNN (=APN)
- PDU Session Type
- PDU Session UP Security policies
- SSC Mode
- S-NSSAI
- Multi-access PDU Connectivity Service

Protocol Stacks

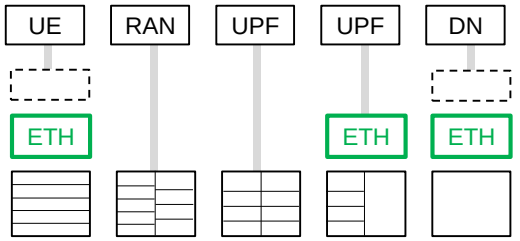


Ethernet

- No IP or MAC assigned by 5GS
- UE belongs to LAN that stretches outside 5GS
- IP is strictly application layer

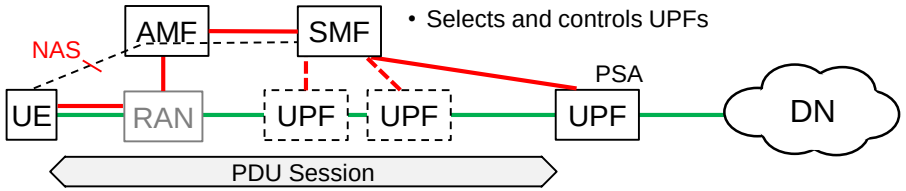


- Selects and controls UPFs
- DHCP in DN
- UPF is a Switch
- Forwards PDUs based on MAC-addr.

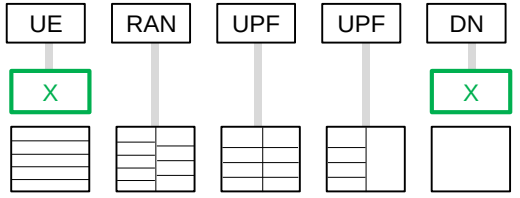


Unstructured

- For Point-to-Point connection with DN
- 5GS is transparent for protocol X



- Selects and controls UPFs
- UPF maps PDU Session to DN access address



5GC	5G Core	PSA	PDU Session Anchor
APN	Access Point Name	RAN	Radio Access Network
DHCP	Dynamic Host Configuration Protocol	SLAAC	Stateless Address Auto configuration
DN	Data Network	SMF	Session Management Function
DNN	Data Network Name	S-NSSAI	Single NSSAI
NAS	Non-Acces Stratum	SSC	Session and Service Continuity
NSSAI	NW Slice Selection Assistance Information	UE	User Equipment
NW	Network	UPF	User Plane Function
PDU	Packet Data Unit	X	Some Protocol / Packet

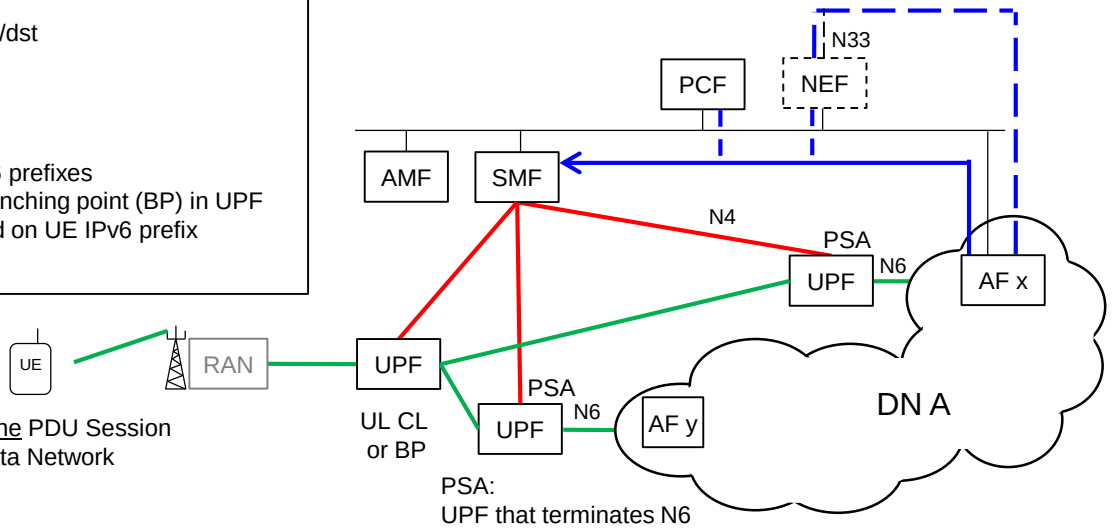
Splitting / Relocating the User Plane

Two technical solutions

Uplink Classifier (UL CL)
- For IPv4, IPv6 and Ethernet
- UE has one IP address (MAC address)
- SMF installs UL CL in UPF
- Classification and Forwarding rules based on:
  - IP or MAC src/dst
  - QoS values

IPv6 Multi-homing
- Only for IPv6
- UE has two IPv6 prefixes
- SMF installs Branching point (BP) in UPF
- Branching based on UE IPv6 prefix

SMF may control user data path so that a PDU Session simultaneously has multiple N6 interfaces.
- optimized traffic handling (for Multi-access Edge Computing, MEC)
- flexible traffic handling (for Session and Service Continuity, SSC)
- redundancy

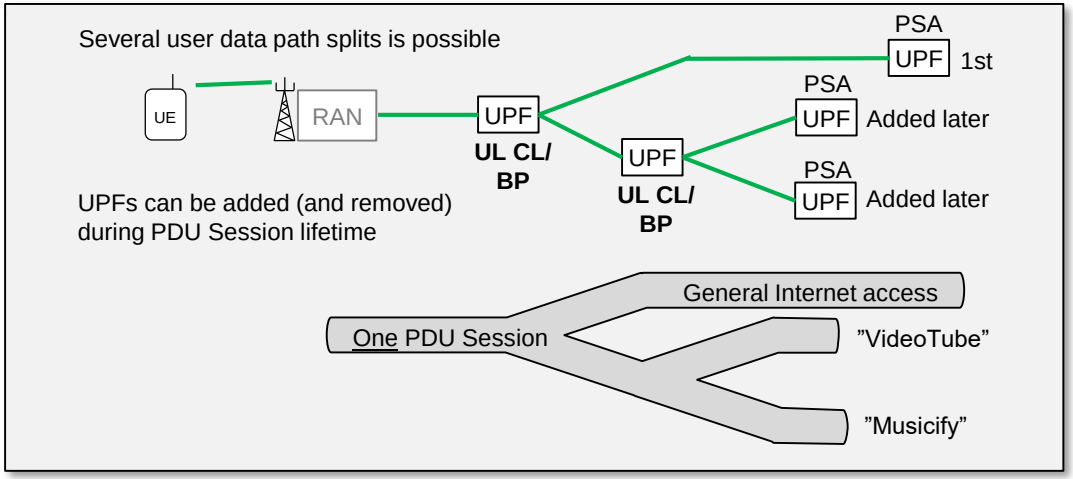


UE has one PDU Session to one Data Network

NEF
External exposure of 5GC NF capabilities
e.g. managing a Session
- External AF may provide Routing and Policy/Charging information to SMF via N33

SMF makes decision to add / change PSA/UPF
e.g. based on input from:
- UPF: traffic detection or load status
- AMF: change of UE access technology
  change of UE location
- AF: e.g. request to enable MEC

Example



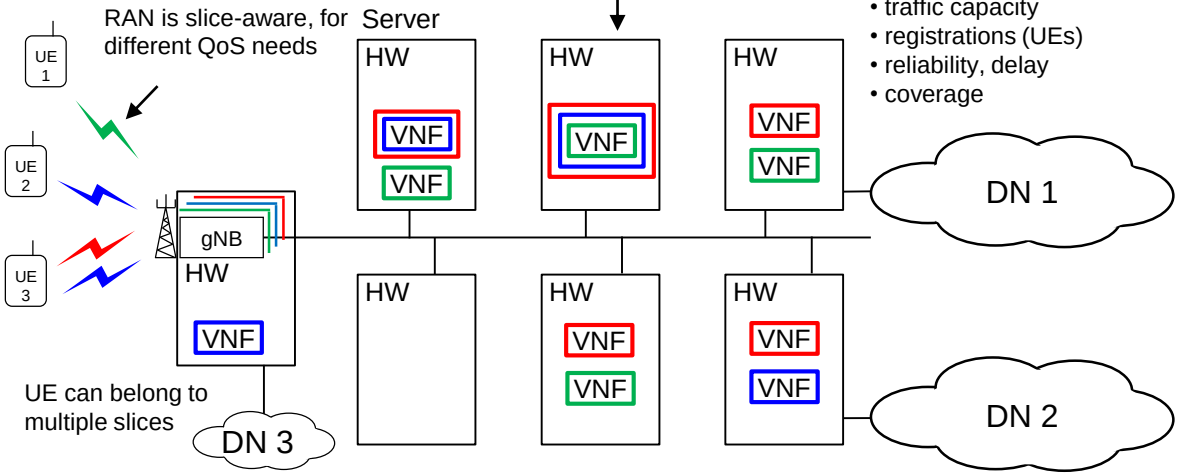
AF	Application Function	MEC	Multi-access Edge Computing	QoS	Quality of Service
AMF	Access and Mobility Mgmnt Function	NEF	Network Exposure Function	RAN	Radio Access Network
ATSSS	Access Traffic Steering Switching Splitting	NF	Network Function	SMF	Session Mgmnt Function
BP	Branching Point	PCF	Policy Control Function	src	Source
DN	Data Network	PDU	Packet Data Unit	UE	User Equipment
dst	Destination	PSA	PDU Session Anchor	UL CL	Uplink Classifier
				UPF	User Plane Function

Network Slicing

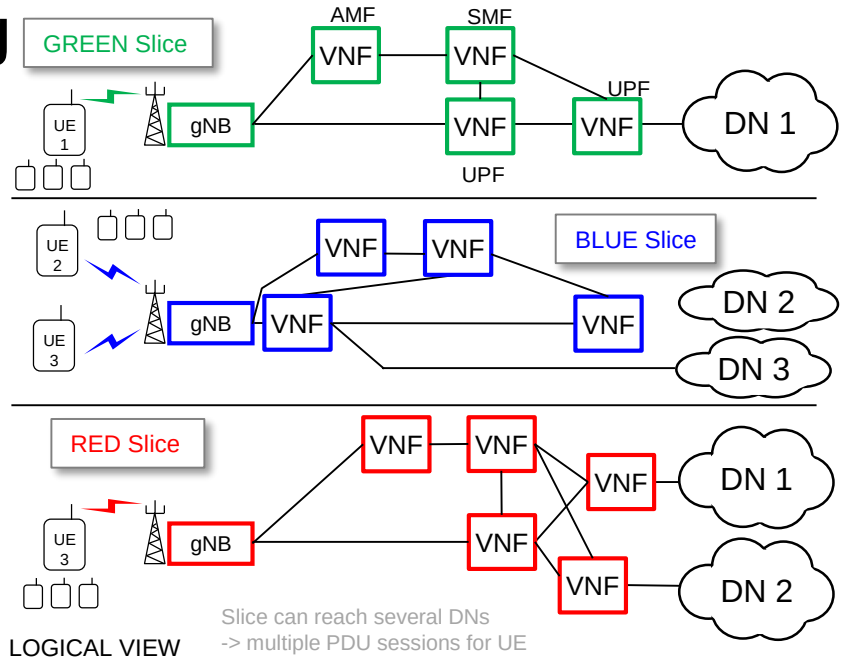
NFV and SDN are main tools to create "logical overlay" network (NW slice)

A VNF can belong to multiple slices

Creating logical networks with different characteristics e.g.:
- traffic capacity
- registrations (UEs)
- reliability, delay
- coverage



PHYSICAL VIEW



LOGICAL VIEW

3GPP NETWORK SLICE DATA MODEL:

NSSAI
A group of up to 8 S-NSSAIs

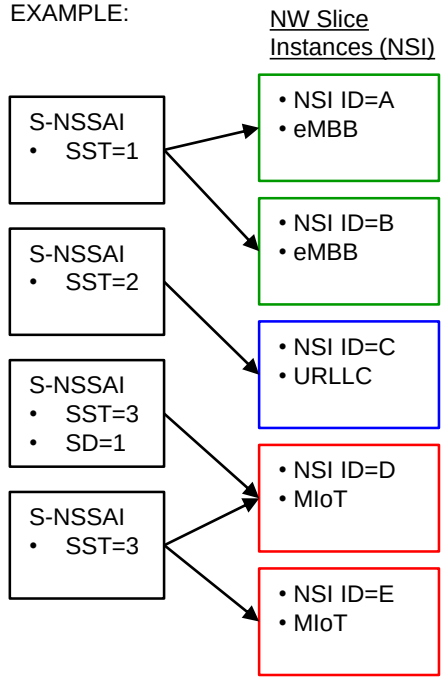
S-NSSAI ("a reference to a slice")
- Helps select a suitable slice

SST
Indicates type of desired slice

1=eMBB	4=V2X
2=URLLC	+ Operator specific
3=MIoT	numbers

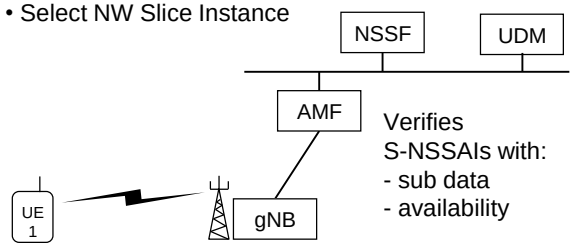
SD (Optional)
Differentiates between slices with the same SST

EXAMPLE:



A Network Slice (instance) may be available in:
- the whole Network, or
- one or more Tracking Areas

NSSF may help AMF to:
- Determine available S-NSSAIs
- Reselect AMF(s)
- Select NW Slice Instance



Can include NSSAI at registration

Selects initial AMF

AMF	Access and Mobility Management Function	NFV	Network Functions Virtualization	SD	Slice Differentiator
DN	Data Network	NRF	Network Resource Function	SDN	Software-Defined Networking
eMBB	enhanced Mobile BroadBand	NSI	Network Slice Instance	S-NSSAI	Single NSSAI
MIoT	Massive Internet-of-Things (mMTC)	NST	Network Slice Template	SST	Slice/Service Type
mMTC	Massive Machine-Type Communication	NSSAI	Network Slice Selection Assistance Information	UE	User Equipment
NF	Network Function	NSSF	Network Slice Selection Function	URLLC	Ultra-Reliable Low-Latency Communication
				V2X	Vehicle to anything

MEC and LADN

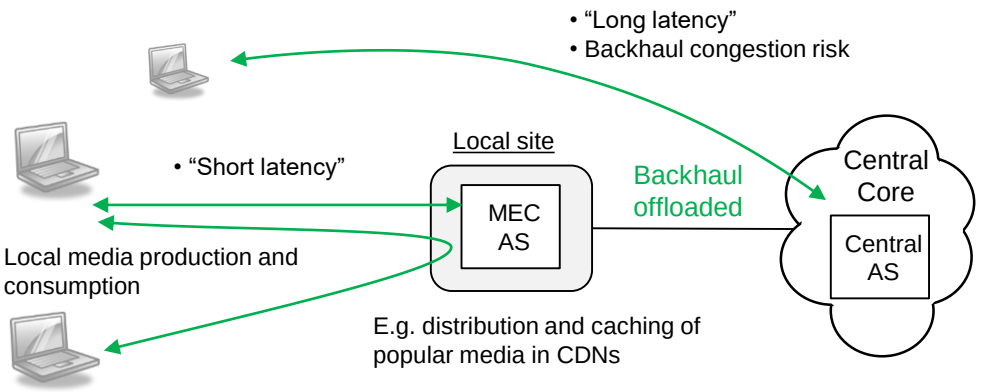
ETSI MEC

- General architecture for edge applications
- Fixed and mobile access
- ETSI also defines NFV

Formerly "Mobile"

Multi-access Edge Computing

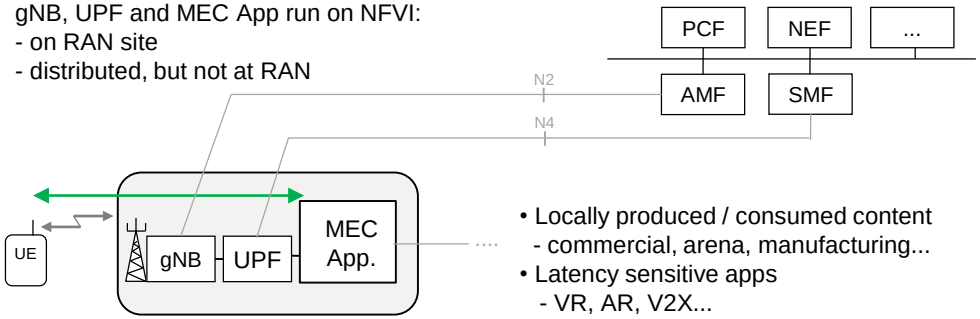
Services hosted close to UE



5GC (SMF) selects UPF:
- close to UE
- with N6 to local Data Network.

Based on e.g. input from PCF, AF, NEF

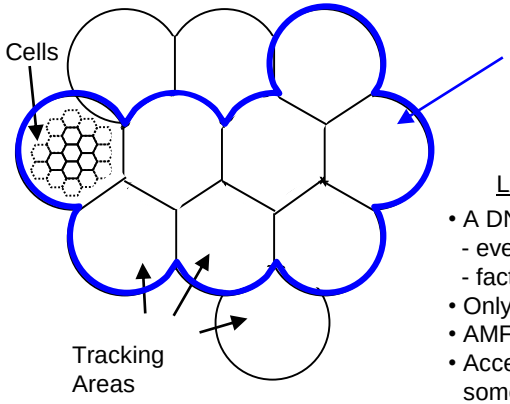
gNB, UPF and MEC App run on NFVI:
- on RAN site
- distributed, but not at RAN



- Locally produced / consumed content
  - commercial, arena, manufacturing...
- Latency sensitive apps
  - VR, AR, V2X...
- Pre-processing of data (IoT GW)
- Caching of popular media

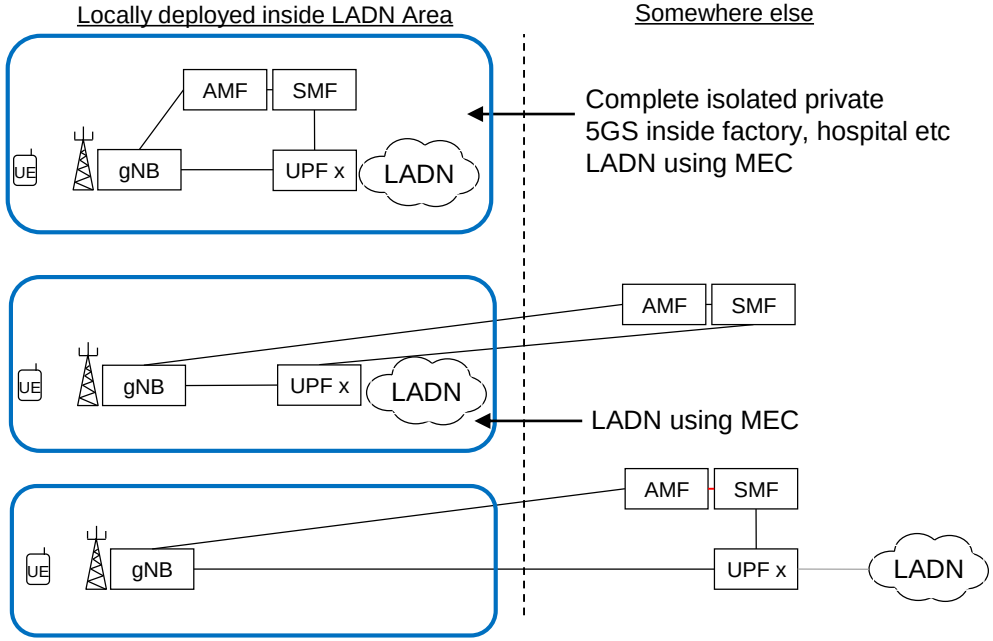
Note: At UE handover between RAN sites, MEC Application may need live migration for seamless service

Local Area Data Network



LADN

- A DN available in only some TA(s)
  - event arena, campus area
  - factory, hospital, smart city
- Only available from 3GPP access
- AMF informs UE about LADN availability
- Access to LADN can be open or limited to some UEs



AMF	Access and Mobility Management Function	MEC	Multi-access Edge Computing	SMF	Session Management Function
AS	Application Server	NEF	Network Exposure Function	TA	Tracking Area
CDN	Content Delivery Network	NFV	Network Function Virtualization	UE	User Equipment
COTS	Common / Commercial Off The Shelf	NFVI	NFV Infrastructure	UPF	User Plane Function
DN	Data Network	PCF	Policy Control Function	V2X	Vehicle to Anything
ETSI	European Telecommunications Standards Institute	PDU	Packet Data Unit		
LADN	Local Area Data Network	RAN	Radio Access Network		

NG-RAN Overview

TS 38.300

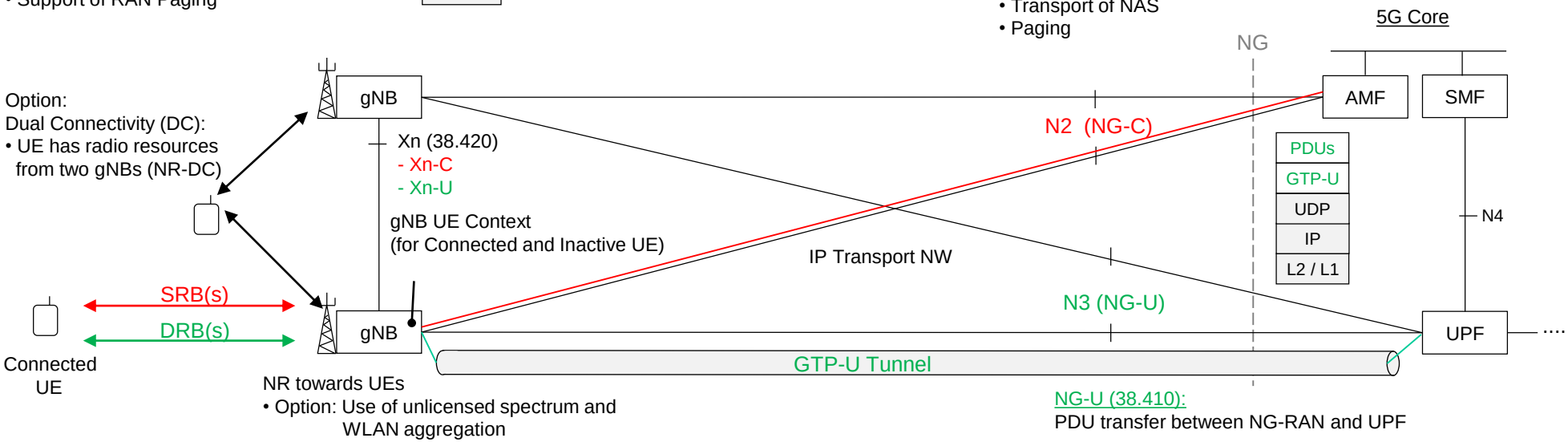
Xn-C:
- Protocol: XnAP (38.423)
- Mobility related signalling
- UE Context transfer
- Managing resources in 2nd node (for DC)
- Support of RAN Paging

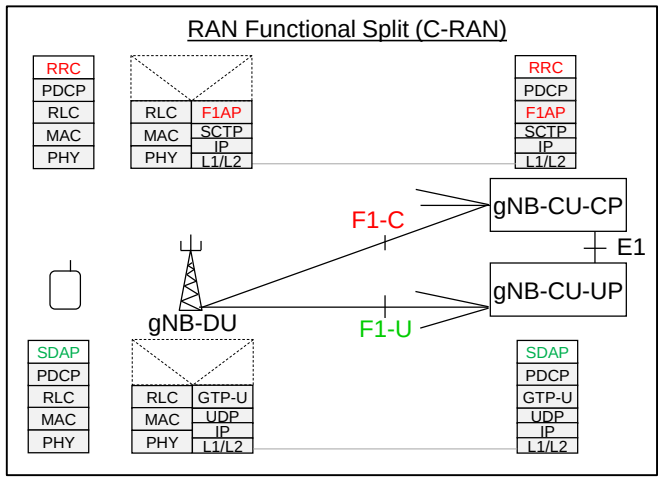
	PDUs
XnAP	GTP-U
SCTP	UDP
IP	
L2 / L1	

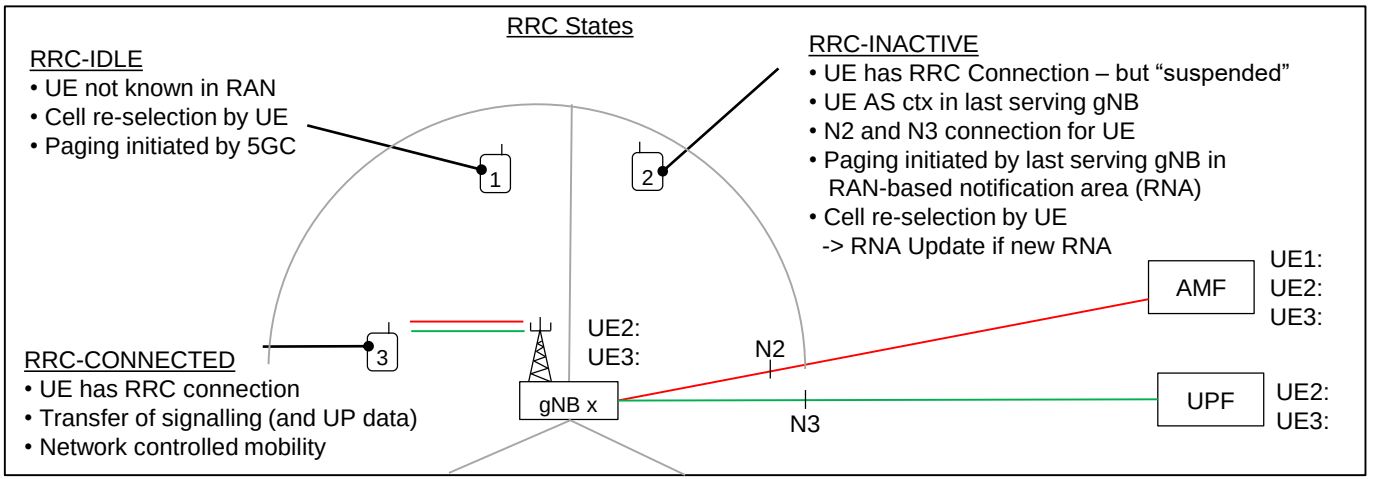
Xn-U
- Protocol: GTP-U
- PDU transfer between xNBs
  - at Handover
  - during DC

NGAP
SCTP
IP
L2 / L1

N2 (NG-C) : gNB to AMF
- Protocol: NGAP (38.413)
- Interface mgmnt
- UE ctx mgmnt
- UE mobility related signalling
- UE session related signalling
- Transport of NAS
- Paging



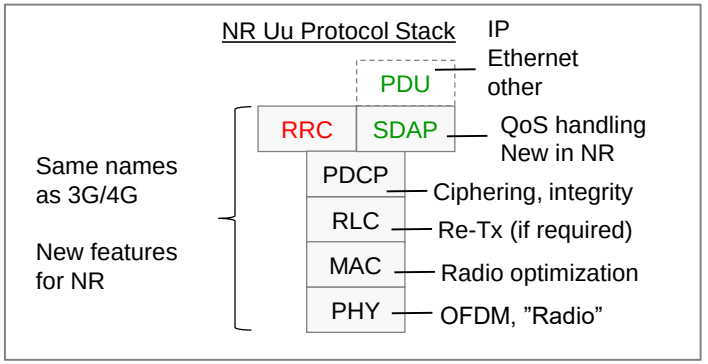




AMF	Access and Mobility Management Function	DRB	Data Radio Bearer	MAC	Medium Access Control	SCTP	Stream Control Transport Protocol
BBU	Base Band Unit	DRX	Discontinous Reception	NGAP	NG Application Protocol	SDAP	Service Data Adaptation Protocol
CM	Connection Management	DU	Distributed Unit	RLC	Radio Link Control	SMF	Session Management Function
CP	Control Plane	F1AP	F1 Application Protocol	RNA	RAN Notification Area	SRB	Signalling Radio Bearer
C-RAN	Centralized (Cloud) RAN	gNB	NR NodeB	RRC	Radio Resources Control	UDP	User Datagram Protocol
Ctx	Context	GTP	GPRS Tunneling Protocol	RRH	Remote Radio Head	UPF	User Plane Function
CU	Central Unit						

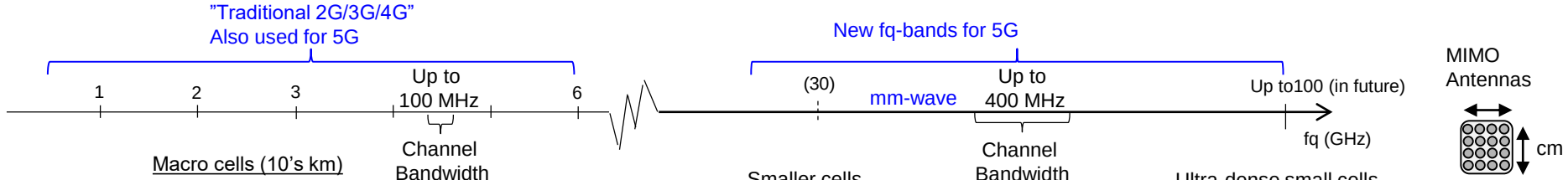
NR – New Radio

38.300, 38.xxx

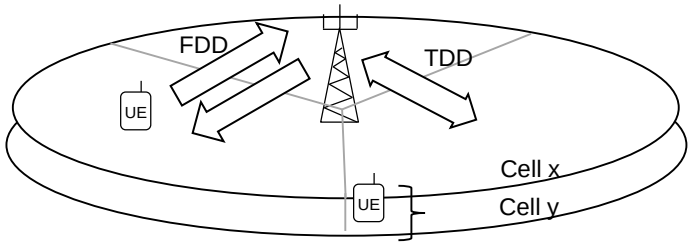


Some New Radio Characteristics:

- Still OFDM like in 4G
- More flexible radio (3 use cases, new fq-bands)
  - ”numerologies”
- High fq-bands (mm-wave)
- Use of unlicensed fq-spectrum
- Wide Carriers (up to 400 MHz)
- Carrier Aggregation (up to 32 CC)
- Dual Connectivity (multi-RAT)
- Massive MIMO
- Beamforming / beamtracking
- High modulation (BPSK -> up to 256QAM, more later...)
- ”Lean design” – e.g. Reference Signals only sent when required
- New Channel coding: LDPC and Polar

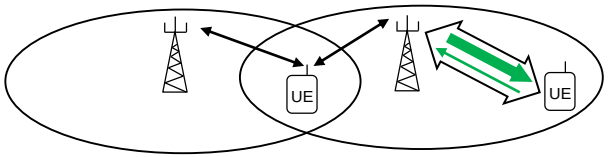


Macro cells (10’s km)



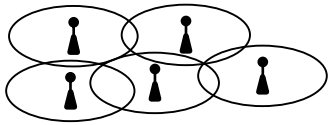
Carrier Aggregation:
>1 carrier from a gNB is used for a UE
(Component Carriers)

Smaller cells



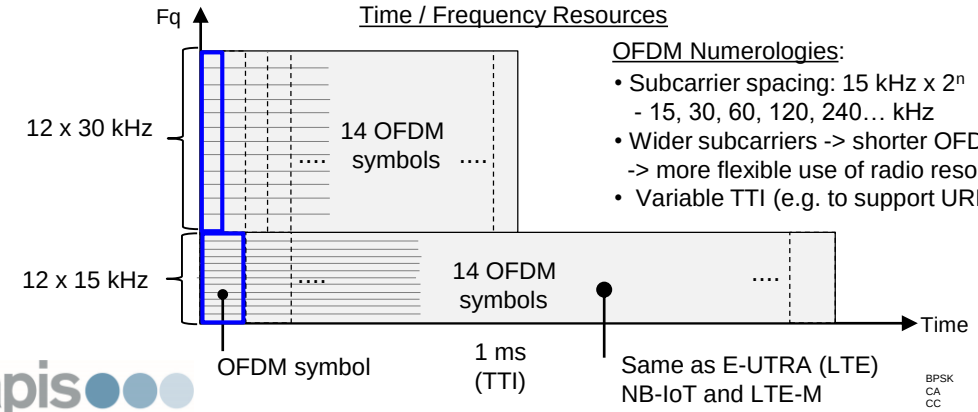
Dual Connectivity:
- Resources from different gNBs used for a UE

Ultra-dense small cells



High path loss
Affected by leaves, rain, hands etc
Cell size: 10’s of meters
Ultra-high capacity per km2

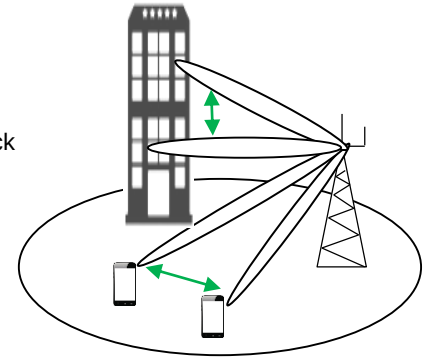
Time / Frequency Resources



OFDM Numerologies:
- Subcarrier spacing: 15 kHz x 2^n
  - 15, 30, 60, 120, 240… kHz
- Wider subcarriers -> shorter OFDM symbols
  -> more flexible use of radio resources
- Variable TTI (e.g. to support URLLC)

High fq-bands:
Beamforming
to increase gain
Requires fast feedback

Beamforming / Beamtracking



5GO_SF_8

BPSK	Binary Phase Shift Keying	LTE-M	LTE for Machine-type Communication	NR-DC	NR-NR Dual Commectivity	SDAP	Service Data Adaptation Protocol
CA	Carrier Aggregation	MAC	Medium Access Control	OFDM	Orthogonal Frequency Division Multiplexing	SN	Secondary Node
CC	Component Carrier	MIMO	Multiple Input Multiple Output	QAM	Quadrature Amplitude Modulation	TDD	Time Division Duplex
DC	Dual Connectivity	MN	Master Node	PDCP	Packet Data Convergence Protocol	TTI	Transmission Time Interval
FDD	Frequency Division Duplex	NB-IoT	Narrowband IoT	RLC	Radio Link Control	URLLC	Ultra-Reliable Low Latency Communication
LDPC	Low-Density Parity-Check Code	NR	New Radio	RRC	Radio Resources Control		

5G QoS – Quality of Service

23.501, 23.502, 23.503

General QoS Parameters:
- Bit rate (Guaranteed, Maximum...)
- Delay / Latency (can be measured in many ways)
- Priority
- Error rate

5QI – 5G QoS Identifier
5QI Value is a reference to:
- Resource type: GBR or non-GBR
- Priority level: 5....90
- Delay budget: 5....300 ms
- Packet error rate: 10^{-2}....10^{-6}

- general policies
- 5QI values
- SDF Templates

- Subscriber data
  - QoS info

AF:
may influence QoS for traffic
- can contact PCF, or
- via NEF for 3rd party AFs

PCF, UDM, AF, NEF, N33, AMF, SMF, N2, N4 (PFCP), N3, UPF, PSA, gNB, UE, Uu, Data Network

SMF
- gets sub data from UDM
- gets policy info from PCF
- Binds SDFs to QoS Flows
- sends various Rules to UPF (over N4)
- sends QoS Profiles to gNB (via AMF and N2)
- sends QoS Rules to UE (using NAS SM)

QoS Rules

QoS Flow X
- QoS Rule ID
- QFI (can be same as 5QI)
- Packet Filter Set
  - IP addr, MAC addr
  - port numbers, VLAN tag...
- QoS parameters
  - 5QI
  - GFBR / MFBR

QoS Flow to DRB mapping

QoS Profiles

QoS Flow X:
- QoS Parameters
  - 5QI
  - GFBR / MFBR
  - ARP
- Notification control
- (Reflective QoS indication)

QoS Flow to DRB mapping

PDR, FAR, QER, URR

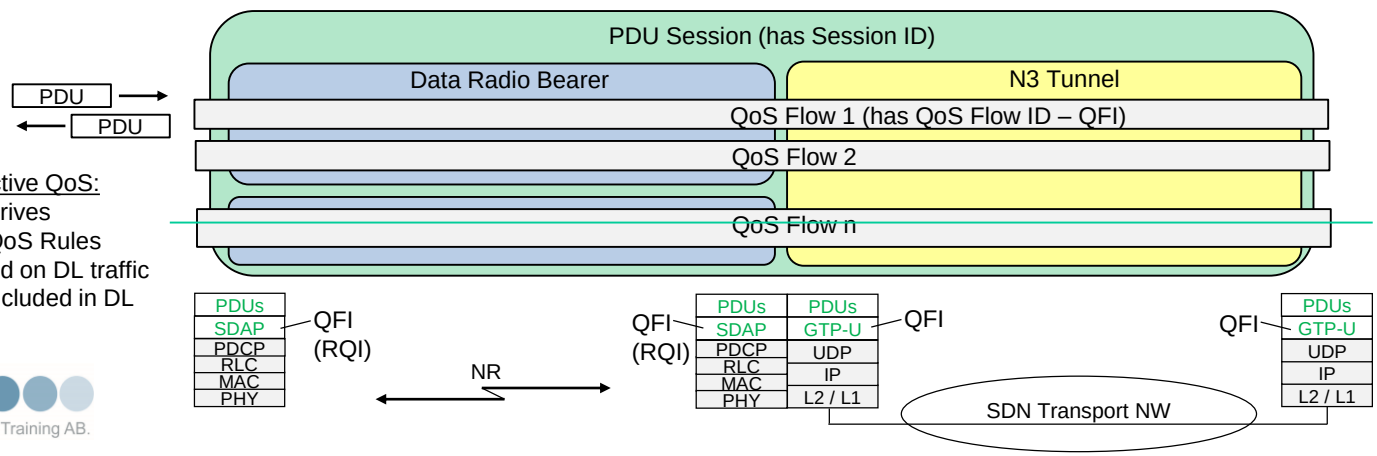
QoS Flow X
- Packet Filter Set
  - IP addr, MAC addr....
- Actions
- QoS parameters

Network Slice Instance ID: A

UE:
- maps UL PDUs to QoS Flows
- QoS Flows -> DRBs

gNB:
- Radio QoS handling
- maps DL between QoS Flows and DRBs
- transport level marking UL (e.g. DSCP)

UPF (PSA):
- maps DL PDUs to QoS Flows
- forward / drop / buffer / duplicate
- QoS enforcement
  - transport level marking DL (e.g. DSCP)
- Usage reporting to SMF



One or more SDFs per QoS Flow

Reflective QoS:
UE derives
- UL QoS Rules
- based on DL traffic
RQI included in DL

5QI	5G QoS Identifier	SDAP	Service Data Adaptation Protocol
AMF	Access and Mobility Mgmnt Function	SDF	Service Data Flow
ARP	Allocation Retention Priority	SDN	Software Defined Networking
DL	Downlink	SMF	Session Management Function
DSCP	DiffServ Code Point	UDM	Unified Data Management
FAR	Forwarding Action Rule	UDP	User Datagram Protocol
GFBR	Guaranteed Flow Bit Rate	UE	User Equipment
GTP-U	GPRS Tunneling Protocol – User Plane	UL	Uplink
MFBR	Maximum Flow Bit Rate	UP	User Plane
PCF	Policy Control Function	URR	Usage Reporting Rule
PDR	Packet Detection Rule	UPF	User Plane Function
PDU	Packet Data Unit	QER	QoS Enforcement Rule
PSA	PDU Session Anchor	QFI	QoS Flow Identifier
RQI	Reflective QoS Indication		

Network Exposure

Network Exposure Function (NEF).
Provides NF Services on SBI (Nnef_....)
For secure external exposure of capabilities 5G NFs:

- Monitoring capability
  AF can be informed about e.g.:
  - UE location
  - UE reachability
  - change of physical device (PEI <-> SUPI)

- Provisioning capability
  AF can provision NFs with e.g.:
  - Expected UE behaviour
  - Mobility and/or Communication pattern
  - traffic descriptions (PFDs)

- Policy / Charging capability
  AF may influence e.g.:
  - QoS / charging of traffic
  - routing of UP traffic (e.g. for MEC)

- Analytics reporting capability
  AF may e.g.:
  - fetch or subscribe to analytics generated by 5GS

Translation of internal/external info e.g.
- GPSI <-> SUPI (or MSISDN)
- cell / TA <-> street / coordinates

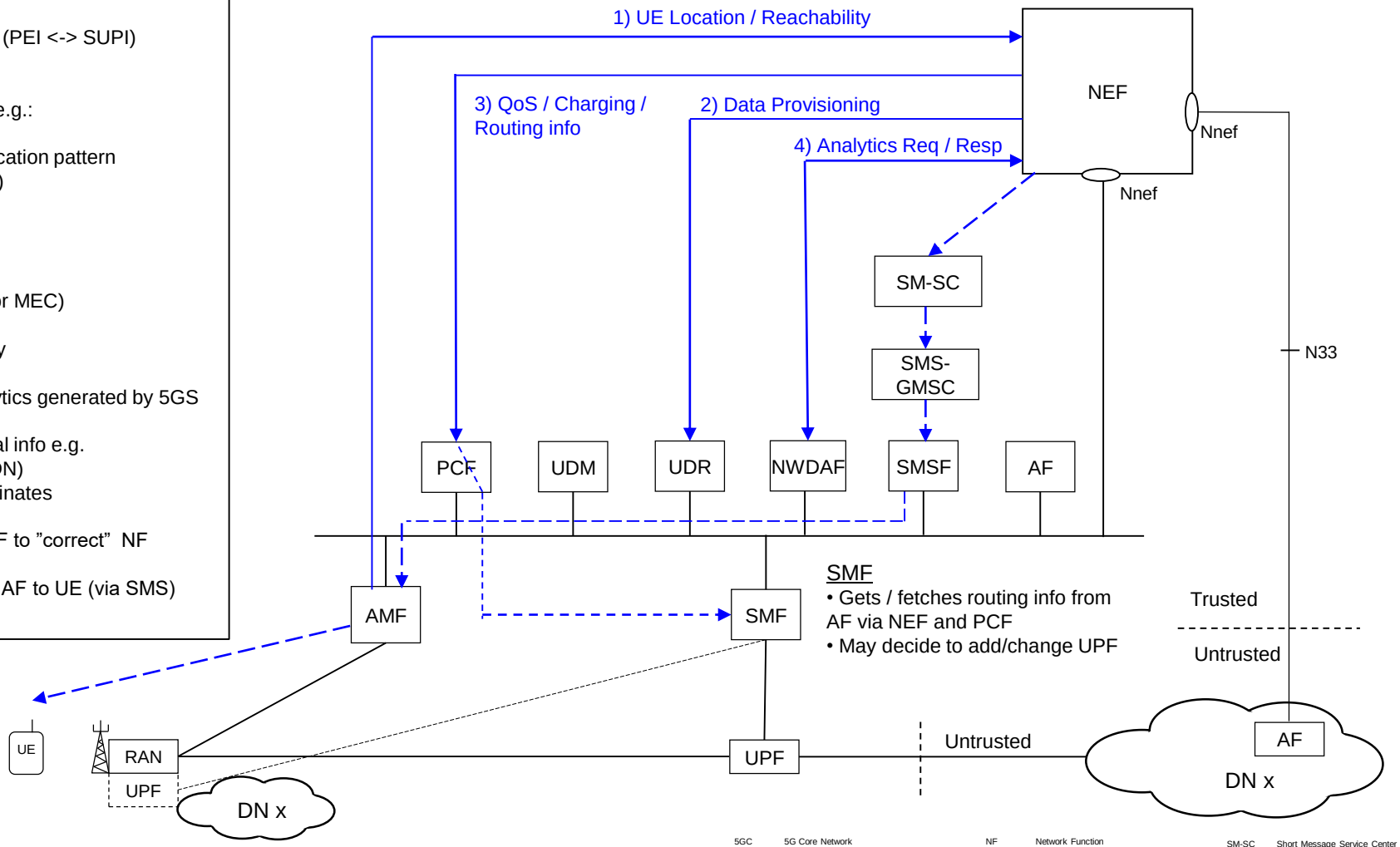
Provides info from external AF to ”correct” NF

Can provide ”trigger” from an AF to UE (via SMS)

NEF is an enabler for interworking between 5GS and authorized 3rd parties:
- OTT players, enterprises, utilities, public safety, governments etc

Benefits:
- New services from operator
- Network resources optimization
- Better user / UE experience

Security on N33
- Mutual authentication (using certificates)
- Support (TLS) for
  - confidentiality
  - integrity
  - replay protection



5GC	5G Core Network
5GS	5G System
AF	Application Function
AMF	Access and Mobility Management Function
DN	Data Network
GPSI	Generic Public Subscription Identifier
MEC	Multi-access Edge Computing
NEF	Network Exposure Function
NF	Network Function
NWDAF	Network Data Analytics Function
PCF	Policy Control Function
PFD	Packet Flow Description
SBI	Service Based Interface
SCEF	Service Capability Exposure Function
SMF	Session Management Function
SM-SC	Short Message Service Center
SMS-GMSC	SMS Gateway MSC
TLS	Transport Layer Security
UDM	Unified Data Management
UDR	Unified Data Repository
UE	User Equipment
UPF	User Plane Function

33.210
33.501
23.502

5G Security Architecture - Overview

Outside 3GPP scope, but:
- PDU Session is ”bearer”
- Secondary Authentication UE–DN AAA can be used

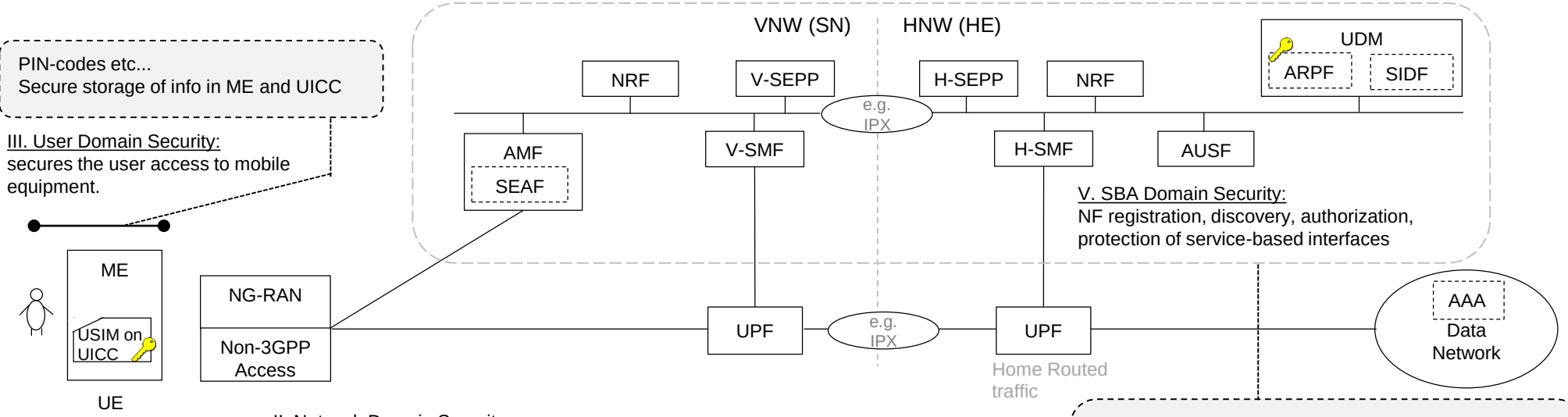
IV. Application Domain Security:
enables applications in user domain and provider domain to exchange messages securely.

I. Network Access Security:
enables UE to authenticate and access services via the network securely
protects against attacks on the (radio) interfaces
-> security context delivery from SN to UE for access security.

Primary Authentication and Key Agreement (5G AKA or EAP-AKA’)
-> Mutual Authentication (UE – NW)
Encryption and Integrity on NAS and Radio CP and UP
Use of SUCI and 5G-TMSI

PIN-codes etc...
Secure storage of info in ME and UICC

III. User Domain Security:
secures the user access to mobile equipment.



V. SBA Domain Security:
NF registration, discovery, authorization, protection of service-based interfaces

II. Network Domain Security:
enables network nodes to securely exchange CP and UP info

- O&M configuration of gNBs requires authentication & authorization
- Protection of IP interfaces for 5GC and 5G-AN shall be supported according to NDS/IP
  - integrity and replay protection
  - sensitive data, e.g. cryptographic keys, also confidentiality protected

NFs shall support:
- mutual authentication using certificates between NF consumer and NF producer
- TLS
- Access Tokens used when requesting NF Service

Other non-3GPP specific
- Data Center and RAN site security
  - physical / cyber attacks
- Transport network security / redundancy

5G-TMSI	5G Temporary Mobile Subscriber Identity
AAA	Authentication Authorization Accounting
AKA	Authentication and Key Agreement
AMF	Access and Mobility Mgmnt Function
AMF	Authentication Mgmnt Field
ARPF	Authentication credential Repository and Processing Function
CP	Control Plane
EAP	Extensible Authentication Protocol
EAP	Extensible Authentication Protocol
HE	Home Environment
IPX	IP eXchange
NDS/IP	Network Domain Security / IP
NF	Network Function
O&M	Operation and Maintenance
SEAF	Security Anchor Function
SBA	Service Based Architecture
SIDF	Subscription Id De-concealing Function
SN	Serving Network
SUCI	Subscriber Concealed Identity
TLS	Transport Layer Security
UDM	Unified Data Management
UDR	Unified Data Repository
UE	User Equipment
UP	User Plane
UPF	User Plane Function