UE States and PDU Session functionalities

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Learning objectives

Upon completion of this module, you should be able to:

- Describe the Protocol Stacks between UE and 5GC
- Identify 5GMM and 5GSM states
- Explain UE Registration and Connection Management procedures
- Explain UE PDU Session functionalities

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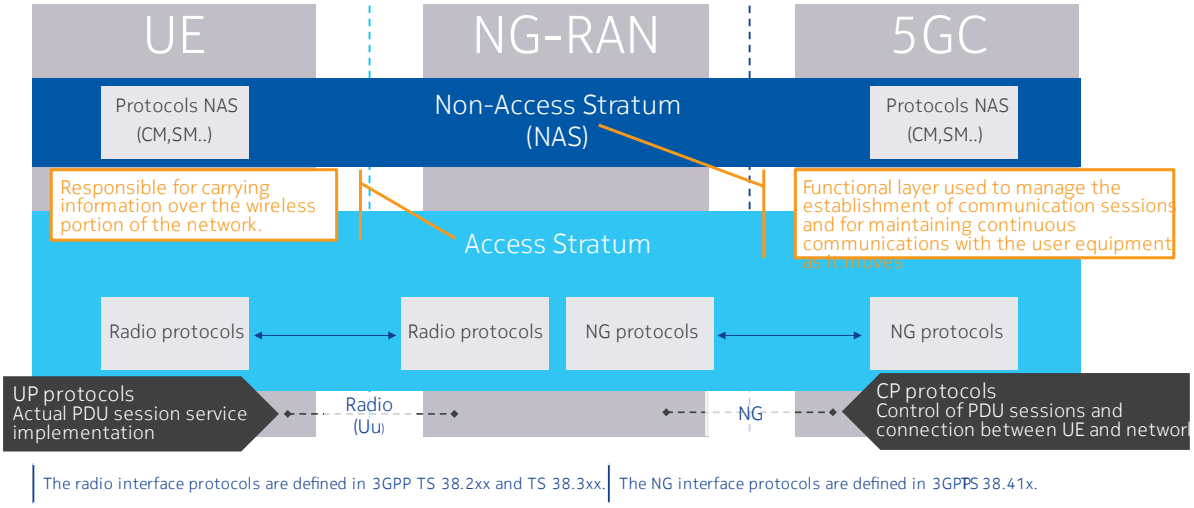
Protocol Stacks between UE and 5GC

Protocol Stacks between UE and 5GC
Access Stratum and Non-Access Stratum



The PDU Session Resource service is offered from the Service Access Point (SAP) to SAP by the Access Stratum. This diagram shows the protocols on the air interface Uu and the NG interfaces that linked together provide this PDU Session Resource service.

Remember, the Non-access stratum (NAS) is a functional layer in the protocol stacks between the core network and user equipment. This layer is used to manage the establishment of communication sessions and for maintaining continuous communications with the user equipment as it moves. The NAS is defined in contrast to the Access Stratum which is responsible for carrying information over the wireless portion of the network.

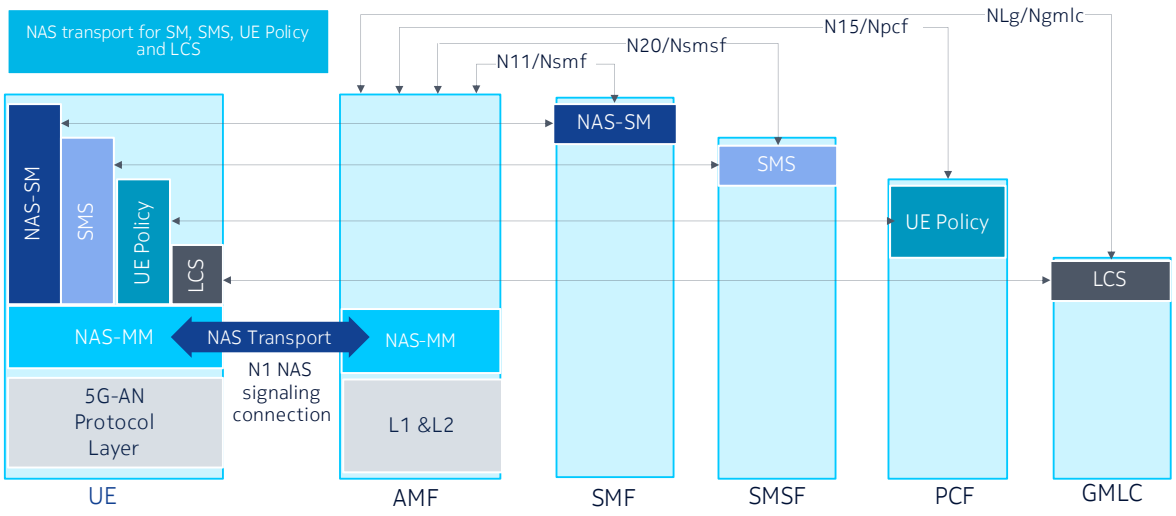
The protocols over Uu and NG interfaces are divided into two structures:

- **User plane protocols**: These are the protocols implementing the actual PDU Session service, for example carrying user data through the access stratum.
- **Control plane protocols**: These are the protocols for controlling the PDU Sessions and the connection between the UE and the network from different aspects (including requesting the service, controlling different transmission resources, handover etc..). Also a mechanism for transparent transfer of NAS messages is included.

Both the Radio protocols and the NG protocols contain a mechanism to transparently transfer NAS messages.

Protocol Stacks between UE and 5GC

Control Plane Protocol Stacks between the UE and the5GC



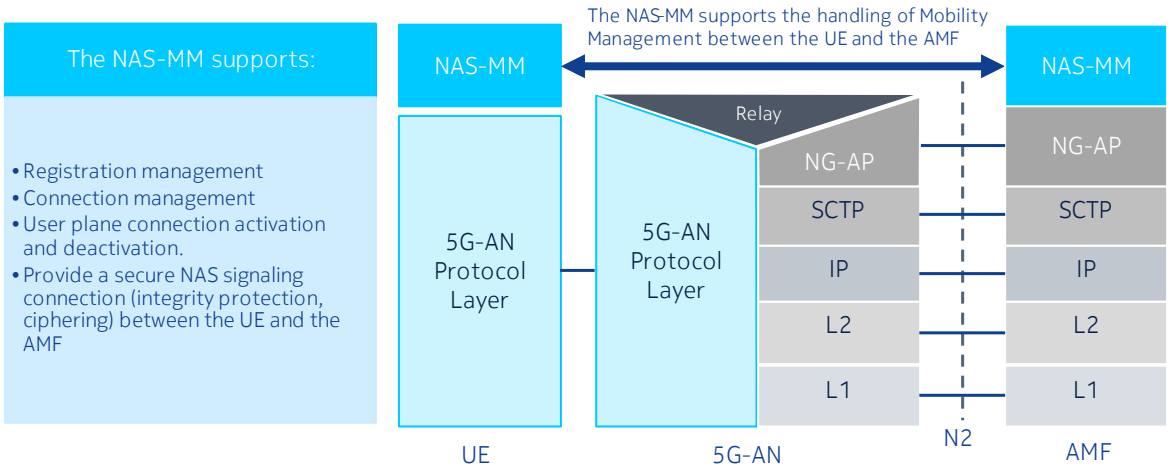
The Non-Access Stratum (NAS) protocol comprises a NAS-Mobility Management (MM) and a NAS-Session Management (SM) component. The NAS-SM supports the handling of Session Management between the UE and the SMF. The NAS-MM supports the handling of Mobility Management between the UE and the AMF.

A single N1 NAS signaling connection is used for each access to which the UE is connected. The single N1 termination point is located in AMF. The single N1 NAS signaling connection is used for both Registration Management and Connection Management and for SM-related messages and procedures for a UE.

The protocols between the UE and a core network function (excluding the AMF) that need to be transported over N1 via NAS-MM protocol are: Session Management Signaling, SMS, UE Policy and LCS. It is possible to transmit the other type of NAS message (e.g., NAS SM) together with an RM/CM NAS message by supporting NAS transport of different types of payload or messages that do not terminate at the AMF, i.e. NAS-SM, SMS, UE Policy and LCS between the UE and the AMF. This includes:

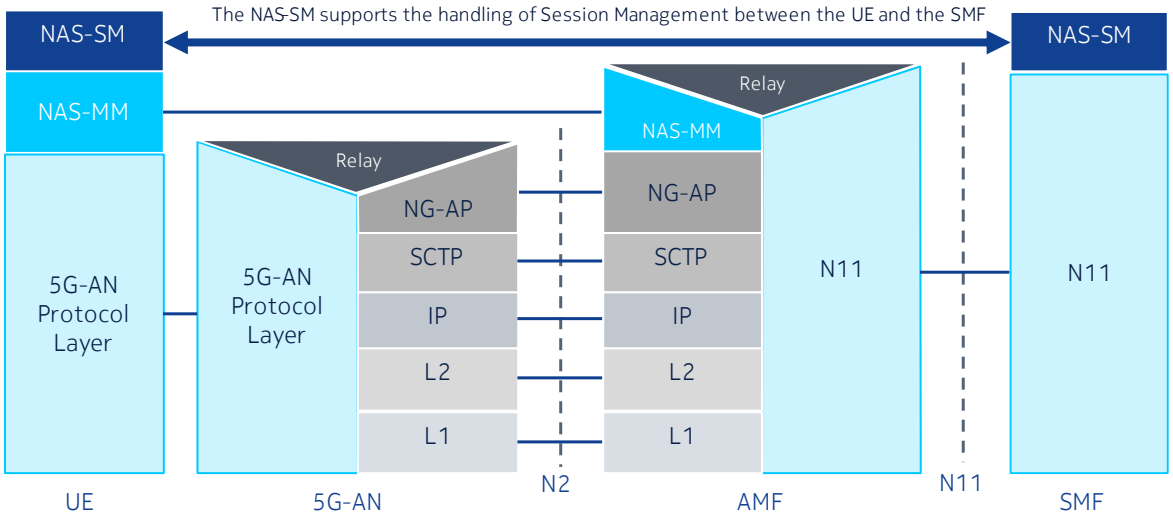
- Information about the Payload type;
- Additional Information for forwarding purposes
- The Payload (e.g. the SM message in the case of SM signaling).

Protocol Stacks between UE and 5GC
Control Plane between the UE and the AMF



The NAS protocol for MM functionality supports registration management functionality, connection management functionality and user plane connection activation and deactivation. It is also responsible of ciphering and integrity protection of NAS signaling.

Protocol Stacks between UE and 5GC
Control Plane between the UE and the SMF



The NAS protocol for SM functionality supports user plane PDU Session Establishment, modification and release. It is transferred via the AMF, and transparent to the AMF.

The SM signaling message is created and processed, in the NAS-SM layer of UE and the SMF. The content of the SM signaling message is not interpreted by the AMF.

The NAS-MM layer handles the SM signaling is as follows:

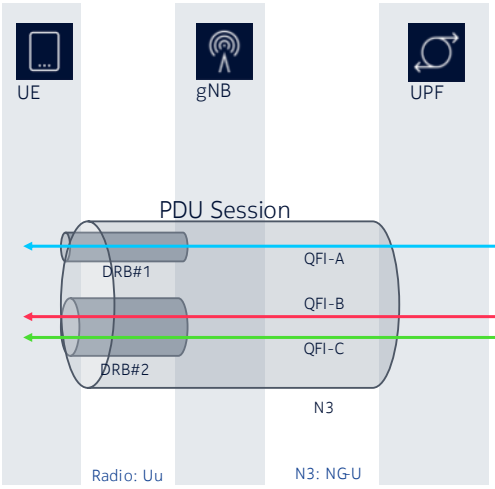
- For transmission of SM signaling: The NAS-MM layer creates a NAS-MM message, including security header, indicating NAS transport of SM signaling, additional information for the receiving NAS-MM to derive how and where to forward the SM signaling message.
- For reception of SM signaling: The receiving NAS-MM processes the NAS-MM part of the message, i.e. performs integrity check, and interprets the additional information to derive how and where to derive the SM signaling message.

Protocol Stacks between UE and 5GC
PDU Session

A PDU Session is an association between the UE and a Data Network that provides a PDU connectivity service.

For each UE, the 5GC establishes one or more PDU Sessions.

- For each UE, the NG-RAN establishes one or more Data Radio Bearers (DRBs) per PDU Session.
- The NG-RAN maps packets belonging to different PDU sessions to different DRBs.
- Hence, the NGRAN establishes at least one default DRB for each PDU Session.

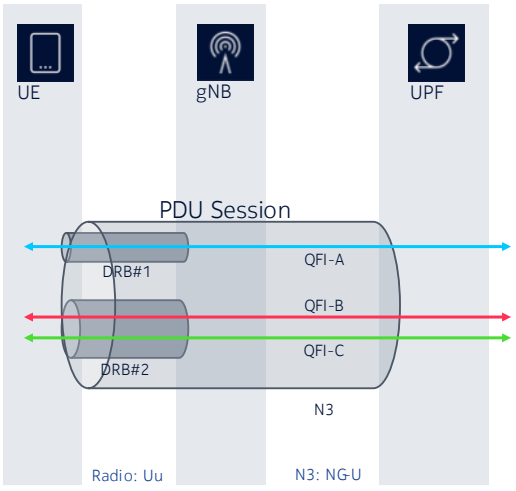


A PDU Session is an association between the UE and a Data Network that provides a PDU connectivity service. PDU sessions can remain established even if the radio and network resources constituting the corresponding PDU session between the UE and the SMF are temporarily released.

For each UE, the 5GC establishes one or more PDU Sessions.

For each UE, the NG-RAN establishes one or more Data Radio Bearers (DRBs) per PDU Session. The NG-RAN maps packets belonging to different PDU sessions to different DRBs. Hence, the NG-RAN establishes at least one default DRB for each PDU Session.

Protocol Stacks between UE and 5GC
PDU Session



A QoS flow is the finest granularity of QoS differentiation within a PDU session.

A PDU Session may have multiple QoS Flows with One Default QoS Flow

User data packets are mapped to QoS flows at the UE(UL) and at the 5GC UPF(DL)

UE and NG-RAN maps the QoS flows to DRB (based on NG-RAN decision)

Separate DRBs may be established for QoS flows requiring different packet forwarding treatment, or several QoS Flows belonging to the same PDU session can be mapped to the same DRB.

A single NG-U/N3 Tunnel transports all QoS Flows of a PDU Session(case of Dual Connectivity there may be more than one NG-Tunnel i.e. one to MN and one to SN)

A 5G QoS Flow is the finest granularity of QoS differentiation within a PDU session: It is the finest granularity for QoS forwarding treatment in the 5G System. All traffic mapped to the same 5G QoS Flow receive the same forwarding treatment (for example, scheduling policy, queue management policy, rate shaping policy, RLC configuration, etc..).

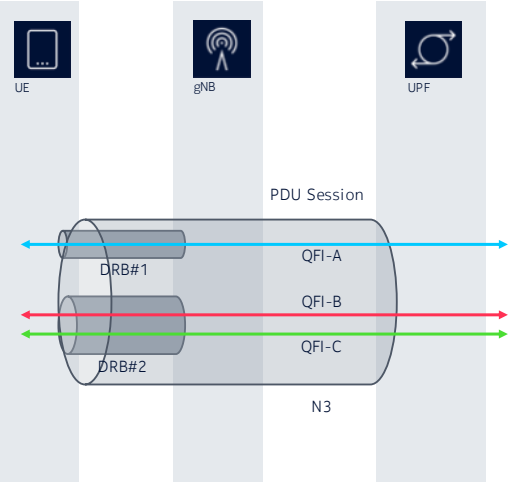
Providing different QoS forwarding treatment requires separate 5G QoS Flows. A PDU Session may have multiple QoS Flows with One Default QoS Flow.

User data packets are mapped to QoS flows at the UE (in the Uplink) and at the 5GC UPF (in the Downlink). The UE and NG-RAN maps the QoS flows to Data Radio Bearer (based on the NG-RAN decision).

Protocol Stacks between UE and 5GC
PDU Session

The QoS Flow Identifier (QFI) uniquely identifies the QoS profile within a PDU session. It is signaled by the SMF and spans UE, AN (radio), and UPF

5G QoS Identifier (5QI) used to determine QoS characteristics of a flow (resource type, priority, delay, loss, etc..)



5G Core has no bearers, QoS is applied to individual flow groups. The SMF sends packet filters identifying QoS profiles for specific flows, and a default profile for all other flows.

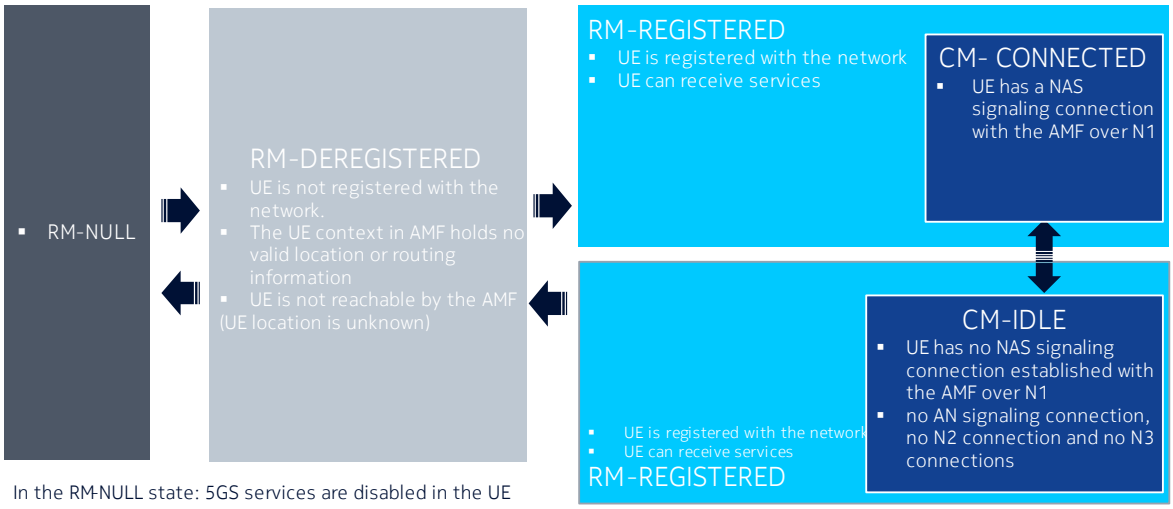
Protocol Stacks between UE and 5GC
Quiz 1

1. Where a single N1 termination point is located?
   a. in UPF
   b. in AMF
   c. in SMF
2. What is a PDU Session?
   a. A service that provides exchange of PDUs between a UE and a UPF
   b. The finest granularity for QoS forwarding treatment in the 5G System
   c. An association between the UE and a Data Network that provides a PDU connectivity service
3. What is a 5G QoS Flow?
   a. A scalar that is used as a reference to a specific QoS forwarding behavior
   b. An association between the UE and a Data Network that provides a PDU connectivity service
   c. The finest granularity of QoS differentiation within a PDU session

5GMM and 5GSM States

5GMM and 5GSM States

Registration and Connection Management States



In the RM-NULL state: 5GS services are disabled in the UE

The 5GS mobility management (5GMM) sublayer of the UE and the network is described by means of different state machines. The 5GMM sublayer state is managed per access type independently, that is to say 3GPP access or non-3GPP access.

Two Registration Management (RM) states are used in the UE and the AMF that reflect the registration status of the UE in the selected PLMN: RM-DEREGISTERED and RM-REGISTERED.

Two Connection Management (CM) states are used to reflect the NAS signaling Connection of the UE with the AMF: CM-IDLE and CM-CONNECTED.

Remember that the CM states for 3GPP access and Non-3GPP access are independent of each other, which means that one can be in CM-IDLE state at the same time when the other is in CM-CONNECTED state.

In the state 5GMM-REGISTERED, a 5GMM context has been established. Additionally, one or more PDU session(s) may be activated at the UE. The UE may initiate the non-initial registration procedure (including the normal registration update and periodic registration update) and the service request procedure. The UE in the state 5GMM-REGISTERED over non-3GPP access shall not initiate the periodic registration update procedure.

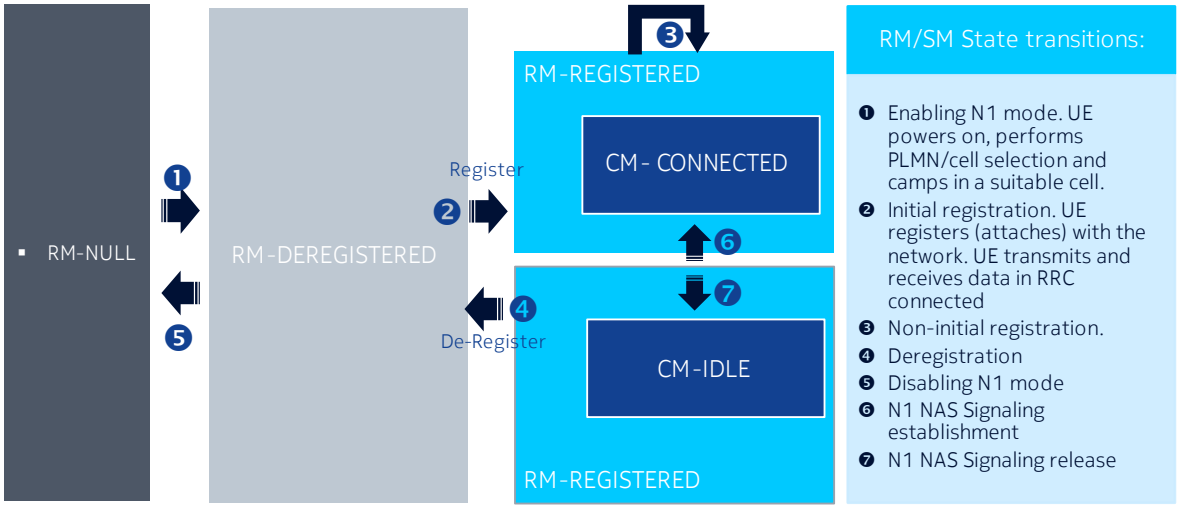
In the RM DEREGISTERED state, the UE is not registered with the network. The UE context in AMF holds no valid location or routing information for the UE so the UE is not reachable by the AMF. However, some parts of UE context may still be stored in the UE and the AMF e.g. to avoid running an authentication procedure during every Registration procedure.

A UE in CM-IDLE state has no NAS signaling connection established with the AMF over N1. The UE performs cell selection/cell reselection and PLMN selection.

There are no AN signaling connection, N2 connection and N3 connections for the UE in the CM-IDLE state.

In the RM-NULL state: 5GS services are disabled in the UE: No MM can be performed.

5GMM and 5GSM States
RM and CM States Transitions



NAS State transitions:

(1) Enabling N1 mode. UE powers on, performs PLMN/cell selection and camps in a suitable cell.

(2) Initial registration. UE registers (attaches) with the network. UE transmits and receives data in RRC connected

(3) Non-initial registration.

(4) Deregistration

(5) Disabling N1 mode

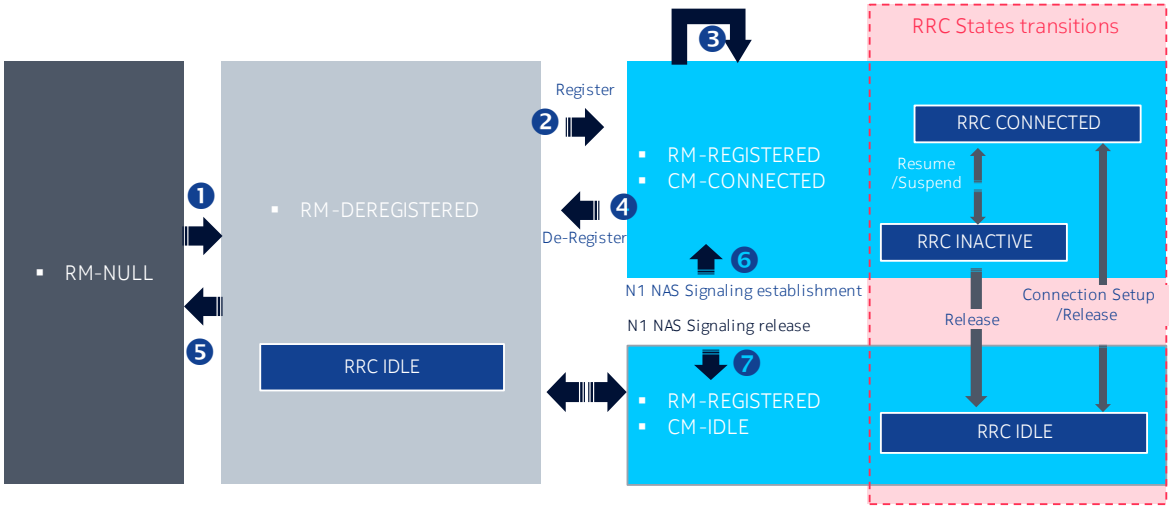
(6) N1 NAS Signaling establishment

(7) N1 NAS Signaling release.

When the UE state in the AMF is RM-REGISTERED, The UE shall enter CM-CONNECTED state whenever an signaling connection is established between the UE and the AN (entering RRC Connected state over 3GPP access, or at the establishment of the UE-N3IWF connectivity over non-3GPP access). The transmission of an Initial NAS message (Registration Request, Service Request or Deregistration Request) initiates the transition from CM-IDLE to CM-CONNECTED state.

The UE in 5GMM DEREGISTERED state enters to RM-NULL state be disabling the N1 mode. N1 mode is a mode of the UE allowing access to 5GC via 5G-AN. N1 mode should be enabled for the UE to enter 5GMM DEREGISTERED state.

5GMM and 5GSM States
UE States in NAS and RRC

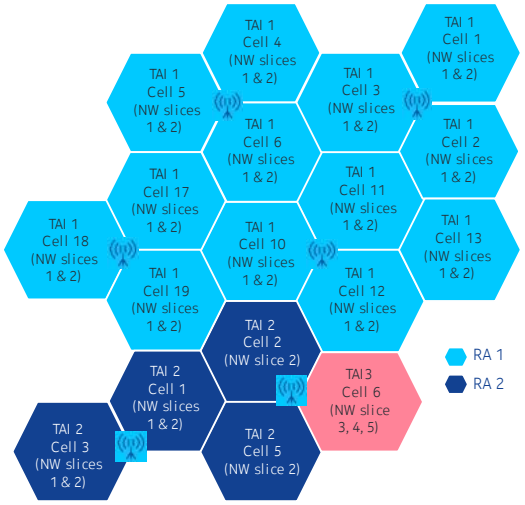


5GMM and 5GSM States
Registration Area Management

- Registration Area consist of one or more Tracking Areas
  - Each Tracking area is defined by TA Identifier (TAI) which is broadcasted in each cell
  - TAI format consisting of MCC, MNC and a 3 -byte TAC only

Registration Area management comprises the functions to allocate and reallocate a Registration area to a UE.

Registration area is managed per access type i.e., 3GPP access or Non-3GPP access.



Registration Area management comprises the functions to allocate and reallocate a Registration area to a UE. Registration area is managed per access type that is to say, 3GPP access or Non-3GPP access.

When a UE registers with the network over the 3GPP access, the AMF allocates a set of tracking areas in TAI List to the UE. **When the AMF allocates registration area, that is to say the set of tracking areas in the TAI List, to the UE it may take into account various information such as Mobility Pattern and Allowed/Non-Allowed Area.

Furthermore, a single TAI dedicated to the Non-3GPP access, the N3GPP TAI, is defined in a PLMN and applies within the PLMN.

When a UE registers with the network over the Non-3GPP access, the AMF allocates a registration area that only includes the N3GPP TAI to the UE.

5GMM and 5GSM States
UE Context in the AMF

Attribute name
supi
supiUnauthInd
gpsiList
pei
udmGroupId
ausfGroupId
drxParameter
subUeAmbr
smsSupport
5gMmCapability
pcfId
restrictedRatList
forbiddenAreaList
serviceAreaRestriction
restrictedCnList
mmContextList (array(MmContext)
sessionContextList (array(PduSessionContext
traceData

Attribute name	Description
accessType	This IE shall contain the access type of the MM context.
nasSecurityMode	contain the used NAS security mode of the UE.
nasDownlinkCount	IE shall contain the NAS downlink count of the UE.
nasUplinkCount	IE shall contain the NAS uplink count of the UE.
ueSecurityCapability	IE shall contain the UE security capability
s1UeNetworkCapability	IE shall contain the S1 UE network capabilities.
allowedNssai	IE shall contain the allowed NSSAI for the access type.
nssaiMappingList	IE shall contain the mapping of the allowed NSSAI for the UE.
nsInstanceList	it shall indicate the Network Slice Instances selected for the UE.
expectedUEbehavior	it shall indicate the expected UE moving trajectory and its validity period.

Attribute name	Description
pduSessionId	Indicates the identifier of the PDU Session.
smContextRef	Indicates the SM context reference.
sNssai	Indicates the associated SNSSAI for the PDU Session.
dnn	Indicates the Data Network Name.
accessType	Indicates the access type of the PDU session.
allocatedEbiList	This IE shall contain the EBIs currently allocated to the PDU session.
hsmfId	This IE shall be present for non-roaming and home-routed PDU sessions. When present, it shall indicate the associated home SMF for the PDU Session.
vsmfId	This IE shall be present if roaming PDU sessions. When present, it shall indicate the associated visit SMF for the PDU Session.
nsInstance	This IE shall Indicate Network Slice Instance for the PDU Session

supi
this IE contains SUPI of the UE.
supiUnauthInd
This IE shall be present if SUPI is present. When present, it shall indicate whether the SUPI is unauthenticated.
gpsiList
this IE shall contain the GPSI(s) of the UE.
pei
this IE shall contain Mobile Equipment Identity of the UE.
udmGroupId
When present, it shall indicate the identity of the UDM Group serving the UE.
ausfGroupId
When present, it shall indicate the identity of the AUSF Group serving the UE.
drxParameter
this IE shall contain the DRX parameter of the UE.
subUeAmbr
This IE shall be present if subscribed UE-AMBR has been retrieved from UDM
When present, this IE shall indicate the value of subscribed UE AMBR of the UE.
smsSupport
Indicates whether the UE supports SMS delivery over NAS via 3GPP access, or via non-3GPP access, or via both the 3GPP and non-3GPP access.
5gMmCapability
When present, this IE shall contain 5G MM capability of the UE.
pcfId
When present, this IE indicates the identity PCF for AM Policy.
restrictedRatList
When present, this IE shall indicate the list of RAT types that are restricted for the UE
forbiddenAreaList
When present, this IE shall indicate the list of forbidden areas of the UE.
serviceAreaRestriction
When present, this IE shall indicate Service Area Restriction for the UE.
restrictedCnList
When present, this IE shall indicate the list of Core Network Types that are restricted for the UE.
mmContextList
this IE contains the MM Contexts of the UE.
sessionContextList
this IE contains the PDU Session Contexts of the UE.
traceData
This IE shall be present if signaling based trace has been activated.

5GMM and 5GSM States
UE Context in the AMF

For a serving PLMN, multiple access-specific RM contexts for an UE:

- a 5G-GUTI (common to 3GPP/Non-3GPP accesses)
- a Registration state per access type
- a Registration Area per access type
- timers for 3GPP access
  - Periodic Registration timer; and
  - a Mobile Reachable timer and an Implicit Deregistration timer.
- timers for non-3GPP access
  - a UE Non-3GPP Deregistration timer; and a Network Non-3GPP Implicit Deregistration timer

Attribute name	Data type	Description
rmState	RmState	Describes the registration management state of the UE
accessType	AccessType	Describes the access type of the UE that applies to the registration management state reported.

Attribute name	Data type	Description
cmState	CmState	Describes the Connectivity management state of the UE
accessType	AccessType	Describes the access type of the UE that applies to the Connectivity management state reported.

An AMF associates multiple access-specific RM (Registration Management) contexts for an UE with:

- a 5G-GUTI that is common to both 3GPP and Non-3GPP accesses. This 5G-GUTI is globally unique.
- a Registration state per access type (3GPP / Non-3GPP)
- a Registration Area (RA) per access type (independent RA).

Timers for 3GPP access:

- a Periodic Registration timer; and
- a Mobile Reachable timer and an Implicit Deregistration timer.

Timers for non-3GPP access:

- a UE Non-3GPP Deregistration timer; and
- a Network Non-3GPP Implicit Deregistration timer.

When served by the same PLMN for 3GPP and non-3GPP accesses, an UE is served by the same AMF.

The AMF assigns to the UE a single 5G-GUTI that is used over 3GPP and Non-3GPP access of the same PLMN or equivalent PLMN.

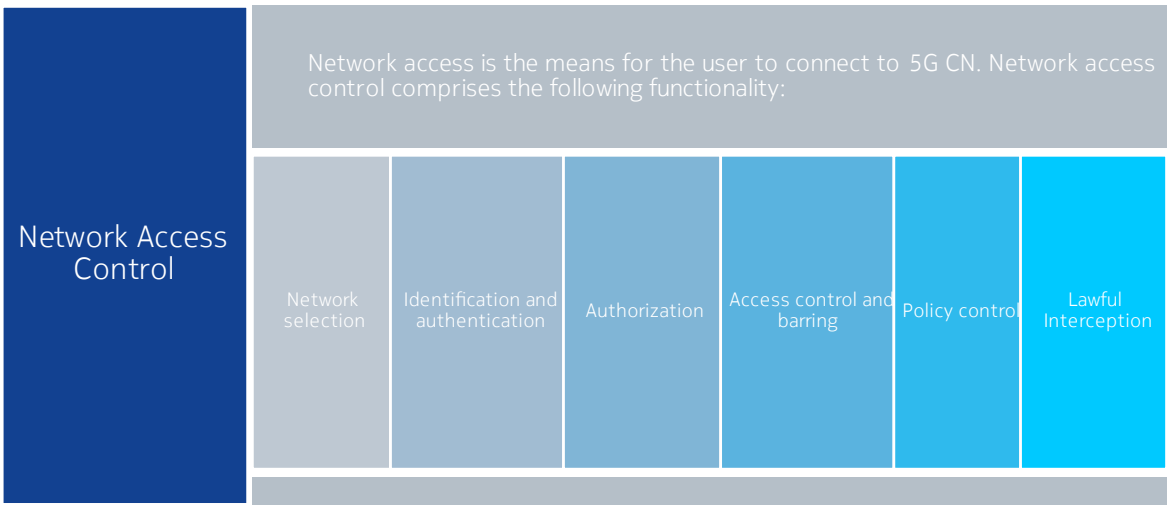
5GMM and 5GSM States
Session Management States

5GMM and 5GSM States
Quiz 2

1. What are the states used to reflect the NAS signaling Connection of the UE with the AMF?
    a. RM-DEREGISTERED and RM -REGISTERED
    b. CM-IDLE and CM-CONNECTED
    c. RRC-IDLE and RRC-CONNECTED
    d. RRC-INACTIVE and RRC -CONNECTED
2. Which of the following are correct statements?
    a. An UE RRC-CONNECTED or RRC -INACTIVE, is CM-CONNECTED
    b. An UE RRC-IDLE is CM-IDLE or RM DEREGISTERED
    c. An UE CM-IDLE is RRC-IDLE
    d. An UE RRC-INACTIVE is CM-IDLE

5GMM and 5GSM Procedures

5GMM and 5GSM Procedures
Network Access Control



Network access is the means for the user to connect to 5G Core. Network access control comprises the following functionalities: Network selection, Identification and authentication, Authorization, Access control and barring, Policy control and Lawful Interception.

Network selection:

In order to determine to which PLMN to attempt registration, the UE performs network selection. The network selection procedure comprises two main parts, PLMN selection and access network selection.

Identification and authentication: The network may authenticate the UE during any procedure establishing a NAS signaling connection with the UE.

Authorization:

The authorization for connectivity of the subscriber to the 5GC and the authorization for the services that the user is allowed to access based on subscription is evaluated once the user is successfully identified and authenticated. This authorization is executed during UE Registration procedure.

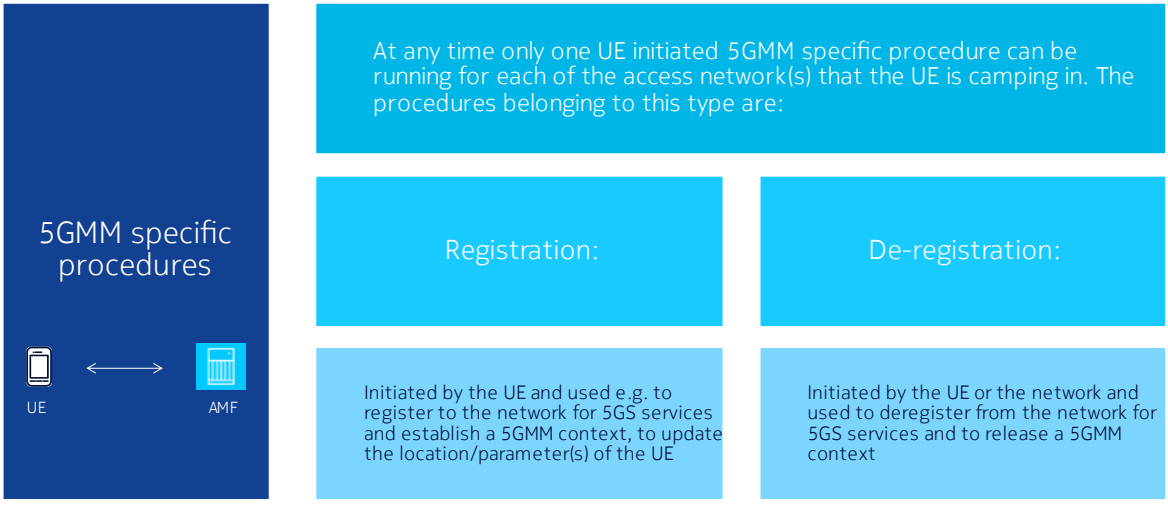
5GC shall provide access to the intercepted Content of Communications and the Intercept Related Information of the mobile target and services related to the target (e.g. Call Forwarding) on behalf of Law Enforcement Agencies (LEAs). More details can be found in TS 33.107 and TS 33.106.

Policy control

Network access control including service authorization may be influenced by Policy control.

Lawful Interception : the action (based on the law) for specific target identity(s), by a network operator/access provider/service provider, of accessing and delivering in real-time certain current information to a Law Enforcement Monitoring Facility. This information includes Intercept Related Information and Content of Communications.

5GMM and 5GSM Procedures
5GS Mobility Management Procedures



The main function of the 5GS mobility management (5GMM) sublayer is to support the identification, security, mobility of a UE as well as generic message transport.

A further function of the 5GMM sublayer is to provide the other sublayer(s) with connection management services.

The Registration Management is used to register or deregister a UE/user with the network, and establish the user context in the network.

5GMM and 5GSM Procedures
5GS Mobility Management Procedures

5GMM Connection Management procedures	Service request	Paging	Notification
	Initiated by the UE and used to establish a secure connection to the network or to request the resource reservation for sending data, or both	Initiated by the network and used to request the establishment of an N1 NAS signaling connection or to prompt the UE to perform re-registration if necessary as a result of a network failure or to request re-establishment of the PDU session(s) associated with non-3GPP access over 3GPP access; not applicable for the non-3GPP access network	▪ Initiated by the network and used to request re-establishment the PDU session(s) associated with non-3GPP access over 3GPP access when the UE is in 5GMM CONNECTED mode over 3GPP access and in 5GMMIDLE mode over non-3GPP access; or ▪ Initiated by the network and used to request re-establishment of the PDU session(s) associated with 3GPP access over 3GPP access when the UE is in 5GMM CONNECTED mode over non3GPP access and in 5GMMIDLE mode over 3GPP access

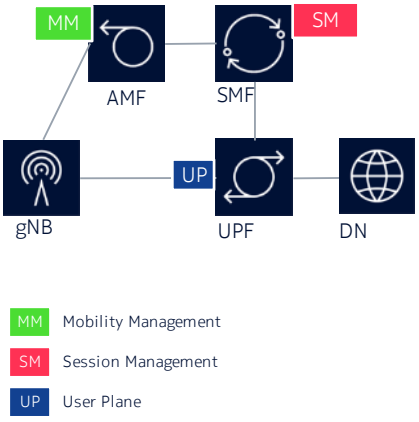
The Connection Management is used to establish and release the signaling connection between the UE and the AMF: Connection management comprises the functions of establishing and releasing a NAS signaling connection between a UE and the AMF over N1. This NAS signaling connection is used to enable NAS signaling exchange between the UE and the core network. It comprises both the Access Network signaling connection between the UE and the Access Network and the N2 connection for this UE between the Access Network and the AMF.

5GMM and 5GSM Procedures
5GS Session Management Procedures

The 5GSM comprises procedures for:

- The authentication and authorization,
- establishment,
- modification
- and release of PDU sessions

- Request for performing handover of an existing PDU session between 3GPP access and non -3GPP access
- or to transfer an existing PDN connection in the EPS to the 5GS



The 5GC supports a PDU Connectivity Service, that is to say a service that provides exchange of PDUs between a UE and a data network identified by a Data Network Name (DNN). The PDU Connectivity Service is supported via PDU Sessions that are established upon request from the UE.

The SMF is responsible for the session management functions to provide the PDU connectivity service to the UE via the SM signaling between UE and SMF.

The 5G session management comprises the procedures shown on the slide.

5GSM procedures can be performed only if a 5GMM context has been established between the UE and the AMF, and if the secure exchange of NAS messages has been initiated by the AMF. Once the UE is successfully registered to a PLMN, a PDU session can be established. If no 5GMM context has been established, the 5GMM sublayer has to initiate the establishment of a 5GMM context by use of the 5GMM procedures.

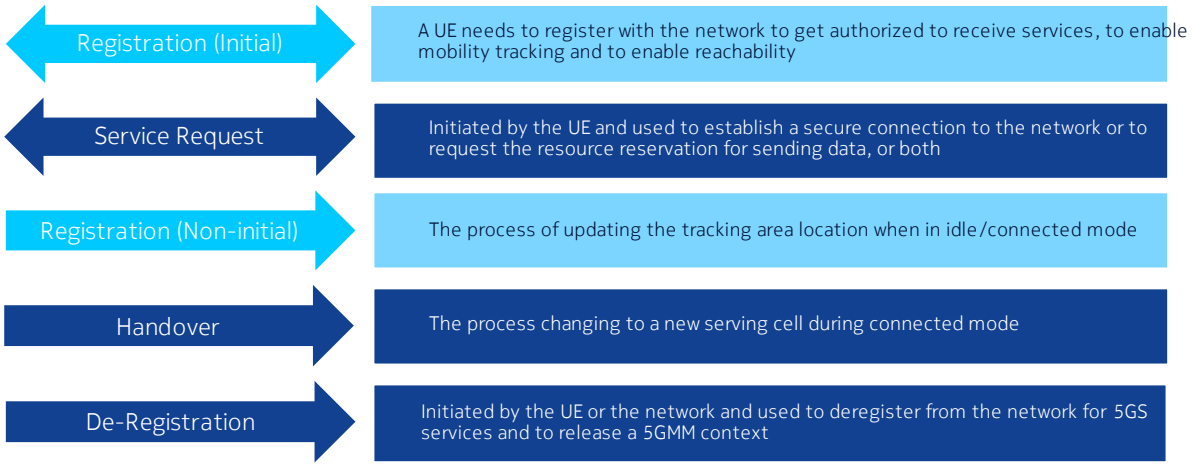
The UE can request the network to modify or release PDU sessions. The network can fulfill such a request from the UE by modifying a PDU session or releasing a PDU session using network-requested procedures.

5GMM and 5GSM Procedures
Quiz 3

1. Why does a UE need to register with the network?
    a. to get authorized to receive services
    b. to perform PLMN/cell selection and camps in a suitable cell
    c. to perform N1 NAS Signaling establishment
    d. to enable mobility tracking and to enable reachability
2. When does the UE perform Mobility Registration Update?(tick 2)
    a. upon changing to a new Tracking Area (TA) outside the UE's Registration Area in both CM-CONNECTED and CM-IDLE
    b. upon changing to a new Tracking Area (TA) outside the UE's Registration Area in CM-IDLE only
    c. when the UE needs to update its capabilities or renegotiate protocol parameters
    d. After the expiry of a predefined time period of inactivity

UE Network Acquisition Process

UE Network Acquisition Process
Basic Call Processing Procedures

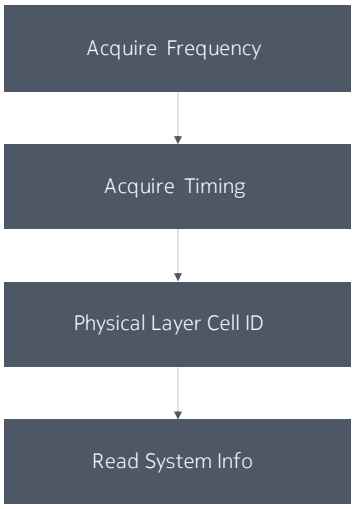


This diagram illustrates the basic call processing procedures.

Registration: Initiated by the UE and used e.g. to register to the network for 5GS services and establish a 5GMM context, to update the location/parameter(s) of the UE.

UE Network Acquisition Process
Cell Search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell



When the UE powers-up, it performs Cell Search procedure.

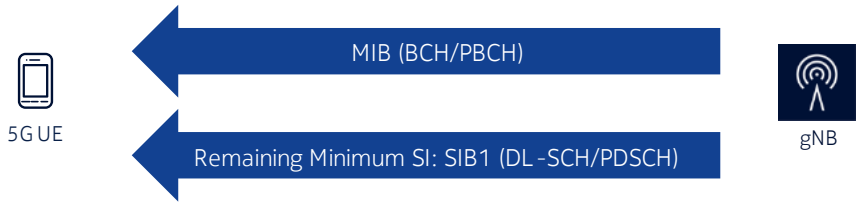
Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell. A UE receives the following synchronization signals (SS) in order to perform cell search: The primary synchronization signal (PSS) and secondary synchronization signal (SSS). PSS is used (at least) for initial symbol boundary, cyclic prefix, sub frame boundary, initial frequency synchronization to the cell. SSS is used for radio frame boundary identification. PSS and SSS together used for cell ID detection.

PSS and SSS together used for cell ID detection.

UE Network Acquisition Process
System Information Acquisition Procedure

System Information Acquisition Procedure used by the UE to acquire the AS- and NAS information.
Minimum SI comprises basic information required for initial access and information for acquiring any other SI. Minimum SI consists of MIB and SIB1.

MIB	contains cell barred status information and essential physical layer information of the cell required to receive further SI



SIB1	defines the scheduling of OSI blocks and contains information required for initial access

The UE applies the SI acquisition procedure to acquire the AS- and NAS information. The procedure applies to UEs in RRC_IDLE, in RRC_INACTIVE and in RRC_CONNECTED.

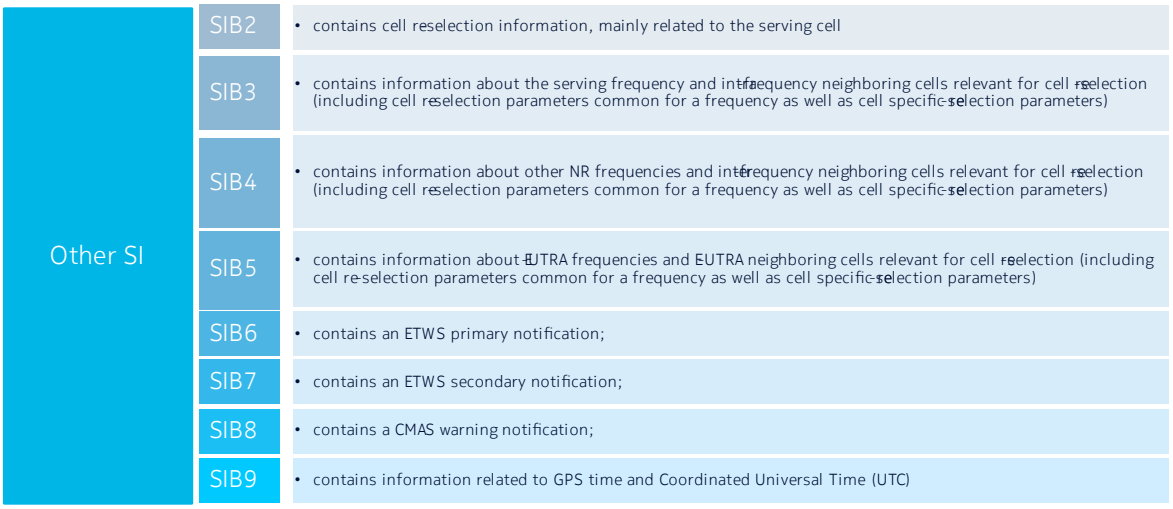
The UE in RRC_IDLE and RRC_INACTIVE shall ensure having a valid version of (at least) the MIB, SIB1 through SIB4 and SIB5 (if the UE supports E-UTRA).

The UE shall apply the SI acquisition procedure upon cell selection (e.g. upon power on), cell-reselection, return from out of coverage, after reconfiguration with sync completion, after entering the network from another RAT, upon receiving an indication that the system information has changed, upon receiving a PWS notification; and whenever the UE does not have a valid version of a stored SIB.

MIB contains cell barred status information and essential physical layer information of the cell required to receive further system information.

SIB1 contains information relevant when evaluating if a UE is allowed to access a cell and defines the scheduling of other SI. It also contains radio resource configuration information that is common for all UEs and barring information applied to the unified access control.

UE Network Acquisition Process
System Information Acquisition Procedure



More other SI are introduced in Release 16 & 17 (see note).

Other SI encompasses all SIBs not broadcast in the Minimum SI. Those SIBs can either be periodically broadcast on DL-SCH, broadcast on-demand on DL-SCH (i.e. upon request from UEs in RRC_IDLE or RRC_INACTIVE), or sent in a dedicated manner on DL-SCH to UEs in RRC_CONNECTED.

More other SI are introduced in Release 16 & 17:

- *SIB10* contains the Human-Readable Network Names (HRNN) of the NPNs listed in SIB1;
- *SIB11* contains information related to idle/inactive measurements;
- *SIB15* contains information related to disaster roaming;
- *SIB16* contains slice specific cell reselection information;
- *SIB17* contains information related to TRS configuration for UEs in RRC_IDLE/RRC_INACTIVE;
- *SIBpos* contains positioning assistance data as defined in TS 37.355 and TS 38.331.
- *SIB18* contains information related to the Group IDs for Network selection (GINs) associated with SNPNs listed in SIB1.

For sidelink, Other SI also includes:

- *SIB12* contains information related to NR sidelink communication;
- *SIB13* contains information related to *SystemInformationBlockType21* for V2X sidelink communication as specified in TS 36.331 clause 5.2.2.28;
- *SIB14* contains information related to *SystemInformationBlockType26* for V2X sidelink communication as specified in TS 36.331 clause 5.2.2.33.

For non-terrestrial network, Other SI also includes:

- *SIB19* contains NTN-specific parameters for serving cell and/or neighbour cells as defined in TS 38.331.

For MBS broadcast, Other SI also includes:

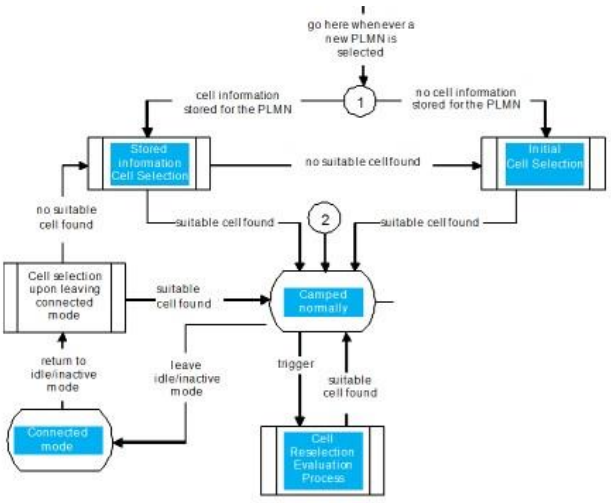
- *SIB20* contains MCCH configuration;
- *SIB21* contains information related to service continuity for MBS broadcast reception.

UE Network Acquisition Process
PLMN Selection and Access Network Selection

In order to determine to which PLMN to attempt registration, the UE performs network selection.

The network selection procedure comprises two main parts:

- PLMN selection
- and access network selection



Network access is the means for the user to connect to 5G Core. Network access control comprises the following functionalities: Network selection, Identification and authentication, Authorization, Access control and barring, Policy control and Lawful Interception.

Network selection:

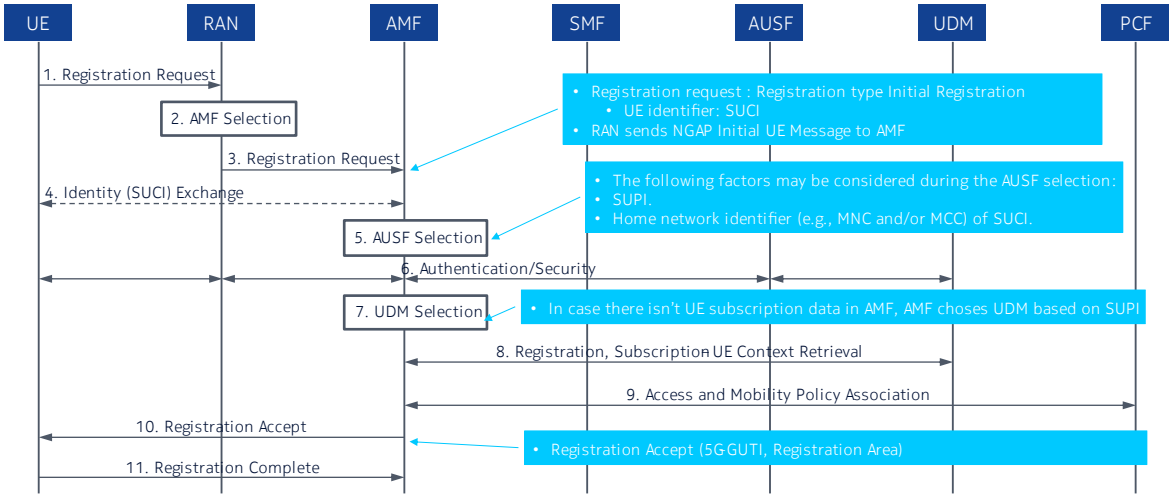
In order to determine to which PLMN to attempt registration, the UE performs network selection. The network selection procedure comprises two main parts, PLMN selection and access network selection.

Cell selection is based on the following principles:

- The UE NAS layer identifies a selected PLMN (and equivalent PLMNs, if any);
- The UE searches the supported frequency bands and for each carrier frequency it searches and identifies the strongest cell. It reads cell broadcast information to identify PLMN(s) and other relevant parameters (e.g. related to cell restrictions);
- The UE seeks to identify a suitable cell; if it is not able to identify a “suitable” cell it seeks to identify an “acceptable” cell.
- A cell is “suitable” if: the measured cell attributes satisfy the cell selection criteria (based on DL radio signal strength/quality); the cell belongs to the selected/equivalent PLMN; cell is not restricted (e.g. cell is not barred/reserved or part of "forbidden" roaming areas);
- An “acceptable” cell is one for which the measured cell attributes satisfy the cell selection criteria and the cell is not barred.
- Among the identified suitable (or acceptable) cells, the UE selects the strongest cell, (technically it “camps” on that cell).
- As signaled/configured by the radio network, certain frequencies could be prioritized for camping.

UE Network Acquisition Process

Registration Procedure -Simplified Signaling Flow



A UE needs to register with the network to receive services that requires registration. Once registered and if applicable the UE updates its registration with the network : periodically, in order to remain reachable (Periodic Registration Update); or upon mobility (Mobility Registration Update); or to update its capabilities or re-negotiate protocol parameters.

The registration procedure protocol flow is displayed on the slide.

The Initial Registration procedure involves execution of Network Access Control functions as discussed previously (i.e. user authentication and access authorization based on subscription profiles in UDM). As result of the Registration procedure, the identifier of the serving AMF serving the UE in the access through which the UE has registered will be registered in UDM. **3**The AMF associates multiple access-specific RM contexts for a UE as listed below.

As outlined earlier, the registration management procedures are applicable over both 3GPP access and Non-3GPP access. The 3GPP and Non-3GPP RM states are independent of each other.

AMF selection by the 5G-AN:

When the UE provides no 5G-S-TMSI nor the GUAMI to the 5G-AN.

When the UE provides 5G-S-TMSI or GUAMI but the routing information is not sufficient and/or not usable

AMF has instructed AN that the AMF (identified by GUAMI(s)) is unavailable and no target AMF is identified and/or AN has detected that the AMF has failed.

AMF supports the AMF selection functionality to select an AMF for relocation or because the initially selected AMF was not an appropriate AMF to serve the UE (e.g. due to change of Allowed NSSAI).

Other CP NF(s), e.g. SMF, supports the AMF selection functionality to select an AMF from the AMF set when the original AMF serving a UE is unavailable.

An AMF associates multiple access-specific RM contexts for an UE with:
- a 5G-GUTI that is common to both 3GPP and Non-3GPP accesses. This 5G-GUTI is globally unique.
- a Registration state per access type (3GPP / Non-3GPP)
- a Registration Area (RA) per access type (independent RA).
- timers for 3GPP access:
  - a Periodic Registration timer; and
  - a Mobile Reachable timer and an Implicit Deregistration timer.
- timers for non-3GPP access:
  - a UE Non-3GPP Deregistration timer; and
  - a Network Non-3GPP Implicit Deregistration timer.

UE Network Acquisition Process
Quiz 4

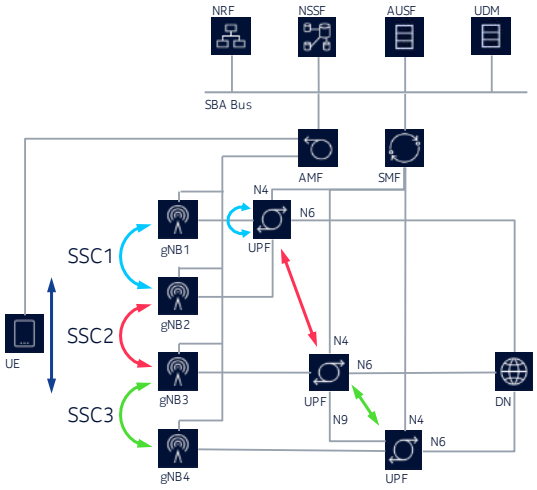
1. Which of the following are Registration types that can be initiated by a 5G UE?
   a. Initial Registration to the 5GS
   b. Mobility Registration Update
   c. Periodic Registration Update
   d. Emergency Registration
2. When an UE may perform an Initial Registration procedure?
   a. When it is in RM-DEREGISTERED state
   b. When it is in RM- REGISTERED state
   c. When it is in RRC Inactive state
   d. When it is in CM-IDLE state

5G PDU Session Functionalities

5G PDU Session functionalities
Per PDU Session and Service Continuity

Session and service continuity (SSC) options:

- SSC Mode 1: Same UPF across gNBs. No loss of connectivity or IP address changes
- SSC Mode 2: Different UPFs across gNBs. Connectivity may not be preserved. IP address may change (break before-make)
- SSC Mode 3: Different UPFs across gNBs with dual PDU session anchor. No loss of connectivity. IP address may change, with the old address temporarily maintained (make-before-break)"



Session management is improved with a new session and service continuity mode that supports a "make before break" option and the relocation of core network functions while maintaining seamless end-user services. This will be essential for ultra-reliable low-latency communications (uRLLC) use cases with moving UEs (for example, V2X). It also supports concurrent local and central access to a data network and multi-access edge computing where the application at the edge data center can influence traffic routing to improve its performance.

Session Continuity means the continuity of a PDU Session which implies that the **IP address is preserved for the lifetime of the PDU Session. Whereas, **the Service Continuity means to the uninterrupted user experience of a service, including the cases where the IP address and/or anchoring point change.

**Session and service continuity modes are supported: SSC mode 1, 2 and 3.

SSC mode 1:
- IP address is preserved
- Anchor UPF is maintained regardless UE mobility
- For any PDU Session type/ Access type.

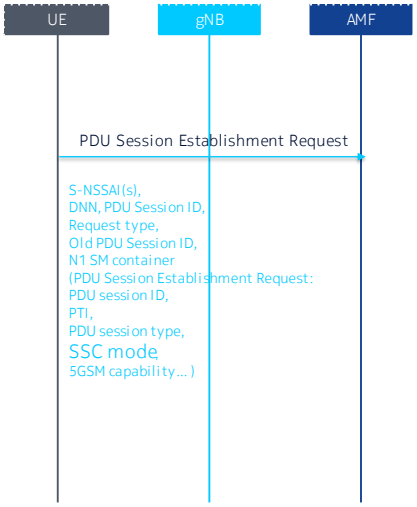
SSC mode 2:
- network release the PDU Session,
- instruct UE to establish a new one immediately
- trigger condition depends (e.g. from AF request)
- new Anchor UPF is selected
- For any PDU Session type/ Access type.

SSC mode 3:
- Make before break
- A connection through new PDU Session Anchor point is established before the previous connection is terminated,
- P address is not preserved when PDU Session Anchor changes
- Might following procedures:
- For a IPv6 PDU Session, new IP prefix is allocated within the same PDU Session (IPv6 multi-homing)
- Or new IP address and/or IP prefix is allocated within a new PDU Session
- UE is triggered to establish.
- In this Release, only for IP PDU Session type/ any access type.

5G PDU Session functionalities
SSC Mode Selection

SSC mode selection

- UE requests PDU Session Establishment with an SSC mode
  - Network may provide SSCMSP rule to UE
- SMF based on subscription
  - SMF receives from the UDM the list of supported SSC modes and the default SSC mode per DNN per S-NSSAI
  - Either Accept the requested SSC mode
  - Or reject with cause and the SSC mode(s) allowed
  - UE may request a new PDU Session Establishment
- If there's no requested SSC mode, network determines the SSC mode

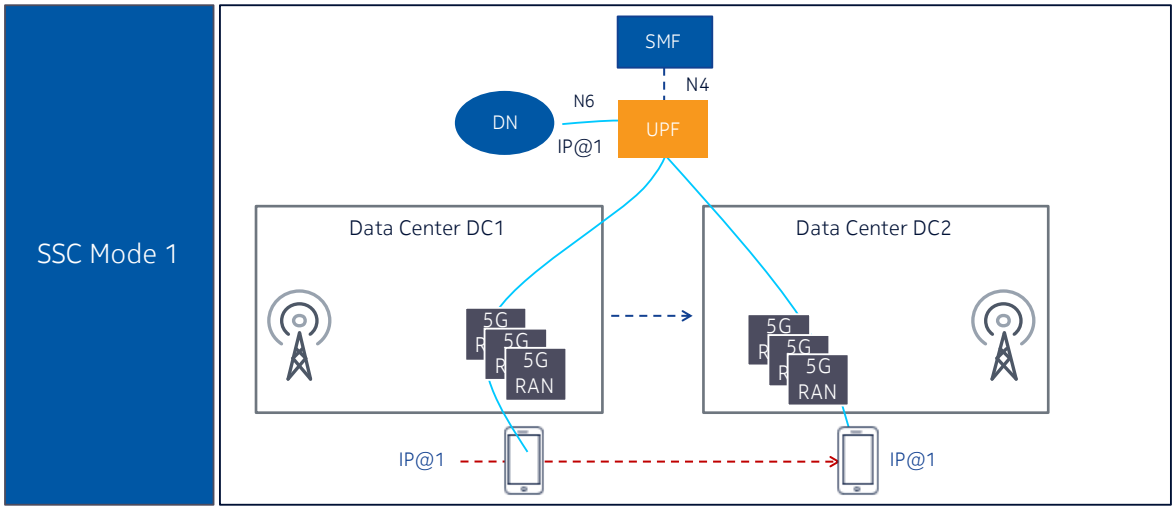


SSCMSP rule

Possible for the operator to provision the USSC mode associated with an application group of applications with SSC mode selection policy.
may include a default SSC mode selection policy rule

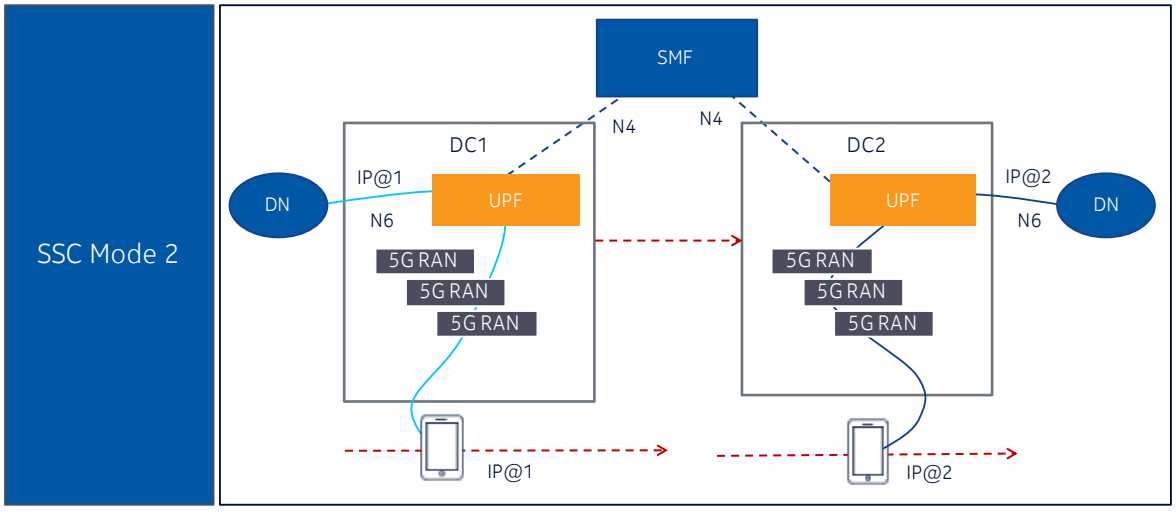
If a UE provides an SSC mode when requesting a new PDU Session, the SMF selects the SSC mode by either accepting the requested SSC mode or rejecting the PDU Session Establishment Request message with the cause value and the SSC mode(s) allowed to be used back to UE based on subscription and/or local configuration.

5G PDU Session functionalities
Session and Service Continuity Modes



The Session and service continuity includes the more traditional mode (SSC 1), where the IP anchor remains stable to provide continual support of applications and maintenance of the path towards the UE as its location is updated.

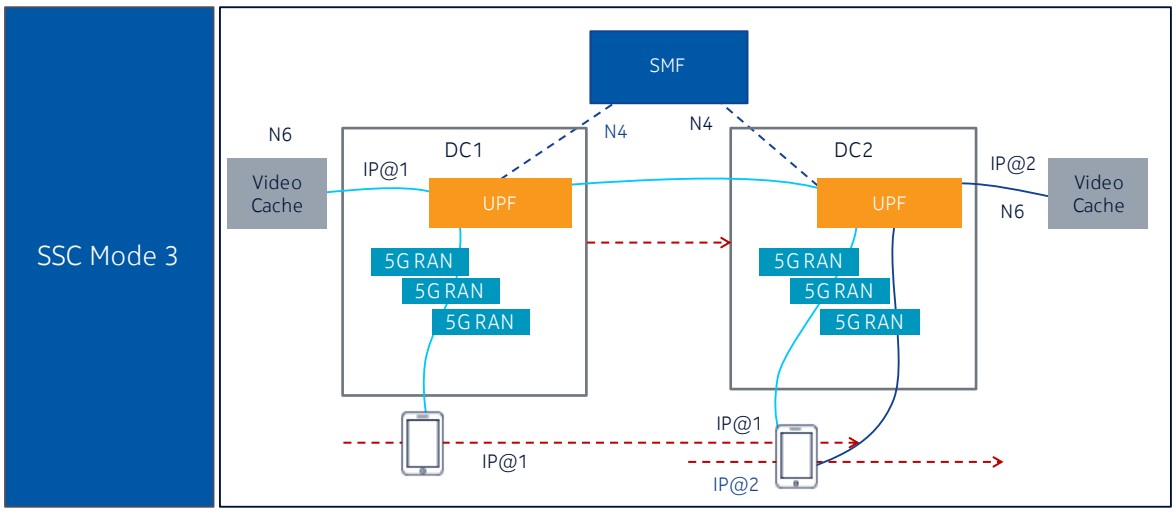
5G PDU Session functionalities
Session and Service Continuity Modes



The new modes allow for relocating the IP anchor. There are two options, make-before-break (SSC mode 3) and break-before-make (SSC mode 2).

In SSC mode 2, the IP address may be changed during UE mobility via connection release and reconnection.

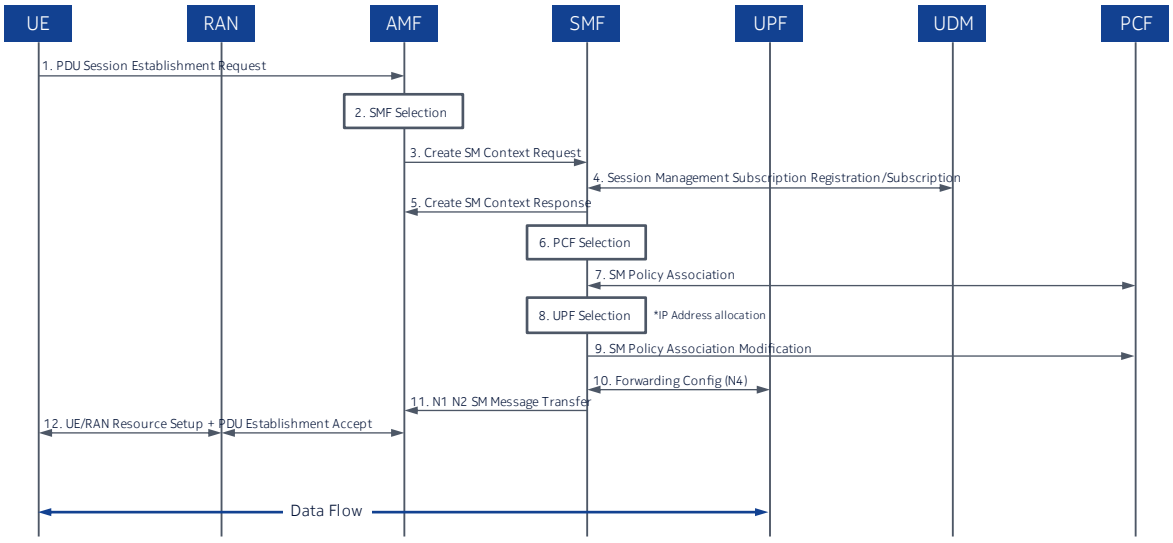
5G PDU Session functionalities
Session and Service Continuity Modes



In SSC mode 3, the IP address may be changed during UE mobility with the old address maintained during transition.

Typical UE Call Processes

Simplified PDU Session Establishment Call Flow



This Call flow shows end to end procedures during a PDU session establishment procedure.

PDU Sessions are established (upon UE request), modified (upon UE and 5GC request) and released (upon UE and 5GC request) using NAS SM signaling exchanged over N1 between the UE and the SMF. Upon request from an Application Server, the 5GC is able to trigger a specific application in the UE. When receiving that trigger message, the UE shall pass it to the identified application in the UE. The identified application in the UE may establish a PDU Session to a specific DNN.

PDU Session Establishment:

- a UE initiated PDU Session Establishment procedure.
- a UE initiated PDU Session handover between 3GPP and non-3GPP.
- a UE initiated PDU Session handover from EPS to 5GS.
- a Network triggered PDU Session Establishment procedure:

  network sends device trigger message to UE

  The payload in Device Trigger Request message contains information on which application to trigger the PDU Session establishment request.

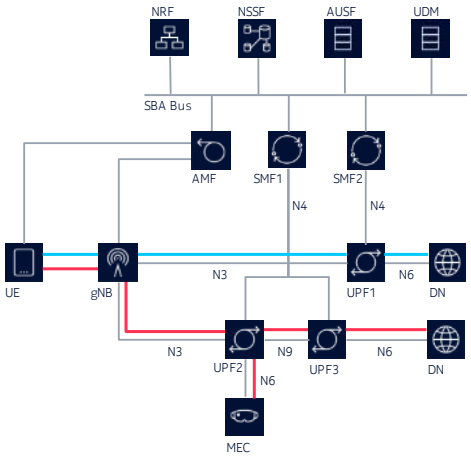
Detailed flow is given in coming slides.

5G PDU Session functionalities
Single and Multiple PDU Session Anchors

PDU Session Anchor is where a UPF delivers traffic to a Data Network (via N6)

A PDU session can have multiple PDU Session Anchors to the same Data Network, allowing for local content access

PDU Session Anchors can be inserted or removed dynamically by the SMF



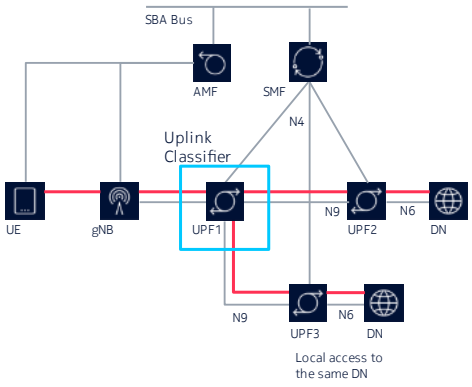
5G PDU Session functionalities
Single and Multiple PDU Session Anchors

Selective Routing Method 1: Uplink Classifiers

An Uplink Classifier (UL CL) diverts uplink traffic based on filters configured by the SMF. It also merges downlink traffic to the UE

The UE is unaware of the existence of any UL CL in its PDU Sessions. Multiple UL CLs can be added to a PDU Session

An UPF performing the UL CL role can also act as a PDU Session Anchor.



Enables multiple PDU Session Anchors for IPv4, IPv6 and Ethernet.

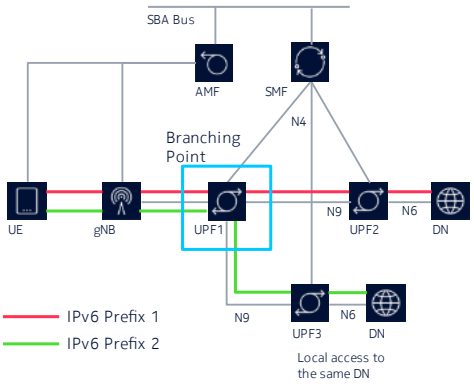
5G PDU Session functionalities
Single and Multiple PDU Session Anchors

Selective Routing Method 2: IPv6 Multi-Homing

A Branching Point diverts uplink traffic basic on source routing, configured by the SMF. It also merges downlink traffic to the UE

The UE selects which IPv6 prefix to use according to the desired route. It can also be used to provide SSC mode 3 (make-before-break relocation)

An UPF performing the Branching Point role can also act as a PDU Session Anchor.

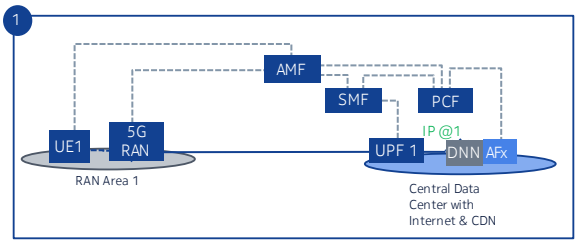


Enables multiple PDU Session Anchors for IPv6.

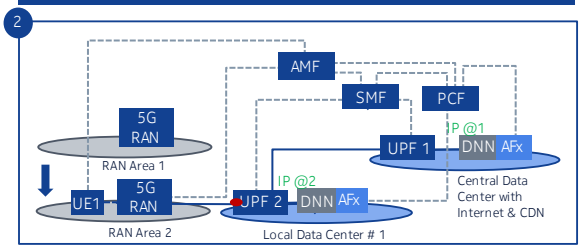
5G PDU Session functionalities
Single and Multiple PDU Session Anchors

Mobility & SSC 3 Example

UE 1 served by PDU session anchored centrally at UPF1(IP@1)



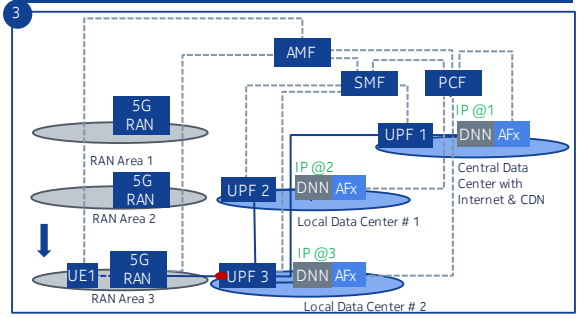
UE 1 moves to new (R)AN service area. UPF1 deemed sub-optimal for selected flows. User Plane Reselection undertaken, UPF2(IP@2) selected. Ongoing data flows anchored at UPF1(IP@1) maintained until completion (SSC Mode 3). New requests use UPF2(IP@2) & UPF1(IP@1)



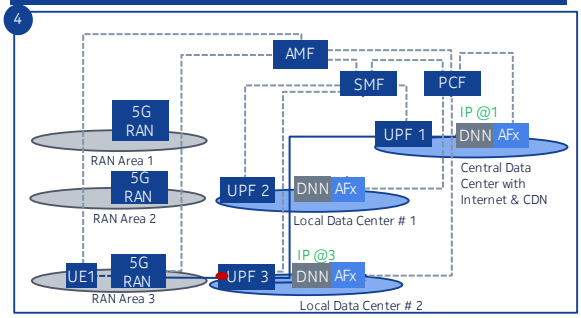
5G PDU Session functionalities
Single and Multiple PDU Session Anchors

Mobility & SSC 3 Example

UE 1 moves to new (R)AN service area. UPF2 deemed sub-optimal for selected flows. User Plane Reselection undertaken, UPF3(IP@3) selected. Ongoing data flows anchored at UPF2(IP@2) maintained until completion (SSC Mode 3). New requests use UPF3(IP@3) & UPF1(IP@1)



After flows anchored at UPF2(IP@2) cease UPF2 is removed from PDU Session and IP@2 can be released



5G PDU Session functionalities

Quiz 7

1. What is SSC mode 2?
    a. Break-before-make: IP address may be changed during UE mobility via connection release and reconnection
    b. The IP anchor remains stable to provide continual support of applications and maintenance of the path towards the UE as its location is updated
    c. Make-before-break: IP address may be changed during UE mobility with old address maintained during transition
2. What is SSC mode 3?
    a. Break-before-make: IP address may be changed during UE mobility via connection release and reconnection
    b. The IP anchor remains stable to provide continual support of applications and maintenance of the path towards the UE as its location is updated
    c. Make-before-break: IP address may be changed during UE mobility with old address maintained during transition

Wrap-up

In this module we have covered the following items

- Describe the Protocol Stacks between UE and 5GC
- Identify 5GMM and 5GSM states
- Explain UE Registration and Connection Management procedures
- Explain UE PDU Session functionalities