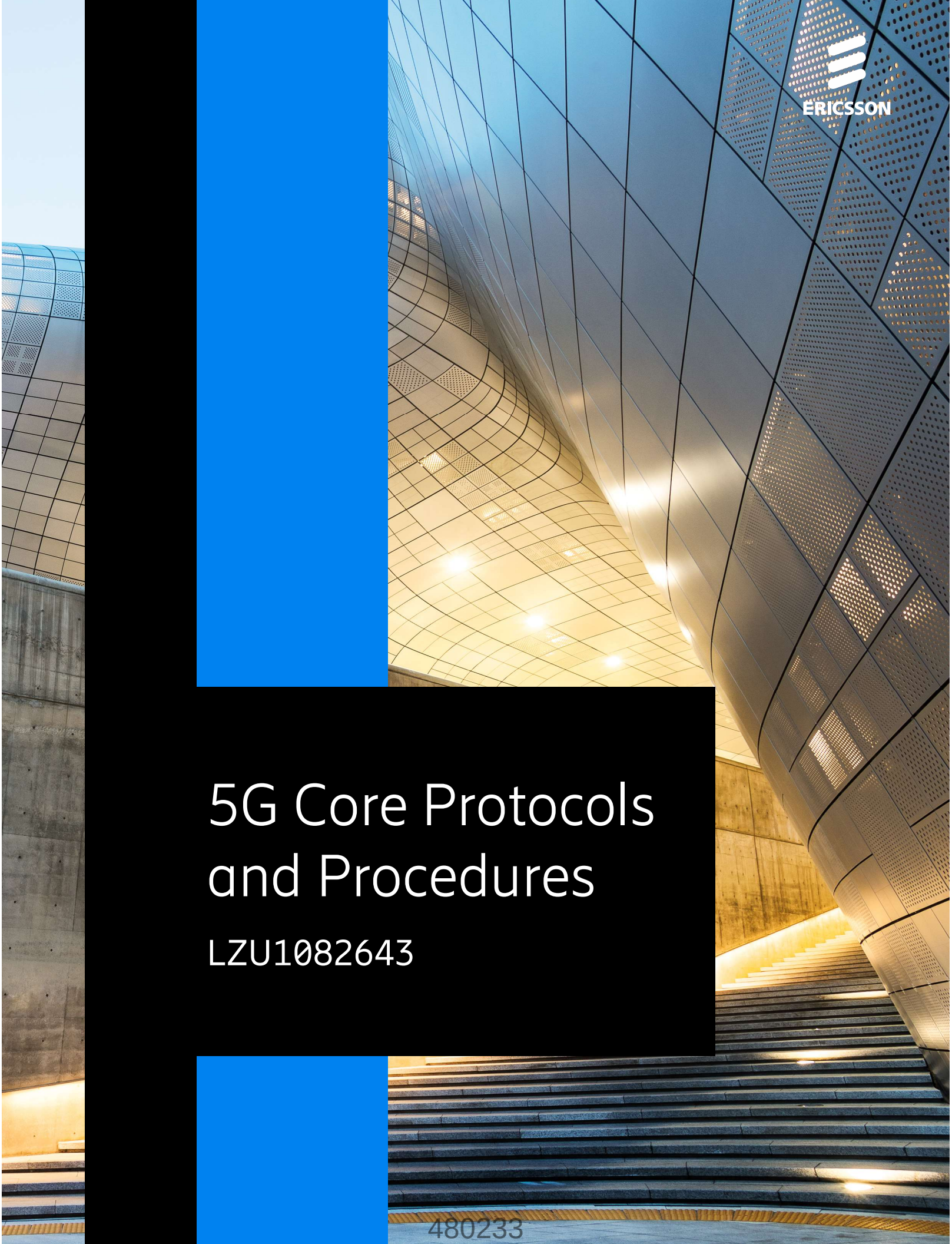


5G Core Protocols and Procedures

LZU1082643

5G Core Protocols and Procedures

STUDENT BOOK
LZT1382060 R3A

DISCLAIMER

This book is a training document and contains simplifications. Therefore, it must not be considered as a specification of the system.

The contents of this document are subject to revision without notice due to ongoing progress in methodology, design and manufacturing.

Ericsson shall have no liability for any error or damage of any kind resulting from the use of this document.

This document is not intended to replace the technical documentation that was shipped with your system. Always refer to that technical documentation during operation and maintenance.

This document was produced by Ericsson.

This Student Book, LZT1382060, R3A supports course number LZU1082643.

Course Objectives

On completion of this course the participants will be able to:

- Explain the basic conceptual network architecture and technology for the 5G Core
- List and explain Identifiers relevant for the 5GC
- List the interfaces and explain the signaling, protocols and service exchange between the network functions

Student Notes

Table of contents

Student Notes

5G Core Protocols and Procedures

Chapter 1
Introduction

Student Notes

Chapter Objectives

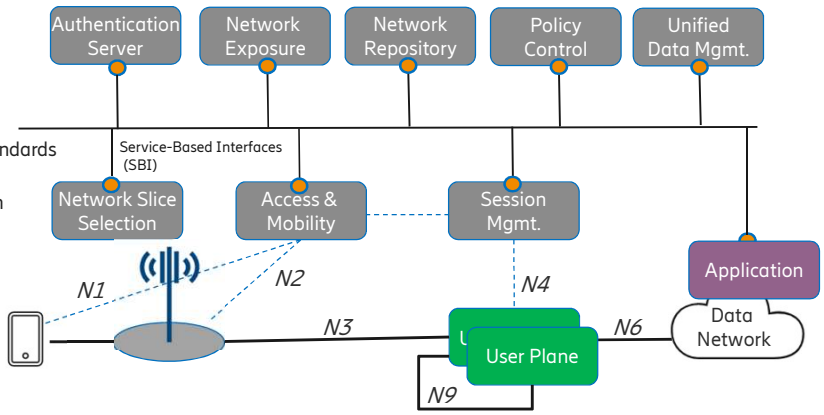
On completion of this chapter, the participants will be able to:

— Explain the basic conceptual network architecture and technology for the 5G Core

Student Notes

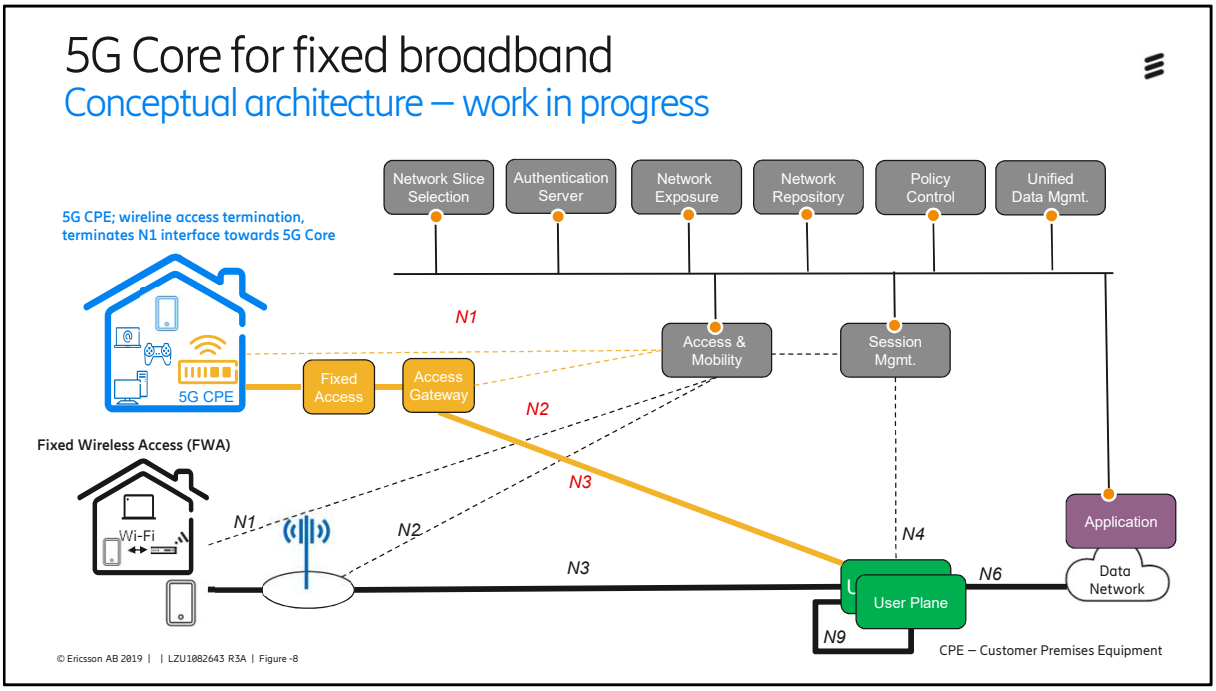
5G Core Basic Architecture

- Support:
  - SA & NSA NR
  - non-SIM devices
  - non-3GPP access
- Service Based Architecture
  - Fast new service creation w/o standards impact (some limits)
  - Cloud Native core implementation
- Capabilities:
  - UE connect to multiple network slices simultaneously
  - Improved and simplified QoS
  - UE access local and centralized networks within single connection



SA: Stand Alone
NSA: Non-Stand Alone
FWA: Fixed Wireless Access

Student Notes



Student Notes

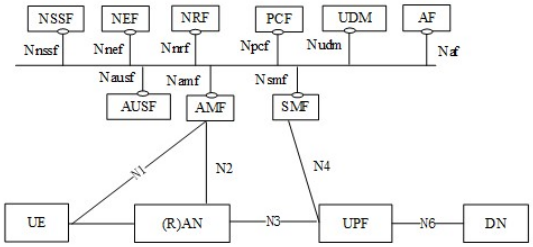
5G System Architecture

3GPP TS 23.501 V15.0.0 (2017-12)

5G architecture defined as service-based, interaction between NFs represented in 2 ways:

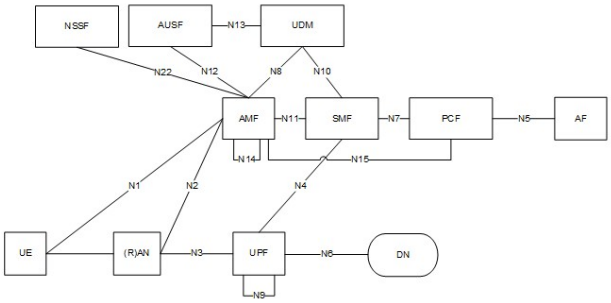
Service-based representation.

where network functions (e.g. AMF) within the control plane enables other authorized network functions to access their services



Reference point representation.

Shows that interaction exist between the NF services in the network functions described by point-to-point reference point (e.g. N11) between any two network functions (e.g. AMF and SMF)



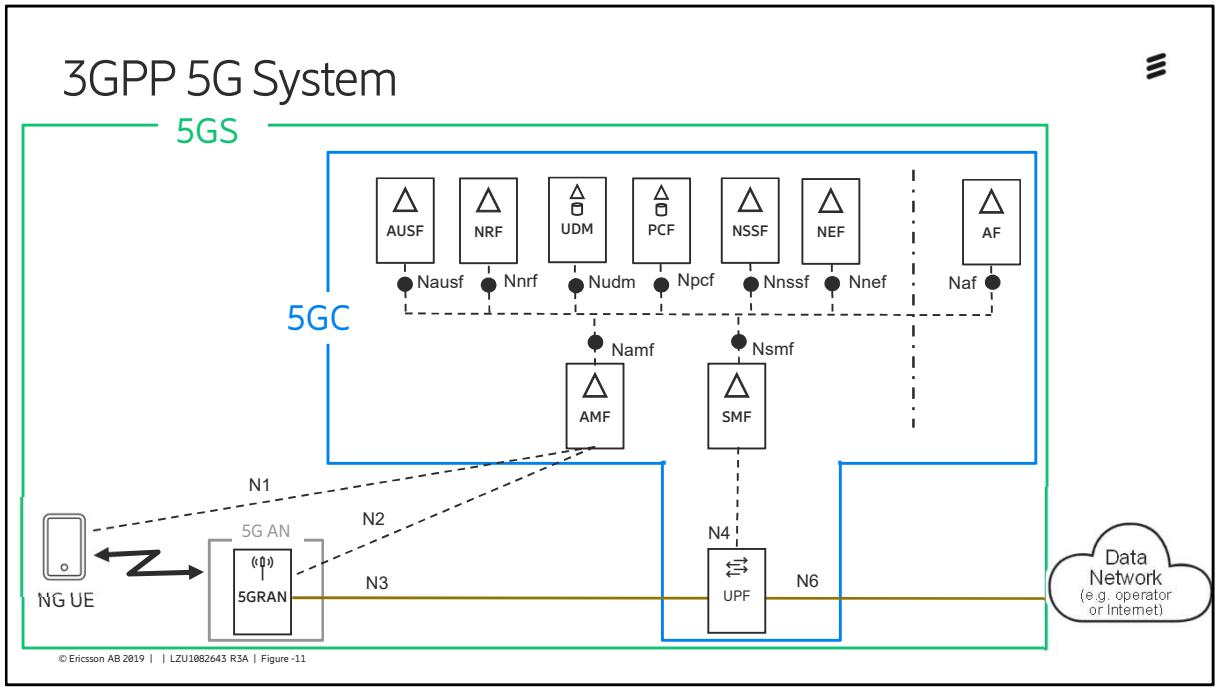
Student Notes

5G Network Definitions

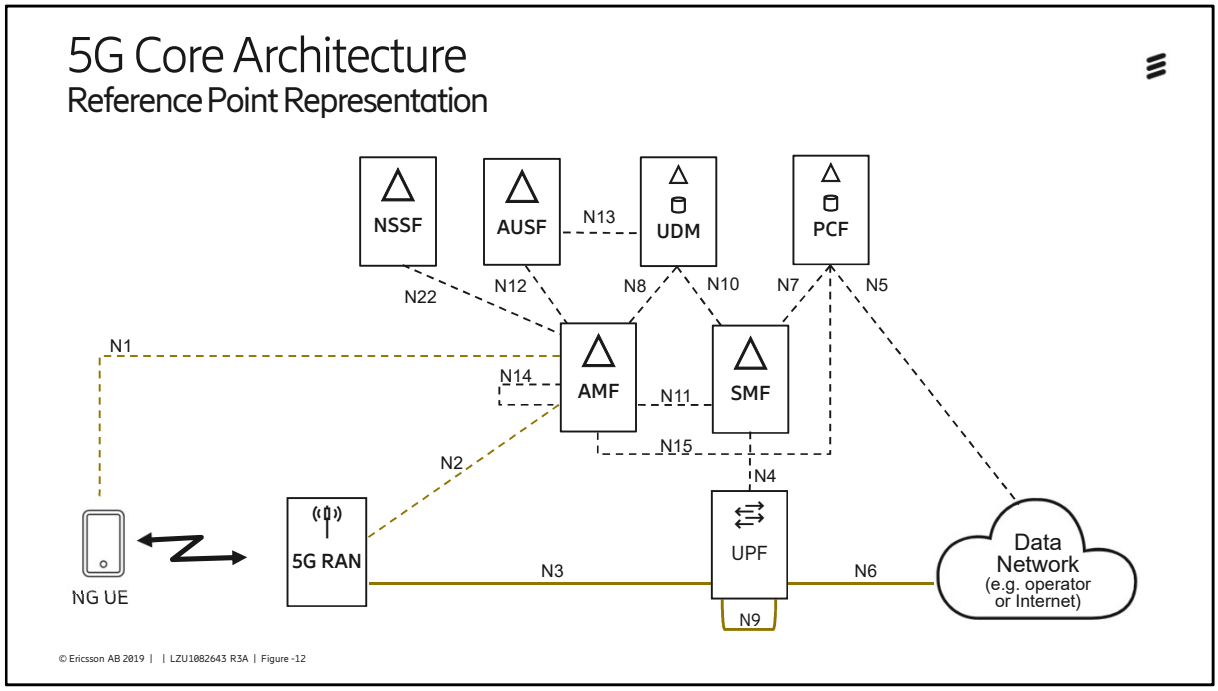
3GPP TS 23.501

- 5G System (5GS)
  - 3GPP system consisting of 5G Access Network (AN), 5G Core Network (5GC) and UE
- 5G Access Network (AN)
  - An access network comprising a 5G-RAN and/or non-3GPP AN connecting to a 5G Core Network
- 5G Core Network (5GC)
  - Core network specified in 3GPP TS 23.501. Connects to 5G AN.
- 5G-RAN
  - Radio access network; supports standalone (SA) and non-standalone (NSA) New Radio (NR)

Student Notes



Student Notes



Student Notes

3GPP Definition of Network Function

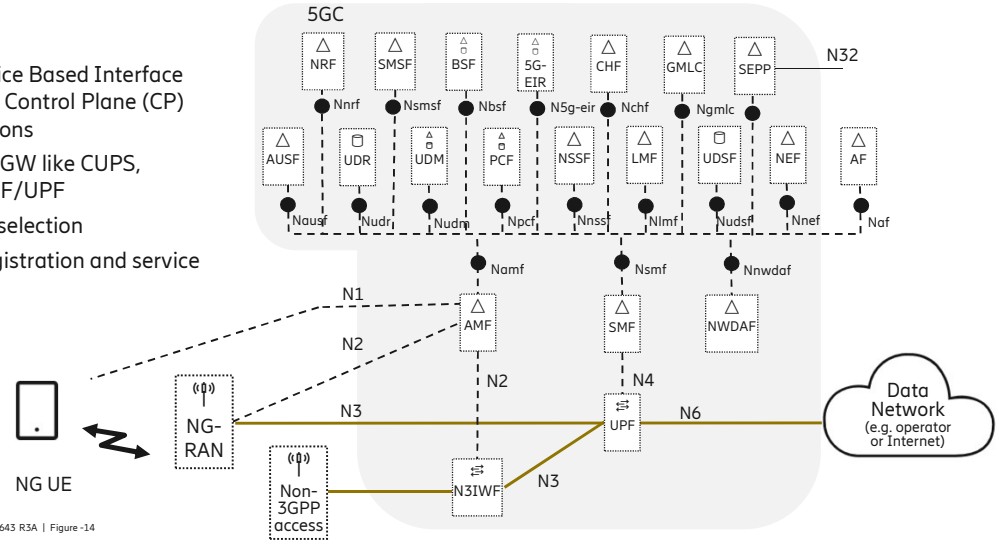
- Network function (NF)
  - 3GPP adopted or 3GPP defined processing function in network, with defined functional behaviour and 3GPP defined interfaces
  - Physical Network Function (PNF)
    - NF implemented as software instance on dedicated hardware
  - Virtual Network function (VNF)
    - NF implemented as software instance on cloud infrastructure

Student Notes

5G System Architecture

Includes 21 5GC NFs (Rel-15)

- 5GC with Service Based Interface (SBI) between Control Plane (CP) network functions
- CP/UP split of GW like CUPS, realized by SMF/UPF
- NSSF for slice selection
- NRF for NF registration and service discovery



Student Notes

5GC Network Functions

- 5G-EIR 5G Equipment Register
- AF Application Function
- AMF Access and Mobility Management Function
- AUSF Authentication Server Function
- BSF Binding Support Function
- CHF Charging Function
- GMLC Gateway Mobile Location Center
- LMF Location Management Function
- N3IWF Non-3GPP InterWorking Function
- NEF Network Exposure Function
- NRF Network Repository Function
- NSSF Network Slice Selection Function
- NWDAF Network Data Analytics Function
- PCF Policy Control Function
- SEPP Security Edge Protection Proxy
- SMF Session Management Function
- SMSF Short Message Service Function
- UDM Unified Data Management
- UDR Unified Data Repository
- UDSF Unstructured Data Storage Function
- UPF User Plane Function

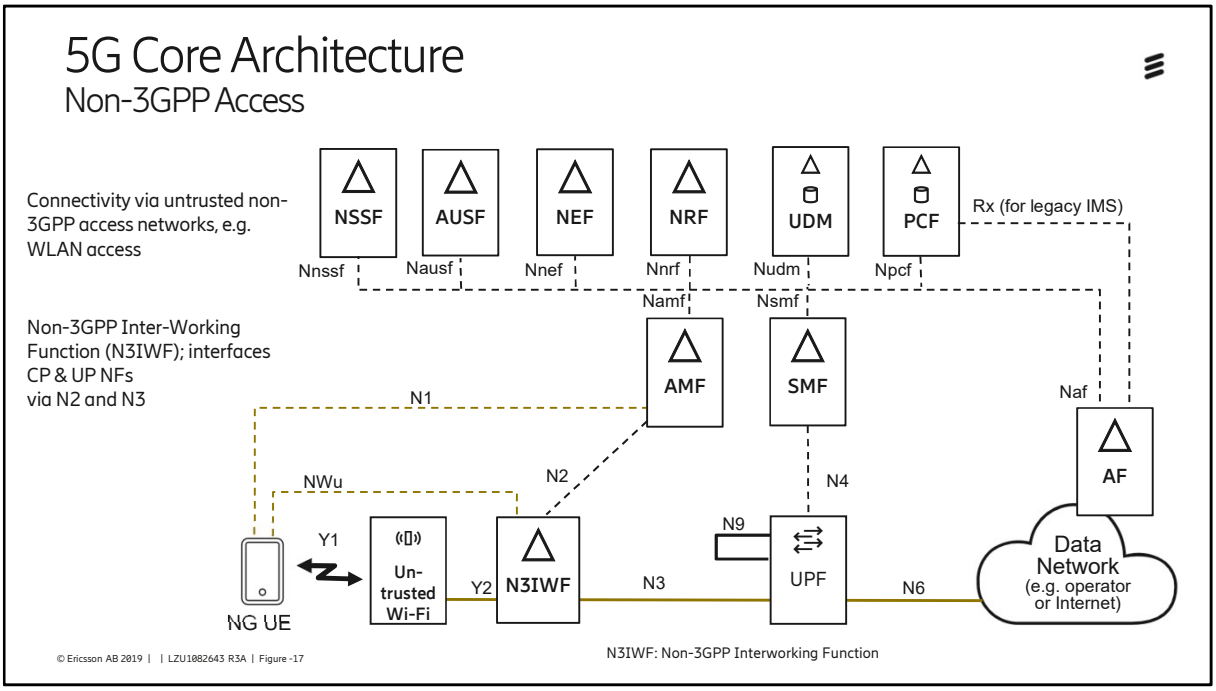
Student Notes

5G System architecture

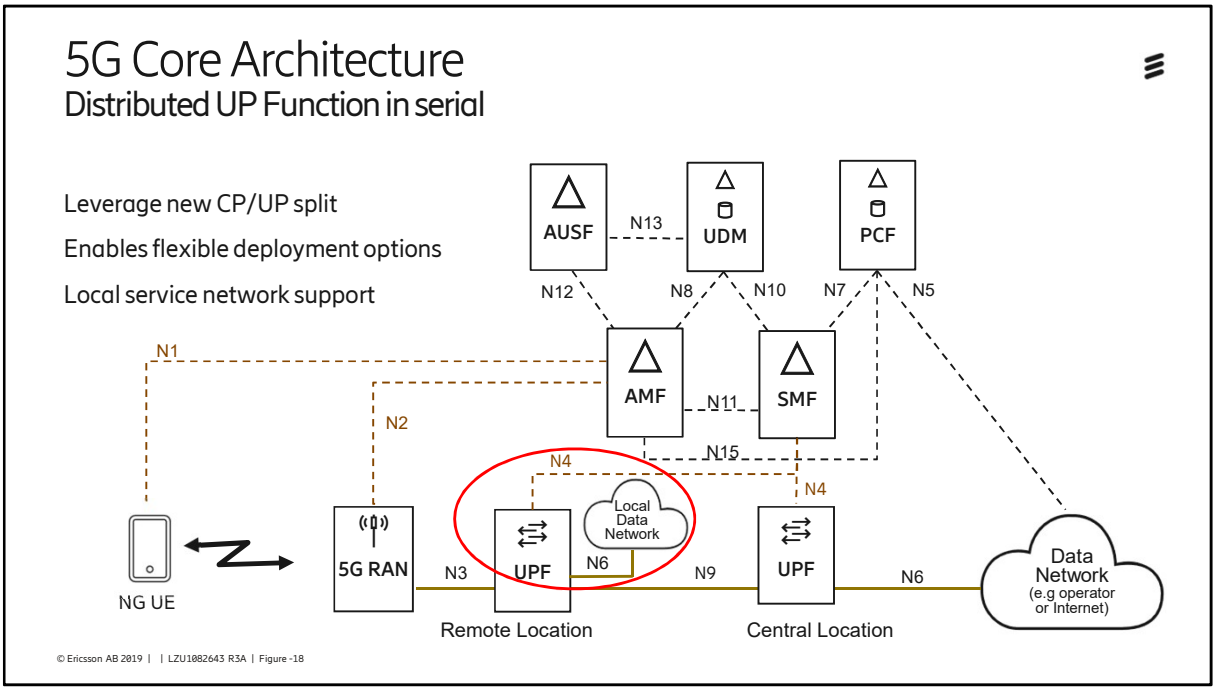
Reference points (Rel-15)

N-interface	Node	Node	N-interface	Node	Node
N1	UE	AMF	N21	SMSF	UDM
N2	AN	AMF	N22	AMF	NSSF
N3	AN	UPF	N23	PCF	NWDAF
N4	SMF	UPF	N24	vPCF	hPCF
N5	PCF	AF	N25	-	-
N6	UPF	DN	N26	AMF	MME
N7	SMF	PCF	N27	NRF	NRF
N8	AMF	UDM	N28	CHF	PCF
N9	UPF	UPF	N29	NEF	SMF
N10	SMF	UDM	N30	NEF	PCF
N11	AMF	SMF	N31	vNSSF	hNSSF
N12	AMF	AUSF	N32	vSEPP	hSEPP
N13	UDM	AUSF	N33	NEF	AF
N14	AMF	AMF	N34	NSSF	NWDAF
N15	AMF	PCF	N35	UDM	UDR
N16	vSMF	hSMF	N36	PCF	UDR
N17	AMF	5G-EIR	N37	NEF	UDR
N18	NF	UDSF	N38	-	-
N19	-	-	N39	-	-
N20	AMF	SMSF	N40	SMF	CHF

Student Notes

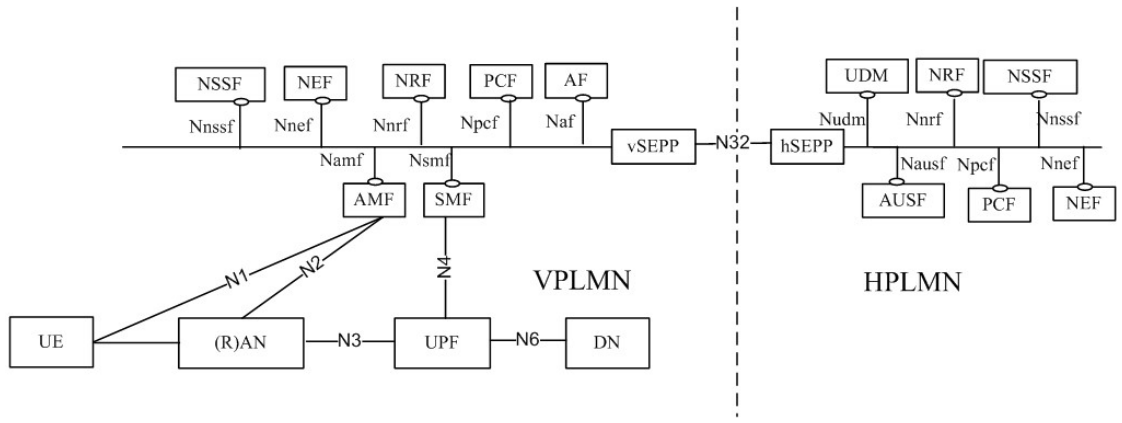


Student Notes



Student Notes

Roaming 5GS Architecture – Local Breakout

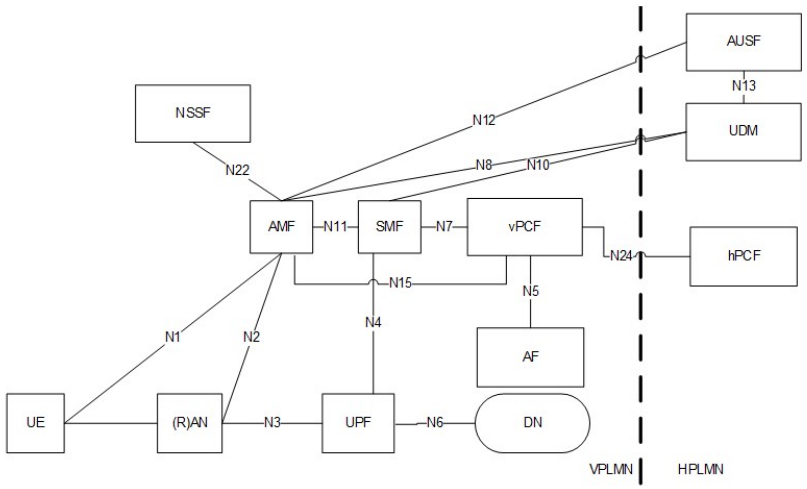


SEPP – Security Edge Protection Proxy

Student Notes

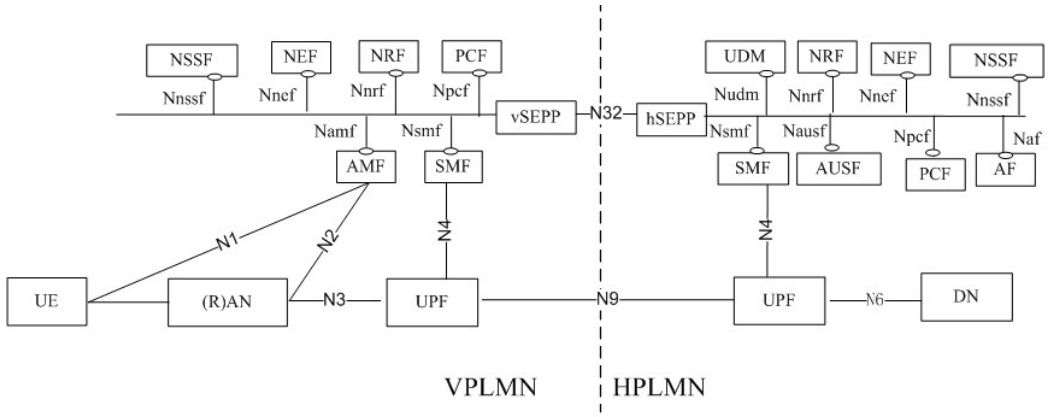
Roaming 5GS Architecture –Local Breakout

(Reference Points)



Student Notes

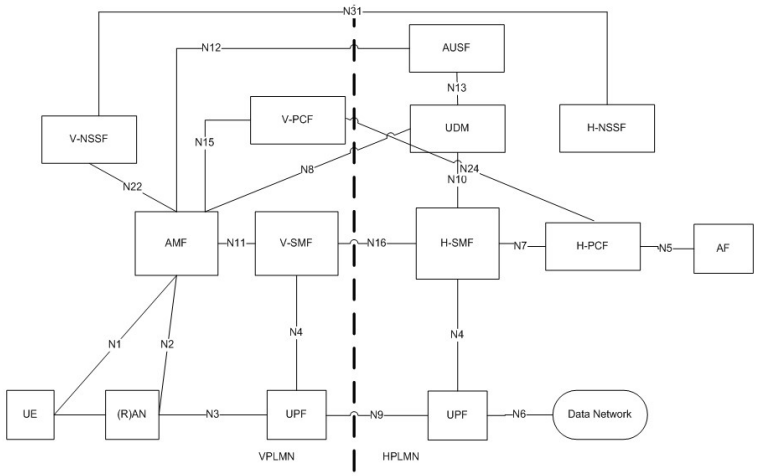
Roaming 5GS Architecture – Home Routed



SEPP – Security Edge Protection Proxy

Student Notes

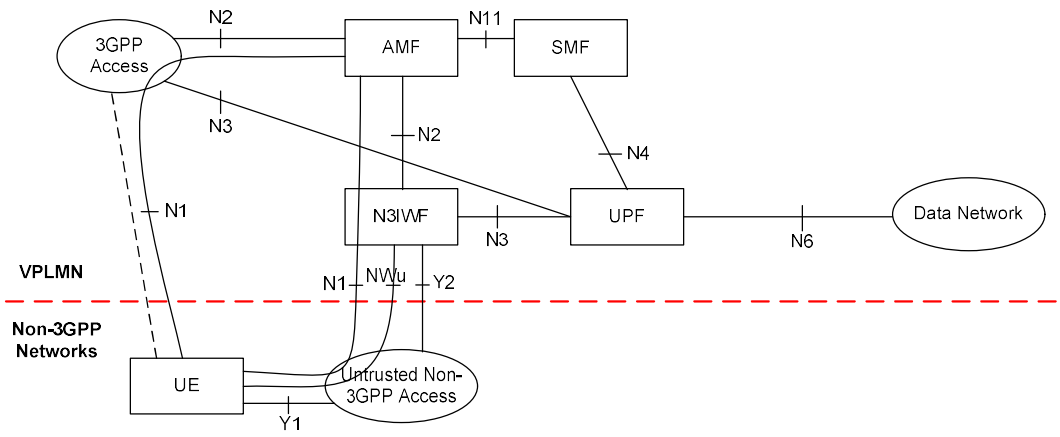
Roaming 5GS Architecture – Home Routed
(Reference Points)



Student Notes

Roaming 5GS Architecture

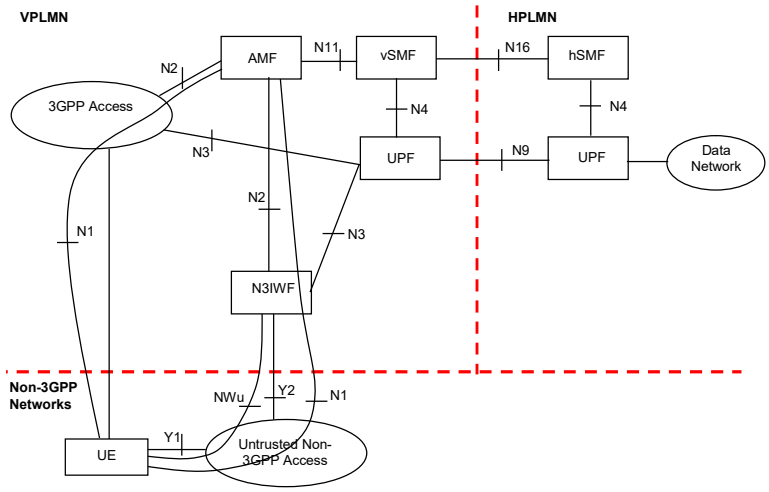
Non-3GPP Access Local Breakout



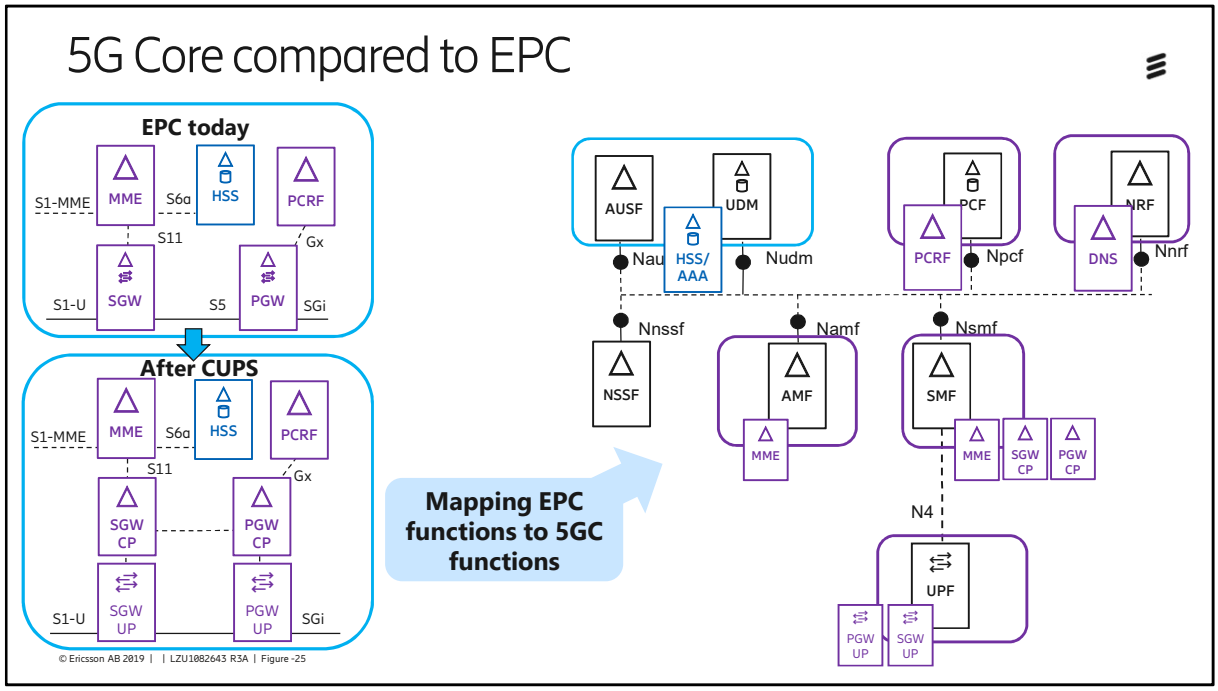
Student Notes

Roaming 5GS Architecture

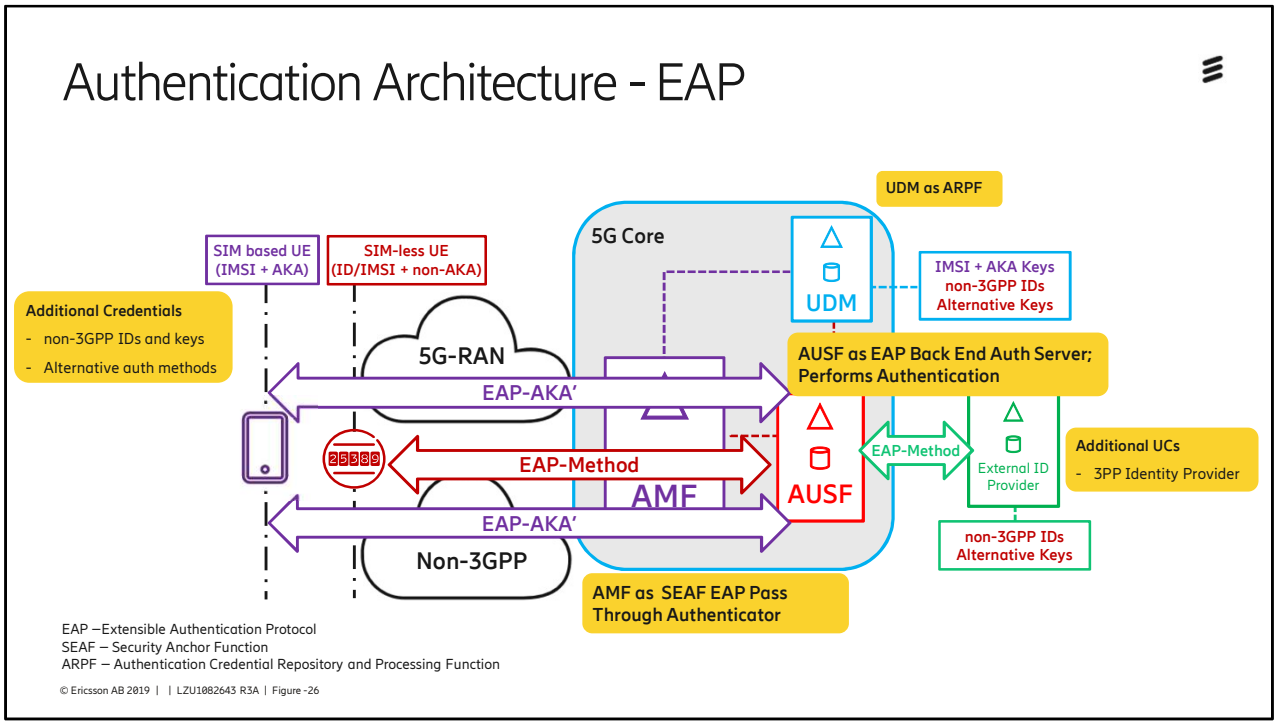
Non-3GPP Access Home Routed



Student Notes

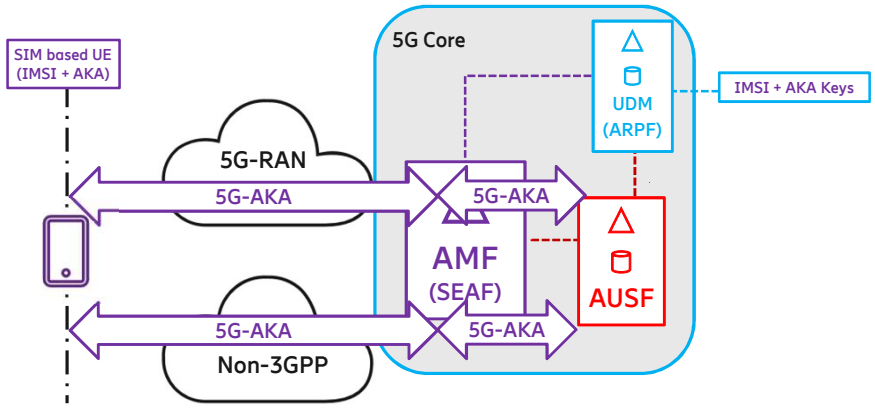


Student Notes



Student Notes

Authentication Architecture – 5G AKA



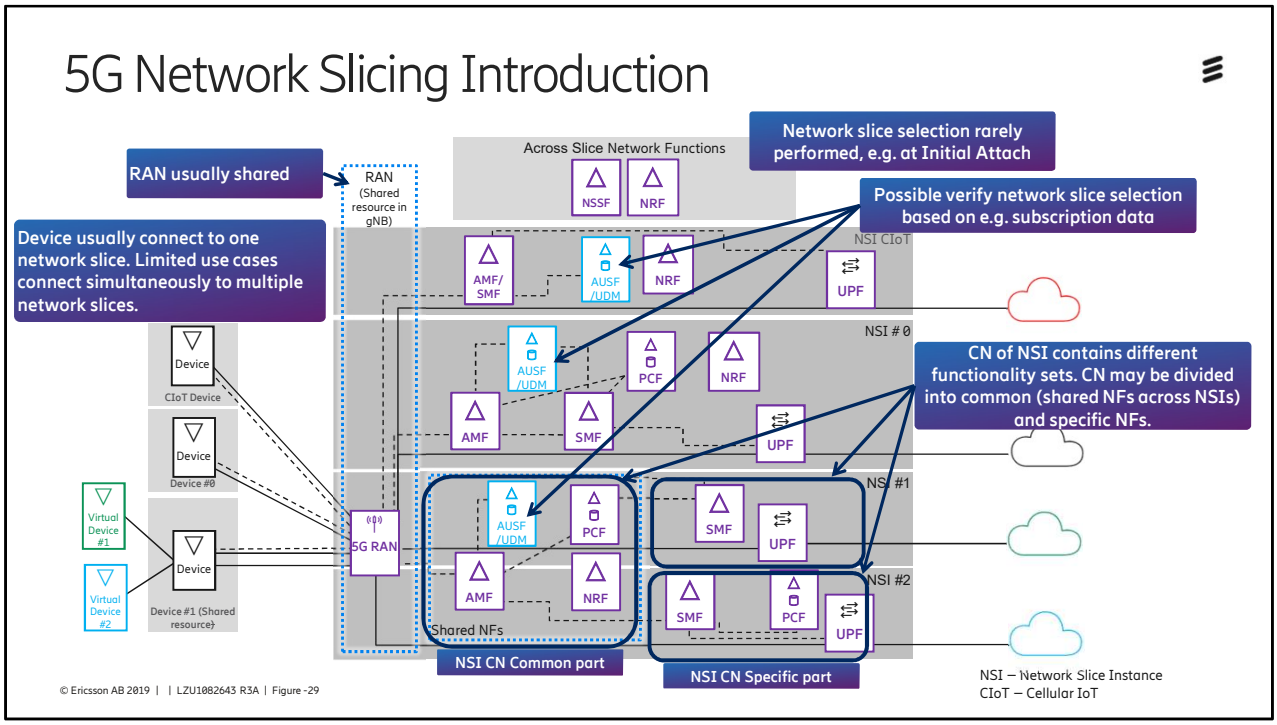
SEAF – Security Anchor Function
ARPF – Authentication Credential Repository and Processing Function

Student Notes

5G Network Slicing

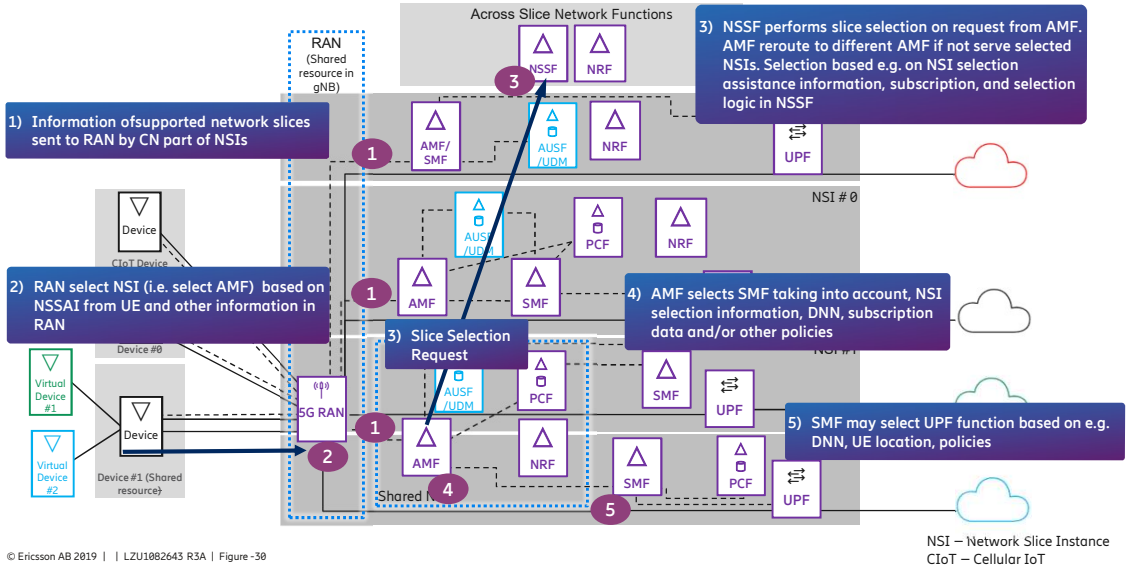
- Network slice may include:
  - 5GC CP and UP NFs
  - 5G RAN
  - N3IWF for non-3GPP Access Network
- UE simultaneously served by one or more Network Slice instances via 5G-AN
  - AMF serving UE logically belong to each Network Slice instances
    → Common function for Network Slice instances serving UE
- 1 PDU session belongs only to 1 Network Slice instance per PLMN
  - Different slices may have slice-specific PDU sessions using same DNN

Student Notes



Student Notes

Network Slice Selection in 5GS



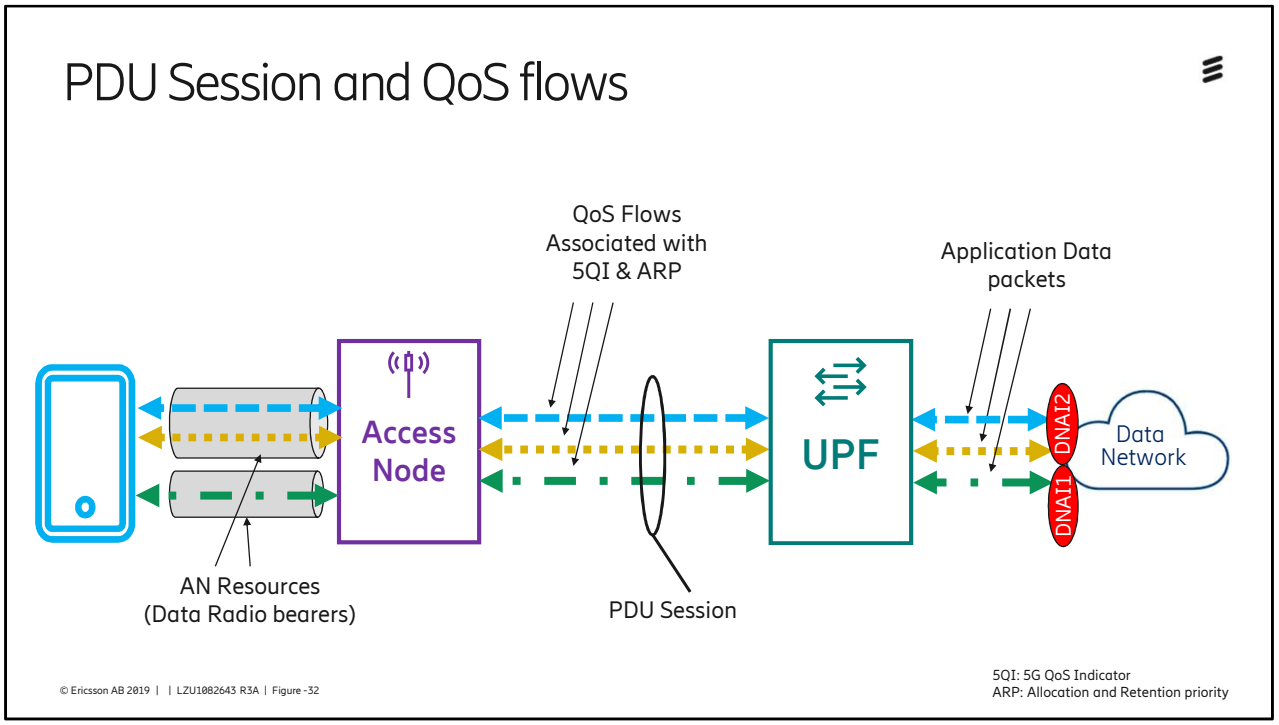
Student Notes

PDU Session Concepts

- PDU Connectivity Service
  - Provides exchange of PDUs between UE and Data Network
- PDU Session
  - Association between UE and Data Network that provides PDU Connectivity Service
- Data Network Name (DNN)
  - Identifier of Data Network (DN)
- DN Access Identifier (DNAI)
  - Identifier of UP access to one or more DN(s) where applications are deployed
- 5G QoS Flow
  - Finest granularity for QoS forwarding treatment in 5G System. All traffic mapped to same 5G QoS Flow receive same forwarding treatment.
- 5G QoS Indicator (5QI)
  - Scalar used as reference to specific QoS forwarding behaviour

PDU: Protocol Data Unit

Student Notes



Student Notes

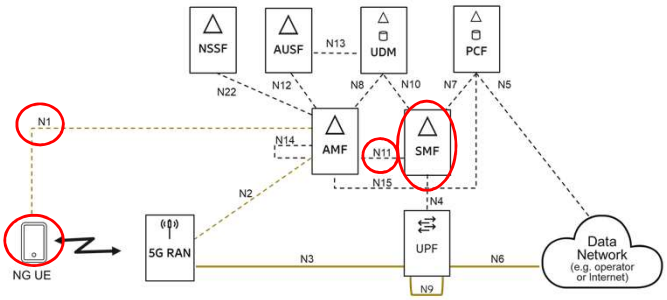
PDU Session Types

- 5GC supports exchange of PDUs between UE and data network identified by DNN (PDU Connectivity Service)
- PDU Connectivity Service realized via PDU sessions established upon UE requests
- Each PDU Session supports single type of PDU:
  - IPv4
  - IPv6
  - IPv4v6
  - Ethernet
  - Unstructured (PDU type totally transparent to the 5GS)

Student Notes

PDU Session Establishment

- PDU Sessions handled using NAS SM signaling over N1 between UE and SMF
  - Established upon UE request
  - Modified upon UE and 5GC request
  - Released upon UE and 5GC request
- Application request 5GC to trigger UE to establish PDU session to specific DNN



Student Notes

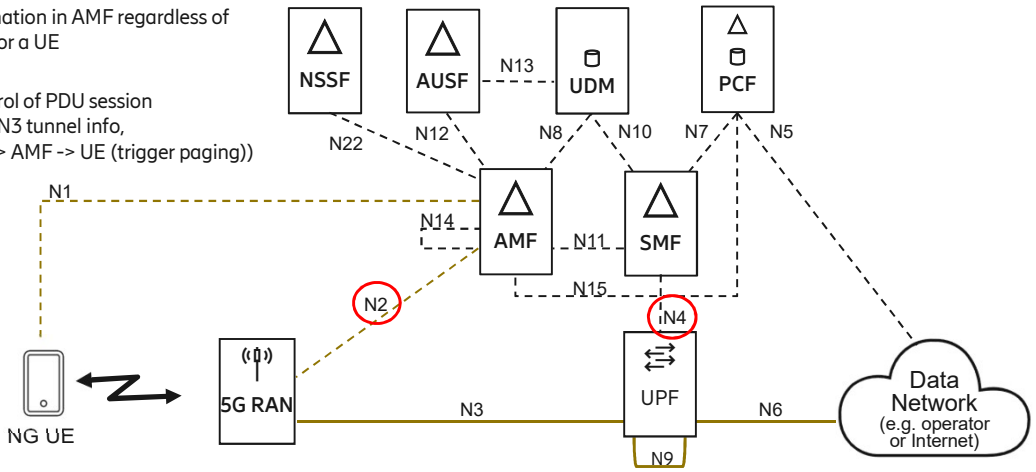
PDU Session Attributes

PDU session attribute	Modification allowed during PDU session lifetime	Notes
S-NSSAI	No	S-NSSAI and DNN are used by AMF to select a SMF to handle a new session.
DNN (Data Network Name)		If it is not provided by UE, network determines the parameter based on default information received in user subscription. Subscription to different DNN(s) and S-NSSAI(s) may correspond to different default SSC modes and different default PDU Session Types. S-NSSAI and DNN are used by AMF to select a SMF to handle a new session.
PDU session Type		Each PDU Session supports a single PDU Session type i.e. supports the exchange of a single type of PDU requested by the UE at the establishment of the PDU Session. The following PDU Session types are defined: IPv4, IPv6, Ethernet, Unstructured.
SSC mode		If it is not provided by the UE, the network determines the parameter based on default information received in user subscription. Subscription to different DNN(s) may correspond to different default SSC modes and different default PDU session Types
PDU Session Id		Must be provided by the UE

Student Notes

AMF and SMF interaction (N2&N4)

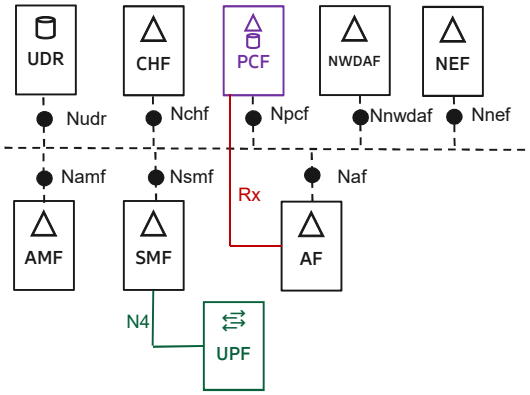
- N2:
  - Unique termination in AMF regardless of PDU session for a UE
- N4:
  - SMF e2e control of PDU session (no downlink N3 tunnel info, UPF -> SMF -> AMF -> UE (trigger paging))



Student Notes

5G Policy Framework

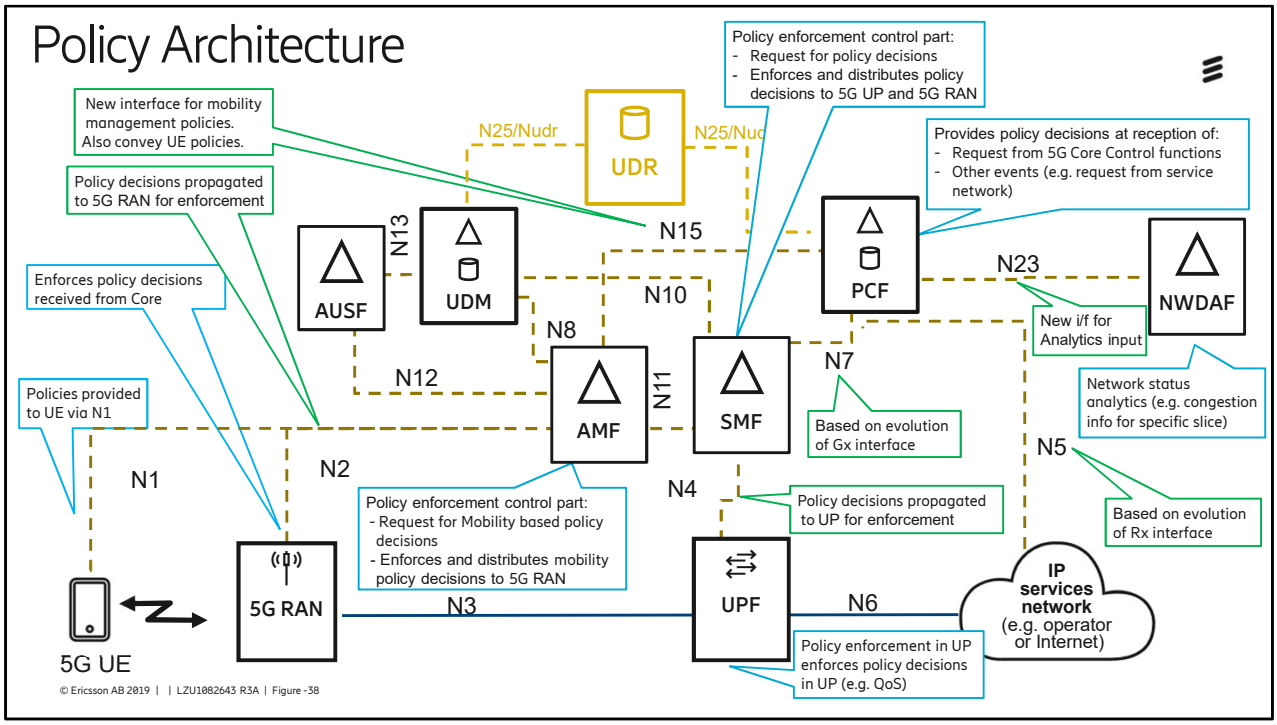
- PCF, SA function
  - Policy decisions to SMF & AMF
  - Policy subscription profile from UDR
  - Same functionality as in EPC; usage monitoring, gating, traffic steering, spending limits...
  - Rx i/f to AF
  - New N15 i/f to AMF:
    - Access and MM policies
    - UE route selection policies
- NWDAF (Network Data Analytics Function);
  - Slice specific network data analytics for policy decisions to PCF (N23) & NSSF (N24)
  - I/f NEF for exposure & new use cases



5G non-roaming policy framework architecture SBA representation

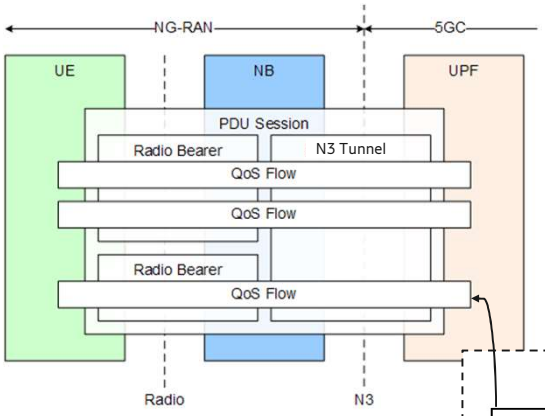
NWDAF: Network Data Analytics Function
CHF: Charging Function

Student Notes

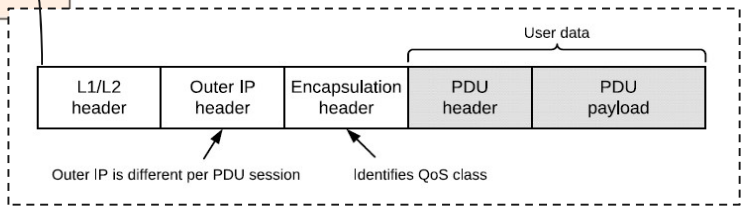


Student Notes

5G QoS Overview

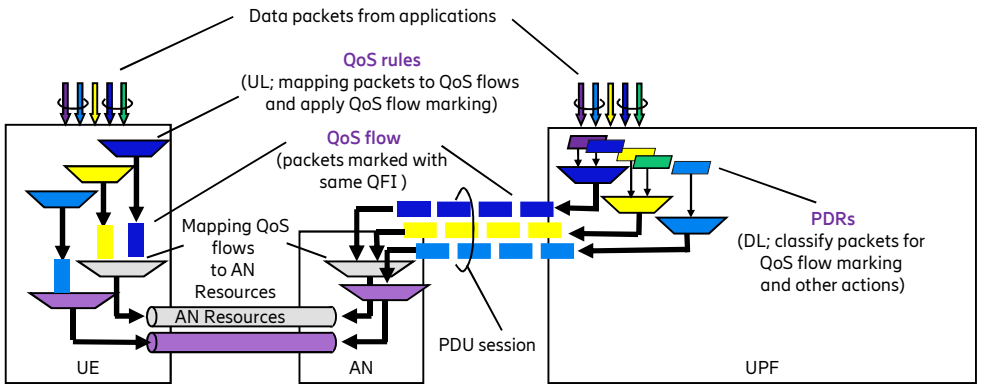


- QoS flow; finest granularity of QoS differentiation in PDU session
  - Each QoS flow associated with QoS parameters used to enforce correct traffic forwarding treatment
  - Each packet belongs to one QoS flow
- One PDU session carry one or several QoS flows
  - All QoS flows sent over same N3 tunnel
- Radio Bearer carry one or several QoS flows
  - Each PDU session have unique set of Radio bearers
  - RAN decide which Radio Bearer one QoS flow sent over



Student Notes

Mapping of QoS Flows to Access Network resources



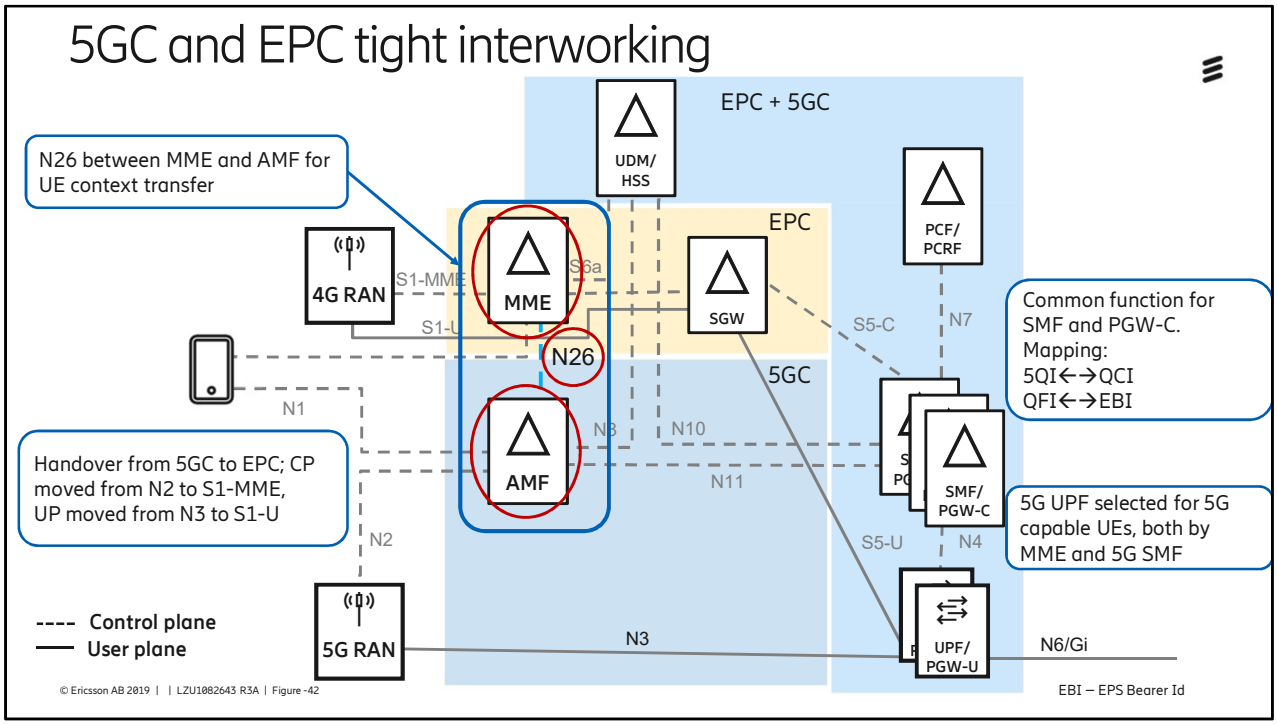
QFI – QoS Flow Identifier
PDR – Packet Detection Rule

Student Notes

Control of QoS Flows

- Two options:
  1. Standardized or pre-configured 5QIs are used as QFI
     - Used for Non-GBR QoS flows with 5QI < 64
     - Pre-configured 5QIs cannot be used when the UE is roaming
  2. Dynamically assigned QFI
     - Used for all other cases

Student Notes



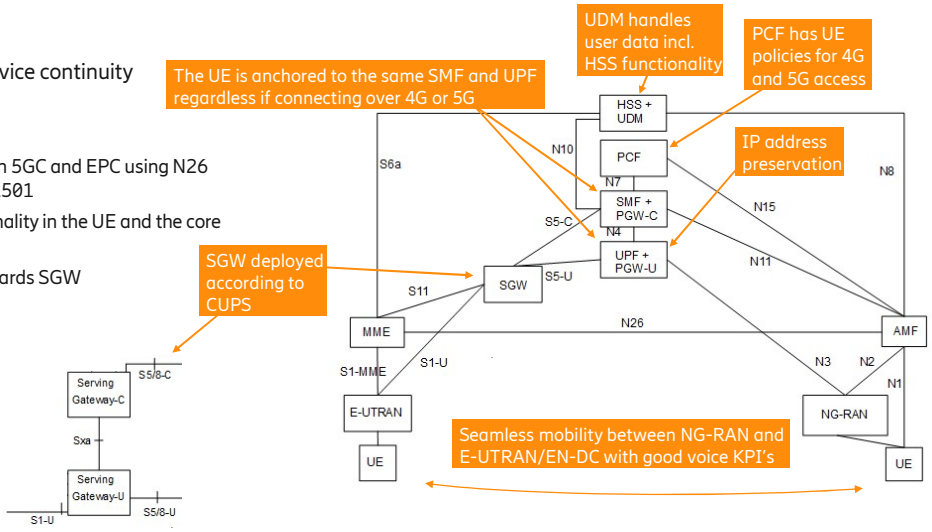
Student Notes

3GPP: EPC-5GC tight interworking + CUPS

Enables voice and data service continuity

The architecture is built on:

- Tight interworking between 5GC and EPC using N26 as specified in 3GPP TS 23.501
- Single-registration functionality in the UE and the core network
- SMF and UPF with S5 towards SGW
- Combined HSS/UDM
- PCF with Rx
- 3GPP Rel-14 CUPS

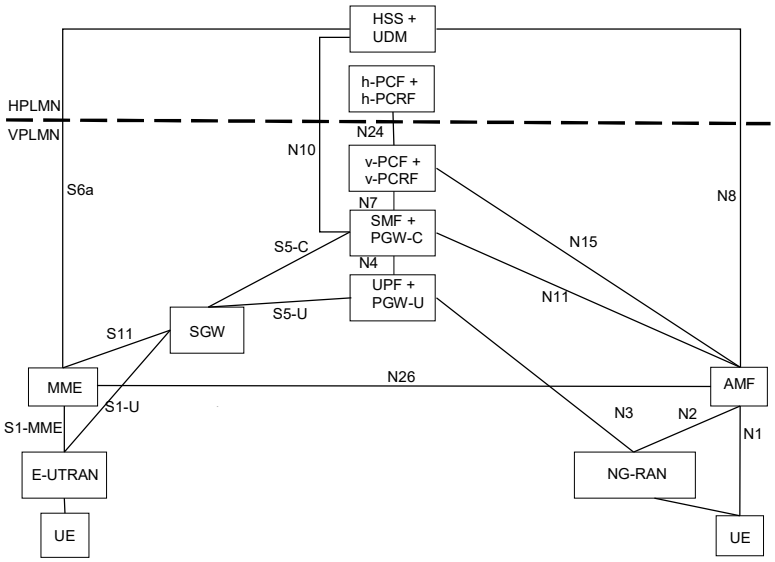


Student Notes

5GC and EPC Interworking

Roaming Architecture Local Breakout

— From 3GPP 23.501



Student Notes

Chapter Summary

On completion of this chapter, the participants are able to:

— Explain the basic conceptual network architecture and technology for the 5G Core

Student Notes

5G Core Protocols and Procedures

Chapter 2
5GC Identifiers

Student Notes

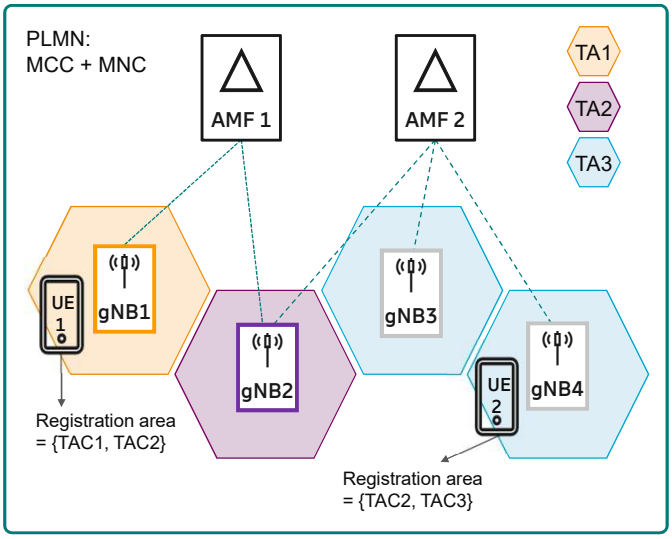
Chapter Objectives

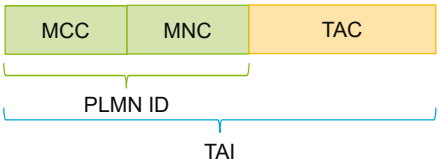
On completion of this chapter, the participants will be able to:

— List and explain the identifiers relevant for the 5GC

Student Notes

Tracking Area (TA) & Registration Area





RA ↔ Tracking Area List

RA – Registration Area
TA – Tracking Area
TAC – Tracking Area Code
TAI – Tracking Area Identity
MCC – Mobile Country Code
MNC – Mobile Network Code

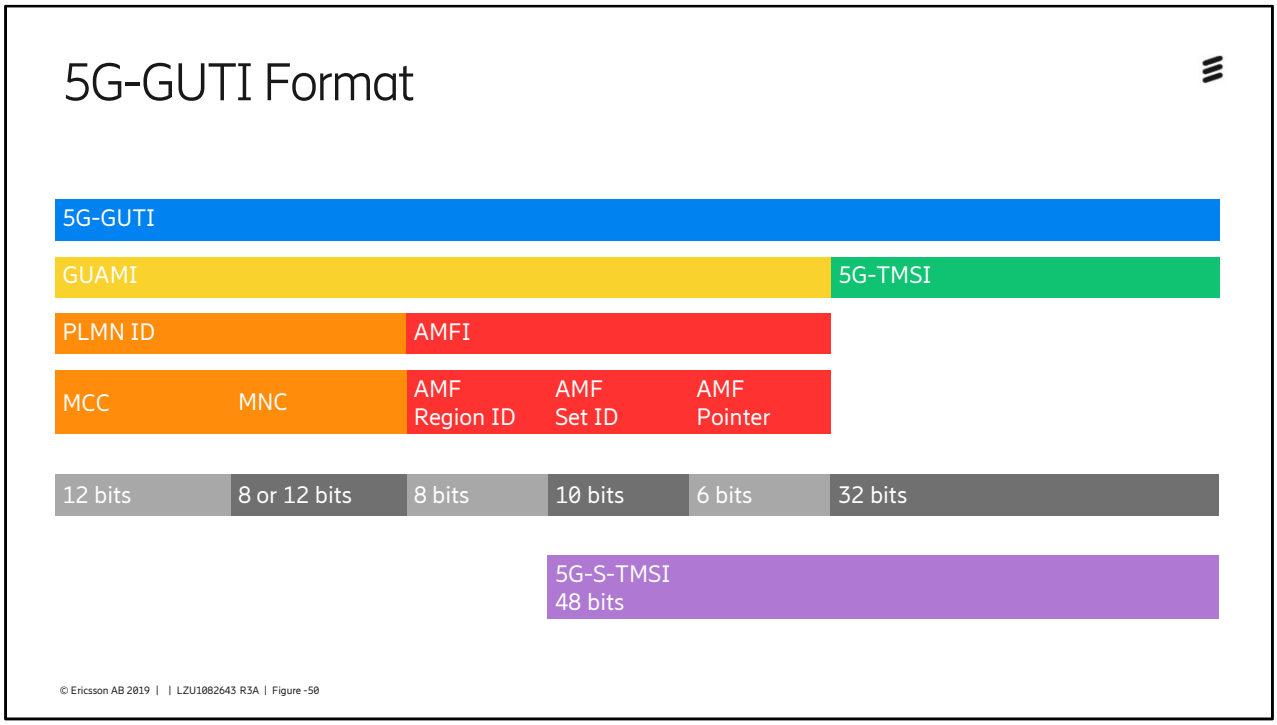
Student Notes

Identifiers
5G Globally unique Temporary Identity (5G-GUTI)

- AMF allocates 5G-GUTI to UE, common for both 3GPP and non-3GPP access, and may re-assign new 5G-GUTI to UE at any time
- 5G-GUTI shall be structured as:
  - <5G-GUTI>=<GUAMI><5G-TMSI>
  - GUAMI identifies AMF and 5G-TMSI identifies UE uniquely within AMF
- Globally Unique AMF Id (GUAMI) shall be structured as:
  - <GUAMI>=<MCC><MNC><AMF Region ID><AMF Set ID><AMF Pointer>
- 5G-S-TMSI shortened form of GUTI defined as:
  - <5G-S-TMSI>=<AMF Set Id><AMF Pointer><5G-TMSI>

TMSI – Temporary Mobile Subscription Identifier

Student Notes



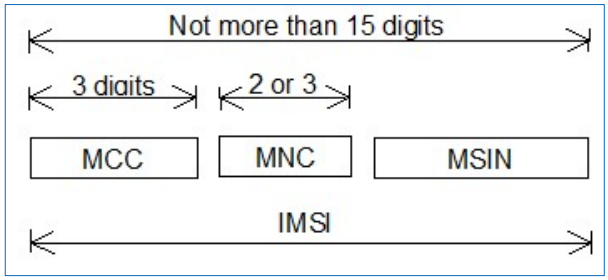
Student Notes

Identifiers
Subscriber Permanent Identifier (SUPI)

- Globally unique SUPI shall be allocated to each subscriber in 5GS
- Following identified valid SUPI types:
  - IMSI as defined by TS 23.003
  - Network Access Identifier (NAI) defined by RFC 7542 and applied according to TS 23.003
    - Using NAI possible to also use non-IMSI based SUPIs
- Possible for representation of IMSI within NAI for SUPI
  - Used over non-3GPP Access
- SUPI shall contain address of home network in order to enable roaming
  - MCC and MNC in case of IMSI based SUPI
- SUPI allocated for 3GPP UE always based on IMSI
  - To enable EPC interworking

Student Notes

SUPI Two Formats



NAI Format: username@realm
Example: IMSI@realm

IMSI: International Mobile Subscription Identity
MCC: Mobile Country Code
MNC: Mobile Network Code
MSIN: Mobile Subscriber Identification Number

Student Notes

Identifiers

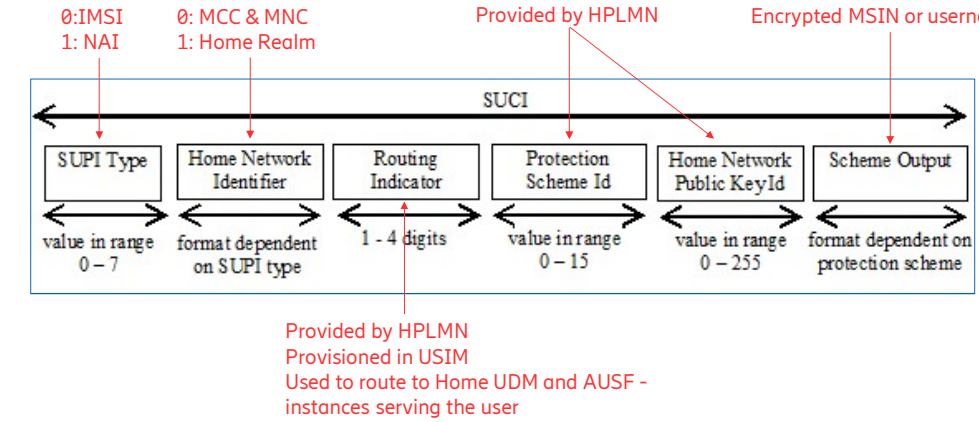
Subscriber Concealed Identifier (SUCI)

- One-time use subscription identifier
- Constructed by UE including:
  - Protection scheme Id (stored on USIM)
  - Home Network public key (stored on USIM)
  - Home network Id, e.g. MCC and MNC (not concealed)
  - Protection scheme-output
- Calculation of SUCI shall be performed by USIM or ME
  - Indicated by USIM
  - No Indication present → Calculated in ME
- Provisioning and updating of Home Network public key can be done with the Over the Air (OTA) mechanism
- ME shall support the null-scheme if no public key available
  - No SUPI protection in initial registration

3GPP 33.501
3GPP 23.003

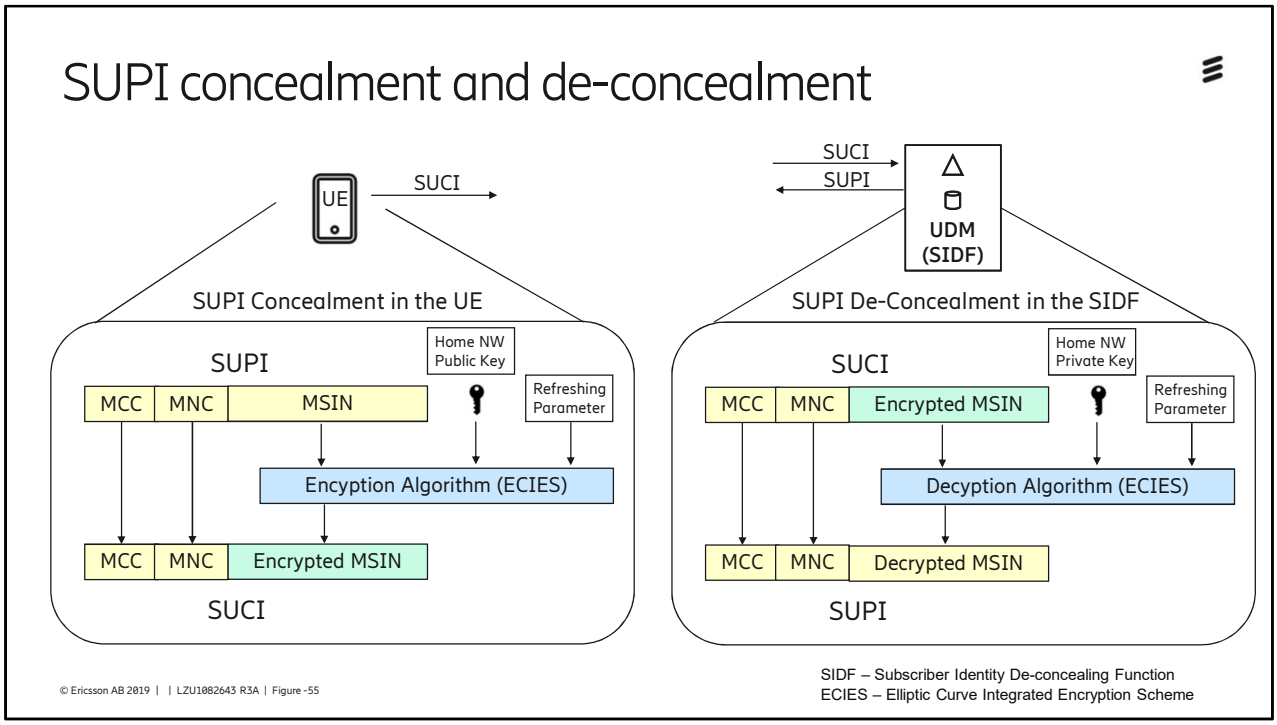
Student Notes

SUCI Two Formats



NAI Format: username@realm
Example: SUCI@realm

Student Notes



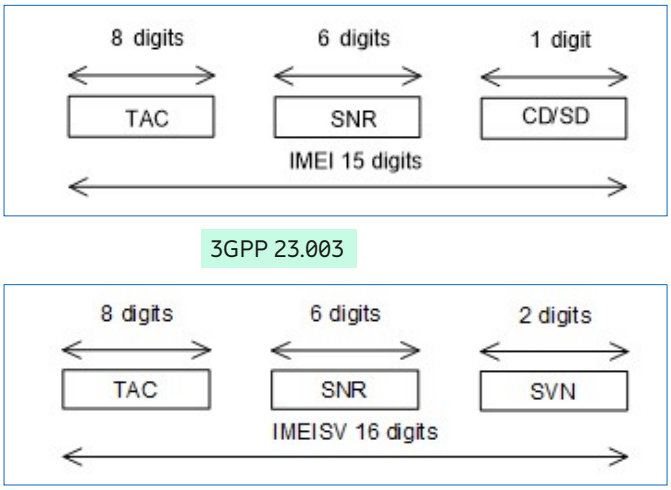
Student Notes

Identifiers
Permanent Equipment Identifier (PEI)

- PEI defined for 3GPP UE accessing 5GS
- PEI can assume different formats for different UE types and use cases
  - UE shall present PEI to network together with indication of PEI format used
- If UE supports at least one 3GPP access, PEI must be allocated in IMEI format

Student Notes

PEI Two Formats



IMEI: International Mobile station Equipment ID
IMEISV: IMEI and Software Version Number
TAC: Type Allocation Code
SNR: Serial Number
CD/SD: Check Digit / Spare Digit
SVN: Software Version Number

Student Notes

Identifiers

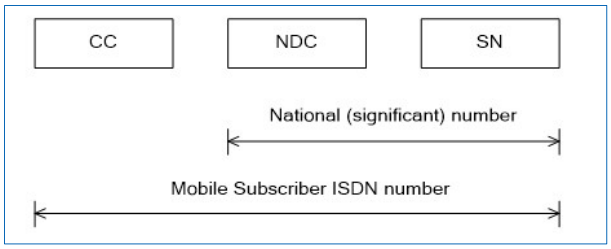
Generic Public Subscription Identifier (GPSI)

- GPSIs public identifiers used both inside and outside of 3GPP system
- GPSI either MSISDN or External Identifier (TS 23.003)
  - If MSISDN included in subscription data, same MSISDN value can be supported in both 5GS and EPS

Student Notes

GPSI Two Formats

MSISDN:



3GPP 23.003

External ID:

username@domain
Example: MSISDN@domain

CC: Country Code
NDC:National Destination Code
SN: Subscriber Number

Student Notes

Identifiers
Network Slice (NSSAI)

- Network Slice
  - Logical network that provides specific network capabilities and network characteristics
- Network Slice instance
  - Set of Network Function instances and required resources (e.g. compute, storage and networking resources) which form deployed Network Slice
- NSSAI (Network Slice Selection Assistance Information)
  - The NSSAI is a collection of S-NSSAIs
- S-NSSAI (Single Network Slice Selection Assistance Information)
  - Identifies a Network Slice instance
  - There can be at most 8 S-NSSAIs in the NSSAI sent in signaling messages between the UE and the Network
  - The same Network Slice instance may be selected by means of different S-NSSAIs
  - Can have standard values or PLMN-specific values

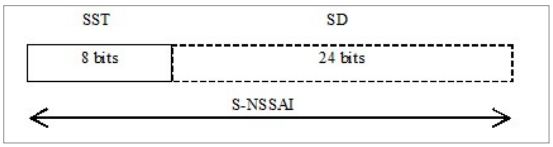
NSSAI
S-NSSAI #1
S-NSSAI #2
S-NSSAI #3
S-NSSAI #4
S-NSSAI #5
S-NSSAI #6
S-NSSAI #7
S-NSSAI #8

Student Notes

S-NSSAI Format

— An S-NSSAI is comprised of:
  — Slice/Service Type (SST), which refers to the expected Network Slice behavior in terms of features and services
  — Slice Differentiator (SD), which is optional information that complements the Slice/Service type(s) to differentiate amongst multiple Network Slices of the same Slice/Service type

Slice/Service type	SST value	Characteristics
eMBB	1	Slice suitable for the handling of 5G enhanced Mobile Broadband
URLLC	2	Slice suitable for the handling of ultra- reliable low latency communications
MIoT	3	Slice suitable for the handling of massive IoT



3GPP 23.003

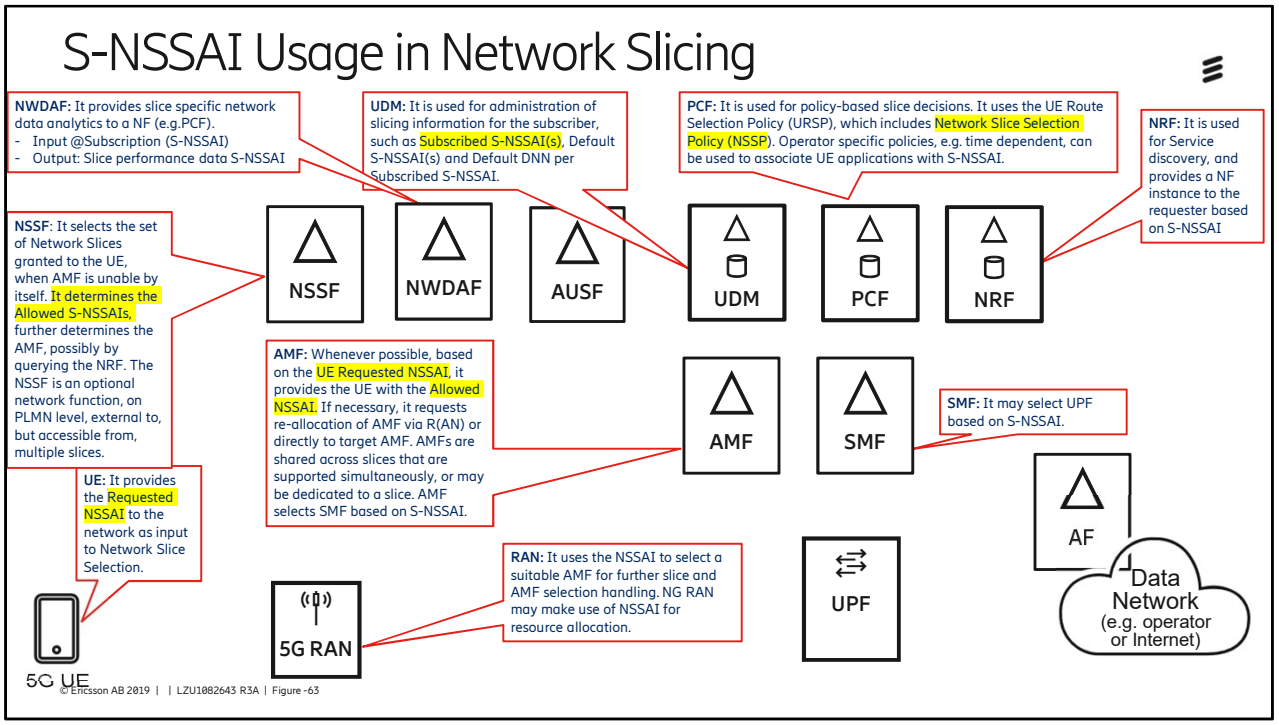
eMBB – enhanced Mobile Broad Band
URLLC – Ultra Reliable Low Latency Communication
MIoT – Massive IoT

Student Notes

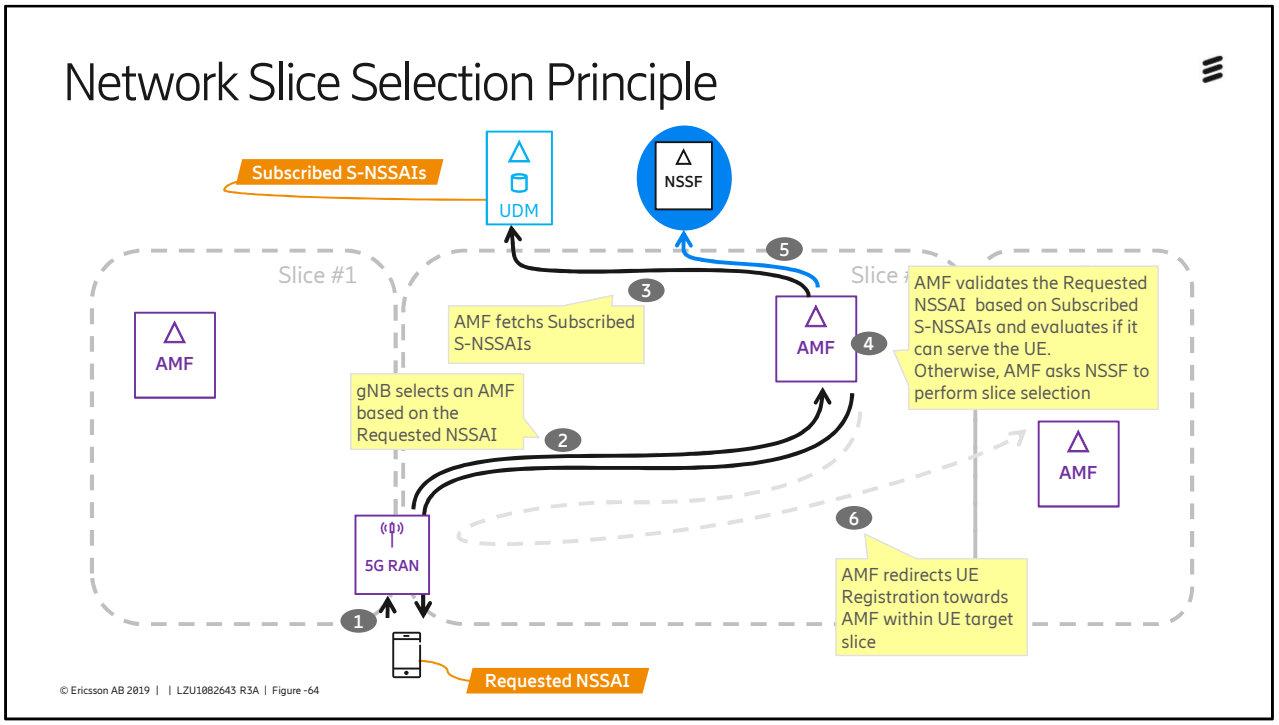
NSSAI "Types"

- Requested NSSAI
  - The NSSAI that may provided by the UE (in NAS messages) to the Serving PLMN during Registration
- Subscribed NSSAI
  - The S-NSSAI based on subscriber information, which a UE is subscribed to use in a PLMN
  - One or more of the Subscribed S-NSSAIs can be marked as default S-NSSAI
- Allowed NSSAI
  - The NSSAI provided by the serving PLMN during e.g. a Registration procedure, indicating the NSSAI allowed by the network for the UE in the serving PLMN for the current Registration Area
- Configured NSSAI
  - The NSSAI that may be provisioned in the UE, per one or more PLMNs
- Rejected NSSAI
  - The UE shall not re-attempt to register to an S-NSSAI rejected in the PLMN; or until it moves out of the current Registration Area

Student Notes



Student Notes



Student Notes

Chapter Summary

On completion of this chapter, the participants are able to:

— List and explain the identifiers relevant for the 5GC

Student Notes

5G Core Protocols and Procedures

Chapter 3
Interfaces and Protocols

Student Notes

Chapter Objectives

On completion of this chapter, the participants will be able to:

- Explain service-based interfaces
- Explain the N1 and N2 control plane interfaces towards access networks
- Explain the N3 user plane interface towards access networks
- Explain the N4 interface between control plane and user plane

Student Notes

5G Core Protocols and Procedures

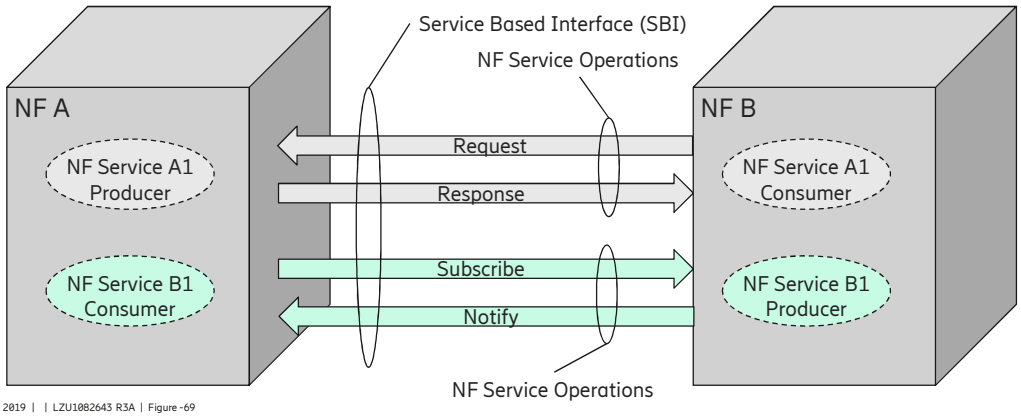
3.1 Service Based Interfaces

Student Notes

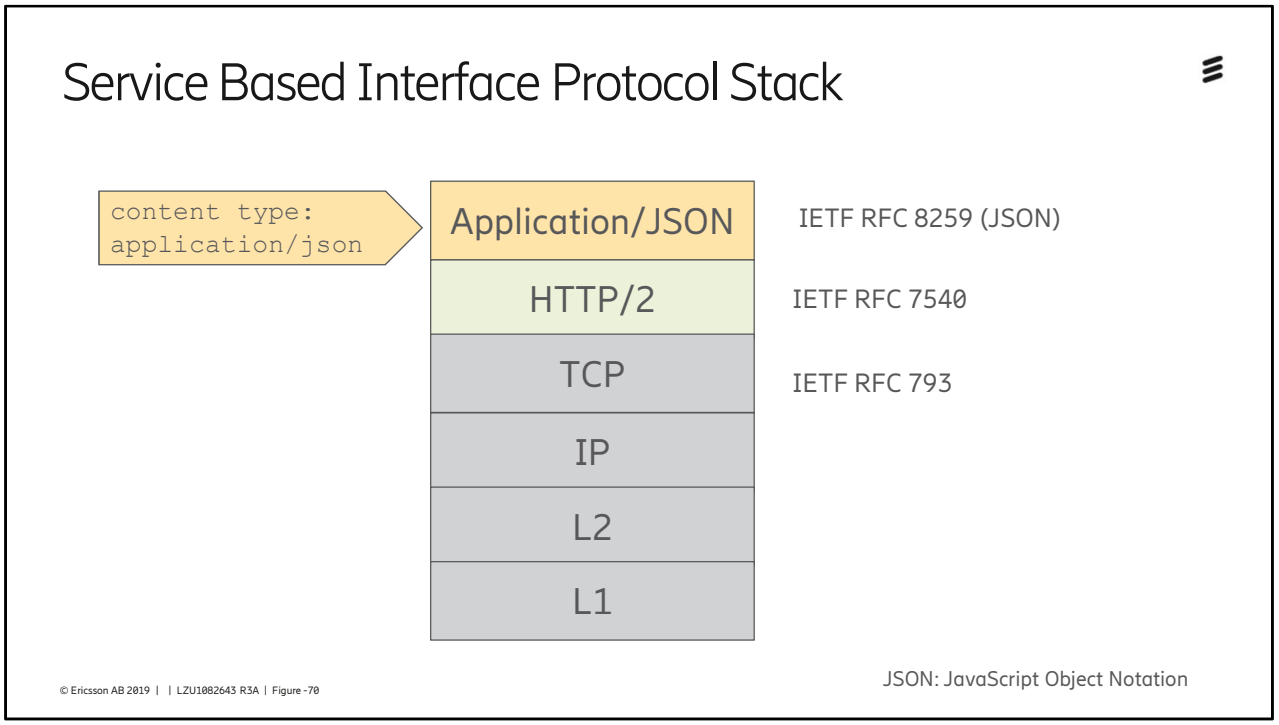
Service-based interface in 5GC

Services and Operations

- CP NF provide one or more NF services
- NF service consist of operations based on request-response or subscribe-notify model
- Common control protocol using e.g. HTTP based API replacing protocols like Diameter and GTP-C



Student Notes



Student Notes

JSON (JavaScript Object Notation)

- Minimal readable format for structuring data
- Used to transmit data between server and web application
- Alternative to XML

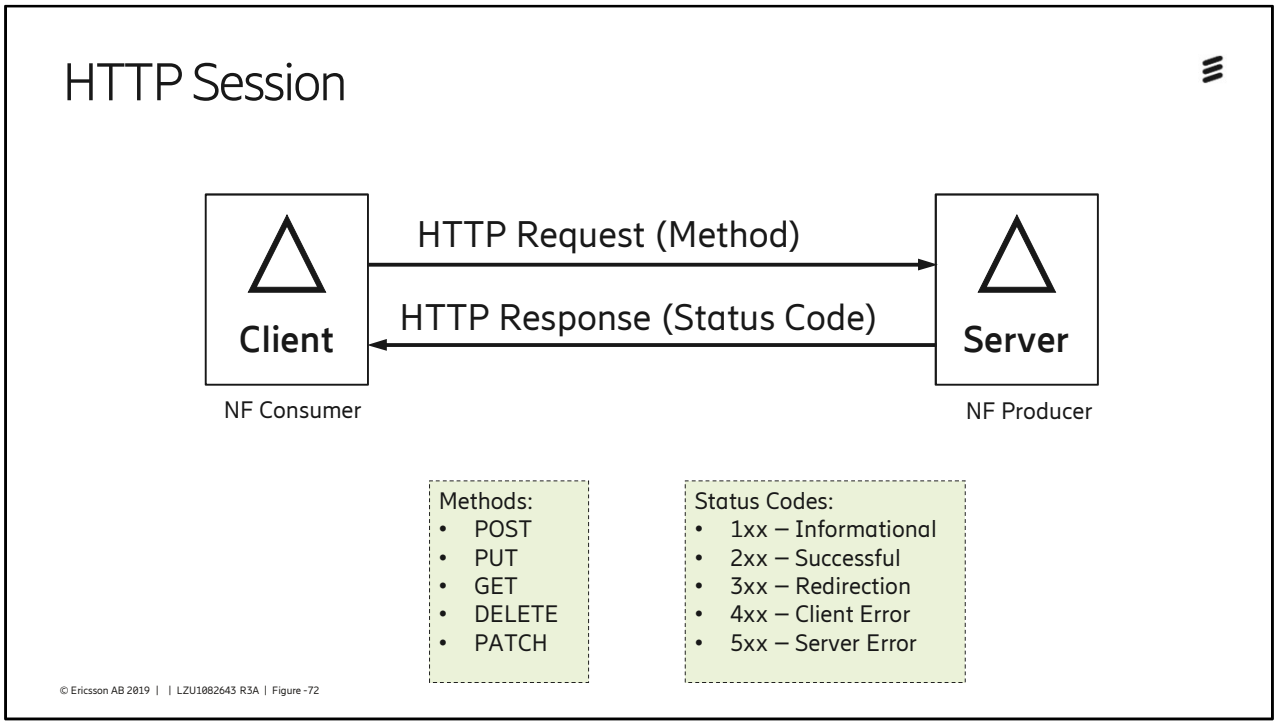
- Primary parts: Keys and Values, make a Key/Value Pair

String enclosed in quotation marks

string, number, boolean, array or object

- Example: “firstName” : “Kent”

Student Notes



Student Notes

HTTP status codes supported for SBI

M: Mandatory
O: Optional
C: Conditional
N/A: Not Applicable

C1: Used to Modify Resource or INVOKE Method → O
else → N/A

C2: Used to Create Resource → M
else → N/A

HTTP status code	HTTP method				
	DELETE	GET	PATCH	POST	PUT
100 Continue					
200 OK (NOTE 1)	O	M	O	C1	O
201 Created	N/A	N/A	N/A	C2	C2
202 Accepted	O	N/A	O	O	O
204 No Content (NOTE 2)	O	N/A	O	C1	O
300 Multiple Choices					
307 Temporary Redirect					
308 Permanent Redirect					
400 Bad Request	M	M	M	M	M
403 Forbidden					
404 Not Found				N/A	N/A
406 Not Acceptable	N/A				
408 Request Timeout					
409 Conflict		N/A		N/A	
410 Gone					
413 Payload Too Large					
414 URI Too Long					
415 Unsupported Media Type	N/A	N/A			
500 Internal Server Error	M	M	M	M	M
501 Not Implemented					
503 Service Unavailable					
504 Gateway Timeout					

Student Notes

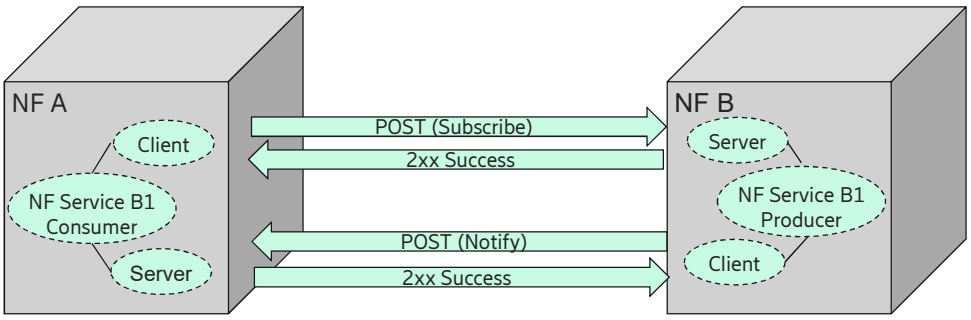
Mandatory HTTP standard headers

Name	Reference	Description
Accept	IETF RFC 7231 [11]	This header is used to specify response media types that are acceptable.
Content-Length	IETF RFC 7230 [12]	This header is used to provide the anticipated size, as a decimal number of octets, for a potential payload body.
Content-Type	IETF RFC 7231 [11]	This header is used to indicate the media type of the associated representation.
Location	IETF RFC 7231 [11]	This header is used in some responses to refer to a specific resource in relation to the response.
Retry-After	IETF RFC 7231 [11]	This header is used in some responses to indicate how long the user agent ought to wait before making a follow-up request.

Student Notes

Server-initiated Communication

- Used for Subscribe-Notify service operations
  - Require bidirectional communication between NFs
  - Supported with two TCP connections, one per direction



Student Notes

Resource URI Structure

- URI uniquely identifies a resource
- For 5GC SBI APIs resource URI specified as follows:
  - {apiRoot}/{apiName}/{apiVersion}/{apiSpecificResourceUriPart}

    - **apiRoot**: http(s):// host(:port)
    - **apiName**: defines the name of the API, e.g. "*namf-comm"*
    - **apiVersion**: Version of the API, e.g. *"v1"*

    Base URI

    - **apiSpecificResourceUriPart**: Defines a resource URI of the API relative to the base URI, e.g. *"../ue-contexts/{ueContextId}"*

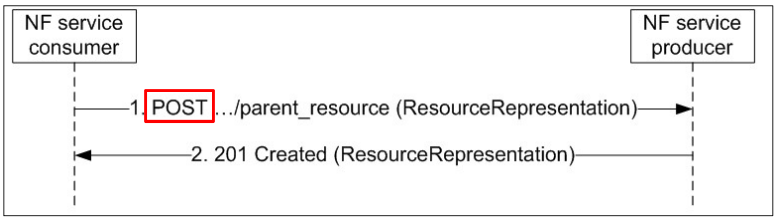
3GPP 29.501

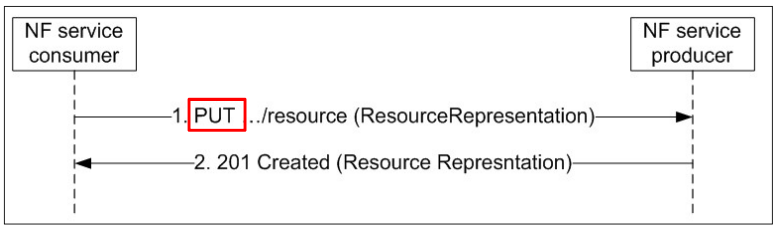
Student Notes

Creating a Resource

Two HTTP methods be used:

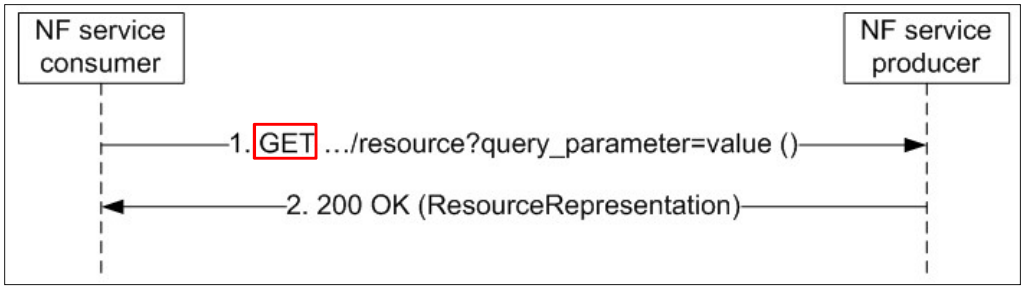
- POST
  - Producer selects Resource URI
- PUT
  - Consumer selects Resource URI





Student Notes

Reading a Resource

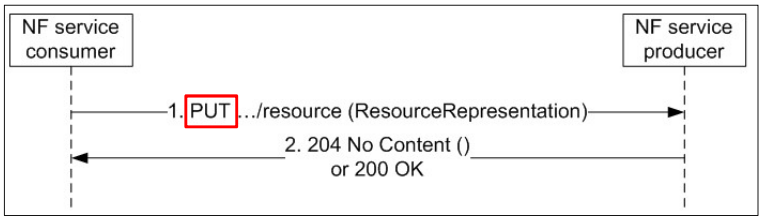


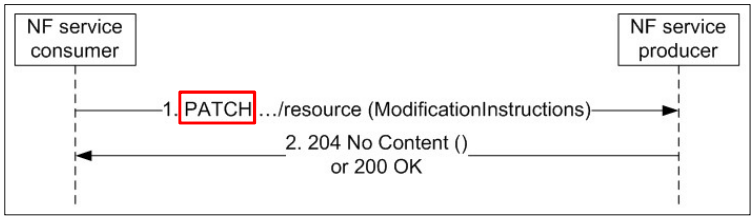
Student Notes

Updating a Resource

Two HTTP methods be used:

- PUT
  - Complete replacement of resource
- PATCH
  - Partial replacement of resource





Student Notes

Deleting a Resource

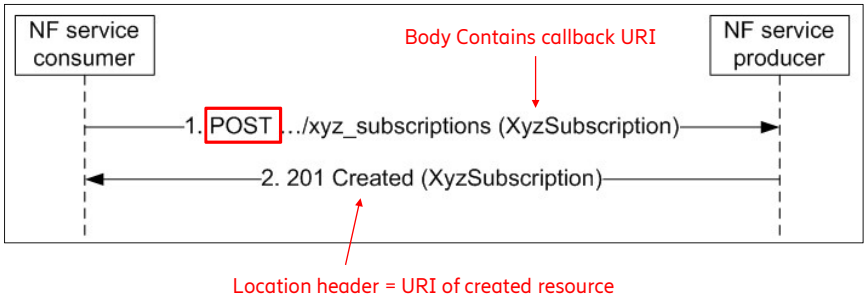
Student Notes

Subscribe/Notify Service Operations

- Two types of subscriptions:
  - Implicit: Not explicitly created and cannot be deleted only modified, suspended or resumed
    - Example: AMF is implicitly subscribed in the PCF to be notified of changes in policies
  - Explicit: Explicitly created and a callback URI is provided for the corresponding notifications
- HTTP methods
  - Create a subscription: POST
  - Modify a subscription: PUT or PATCH
  - To unsubscribe: DELETE

Student Notes

Creation of an Explicit Subscription

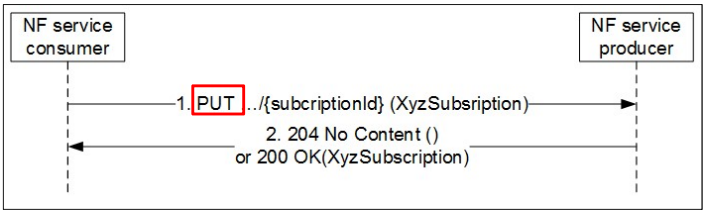


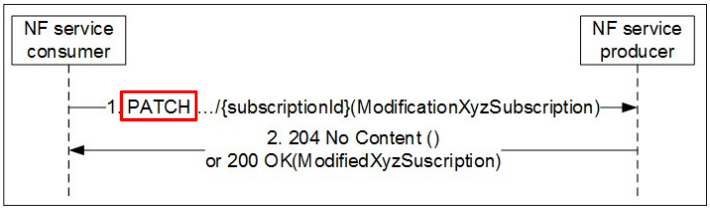
Student Notes

Modify a Subscription

Two HTTP methods be used:

- PUT
  - Complete replacement of subscription
- PATCH
  - Partial replacement of subscription



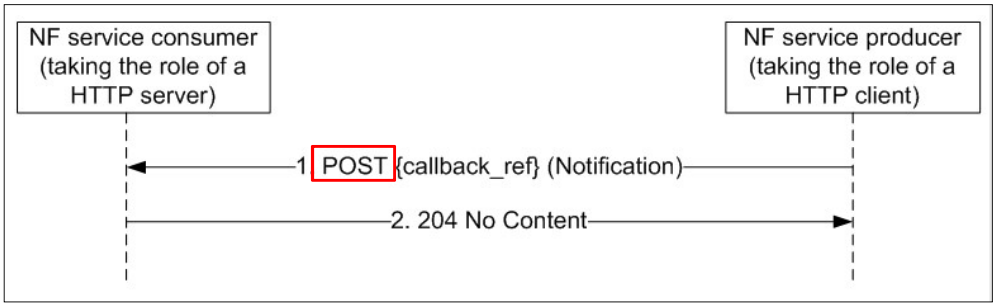


Student Notes

Delete a Subscription

Student Notes

Notifications



Student Notes

NF Services Naming

- NF Service naming
  - *Nnfname_ServiceName* (<service-based interface name>_<service name>)
  - Example from AMF: *Namf_Communication*
- NF Service operation naming
  - *Nnfname_ServiceName_ServiceOperation[Method]*
  - Example from AMF: *Namf_Communication_UEContextTransfer[Request]*

Student Notes

NF Services – 3GPP 23.502

AMF Example

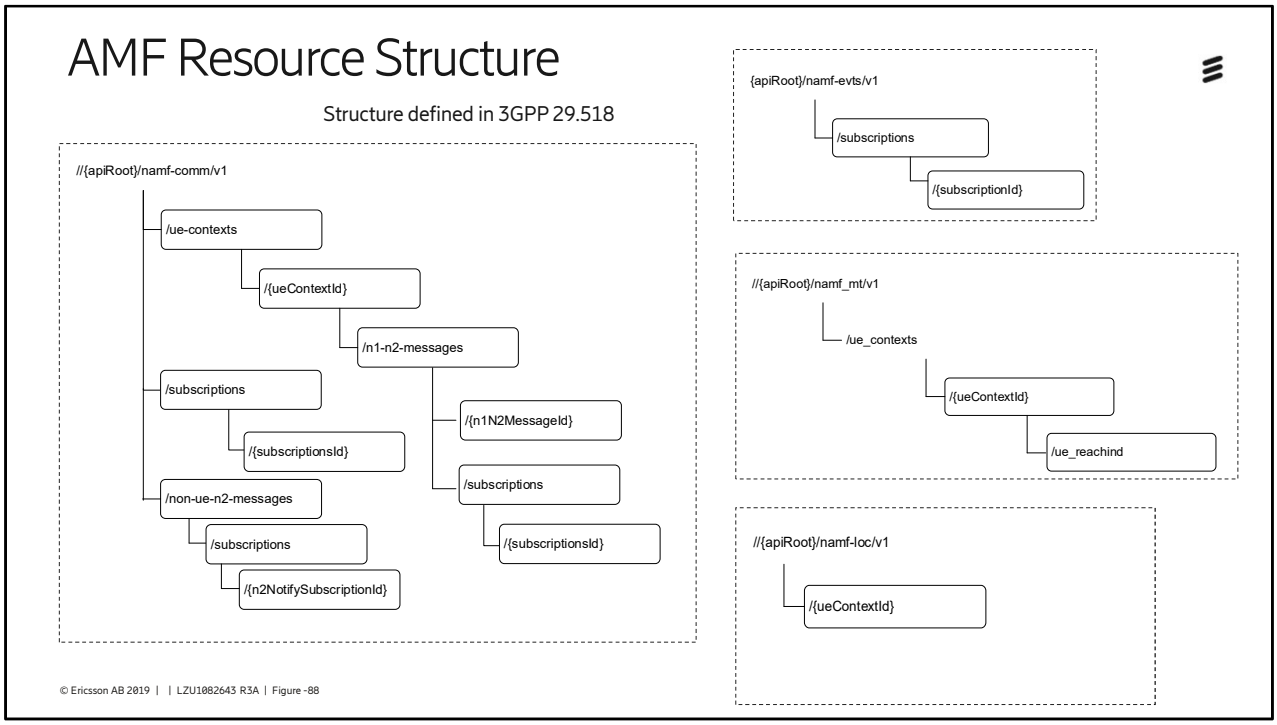
AMF NF services according to 23.502

- Service operation examples:
  - Namf_Communication_UEContextTransfer [Request/Response]
  - Namf_EventExposure_Subscribe

Service Name	Service Operations	Operation Semantic	Known Consumer(s)
Namf_Communication	UEContextTransfer	Request/ Response	Peer AMF
	RegistrationCompleteNotify	Subscribe / Notify	Peer AMF
	N1MessageNotify	Subscribe / Notify	SMF, SMSF, PCF, NEF, LMF
	N1MessageSubscribe		SMF, SMSF, PCF, NEF
	N1MessageUnSubscribe		SMF, SMSF, PCF, NEF
	N1N2MessageTransfer	Request/ Response	SMF, SMSF, PCF, NEF, LMF
	N2InfoSubscribe	Subscribe / Notify	SMF
	N2InfoUnSubscribe		SMF
	N2InfoNotify		SMF, LMF
	EBIAssignment	Request/Response	SMF
	AMFStatusChangeSubscribe	Subscribe / Notify	SMF, PCF, NEF, SMSF, UDM
	AMFStatusChangeUnSubscribe	Subscribe / Notify	SMF, PCF, NEF, SMSF, UDM
	AMFStatusChangeNotify	Subscribe / Notify	SMF, PCF, NEF, SMSF, UDM
Namf_EventExposure	Subscribe	Subscribe / Notify	NEF, SMF, PCF, UDM
	Unsubscribe	Subscribe / Notify	NEF, SMF, PCF, UDM
	Notify	Subscribe / Notify	NEF, SMF, PCF, UDM
Namf_MT	EnableUEReachability	Request/Response	NEF, SMF, PCF, UDM
Namf_Location	ProvideLocation	Request/Response	GMLC
	EventNotify	Subscribe / Notify	GMLC

EBI: EPS Bearer Id
LMF: Location Management Function
GMLC: Gateway Mobile Location Center

Student Notes



Student Notes

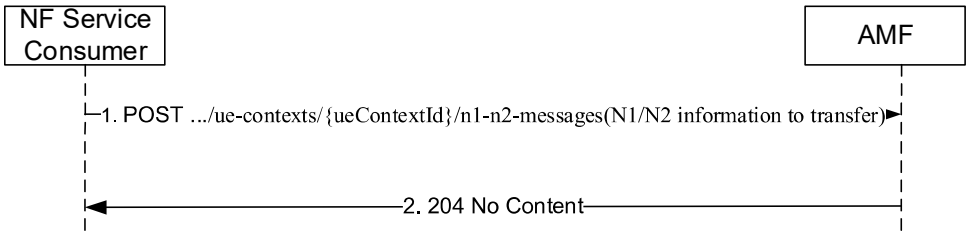
Resources Map to Service Operations

Resource name	Resource URI	HTTP method or custom operation	Description (Mapped Service Operations)
Individual ueContext	.../ue-contexts/{ueContextId}	PATCH	UEContextTransfer, RegistrationCompleteNotify, N2InfoNotify
		PUT	CreateUEContext
	.../ue-contexts/{ueContextId}/release	(POST) release	ReleaseUEContext
	.../ue-contexts/{ueContextId}/assignEbi	(POST) assignEbi	EBIAssignment
ueContext collection	.../ue-contexts	POST	N1MessageNotify
n1N2Message collection	.../ue-contexts/{ueContextId}/n1-n2-messages	POST	N1N2MessageTransfer
N1N2 Subscriptions Collection for Individual UE Contexts	../ue-contexts/{ueContextId}/n1-n2-messages/subscriptions	POST	N1MessageSubscribe, N2InfoSubscribe.
…	…	…	…

3GPP 29.518

Student Notes

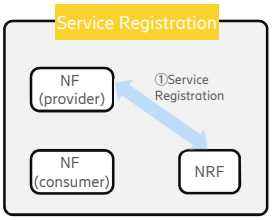
N1N2MessageTransfer Service Operation



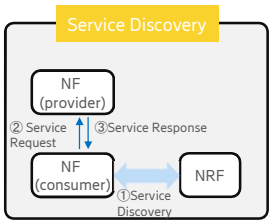
1. The NF Service Consumer should send a *HTTP POST* request to the *N1N2MessageCollection* resource URI:
   - Resource URI: **{apiRoot}/namf-comm/v1/ue-contexts/{ueContextId}/n1-n2-messages**
     {apiRoot}: **HTTP authorization of the AMF NF instance, discovered from NRF**
     {ueContextId}: SUPI ("imsi-[0-9]{5,15}|nai-.+"**) or PEI (**"imei-[0-9]{15}"**) of the target UE.**
   - Payload: **N1/N2 message information container**
   - Optional: Callback-URI for N1N2MessageTransfer Notification
2. If the request is accepted, the AMF shall create a sub-resource with a new unique resource id and return the URI of the created sub-resource in "Location" header in response with the status code *204 No Content*.

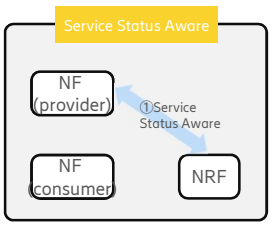
Student Notes

Service Registration and Discovery



- Service instances are defined when system is set up, but number of instances is dynamic (scale up/down, failures, programmed maintenance).
- Need for a new NF (NRF-Network Repository Function) that supports:
  - NF service instance registration and deregistration in NRF as a service producer.
  - NF service consumer instance discovers/selects in NRF available service producers.
  - NRF authorizes NF service consumer access to a producer.
  - Service Status Awareness.





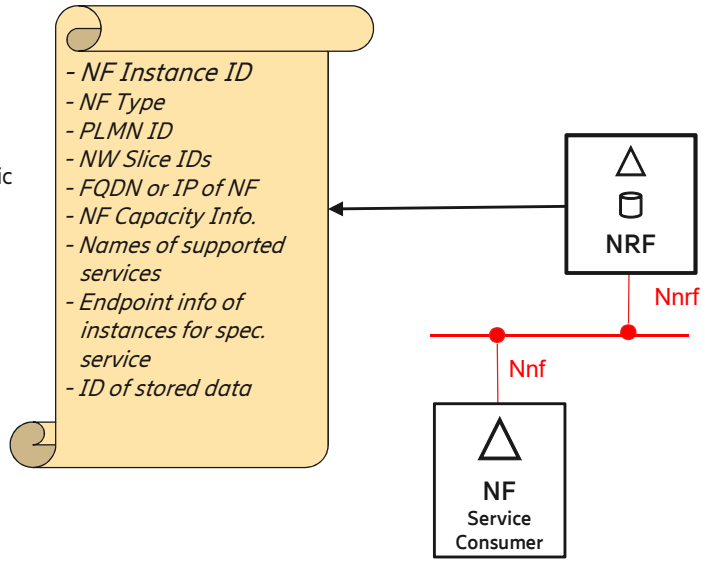
Student Notes

NF Service Discovery and Selection

NF and NF service discovery implemented via NRF

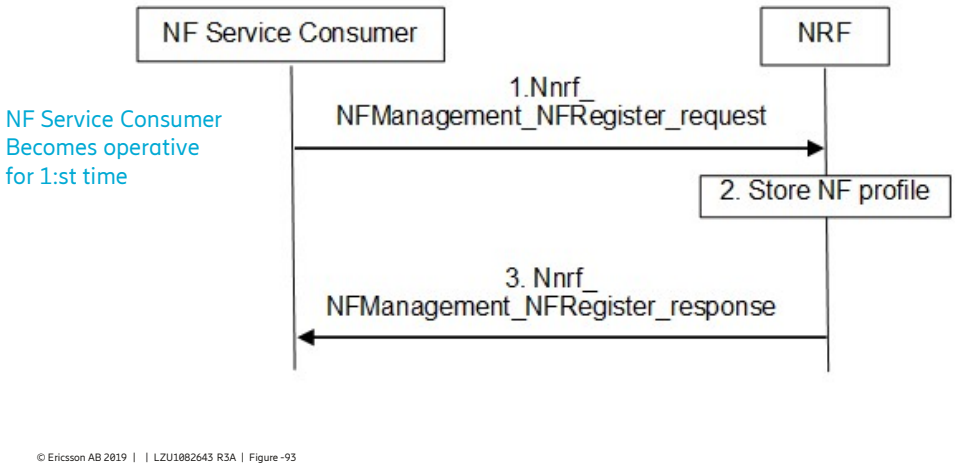
NF Consumer provides NF type or specific service + slice info in NRF request

NRF Replies with target NF (FQDN or IP or relevant NF service)



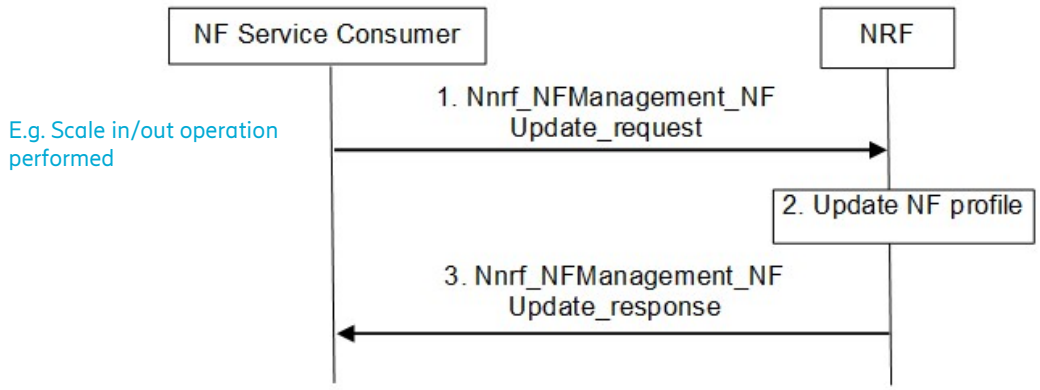
Student Notes

NF Service Registration



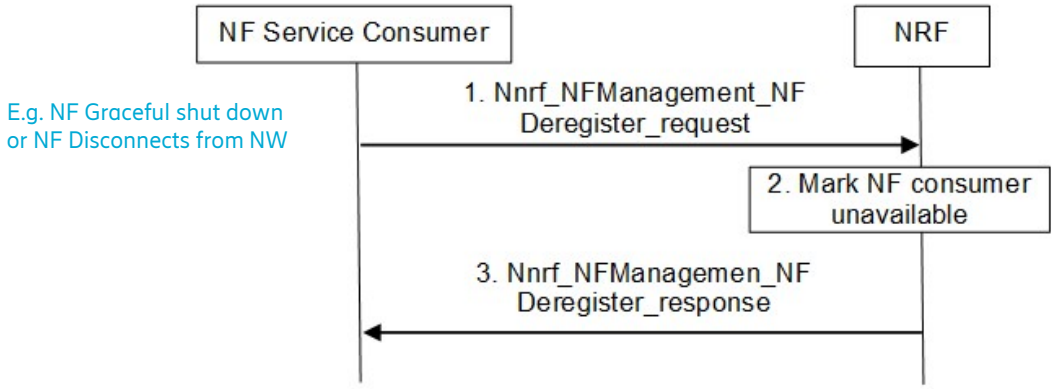
Student Notes

NF Service Update



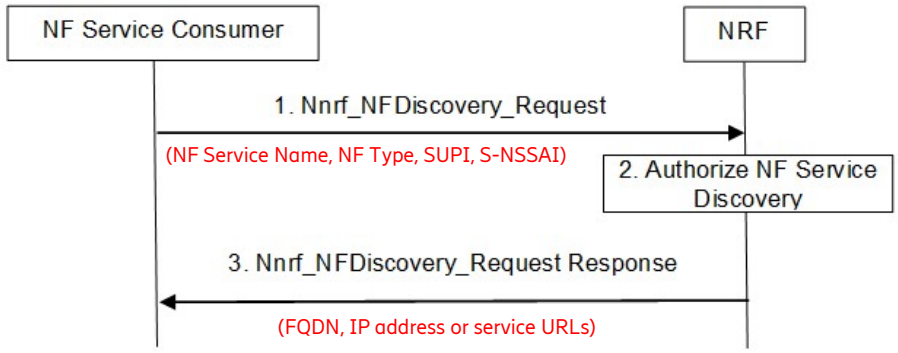
Student Notes

NF Service Deregistration



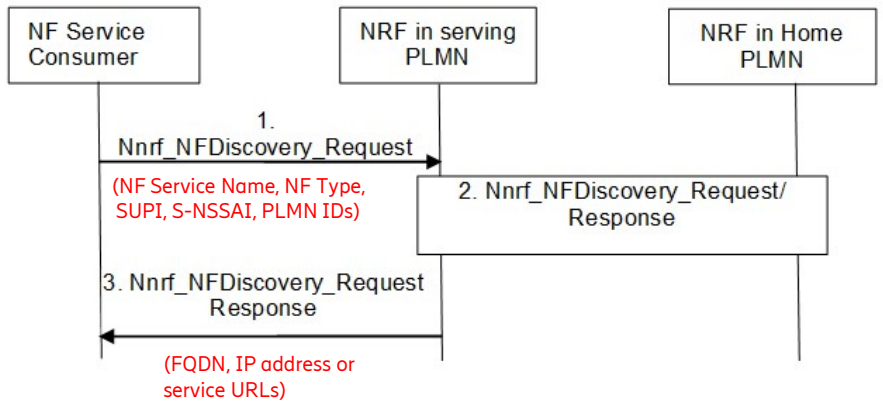
Student Notes

NF/NF Service Discovery – Same PLMN

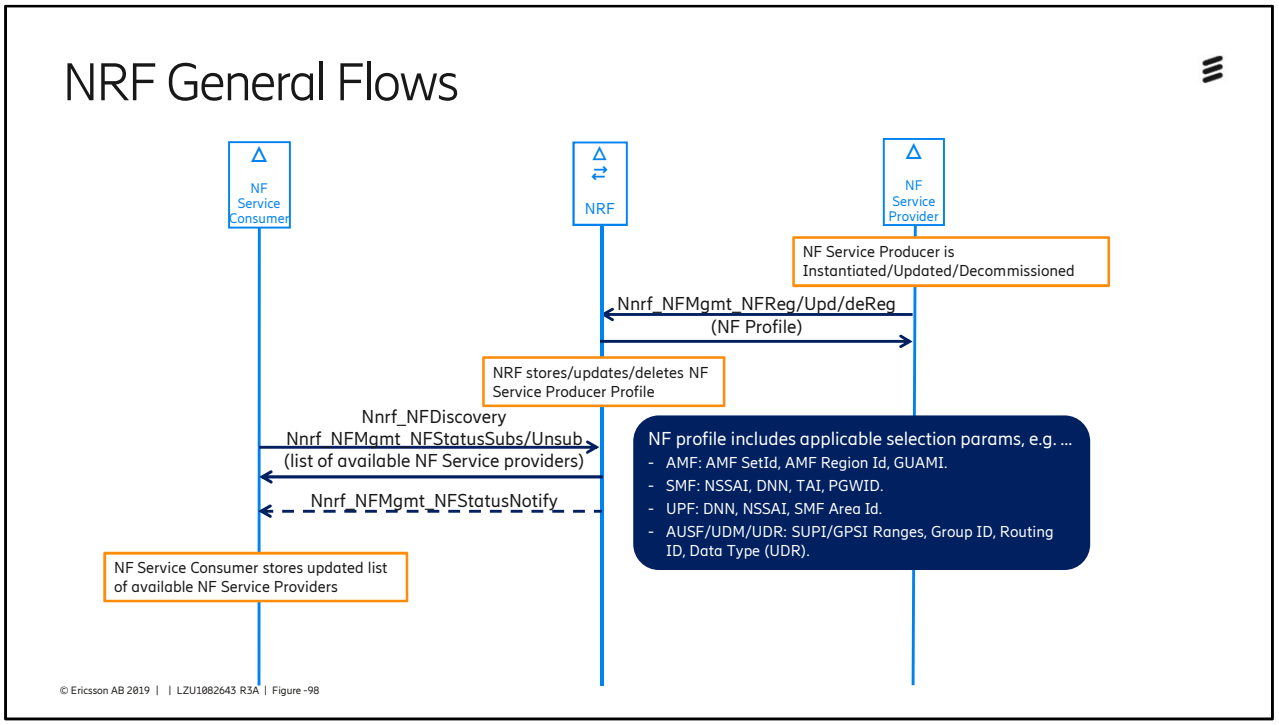


Student Notes

NF/NF Service Discovery – Across PLMNs



Student Notes



Student Notes

AMF Selection

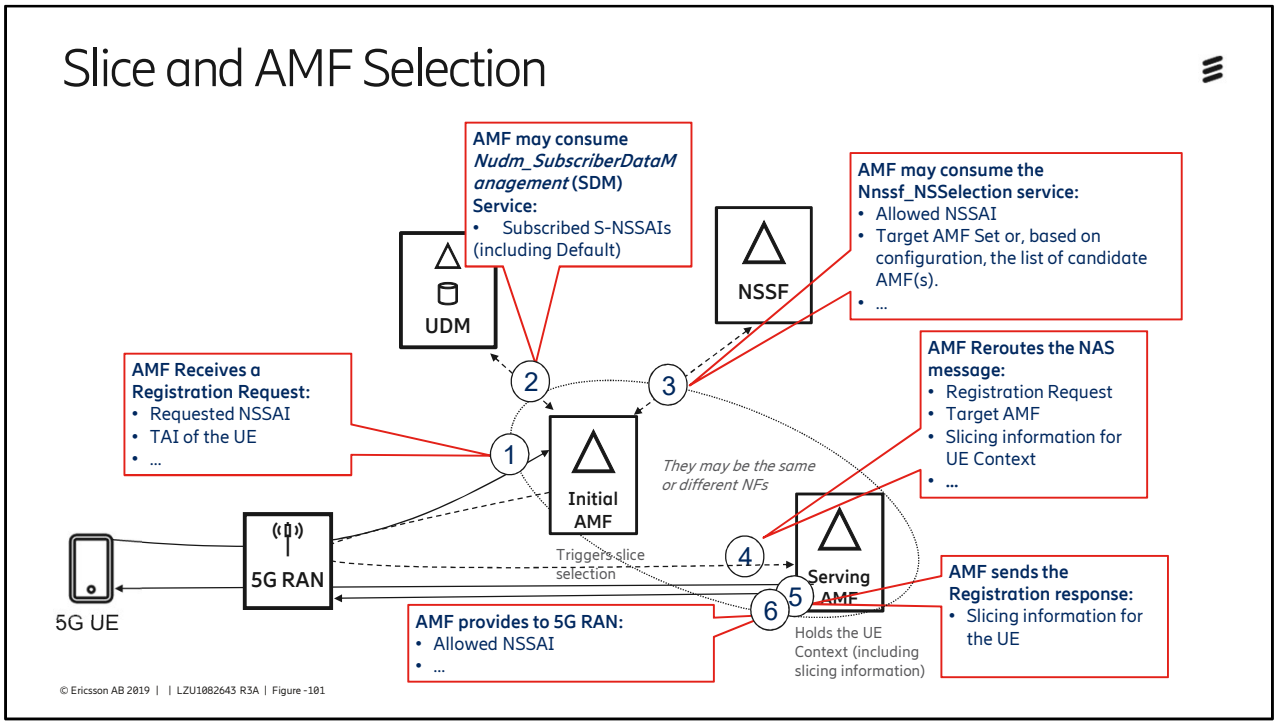
- Used by:
  - 5G Access Network (e.g. RAN and N3IWF) to select AMF for given UE
  - AMF for AMF relocation
  - Other NFs e.g. SMF when original AMF unavailable

Student Notes

AMF Selection Criteria's

- 5G-AN factors for selecting AMF Set:
  - AMF Region Id and AMF Set Id derived from GUAMI
  - Requested NSSAI
  - Local Operator Policies
- 5G-AN or CP NFs factors for selecting AMF in AMF Set:
  - Availability of candidate AMFs (by NRF look up)
  - Load balancing across candidate AMFs
- 5G-AN AMF Selection priorities:
  1. 5G-S-TMSI if present
  2. Requested NSSAI if present
  3. Configured default AMF

Student Notes



Student Notes

SMF Selection

- Supported by AMF to allocate SMF to manage PDU Sessions
- AMF utilizes NRF to receive IP address or FQDN for SMF instance
- SMF can optionally be locally configured in AMF
- Applicable for both 3GPP and non-3GPP access

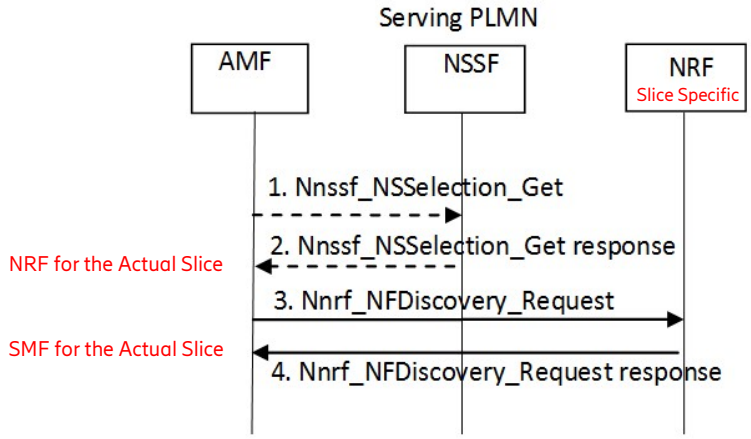
Student Notes

SMF Selection Criteria's

- Selected Data Network Name (DNN)
- S-NSSAI
- Subscription information from UDM, e.g.:
  - per DNN: whether Local Breakout (LBO) roaming allowed
  - per S-NSSAI: subscribed DNN(s)
- Local operator policies (default SMF config)
- Load conditions of candidate SMFs
- Access technology (3GPP or Non-3GPP) used by UE

Student Notes

SMF Selection Procedure

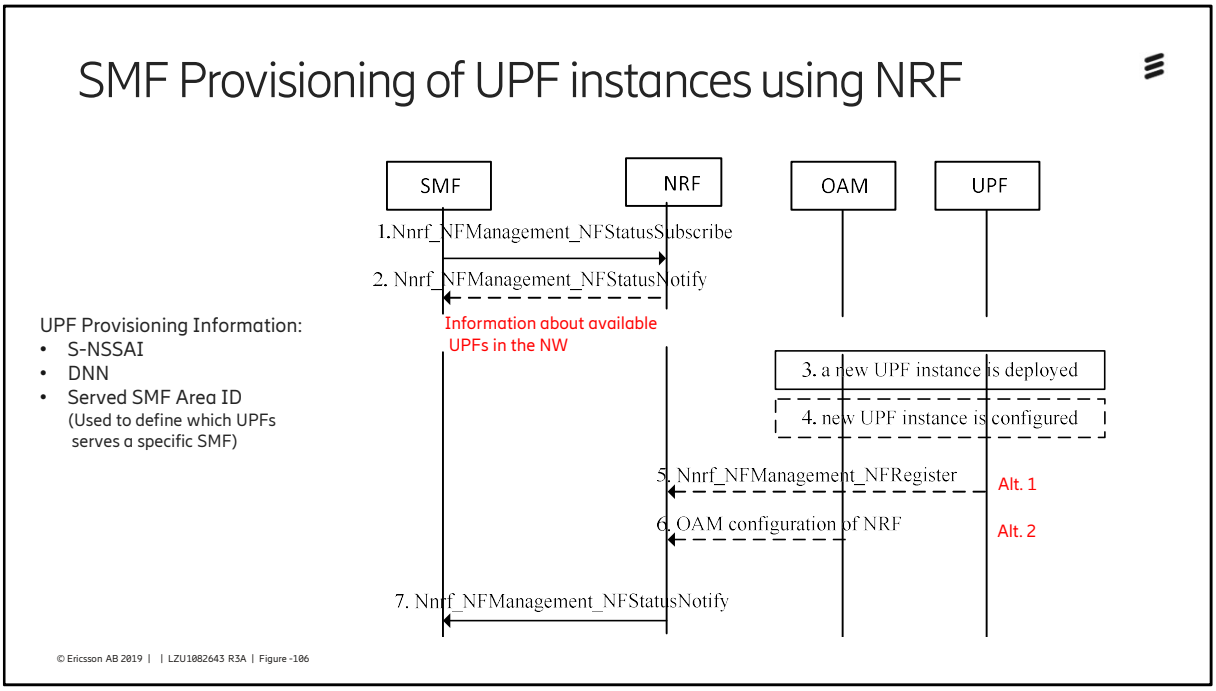


Student Notes

UPF Selection

- Performed by SMF by means of
  - Local configuration about available UPFs
  - Using NRF to discover UPF instances
- Roaming cases:
  - UPF(s) in Home PLMN selected by SMF(s) in H-PLMN
  - UPF(s) in Visited PLMN selected by SMF(s) in V-PLMN

Student Notes



The following takes place when an SMF expects to be informed of UPFs available in the network:

1. The SMF issues a Nnrf_NFManagement_NFStatusSubscribe Service Operation providing the target UPF Provisioning Information it is interested in.
2. The NRF issues Nnrf_NFManagement_NFStatusNotify with the list of all UPFs that currently meet the SMF subscription. This notification indicates the subset of the target UPF Provisioning Information that is supported by each UPF.

The following takes place when a new UPF instance is deployed:

3. At any time a new UPF instance is deployed.
4. The UPF instance is configured with the NRF identity to contact for registration and with its UPF Provisioning Information*. An UPF is not required to understand the UPF Provisioning Information beyond usage of this information to register in step 5..
5. The UPF instance issues an Nnrf_NFManagement_NFRegister Request operation providing its NF type, the FQDN or IP address of its N4 interface, and the UPF Provisioning Information configured in step 4.
6. Alternatively (to steps 4 and 5) OAM registers the UPF on the NRF indicating the same UPF Provisioning Information as provided in step 5. This configuration mechanism is out of scope of this specification.
7. Based on the subscription in step 1, the NRF issues Nnrf_NFManagement_NFStatusNotify to all SMFs with a subscription matching the UPF Provisioning Information of the new UPF

*The UPF Provisioning Information consists of a list of (S-NSSAI, DNN) and of an SMF Area Identity the UPF can serve.

UPF Selection Criteria's

- UPF's dynamic load
- UPF's relative static capacity among UPFs supporting same DNN
- UPF location available at SMF
- UE location information
- Capability of UPF and functionality required for particular UE session
- Data Network Name (DNN)
- PDU Session Type (i.e. IPv4, IPv6, Ethernet Type or Unstructured Type)
- SSC mode selected for PDU Session
- UE subscription profile in UDM
- DNAI as included in PCC Rules
- Local operator policies
- S-NSSAI
- Access technology used by UE

Student Notes

AUSF Selection

- AMF performs AUSF Selection using:
  - NRF to discover AUSF instance(s)
  - Local AMF configuration
- Used for both 3GPP and non-3GPP access
- AUSF selection criteria's
  - SUPI
  - Home Network identifier of SUCI

Student Notes

PCF Selection

- AMF selects PCF for UE
  - Utilizing NRF or locally configured
- SMF selects PCF for PDU session
  - Utilizing NRF or locally configured based on:
    - Local operator policies
    - Selected DNN
    - PCF selected by AMF
- Selected PCF same or different for AMF & SMF

Student Notes

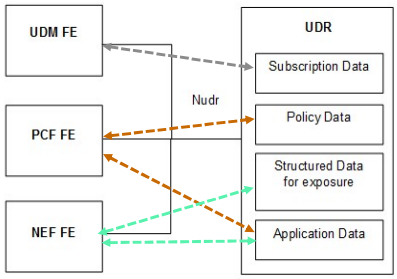
UDM Discovery function

- NF Consumer discovers UDM instance in HPLMN
  - Utilizing NRF or locally configured
- Applicable for both 3GPP and non-3GPP access
- NF Consumer discovers UDM based on:
  - Home Network identifier of SUPI (e.g. MNC and/or MCC)
  - GPSI (used by NEF or PCF)
  - Home Network identifier of SUCI (e.g. MNC and/or MCC)

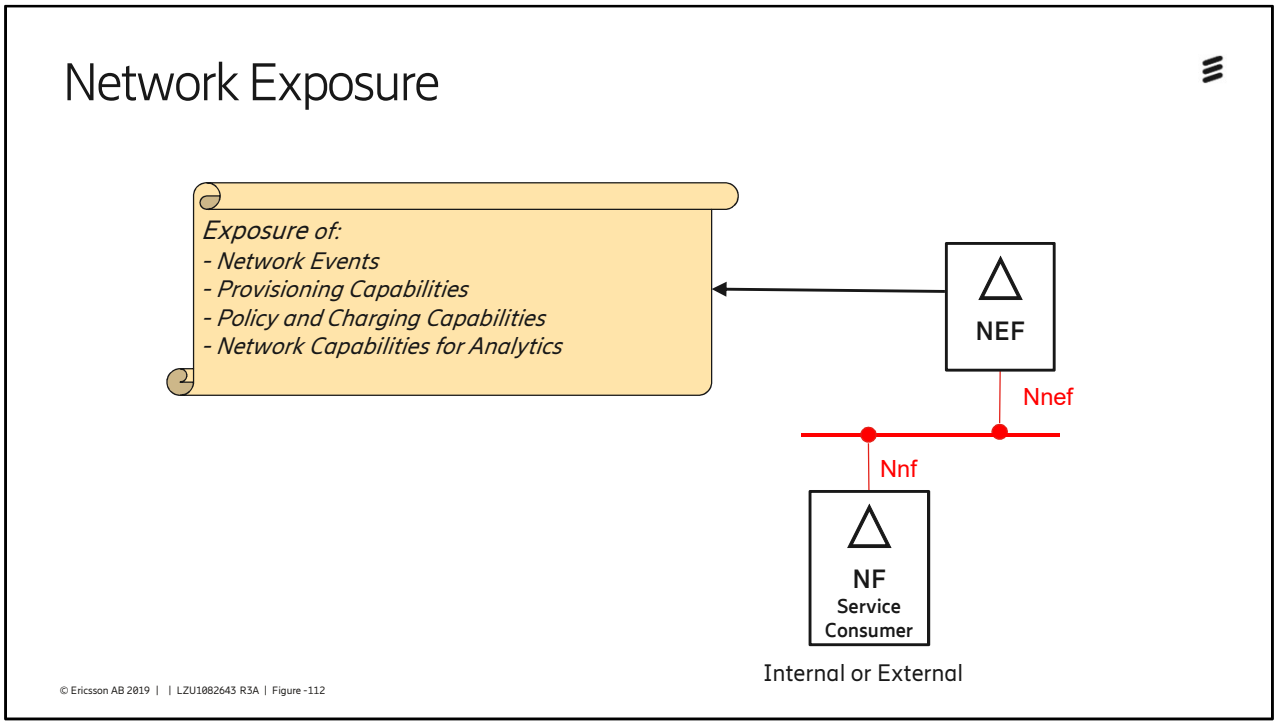
Student Notes

UDR Discovery Function

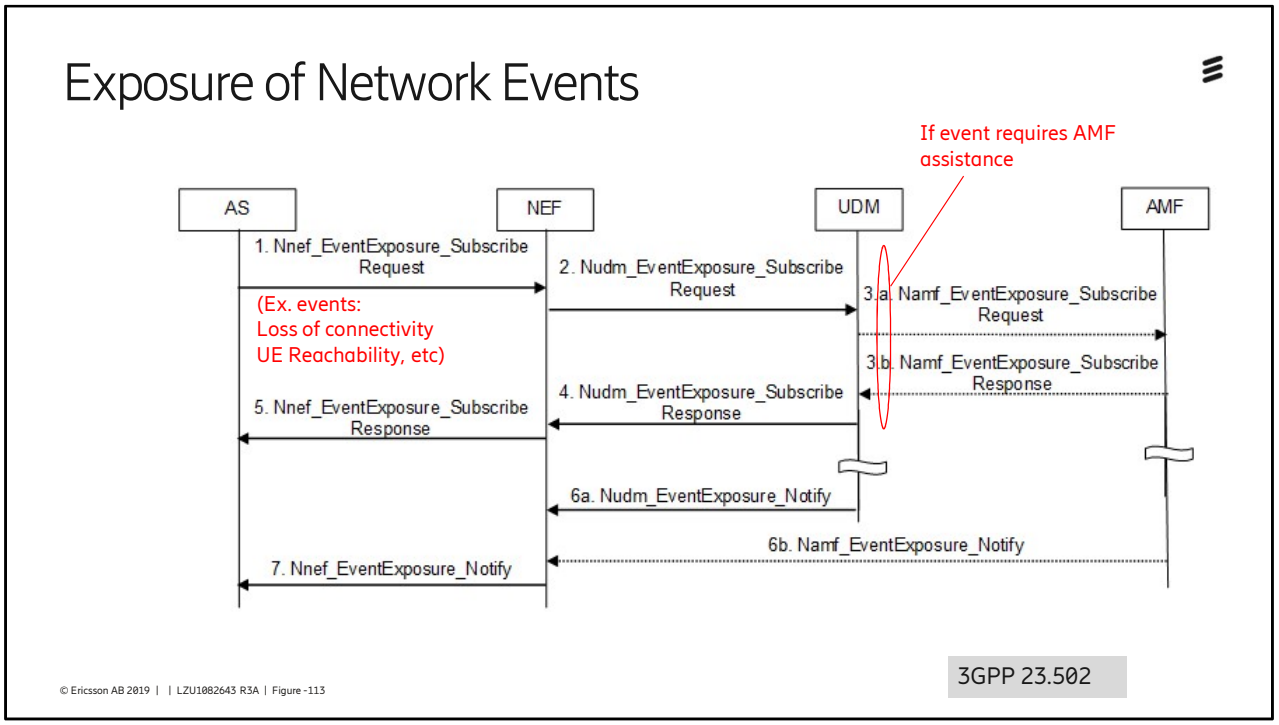
- NF Consumer discovers UDR instance
  - Utilizing NRF or locally configured
- Applicable for both 3GPP and non-3GPP access
- NF Consumer discovers & selects UDR based on:
  - SUPI or GPSI or External Group identifier
  - Data Set identifier, four exist in 3GPP R15:
    - Subscription Data
    - Policy Data
    - Data for Exposure
    - Application Data



Student Notes



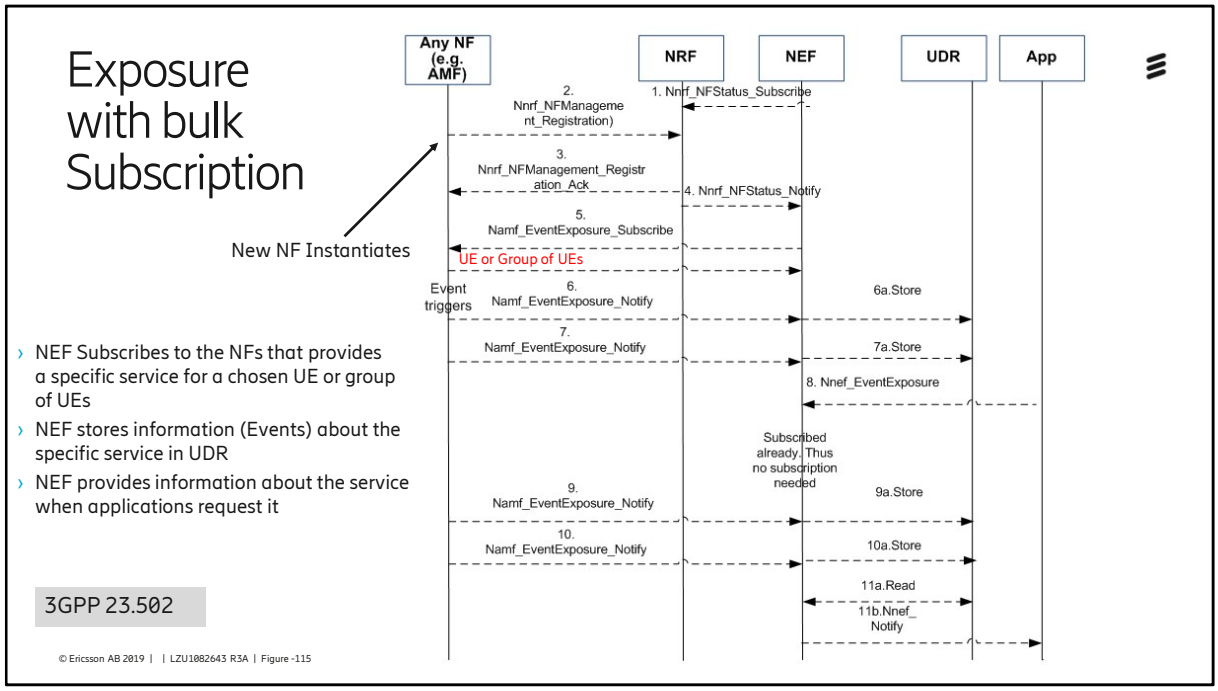
Student Notes



The Monitoring Events feature is intended for monitoring of specific events in 3GPP system and making such monitoring events information reported via the NEF. It is comprised of means that allow NFs in 5GS for configuring the specific events, the event detection, and the event reporting to the requested party.
The procedure is used by an AS to subscribe to notifications about specific network events such as i.e. loss of connectivity, UE reachability, roaming status, number of UEs present in a geographical area, etc.

1. The AS subscribes to one or several monitoring events and provides the associated notification endpoint of the AS by sending *Nnef_EventExposure_Subscribe* request. Reporting options defines the type of reporting requested (e.g. one-time reporting, periodic reporting or event based reporting, for Monitoring Events). If the reporting event subscription is authorized by the NEF, the NEF records the association of the event trigger and the requester identity.
2. The NEF subscribes to received Event(s) to UDM by sending *Nudm_EventExposure_Subscribe request*.
   If the reporting event subscription is authorized by the UDM, the UDM/AMF records the association of the event trigger and the requester identity. Otherwise, the UDM continues in step 4 indicating failure.
3. If the requested event (e.g. monitoring of Loss of Connectivity) requires AMF assistance, then the UDM sends the *Namf_EventExposure_Subscribe (3a)* to the AMF serving the requested user. AMF acknowledges the execution of *Namf_EventExposure_Subscribe (3b)*.

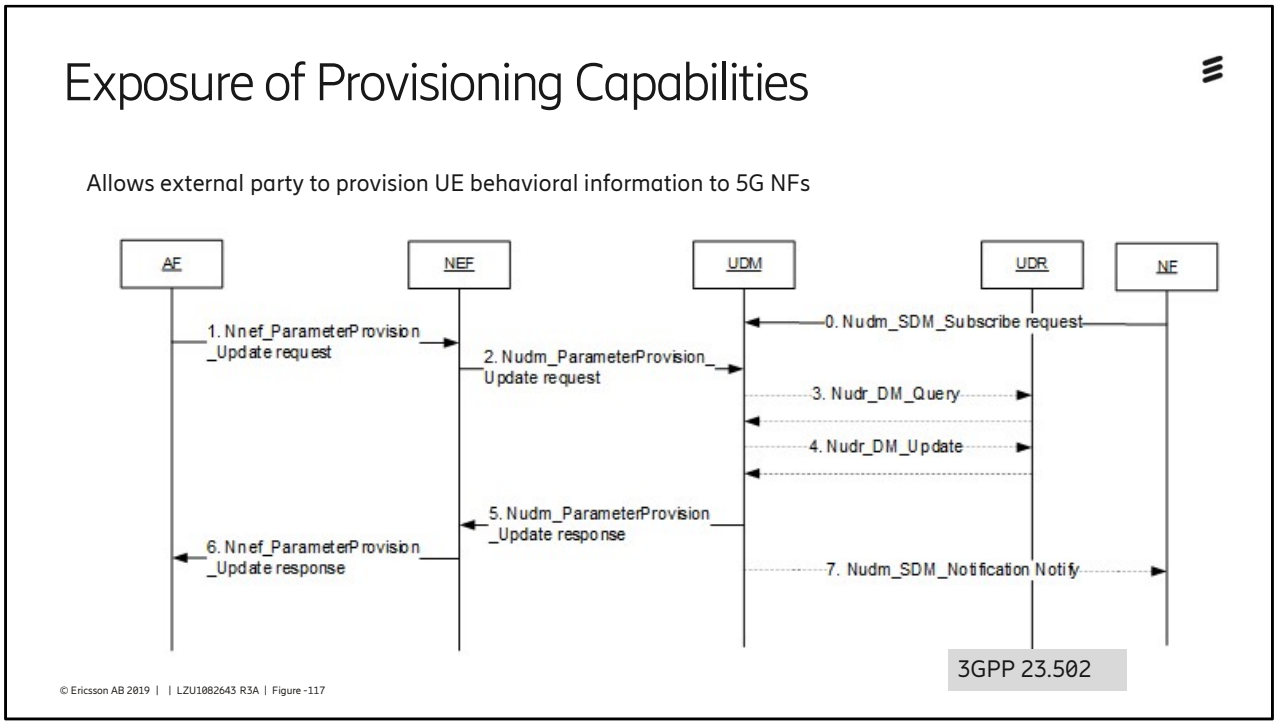
4. UDM acknowledges the execution of *Nudm_EventExposure_Subscribe*.
5. NEF acknowledges the execution of *Nnef_EventExposure_Subscribe* to the requester that initiated the request.
6. The UDM (depending on the Event) detects the event occurs and sends the event report, by means of *Nudm_EventExposure_Notify (6a)* message to the NEF, which has subscribed to the event before. The AMF detects the event occurs and sends the event report, by means of *Namf_EventExposure_Notify (6b)* message to the NEF, which has subscribed to the event before.
7. The NEF forwards to the AS the reporting event received by either *Nudm_EventExposure_Notify* and/or *Namf_EventExposure_Notify*.



Based on operator configuration NEF may perform bulk subscription with the NFs that provides necessary services. When the NEF performs bulk subscription (subscribes for any UE (i.e. all UEs), group of UE(s) (e.g. identifying a certain type of UEs such as IoT UEs)), it subscribes to all the NFs that provide the necessary services (e.g. In a given PLMN, NEF may subscribe to all AMFs that support reachability notification for IoT UEs), Upon receiving bulk subscription from the NEF, the NFs store this information. Whenever the corresponding event(s) occur for the requested UE(s) as in bulk subscription request, NFs notify the NEF with the requested information.
The call flow in the figure shows how network exposure can happen for one UE, groups of UE(s) (e.g. identifying a certain type of UEs such as IoT UEs) or any UE.

1. NEF registers with the NRF for any newly registered NF along with its NF services.
2. When an NF instantiates, it registers itself along with the supported NF services with the NRF.
3. NRF acknowledges the registration
4. NRF notifies the NEF with the newly registered NF along with the supported NF services.
5. NEF evaluates the NF and NF services supported against the pre-configured events within NEF. Based on that, NEF subscribes with the corresponding NF either for a single UE, group of UE(s) (e.g. identifying a certain type of UEs such as IoT UEs), any UE. NF acknowledges the subscription with the NEF.

6. (-7) When the event trigger happens, NF notifies the requested information towards NEF. NEF may store the information in the UDR.
8. Application registers with the NEF for a certain event identified by event filters.
9. (-10) When the event trigger happens, NF notifies the requested information towards NEF. NEF may store the information in the UDR.
11. (a-b) NEF reads from UDR and notifies the application for the corresponding subscribed events.



Provisioning capability allows an external party to provision the expected UE behavioral information to 5G network functions. The provisioning information consists of information on expected UE movement and communication characteristics. Provisioned data can be used by the other NFs.

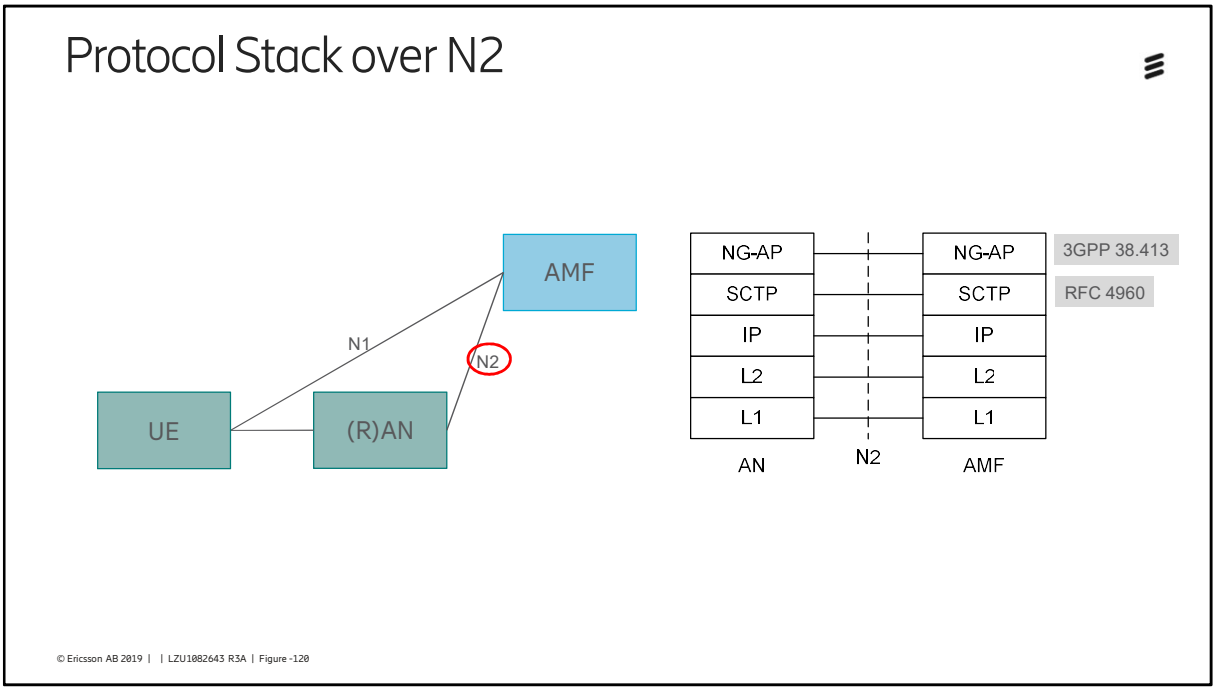
0. NF subscribes to UDM notifications of information updates.
1. An Application Function (AF) provides one or more parameter(s) to be updated in *Nnef_ParameterProvision_UpdateRequest* to the NEF. The Public User Id (PUI) identifies the UE and the Transaction Reference ID identifies the transaction request between NEF and AF.
2. If the AF is authorised by the NEF to provision the parameters, the NEF requests to update and store the provisioned parameters as part of the subscriber data via *Nudm_ParameterProvision_Update Request* message, the message includes the provisioned data and NEF reference ID. If the requester is not authorized to provision data, then the NEF continues in step 6 indicating the reason to failure in *Nnef_ParameterProvision_Update* response.
3. UDM may read from UDR, by means of *Nudr_DM_Query*, corresponding subscriber information in order to validate required data updates and authorize these changes for this subscriber for the corresponding AF.

4. If the AF is authorised by the UDM to provision the parameters for this subscriber, the UDM resolves the GPSI to SUPI, and requests to update and store the provisioned parameters as part of the subscriber data via *Nudr_DM_Update Request* message, the message includes the provisioned data.
   UDR stores the provisioned data as part of the subscription data and responds with *Nudr_DM_Update Response* message.
5. UDM responds the request with *Nudm_ParameterProvision_Update Response*. If the procedure failed, the cause value indicates the reason..
6. NEF responds the request with *Nnef_ParameterProvision_Update Response*. If the procedure failed, the cause value indicates the reason.
7. UDM notifies the subscribed Network Function (e.g., AMF) of the updated subscriber data via *Nudm_SDM_Notification Notify* message.

5G Core Protocols and Procedures

3.2 N1 and N2

Student Notes



Student Notes

Procedures defined over N2

- Procedures related with N2 **Interface management** (not related to an individual UE)
- Procedures related to an individual UE:
  - Procedures related to **NAS Transport management**
  - Procedures related to **UE Context management**
  - Procedures related to **PDU Session Resource management**
  - Procedures related to **Mobility management**
- Two Types of Elementary Procedures (EPs)
  - Class 1 – With response (success and/or failure)
  - Class 2 – Without response

Student Notes

NG-AP Elementary Procedures, class 1(1/2)

Elementary Procedure	Initiating Message	Successful Outcome Response message	Unsuccessful Outcome Response message	
AMF Configuration Update	AMF CONFIGURATION UPDATE	AMF CONFIGURATION UPDATE ACKNOWLEDGE	AMF CONFIGURATION UPDATE FAILURE	NG Interface Management procedures
RAN Configuration Update	RAN CONFIGURATION UPDATE	RAN CONFIGURATION UPDATE ACKNOWLEDGE	RAN CONFIGURATION UPDATE FAILURE	
NG Reset	NG RESET	NG RESET ACKNOWLEDGE		
NG Setup	NG SETUP REQUEST	NG SETUP RESPONSE	NG SETUP FAILURE	
Handover Preparation	HANDOVER REQUIRED	HANDOVER COMMAND	HANDOVER PREPARATION FAILURE	UE Mobility Management procedures
Handover Resource Allocation	HANDOVER REQUEST	HANDOVER REQUEST ACKNOWLEDGE	HANDOVER FAILURE	
Handover Cancellation	HANDOVER CANCEL	HANDOVER CANCEL ACKNOWLEDGE		
Path Switch Request	PATH SWITCH REQUEST	PATH SWITCH REQUEST ACKNOWLEDGE	PATH SWITCH REQUEST FAILURE	

Student Notes

NG-AP Elementary Procedures, class 1(2/2)

Elementary Procedure	Initiating Message	Successful Outcome Response message	Unsuccessful Outcome Response message
PDU Session Resource Modify	PDU SESSION RESOURCE MODIFY REQUEST	PDU SESSION RESOURCE MODIFY RESPONSE	
PDU Session Resource Modify Indication	PDU SESSION RESOURCE MODIFY INDICATION	PDU SESSION RESOURCE MODIFY CONFIRM	
PDU Session Resource Release	PDU SESSION RESOURCE RELEASE COMMAND	PDU SESSION RESOURCE RELEASE RESPONSE	
PDU Session Resource Setup	PDU SESSION RESOURCE SETUP REQUEST	PDU SESSION RESOURCE SETUP RESPONSE	
UE Context Modification	UE CONTEXT MODIFICATION REQUEST	UE CONTEXT MODIFICATION RESPONSE	UE CONTEXT MODIFICATION FAILURE
UE Context Release	UE CONTEXT RELEASE COMMAND	UE CONTEXT RELEASE COMPLETE	
Initial Context Setup	INITIAL CONTEXT SETUP REQUEST	INITIAL CONTEXT SETUP RESPONSE	INITIAL CONTEXT SETUP FAILURE

PDU Session Management procedures

UE Context management procedures

Student Notes

NG-AP Elementary Procedures, Class 2

Configuration Transfer procedures

UE Mobility Management procedures

Paging procedure

PDU Session Management procedures

Elementary Procedure	Message
Downlink RAN Configuration Transfer	DOWNLINK RAN CONFIGURATION TRANSFER
Downlink RAN Status Transfer	DOWNLINK RAN STATUS TRANSFER
Downlink NAS Transport	DOWNLINK NAS TRANSPORT
Error Indication	ERROR INDICATION
Uplink RAN Configuration Transfer	UPLINK RAN CONFIGURATION TRANSFER
Uplink RAN Status Transfer	UPLINK RAN STATUS TRANSFER
Handover Notification	HANDOVER NOTIFY
Initial UE Message	INITIAL UE MESSAGE
NAS Non Delivery Indication	NAS NON DELIVERY INDICATION
Paging	PAGING
PDU Session Resource Notify	PDU SESSION RESOURCE NOTIFY
Reroute NAS Request	REROUTE NAS REQUEST
UE Context Release Request	UE CONTEXT RELEASE REQUEST
Uplink NAS Transport	UPLINK NAS TRANSPORT
AMF Status Indication	AMF STATUS INDICATION

NG Interface Management procedures

NAS Transport procedures

UE Context management procedures

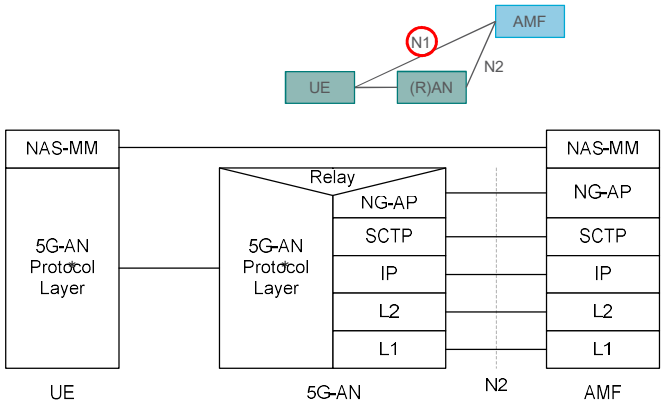
Student Notes

N1: NAS-MM

Supports

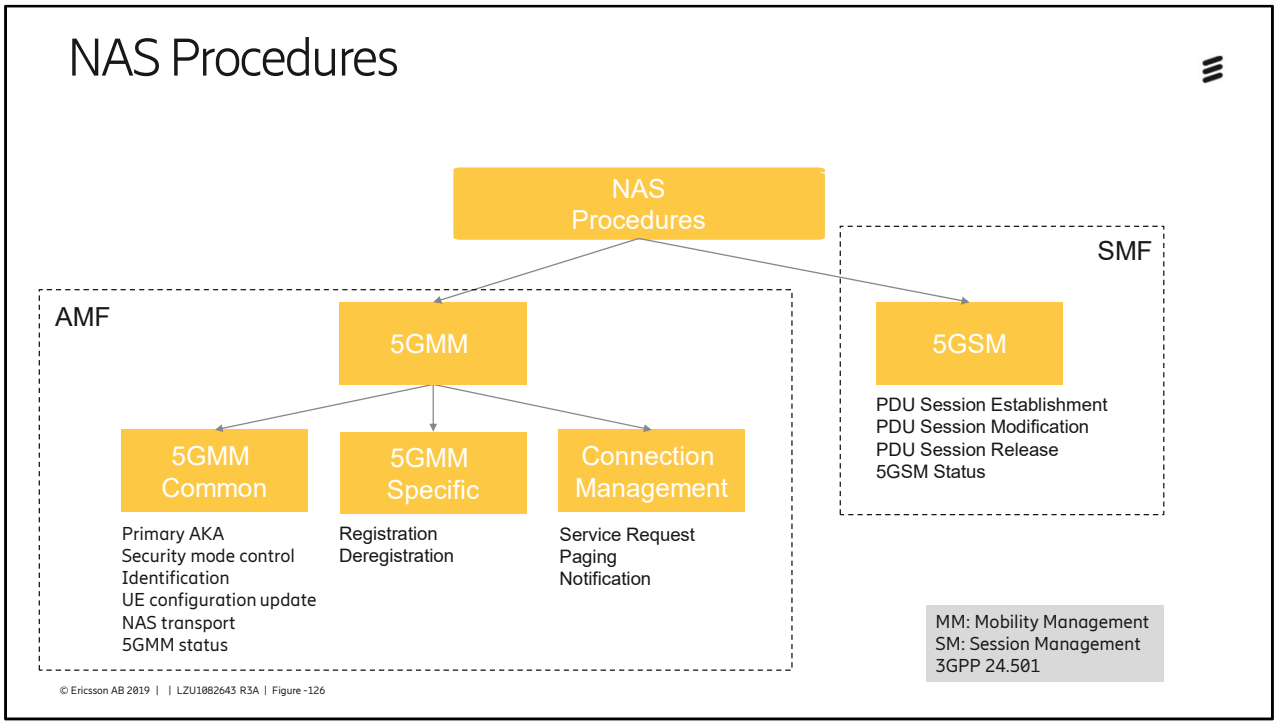
- registration management
- connection management
- user plane connection activation and deactivation

Responsible for ciphering and integrity protection of NAS signaling

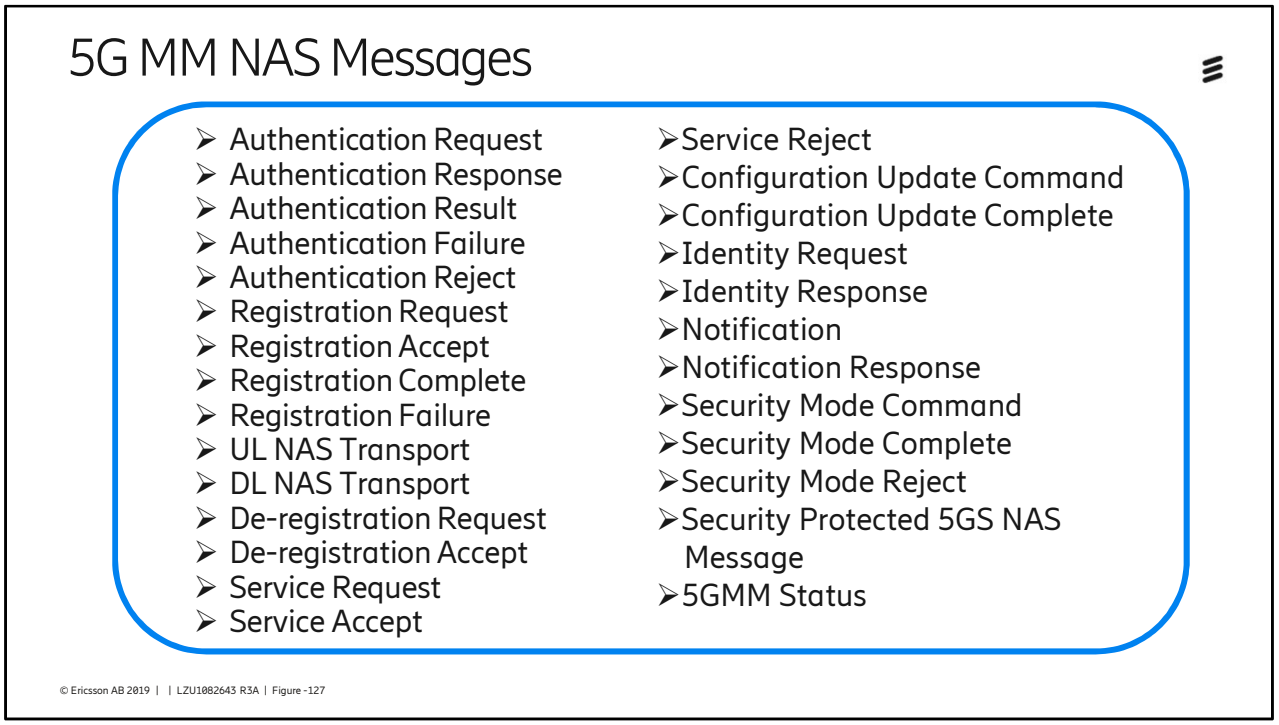


* This set of protocols/layers depends on the 5G-AN.

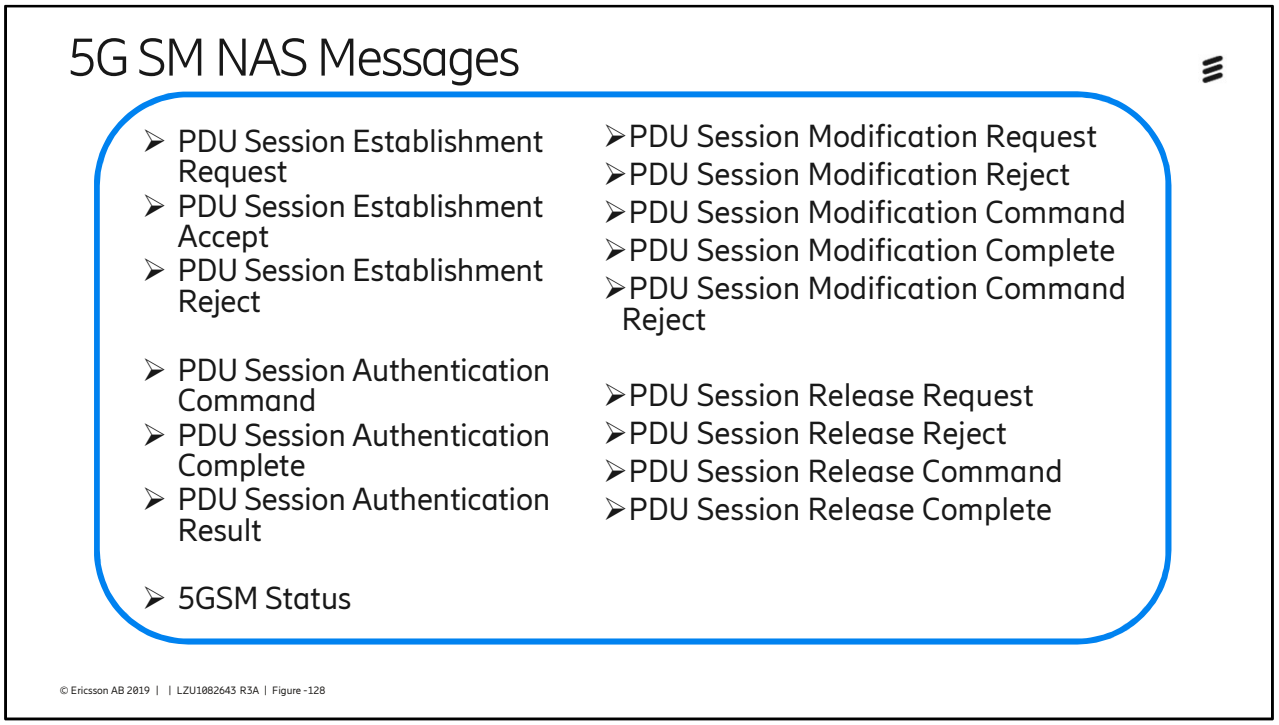
Student Notes



Student Notes



Student Notes

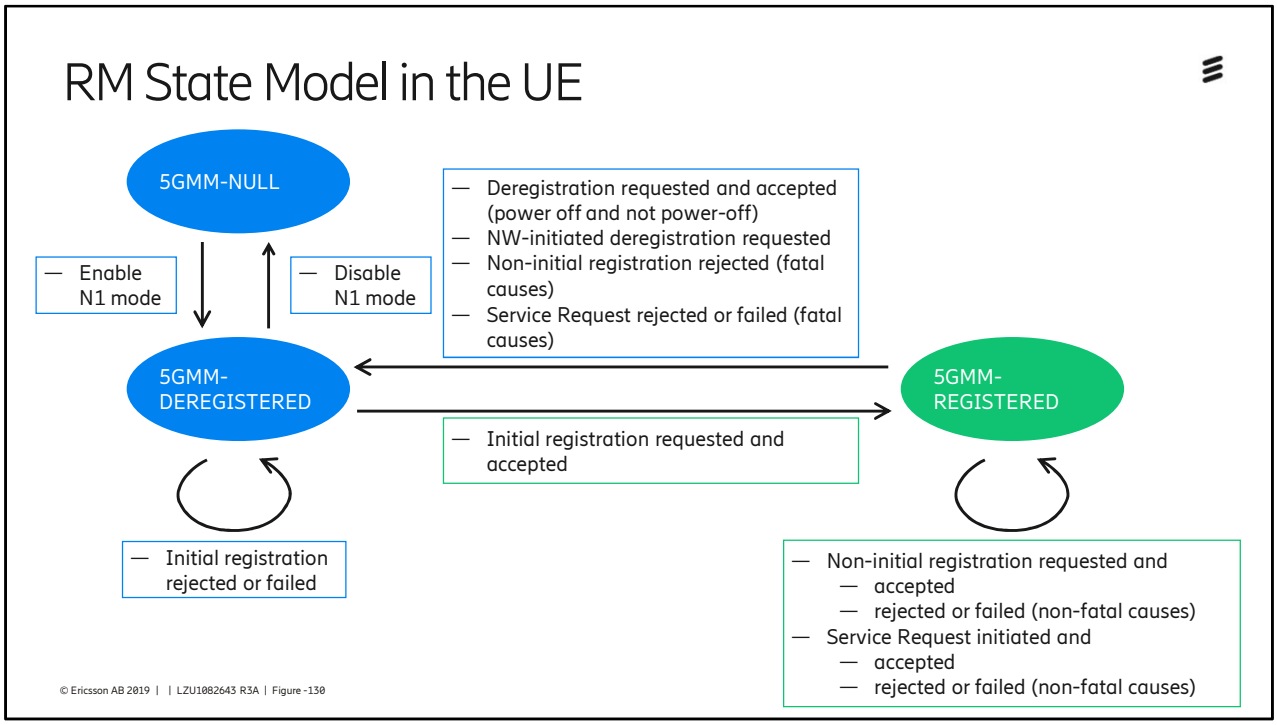


Student Notes

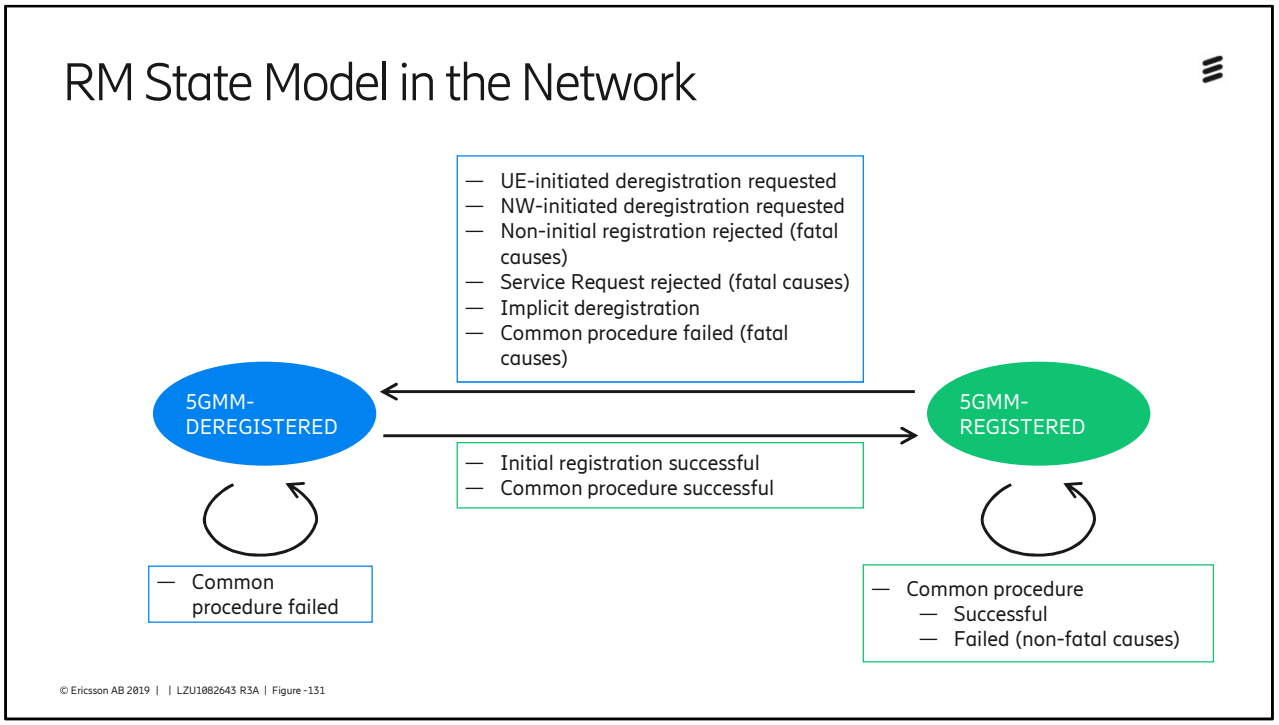
Registration Management (RM)

- Registration Management:
  - Used to register and de-register UE/user with network
  - Establish user context in network
  - **Initial Registration** procedure involves:
    - User authentication and access authorization based on subscription profiles in UDM
    - Result of procedure serving AMF registered in UDM
  - Once registered UE updates its registration with network:
    - Periodically (**Periodic Registration Update**)
    - Upon mobility events (**Mobility Registration Update**)
    - To update its capabilities or re-negotiate protocol parameters (**Mobility Registration Update**)
  - UE in Limited Service State
    - **Emergency Registration**
  - Applicable over both 3GPP and non 3GPP access

Student Notes



Student Notes



Student Notes

UE context in AMF (1/3) – General

Field	Description
SUPI	SUPI (Subscription Permanent Identifier) is the subscriber's permanent identity in 5GS.
SUPI-unauthenticated indicator	This indicates whether the SUPI is unauthorized.
GPSI	The GPSI(s) of the UE. The presence is dictated by its storage in the UDM.
5G-GUTI	5G Globally Unique Temporary Identifier
PEI	Mobile Equipment Identity
Internal Group ID-list	List of the subscribed internal group(s) that the UE belongs to.
UE Specific DRX Parameters	UE specific DRX parameters
UE Network Capability	Indicates the UE network capabilities
Events Subscription	List of the events subscriptions by other CP NFs. Indicating the events being subscribed as well as any information on how to send the corresponding notificators.
AM Policy Information	Information on AM policy provided by PCF.
Subscribed RFSP Index	An index to specific RRM configuration in the RAN that is received from the UDM.
RFSP Index in Use	An index to specific RRM configuration in the RAN that is currently in use.
MICO Mode Indication	Indicates the MICO Mode for the UE.
Voice Support Match Indicator	An indication whether the UE radio capabilities are compatible with the network configuration. The AMF uses it as an input for setting the IMS voice over PS Session Supported Indication.
UE Radio Capability for Paging Information	Information used by the RAN to enhance the paging towards the UE (see clause 5.4.4.1 of TS 23.501 [2]).
Information on Recommended Cells and RAN nodes For Paging	Information sent by the NG RAN, and used by the AMF when paging the UE to help determining the NG RAN nodes to be paged as well as to provide the information on recommended cells to each of the RAN nodes, in order to optimize the probability of successful paging while minimizing the signalling load on the radio path.
SMSF Identifier	The identifier of the SMSF serving the UE in RM-REGISTERED state.
SMS Supported	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.
SEAF data	Master security information received from AUSF.

This figure describes the general parameters for the UE context in the AMF.

MICO: Mobile Initiated Connection Only
RFSP: RAT Frequency Selection Priority
RRM: Radio Resource Management
SEAF: Security Anchor Function
SMSF: SMS Function

UE context in AMF (2/3) – per access type

For each access type level context within the UE access and mobility context:	
Access Type	Indicates the access type for this context.
RM State	Registration management state.
Registration Area	Current Registration Area (a set of tracking areas in TAI List).
TAI of last Registration Update	TAI of the TA in which the last registration request was initiated.
User Location Information	Information on user location.
Mobility Restrictions	Mobility Restrictions restrict mobility handling or service access of a UE in the 5G System. It consists of RAT restriction, Forbidden area, Service area restrictions and Core Network type restriction.
Security Information for CP	As defined in TS 33.501.
Security Information for UP	As defined in TS 33.501.
Allowed NSSAI	Allowed NSSAI consisting of one or more S-NSSAIs for serving PLMN in the present Registration area.
Network Slice Instance (S)	The Network Slice Instance selected by 5GC for this UE.

Student Notes

UE Context in AMF (3/3) – per PDU Session

For each PDU Session level context:	
S-NSSAI	The associated S-NSSAI for the PDU Session
Network Slice Instance id	The network Slice Instance information for the PDU Session
PDU Session ID	The identifier of the PDU Session
SMF addressing information	The associated SMF for the PDU Session
Access Type	The current access type for this PDU session

Student Notes

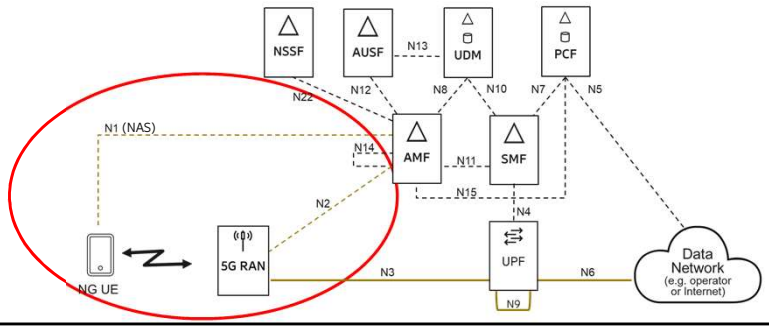
UE Registered over both 3GPP and Non 3GPP access

- AMF associates multiple access-specific RM contexts for UE with
  - Common globally unique Temporary Identifier for 3GPP and Non-3GPP access
  - Registration state per access type (3GPP/Non-3GPP)
  - Registration Areas (RA) per access type
  - Periodic registration timer for 3GPP access
- UE not perform periodic registration update over non-3GPP access
- Temporary Identifier only be used if both accesses in same PLMN
  - UE registered via 3GPP access and selects N3IWF in same PLMN
- Deregistration indication:
  - All accesses or only access over which procedure is run

Student Notes

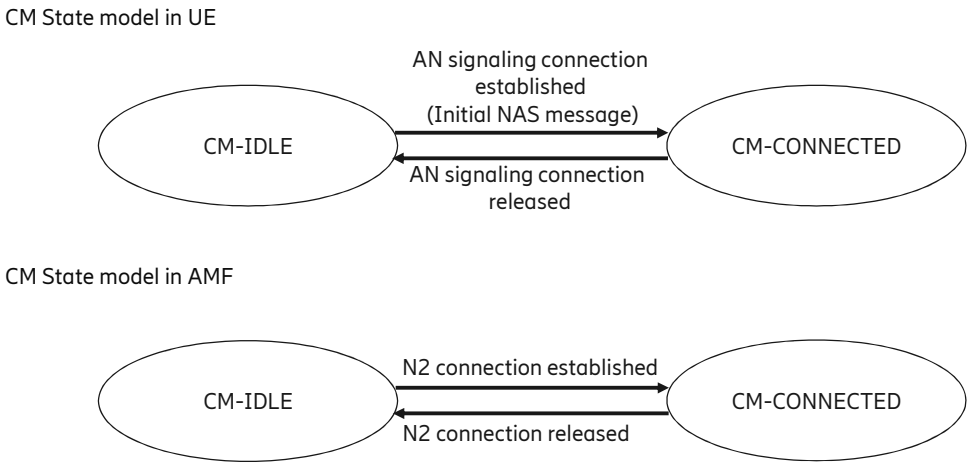
Connection Management (CM)

- Connection Management:
  - Includes functions of establishing and releasing signaling connection between UE and AMF over N1
    - Used to enable NAS signaling between UE and core network
    - Includes signaling connection between UE and AN
    - Includes N2 connection for UE between AN and AMF



Student Notes

5GS CM State models



Student Notes

UE connected over both 3GPP and Non 3GPP access

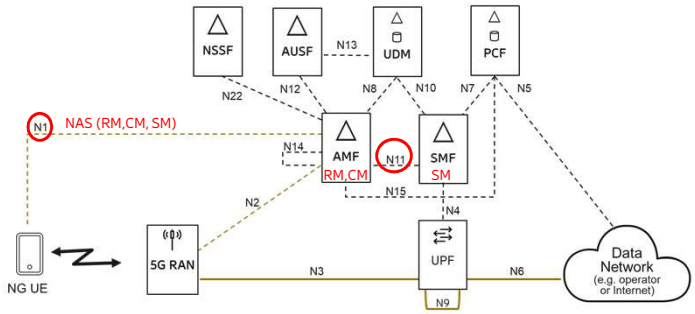
- AMF manages two CM states for UE:
  - CM state for 3GPP access
  - CM state for Non-3GPP access

- UE connected over both 3GPP and Non-3GPP access has two N2 interfaces
  - UE be in any combination of CM states between 3GPP and Non-3GPP access
    - Access1: CM-IDLE Access2: CM-CONNECTED
    - Access1: CM-CONNECTED Access2: CM-IDLE
    - Access1: CM-IDLE Access2: CM-IDLE
    - Access1: CM-CONNECTED Access2: CM-CONNECTED

Student Notes

AMF and SMF Interaction (N1&N11)

- Single N1 NAS used for MM (RM & CM) and SM-related procedures for UE
- AMF handles NAS-MM
- SMF handles NAS-SM
- AMF forwards NAS-SM to SMF (N11)
- SMF indicates to AMF if UP session is released
- Upon successful UP session establishment:
  - AMF stores UE-id and serving SMF-id
  - SMF stores UE-id and serving AMF-id

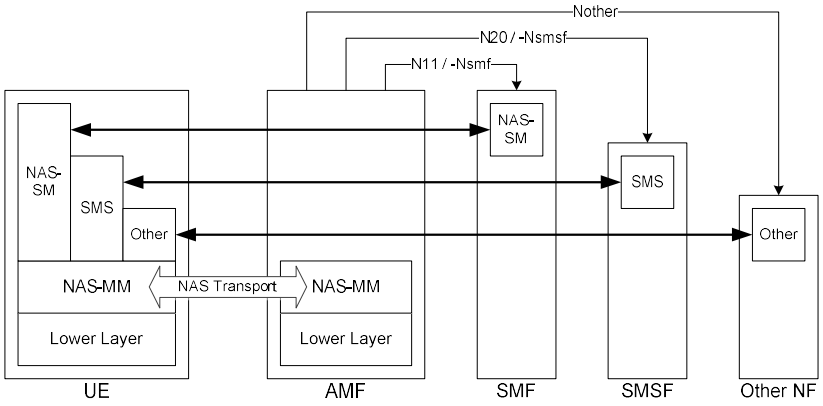


RM – Registration Management
CM – Connection Management
MM – Mobility Management
SM – Session Management

Student Notes

N1: NAS-SM and SMS

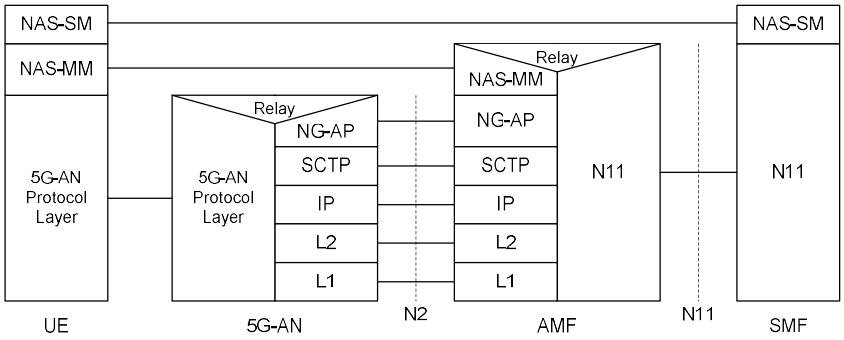
— Protocols needed to be transported between UE and core network function (non-AMF) over N1 via NAS-MM



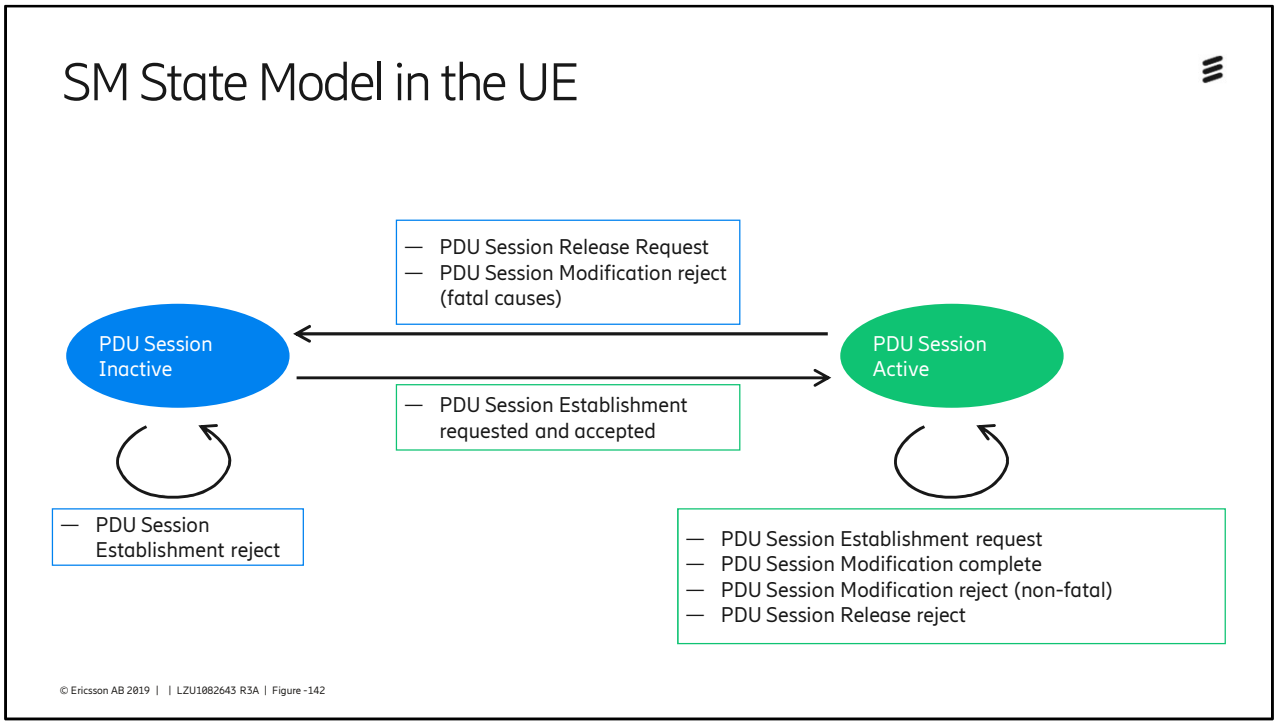
Student Notes

N1: NAS-SM

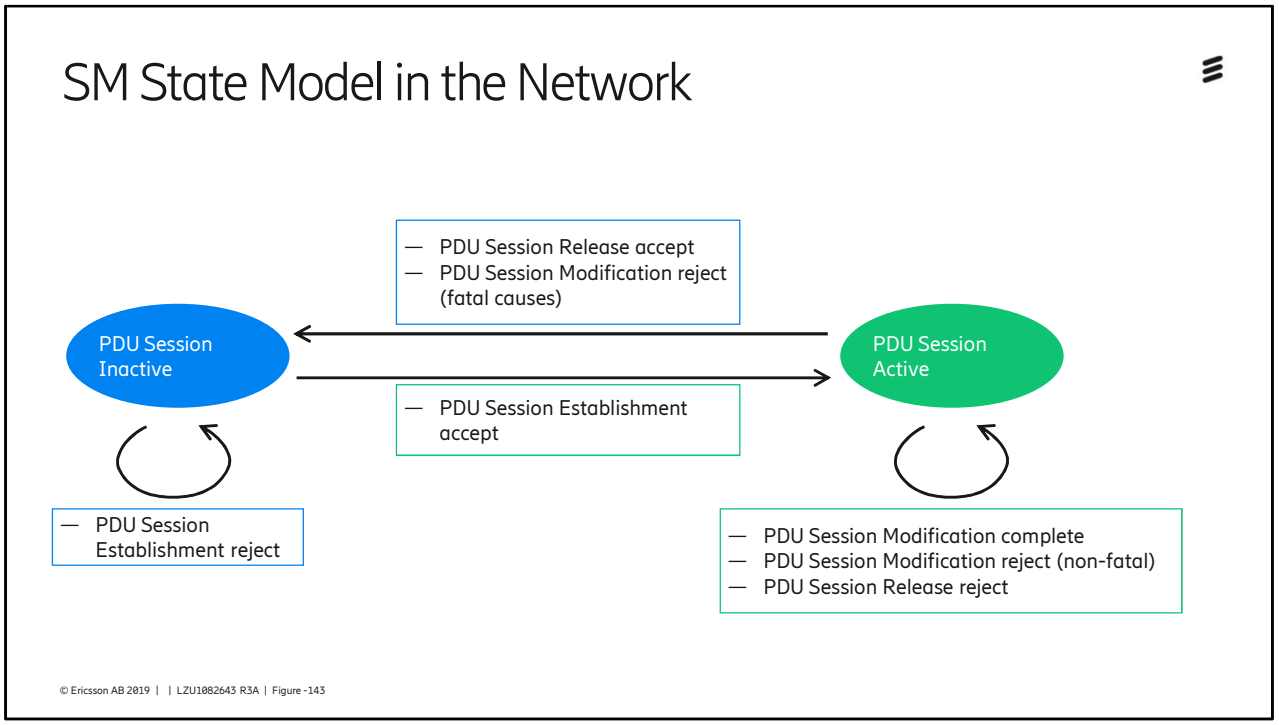
— Supports handling of Session management between UE and SMF
— SM signaling message handled in NAS-SM layer of UE and SMF. Content of message not interpreted by AMF.



Student Notes



Student Notes



Student Notes

Session Management Concepts

- Local Area Data Network
  - DN accessible by UE only specific locations that provides connectivity to specific DNN
- Service Continuity
  - Uninterrupted user experience of service, including cases where IP address and/or anchoring point changes
- Session Continuity
  - Continuity of PDU session. For PDU session of IP type, "session continuity" implies IP address preserved for PDU sessions lifetime
- PDU Session Anchor
  - UP function providing interface to DN

Student Notes

Session Management Subscription Data

Data needed for PDU session establishment

Data Structure
- 5GS: Subscriber → Slice level → DNN level
- EPS: Subscriber → APN-level

Session Management Subscription data contains one or more S-NSSAI level subscription data:	
S-NSSAI	Indicates the value of the S-NSSAI.
Subscribed DNN list	List of the subscribed DNNs for the S-NSSAI.
For each DNN in S-NSSAI level subscription data:	
DNN	DNN for the PDU Session.
UE Address	Indicates the subscribed static IP address(es) for the IPv4 or IPv6 or IPv4v6 type PDU Sessions accessing the DNN, S-NSSAI.
Allowed PDU Session Types	Indicates the allowed PDU Session Types (IPv4, IPv6, IPv4v6, Ethernet, and Unstructured) for the DNN, S-NSSAI.
Default PDU Session Type	Indicates the default PDU Session Type for the DNN, S-NSSAI.
Allowed SSC modes	Indicates the allowed SSC modes for the DNN, S-NSSAI.
Default SSC mode	Indicate the default SSC mode for the DNN, S-NSSAI.
Interworking with EPS indication	Indicates whether interworking with EPS is supported for this DNN and S-NSSAI.
5GS Subscribed QoS profile	The QoS Flow level QoS parameter values (5QI and ARP) for the DNN, S-NSSAI.
Charging Characteristics	This information is defined in TS 32.240; it may e.g. contain information on how to contact the Charging Function. This information, when provided shall override any corresponding predefined information at the SMF
Subscribed-Session-AMBR	The maximum aggregated uplink and downlink MBRs to be shared across all Non-GBR QoS Flows in each PDU Session, which are established for the DNN, S-NSSAI.
Static IP address/prefix	Indicate the static IP address/prefix for the DNN, S-NSSAI.
User Plane Security Policy	Indicates the security policy for integrity protection and encryption for the user plane.

Student Notes

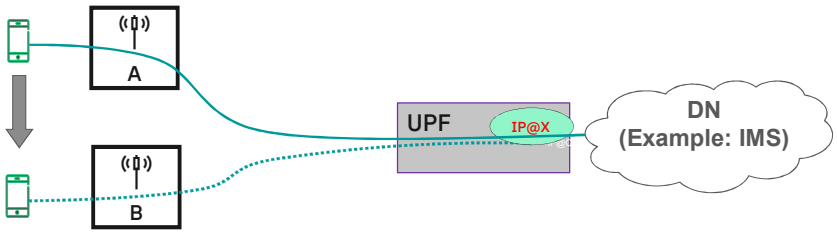
Session and Service Continuity (SSC)

- Session and Service Continuity (SSC) mode
  - SSC mode associated with PDU sessions lifetime
    - Meets various continuity requirements
  - Three types of SSC mode:
    - SSC mode 1
    - SSC mode 2
    - SSC mode 3

Student Notes

SSC Mode 1

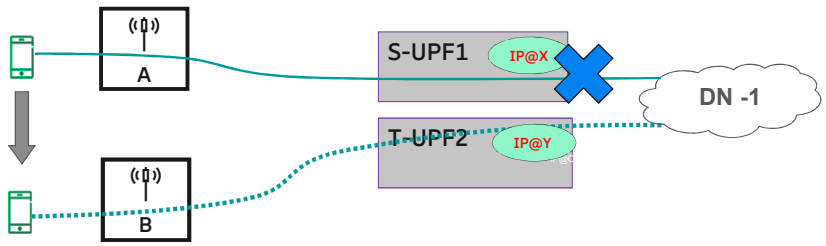
- SSC Mode 1 (keep PDU session)
  - UPF acting as PDU session anchor at PDU session establishment, maintained regardless of access technology
  - IP continuity supported regardless of UE mobility events



Student Notes

SSC Mode 2

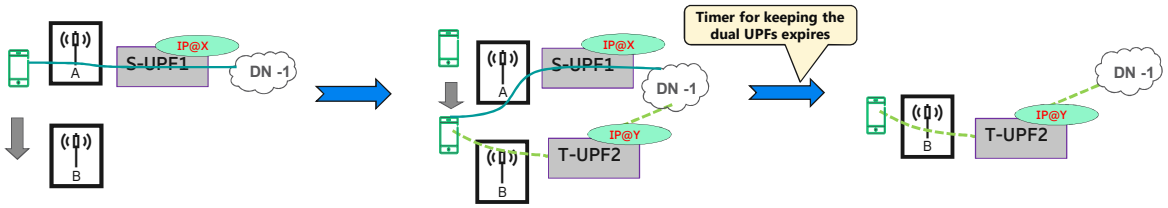
- SSC Mode 2 *(Break before make; new PDU session)*
  - Network trigger release of PDU session, instruct UE to establish new PDU session to same data network immediately
    - Establishment of new PDU Session, new UPF (anchoring point) selected based on UE mobility, local policy (e.g. info of serving area of assigned target UPF)
    - IP continuity not supported, different IP assigned for target UPF



Student Notes

SSC Mode 3

- SSC Mode 3 *(Make before break; keep PDU session)*
  - Allows establishment of UE connectivity via new target UPF (anchoring point) before previous serving UPF released
  - When trigger conditions apply network decides whether to select UPF suitable for UEs new conditions (e.g. network attachment point)
  - IP continuity not supported, different IP assigned for target UPF



Student Notes

SSC mode selection

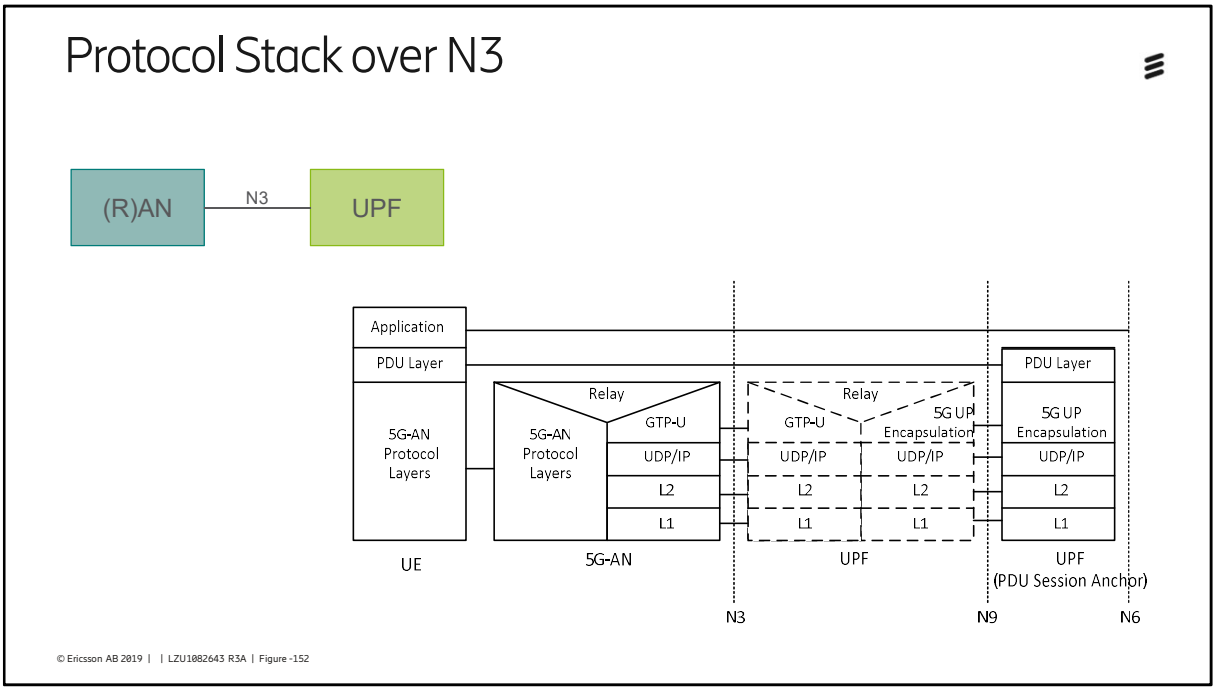
- UE provisioned with one or more SSC mode selection policy rules
  - UE can determine SSC mode associated with an application(s)
  - Policy may include default SSC mode selection policy matching all UE applications
- SMF receives list from UDM of supported SSC modes and default SSC mode per DNN as part of subscription information
- SMF selects SSC mode by either accepting requested SSC mode from UE or modifying SSC mode based on subscription information
- SMF informs UE of selected SSC mode for PDU Session

Student Notes

5G Core Protocols and Procedures

3.3 N3

Student Notes



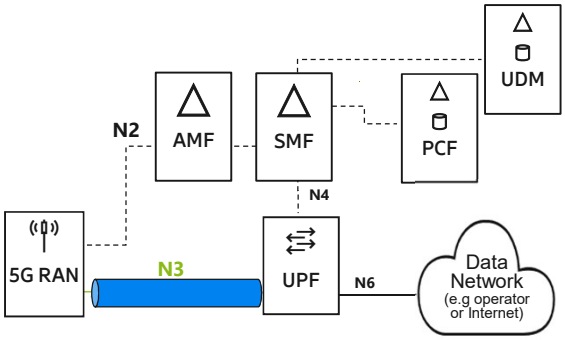
Student Notes

User Plane Tunneling

UP tunneling between RAN and UPF used to handle mobility, different PDU types, etc.

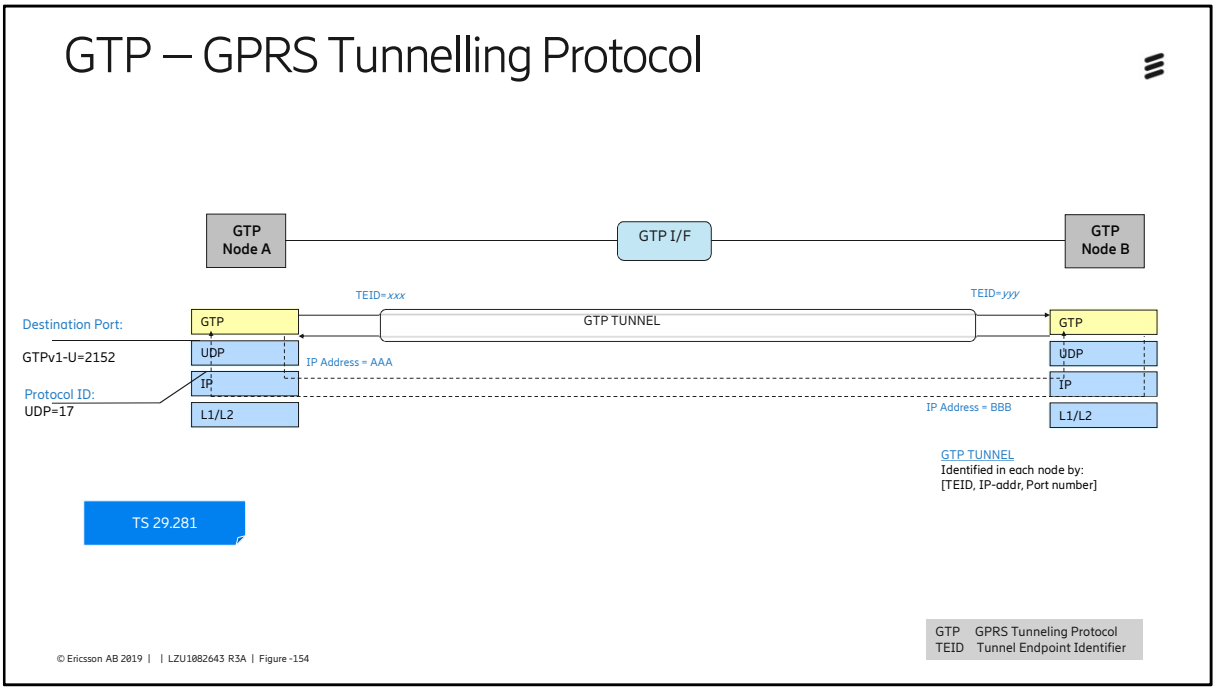
- Per-PDU-Session tunneling preferred (i.e. per-bearer tunneling not supported)
- UP tunneling protocol for N3 is GTP-U

Additional UP options been discussed in 3GPP, e.g. for fixed access, but not included in phase 1.



GTP – GPRS Tunneling Protocol

Student Notes



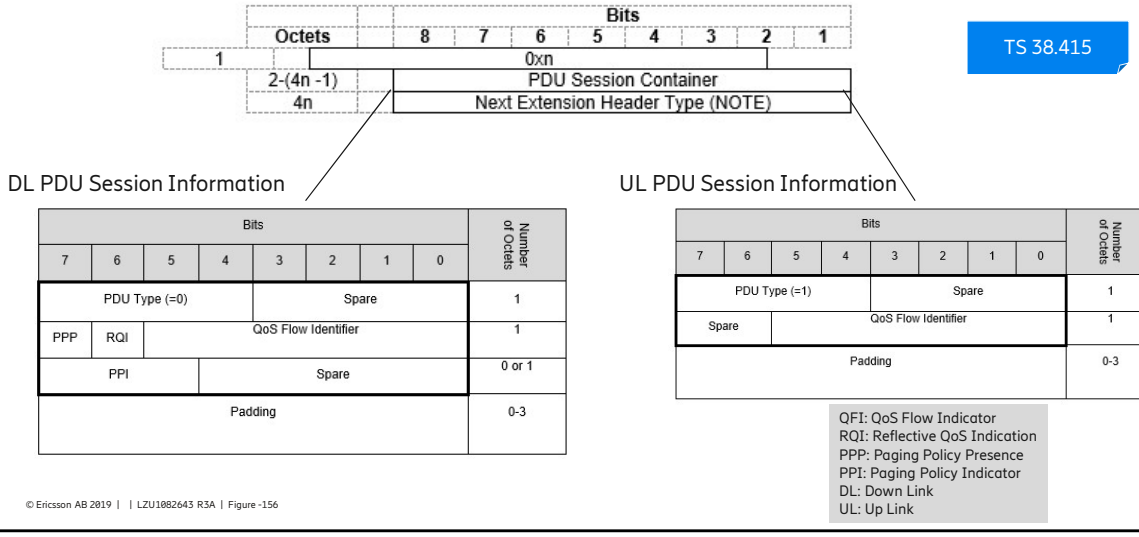
Student Notes

GTPv1 Headers

Octets	Bits 8	7	6	5	4	3	2	1
1	Version			PT	Res.	E	S	PN
2	Message Type							
3	Length (1st Octet)							
4	Length (2nd Octet)							
5	Tunnel Endpoint Identifier (1st Octet)							
6	Tunnel Endpoint Identifier (2nd Octet)							
7	Tunnel Endpoint Identifier (3rd Octet)							
8	Tunnel Endpoint Identifier (4th Octet)							
9	Sequence Number (1st Octet)							
10	Sequence Number (2nd Octet)							
11	N-PDU Number							
12	Next Extension Header							

Student Notes

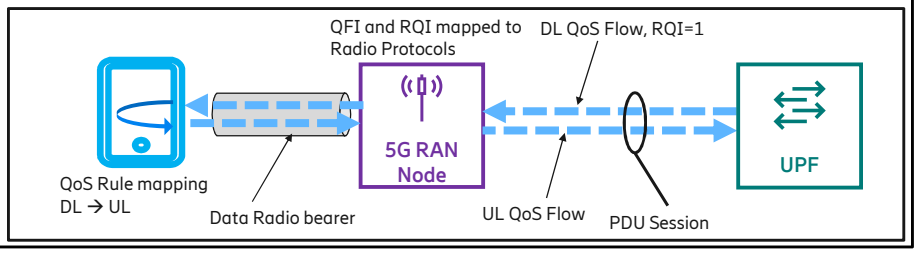
Extension Header for 5GS – PDU Session Container



Student Notes

Reflective QoS

- Enables UE to map UL User Plane traffic to QoS Flows without SMF provided QoS rules.
- UE derives the UL QoS rules based on the received DL traffic
- UE should indicate support of Reflective QoS for every PDU session towards SMF
- Derived UL QoS rule contains:
  - UL Packet Filter – derived from DL Packet Filter
  - QFI – same as for DL Packet
  - Precedence value for the QoS rule
- Controlled on per-packet basis using the Reflective QoS Indication (RQI) over N3 signaled in GTP-U.



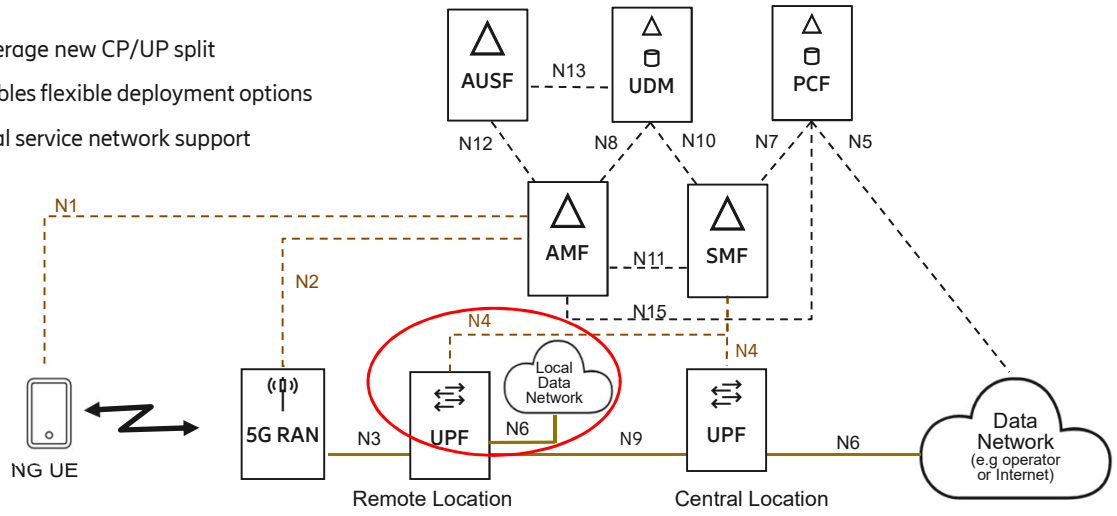
Student Notes

Distributed UPFs in serial

Leverage new CP/UP split

Enables flexible deployment options

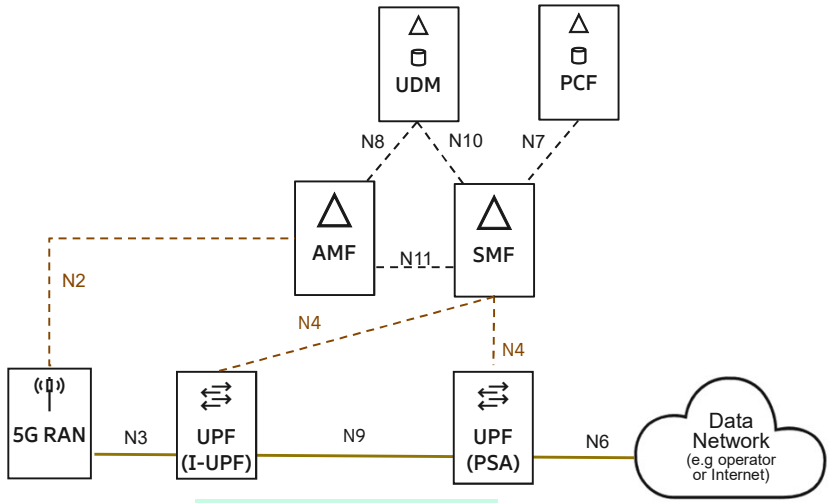
Local service network support



Student Notes

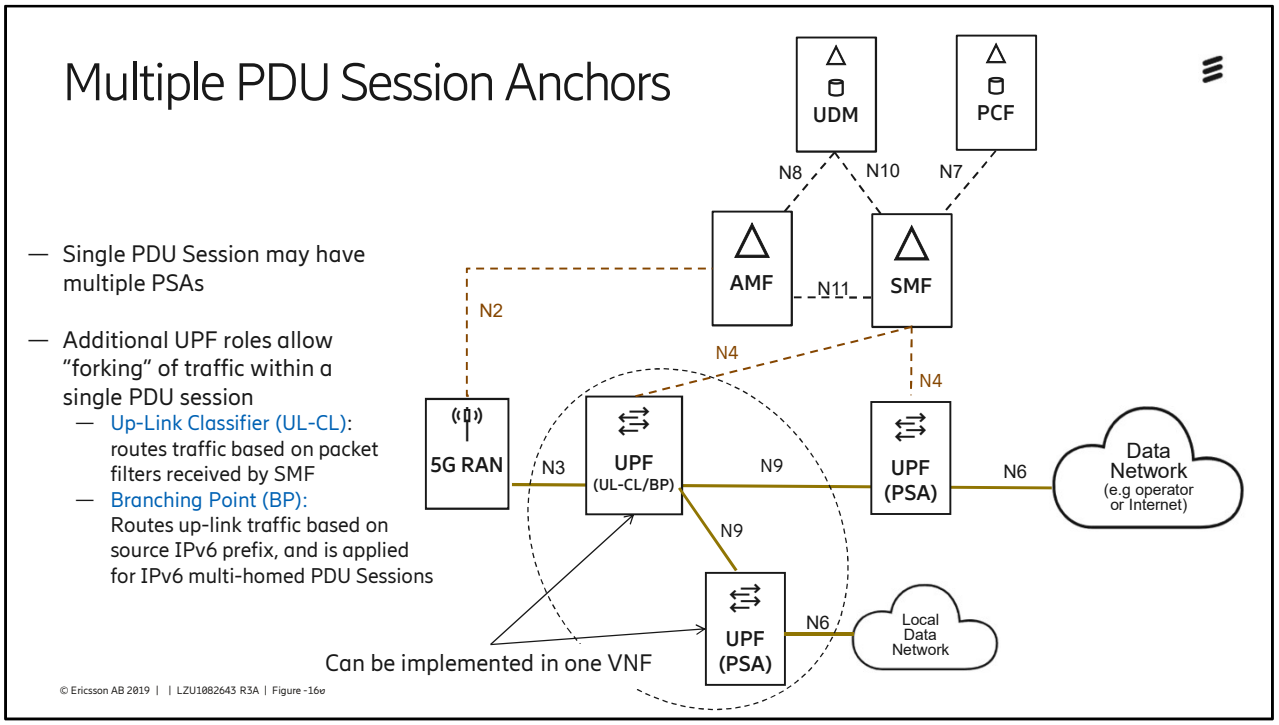
UPF Chaining

- SMF may chain multiple UPFs to build the UP path
  - N9 is the UP inteface between UPFs
- Each UPF may act in different roles for a PDU Session, e.g.:
  - PDU Session Anchor (PSA): UPF with the N6 interface to the data network
  - Intermediate UPF (I-UPF): A UPF that has been inserted between RAN and a PSA
- I-UPF is needed when UE move location and current RAN node cannot connect to UPF/PSA
  - SGW relocation in EPC



Example with two UPFs

Student Notes



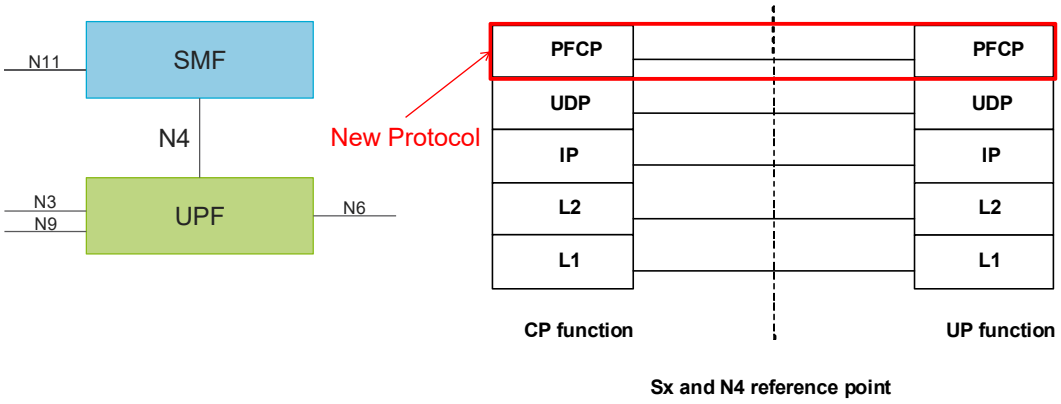
Student Notes

5G Core Protocols and Procedures

3.4 N4

Student Notes

Protocol Stack over N4



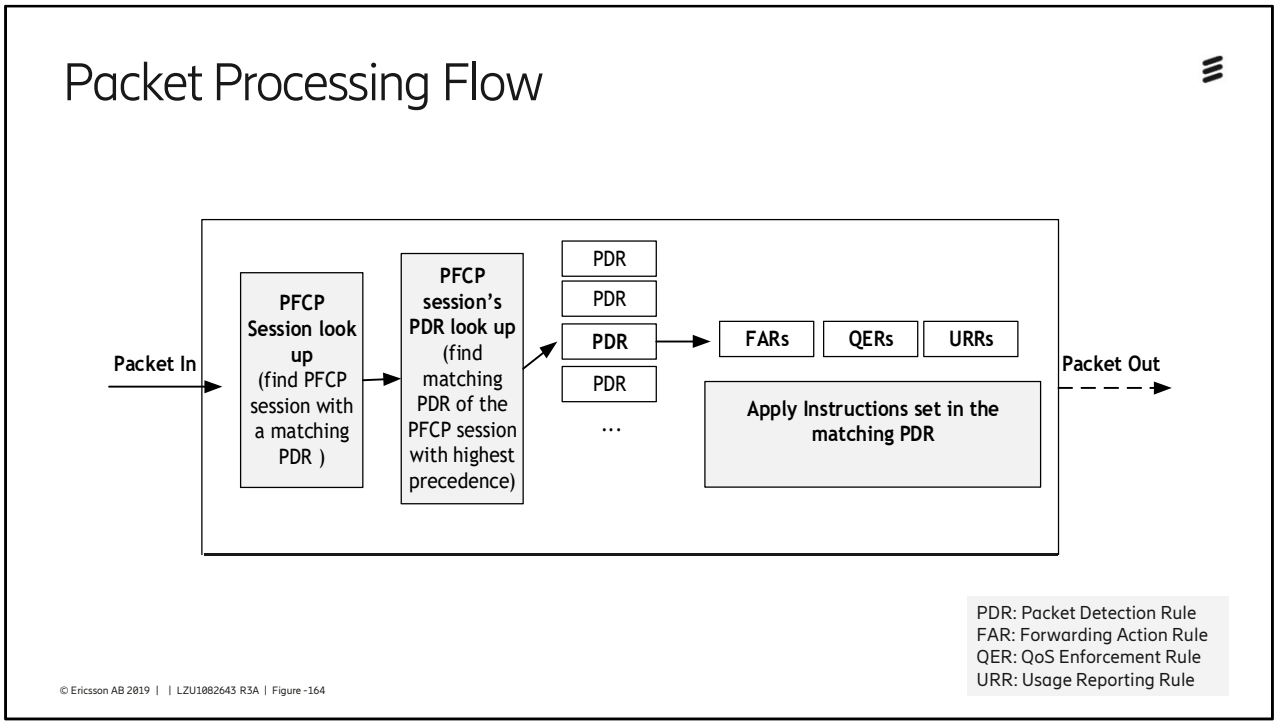
PFCP: Packet Forwarding Control Protocol
3GPP TS 29.244

Student Notes

PFCP Session Contexts

- CP function controls packet processing in UP function by
  1. establishing, modifying or deleting PFCP Session contexts
  2. provisioning (per PFCP session context)
     - PDRs (Packet Detection Rules)
     - FARs (Forwarding Action Rules)
     - QERs (QoS Enforcement Rules)
     - URRs (Usage Reporting Rules) and/or BAR (Buffering Action Rule)
- In 5GC, PFCP session context corresponds to
  - individual PDU session
  - standalone PFCP session (not tied to any PDU session)

Student Notes



Student Notes

Forwarding Action Rule (FAR) Handling

- CP function provision only one FAR for each PDR provisioned in PFCP session
- FAR provides instructions to UP function how to process packets matching PDR
- Setting flag(s) in Apply Action IE in FAR, CP function request UP function to:
  - Drop packets (DROP flag)
  - Forward packets (FORW flag)
  - Buffer downlink packets (BUFF flag)
  - Notify CP function about arrival of first DL packet being buffered (NOCP flag)
  - Duplicate packets (DUPL flag)

Student Notes

Buffering Action Rule (BAR) Handling

- Request UP function to apply specific buffering behavior for packets requested to be buffered and associated to BAR
- Created by CP function for N4 session, associated to FAR(s) of PFCP session
- Sent in N4 Session establishment or N4 Session modification requests
- Buffering parameters:
  - Downlink Data Notification Delay
  - DL Buffering Duration
  - DL Buffering Suggested Packet Count

Student Notes

QoS Enforcement Rule (QER) Handling

- CP request UP to perform QoS enforcement of UP traffic
- Provisioned for PCFP session in N4 Session establishment or N4 Session modification requests
- QoS enforcement actions:
  - Gating control
  - QoS control, i.e. MBR, GBR or packet rate enforcement
  - DL flow level marking for application detection
  - Reflective QoS for uplink traffic (for 5GC)

Student Notes

Message Format

	Bits								
Octets	8	7	6	5	4	3	2	1	
1 to m	PFCP message header								
m+1 to n	Zero or more Information Element(s)								

PFCP Message Format

	Bits							
Octets	8	7	6	5	4	3	2	1
1	Version			Spare	Spare	Spare	MP	S
2	Message Type							
3	Message Length (1st Octet)							
4	Message Length (2nd Octet)							
m to k(m+7)	If S flag is set to 1, then SEID shall be placed into octets 5-12. Otherwise, SEID field is not present at all.							
n to (n+2)	Sequence Number							
(n+3)	Spare							

PFCP Header Format

SEID: Session Endpoint Identifier

A PFCP message shall contain the PFCP message header and may contain subsequent information element(s) (Ies) dependent on the type of message.
PFCP messages use a variable length header. The message header length shall be a multiple of 4 octets.
Where:

- if S = 0, SEID field is not present, k = 0, m = 0 and n = 5;
- if S = 1, SEID field is present, k = 1, m = 5 and n = 13.

The first octet of the header shall be used is the following way:

- Bit 1 represents the "S" flag, which indicates if SEID field is present in the PFCP header or not. If the "S" flag is set to 0, then the SEID field shall not be present in the PFCP header. If the "S" flag is set to 1, then the SEID field shall immediately follow the Length field, in octets 5 to 12. Apart from the node related messages , in all PFCP messages the value of the "S" flag shall be set to "1".
- Bit 2 represents the "MP" flag. If the "MP" flag is set to "1", then bits 8 to 5 of octet 16 shall indicate the message priority.
- Bit 3 is a spare bit. The sending entity shall set it to "0" and the receiving entity shall ignore it.
- Bit 4 is a spare bit. The sending entity shall set it to "0" and the receiving entity shall ignore it.
- Bit 5 is a spare bit. The sending entity shall set it to "0" and the receiving entity shall ignore it.
- Bits 6 to 8, which represent the PFCP version, shall be set to decimal 1 ("001").

The usage of the fields in octets 2 - n of the header shall be as specified below.

- Octet 2 represents the Message type field, which shall be set to the unique value for each type of CP message.
- Octets 3 to 4 represent the Message Length field. This field shall indicate the length of the message in octets excluding the mandatory part of the PFCP header (the first 4 octets). The SEID (if present) and the Sequence Number shall be included in the length count.
- When S=1, Octets 5 to 12 represent the Session Endpoint Identifier (SEID) field. This field shall unambiguously identify a session endpoint in the receiving Packet Forward Control entity. The Session Endpoint Identifier is set by the sending entity in the PFCP header of all CP messages to the SEID value provided by the corresponding receiving entity (CP or UP function). If a peer's SEID is not available the SEID field shall be present in a PFCP header, but its value shall be set to "0", "Conditions for sending SEID=0 in PFCP header".
- Octets 13 to 15 represent PFCP Sequence Number field.

Message Types

Message Type value (Decimal)	Message	Applicability			
		Sxa	Sxb	Sxc	N4
0	Reserved				
1	PFCP Heartbeat Request	X	X	X	X
2	PFCP Heartbeat Response	X	X	X	X
3	PFCP PFD Management Request	-	X	X	X
4	PFCP PFD Management Response	-	X	X	X
5	PFCP Association Setup Request	X	X	X	X
6	PFCP Association Setup Response	X	X	X	X
7	PFCP Association Update Request	X	X	X	X
8	PFCP Association Update Response	X	X	X	X
9	PFCP Association Release Request	X	X	X	X
10	PFCP Association Release Response	X	X	X	X
11	PFCP Version Not Supported Response	X	X	X	X
12	PFCP Node Report Request	X	X	X	X
13	PFCP Node Report Response	X	X	X	X
14	PFCP Session Set Deletion Request	X	X	-	
15	PFCP Session Set Deletion Response	X	X	-	
16 to 49	For future use				
50	PFCP Session Establishment Request	X	X	X	X
51	PFCP Session Establishment Response	X	X	X	X
52	PFCP Session Modification Request	X	X	X	X
53	PFCP Session Modification Response	X	X	X	X
54	PFCP Session Deletion Request	X	X	X	X
55	PFCP Session Deletion Response	X	X	X	X
56	PFCP Session Report Request	X	X	X	X
57	PFCP Session Report Response	X	X	X	X
58 to 99	For future use				
100 to 255	For future use				

1-49: PFCP Node related messages

50-99: PFCP Session related messages

100-255: Other messages

Student Notes

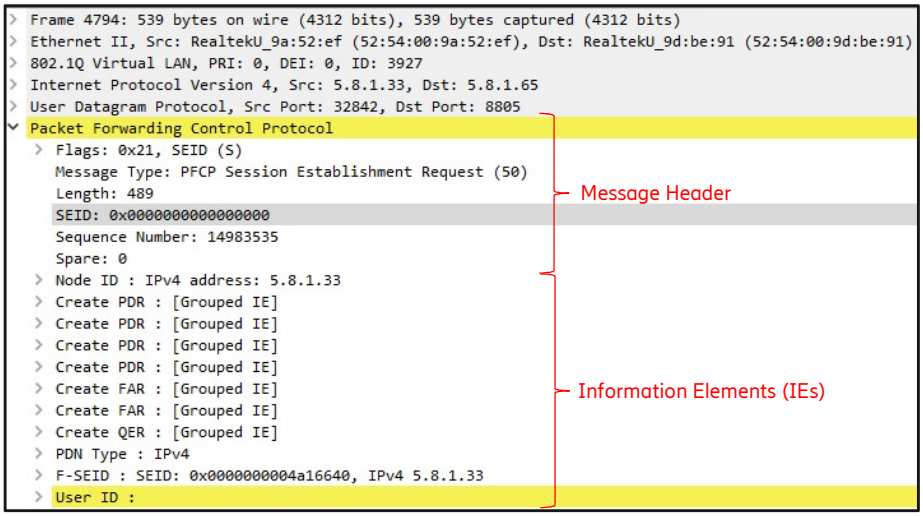
PFCP Session Establishment Request

Information elements	P	Condition / Comment	Appl.				IE Type
			Sxa	Sxb	Sxc	N4	
Node ID	M	This IE shall contain the unique identifier of the sending Node.	X	X	X	X	Node ID
CP F-SEID	M	This IE shall contain the unique identifier allocated by the CP function identifying the session.	X	X	X	X	F-SEID
Create PDR	M	This IE shall be present for at least one PDR to be associated to the PFCP session. Several IEs with the same IE type may be present to represent multiple PDRs.	X	X	X	X	Create PDR
Create FAR	M	This IE shall be present for at least one FAR to be associated to the PFCP session. Several IEs with the same IE type may be present to represent multiple FARs.	X	X	X	X	Create FAR
Create URR	C	This IE shall be present if a measurement action shall be applied to packets matching one or more PDR(s) of this PFCP session. Several IEs within the same IE type may be present to represent multiple URRs.	X	X	X	X	Create URR
Create QER	C	This IE shall be present if a QoS enforcement action shall be applied to packets matching one or more PDR(s) of this PFCP session. Several IEs within the same IE type may be present to represent multiple QERs.	-	X	X	X	Create QER
Create BAR	O	When present, this IE shall contain the buffering instructions to be applied by the UP function to any FAR of this PFCP session set with the Apply Action requesting the packets to be buffered and with a BAR ID IE referring to this BAR.	X	-	-	X	Create BAR
PDN Type	C	This IE shall be present if the PFCP session is setup for an individual PDN connection or PDU session. When present, this IE shall indicate whether this is an IP or non-IP PDN connection/PDU session.	X	X	-	X	PDN Type
SGW-C FQ-CSID	C	This IE shall be included according to the requirements in clause 23 of 3GPP TS 23.007.	X	X	-		FQ-CSID
MME FQ-CSID	C	This IE shall be included when received on the S11 interface or on S5/S8 interface according to the requirements in clause 23 of 3GPP TS 23.007.	X	X	-	-	FQ-CSID
PGW-C FQ-CSID	C	This IE shall be included according to the requirements in clause 23 of 3GPP TS 23.007.	X	X	-	-	FQ-CSID
ePDG FQ-CSID	C	This IE shall be included according to the requirements in clause 23 of 3GPP TS 23.007.	-	X	-	-	FQ-CSID
TWAN FQ-CSID	C	This IE shall be included according to the requirements in clause 23 of 3GPP TS 23.007.	-	X	-	-	FQ-CSID
User Plane Inactivity Timer	O	This IE may be present to request the UP function to send a User Plane Inactivity Report when no user plane packets are received for this PFCP session for a duration exceeding the User Plane Inactivity Timer. When present, it shall contain the duration of the inactivity period after which a User Plane Inactivity Report shall be generated.	-	X	X	-	User Plane Inactivity Timer

The PFCP Session Establishment Request shall be sent over the Sxa, Sxb, Sxc and N4 interface by the CP function to establish a new PFCP session context in the UP function. IEs within PFCP messages shall be specified with one of the following presence requirement (P):

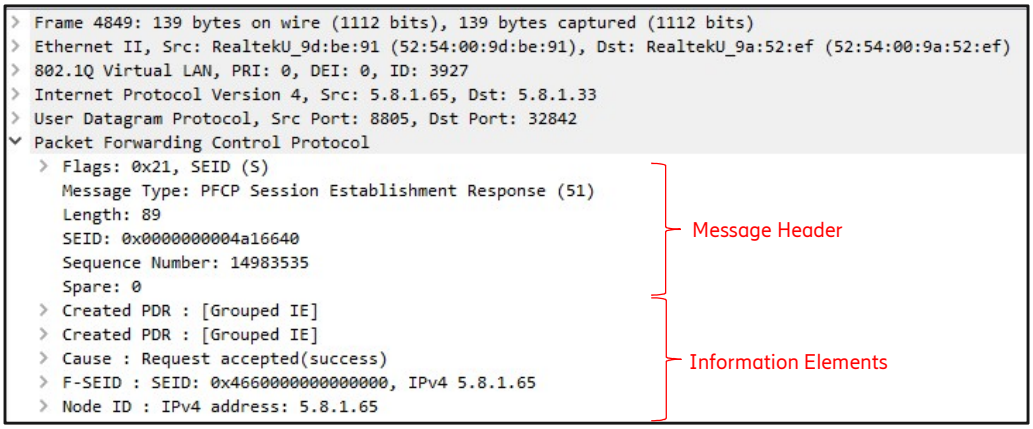
- Mandatory: this means that the IE shall be included by the sending entity, and that the receiver diagnoses a "Mandatory IE missing" error when detecting that the IE is not present. A response including a "Mandatory IE missing" cause, shall include the type of the missing IE.
- Conditional: this means that the IE shall be included by sending entity if the conditions specified are met and the receiver shall check the conditions as specified in the corresponding message type description, based on the parameter combination in the message and/or on the state of the receiving node, to infer if a conditional IE shall be expected. Only if a receiver has sufficient information, if a conditional IE, which is necessary for the receiving entity to complete the procedure, is missing, then the receiver shall abort the procedure.
- Optional: this means that the IE shall be included as a service option. Therefore, the IE may be included or not in a message.

Example of PFCP Session Establishment Request



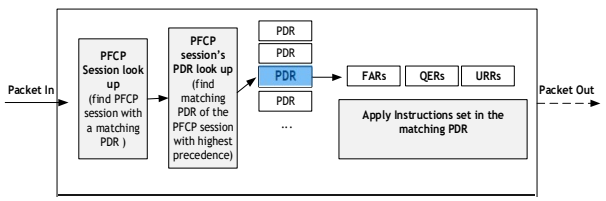
Student Notes

Example of PFCP Session Establishment Response



Student Notes

Example of PDR Creation IE for UL



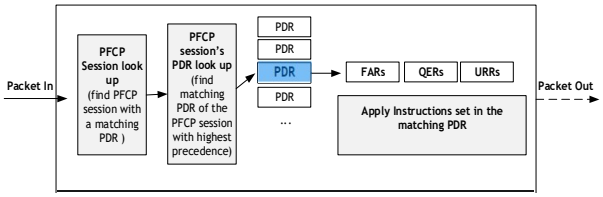

```
Create PDR : [Grouped IE]
    IE Type: Create PDR (1)
    IE Length: 77
  > Packet Detection Rule ID : 3
  > Precedence : 1
  v PDI : [Grouped IE]
      IE Type: PDI (2)
      IE Length: 38
    > Source Interface : Access
    v F-TEID :
        IE Type: F-TEID (21)
        IE Length: 2
      v Flags: 0x0d, CHID (CHOOSE_ID), CH (CHOOSE), V4 (IPv4)
          0000 .... = Spare: 0
          .... 1... = CHID (CHOOSE_ID): True
          .... .1.. = CH (CHOOSE): True
          .... ..0. = V6 (IPv6): Not Present
          .... ...1 = V4 (IPv4): Present
        Choose Id: 00
    v Network Instance :
        IE Type: Network Instance (22)
        IE Length: 6
        Network Instance: media
    > UE IP Address :
    > Application ID :
  > Outer Header Removal : GTP-U/UDP/IPv4
  > FAR ID : Dynamic by CP 1
  > QER ID : Dynamic by CP 1
```


Student Notes

Example of Created PDR IE for UL

Access

Core



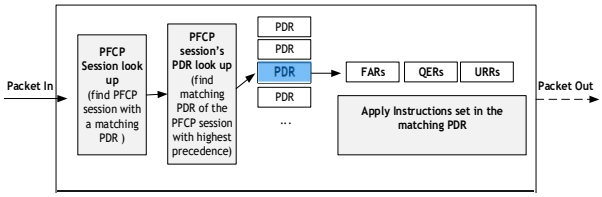

```
Created PDR : [Grouped IE]
    IE Type: Created PDR (8)
    IE Length: 19
  F-TEID : TEID: 0x46600001, IPv4 5.1.0.1
      IE Type: F-TEID (21)
      IE Length: 9
    Flags: 0x01, V4 (IPv4)
        0000 .... = Spare: 0
        .... 0... = CHID (CHOOSE_ID): False
        .... .0.. = CH (CHOOSE): False
        .... ..0. = V6 (IPv6): Not Present
        .... ...1 = V4 (IPv4): Present
      TEID: 0x46600001
      IPv4 address: 5.1.0.1
  Packet Detection Rule ID : 3
```


Student Notes

Example of PDR Creation IE for DL

Core

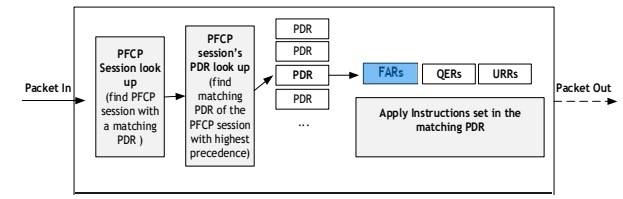
Access




```
Create PDR : [Grouped IE]
    IE Type: Create PDR (1)
    IE Length: 65
  > Packet Detection Rule ID : 4
  > Precedence : 1
  v PDI : [Grouped IE]
      IE Type: PDI (2)
      IE Length: 31
    > Source Interface : Core
    v Network Instance :
        IE Type: Network Instance (22)
        IE Length: 5
        Network Instance: sgi1
    > UE IP Address :
    > Application ID :
  > FAR ID : Dynamic by CP 2
  > QER ID : Dynamic by CP 1
```


Student Notes

Example of FAR Creation IE UL

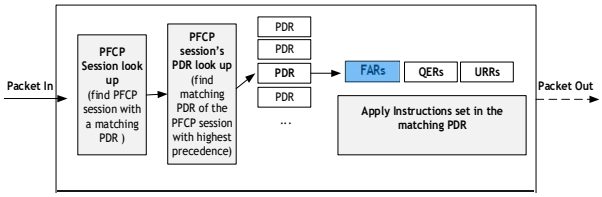



```
Create FAR : [Grouped IE]
    IE Type: Create FAR (3)
    IE Length: 37
  > FAR ID : Dynamic by CP 1
  v Apply Action :
      IE Type: Apply Action (44)
      IE Length: 1
    > Flags: 0x02, FORW (Forward)
  v Forwarding Parameters : [Grouped IE]
      IE Type: Forwarding Parameters (4)
      IE Length: 20
    v Network Instance :
        IE Type: Network Instance (22)
        IE Length: 5
        Network Instance: sgi1
    > Destination Interface : Core
    > DL Transport Level Marking :
```


Student Notes

Example of FAR Creation IE DL

Core Access

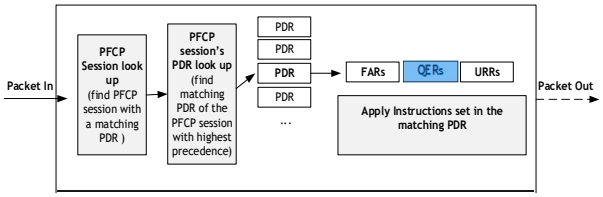



```
Create FAR : [Grouped IE]
    IE Type: Create FAR (3)
    IE Length: 52
  > FAR ID : Dynamic by CP 2
  v Apply Action :
        IE Type: Apply Action (44)
        IE Length: 1
      > Flags: 0x02, FORW (Forward)
  v Forwarding Parameters : [Grouped IE]
        IE Type: Forwarding Parameters (4)
        IE Length: 35
      > Network Instance :
      v Destination Interface : Access
            IE Type: Destination Interface (42)
            IE Length: 1
            0000 .... = Spare: 0
            .... 0000 = Interface: Access (0)
      v Outer Header Creation :
            IE Type: Outer Header Creation (84)
            IE Length: 10
            Outer Header Creation Description: GTP-U/UDP/IPv4  (256)
            TEID: 0xb11c0536
            IPv4 Address: 11.0.1.131
      > DL Transport Level Marking :
```

Tunnel End Point @ NodeB

Student Notes

Example of Create QER IE




```
Create QER : [Grouped IE]
    IE Type: Create QER (7)
    IE Length: 27
  > QER ID : Dynamic by CP 1
  v Gate Status :
        IE Type: Gate Status (25)
        IE Length: 1
      > Flags: 0x00, UL Gate: OPEN, DL Gate: OPEN
  v MBR :
        IE Type: MBR (26)
        IE Length: 10
        UL MBR: 4096
        DL MBR: 4096
```


Student Notes

Chapter Summary

On completion of this chapter, the participants are able to:

- Explain service-based interfaces
- Explain the N1 and N2 control plane interfaces towards access networks
- Explain the N3 user plane interface towards access networks
- Explain the N4 interface between control plane and user plane

Student Notes

5G Core Protocols and Procedures

Chapter 4
5GC Basic Procedures

Student Notes

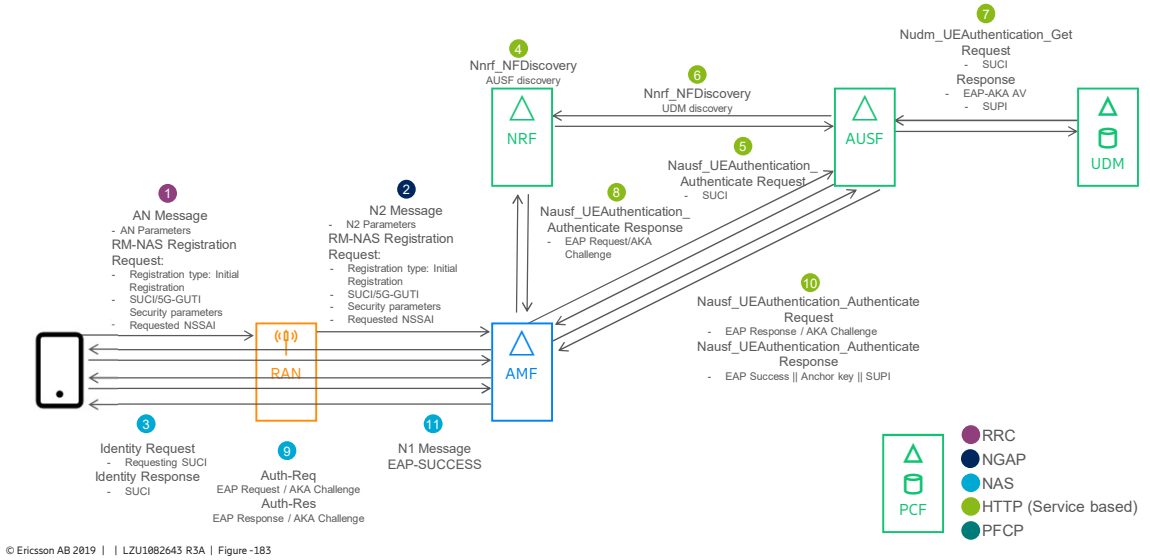
Chapter Objectives

On completion of this chapter, the participants will be able to:

- Analyze the basic procedures for 5GC
  - Explain the Registration Procedures
  - Explore the Service Request Procedures
  - Examine the Session Management Procedures
  - Interpret the Handover Procedures

Student Notes

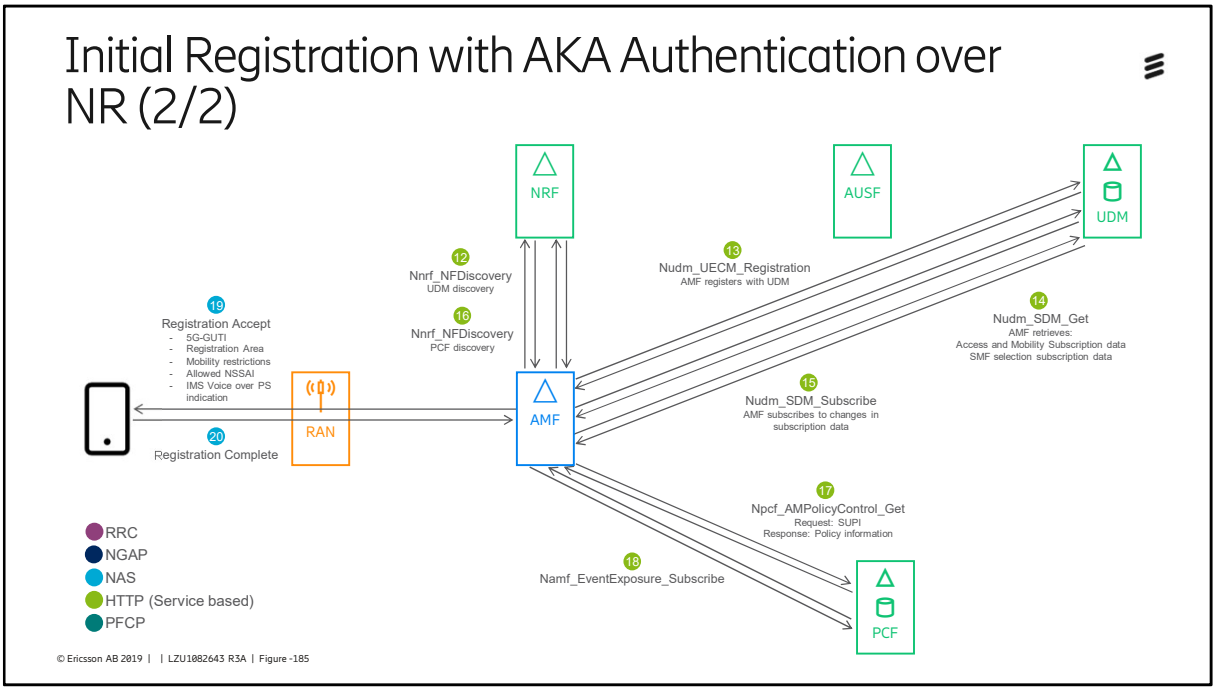
Initial Registration with AKA Authentication over NR (1/2)



1. UE to RAN: AN Message
   The UE sends AN message to the RAN, including AN parameters and an RM-NAS Registration Request.
   The AN parameters include e.g. SUCI or SUPI or the 5G-GUTI, the Selected PLMN ID and Requested NSSAI, the AN parameters also include Establishment cause. The Establishment cause provides the reason for requesting the establishment of an RRC connection.
   The Security parameters are used for Authentication and integrity protection.
   Requested NSSAI indicates the Network Slice Selection Assistance Information.
2. The RAN, selects an AMF based on RAT and Requested NSSAI, if available.
   RAN to AMF: N2 Message
   When NG-RAN is used, the N2 parameters include the Selected PLMN ID, Location Information, Cell Identity, the RAT type related to the cell in which the UE is camping, and the Establishment cause.
3. AMF to UE: Identity Request
   If the SUPI or SUCI is not provided by the UE the Identity Request procedure is initiated by the AMF sending an Identity Request message to the UE requesting the SUCI.
   UE to AMF: Identity Response
   The UE responds with an Identity Response message including the SUCI. The UE derives the SUCI by using the provisioned public key of the HPLMN.

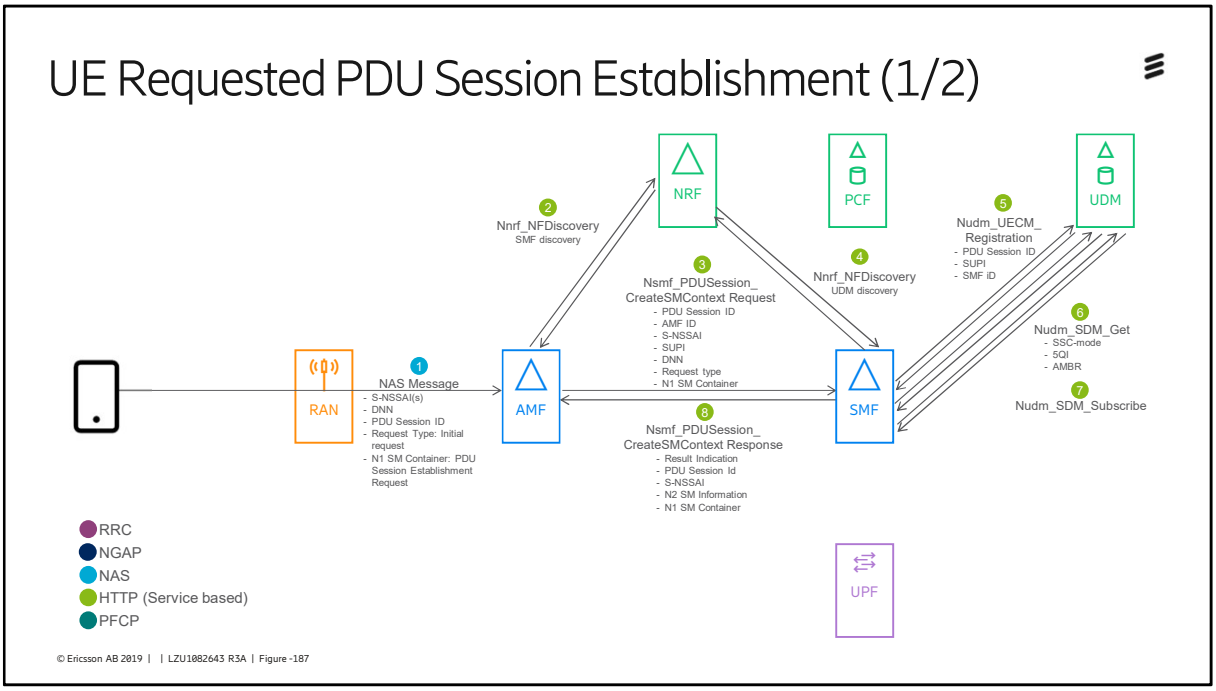
4. The AMF may decide to initiate UE authentication by invoking an AUSF. The AUSF selection function in the AMF shall utilize the NRF to discover the AUSF, unless AUSF information is available by other means, e.g. locally configured on AMF. The AMF will select an AUSF instance based on the obtained AUSF information.
   The following factors may be considered during the AUSF selection:
   - SUPI
   - Home network identifier (e.g., MNC and/or MCC) of SUCI
5. AMF to AUSF: Nausf_UEAuthentication_Authenticate Request
6. AUSF to NRF: UDM discovery
   If there is no locally configured UDM information, AUSF uses NRF to get it, and selects a UDM instance based on the obtained information.
7. AUSF to UDM: Nudm_UEAuthentication_Get Request
   If SUCI was included in the Nudm_UEAuthentication_Get Request, UDM/SIDF shall deconceal the SUPI and then choose EAP-AKA' as authentication method.
   UDM generates and authentication vector, and computes CK' and IK'.
   UDM to AUSF: Nudm_UEAuthentication_Get Response
   UDM sends the new authentication vector (RAND,AUTN,XRES,CK',IK') to the AUSF.
   In case SUCI was included in the Nudm_UEAuthentication_Get Request, UDM will include the SUPI.
8. AUSF to AMF: Nausf_UEAuthentication_Authenticate Response
   The AUSF sends the EAP-Request/AKA' Challenge to the AMF.
9. AMF to UE: NAS Auth-Req
   SEAF shall transparently forward the EAP-Request/AKA'-Challenge message to the UE.
   UE to AMF: NAS Auth-Res
   The USIM computes a response, and sends the EAP-Response/AKA'-Challenge to the AMF.
10. AMF to AUSF: Nausf_UEAuthentication_Authenticate Request
    AMF transparently forwards the EAP-Response/AKA'-Challenge message to the AUSF.
    AUSF to AMF: Nausf_UEAuthentication_Authenticate Response
    AUSF verifies the message, and sends an EAP Success message to the AMF.
11. AMF to UE: N1 message
    AMF transparently forwards the EAP Success to the UE.

After successful authentication, the AMF initiates NAS security functions, and NGAP procedure for securing procedures between the access network and the UE.



12. AMF to NRF: Nnrf_NFDiscovery (UDM Discovery)
13. AMF to UDM: Nudm_UECM_Registration
    AMF registers with the UDM.
14. AMF to UDM: Nudm_SDM_Get
    AMF retrieves the Access and Mobility subscription data and SMF Selection Subscription data.
    AMF creates an MM context for the UE.
15. AMF to UDM: Nudm_SDM_Subscribe
    AMF subscribes to be notified when the data requested is modified.
16. AMF to NRF: Nnrf_NFDiscovery (PCF Discovery)
    AMF requests PCF info from NRF and selects a PCF.
17. AMF to PCF: Npcf_AMPolicyControl_Get
    AMF requests the PCF to apply operator policies for the UE. It retrieves the access and mobility control policy from the PCF.
    PCF to AMF: Npcf_AMPolicyControl_Get Response
    PCF makes a policy decision, and provides Access and mobility related policy information and optionally UE access selection and PDU Session selection related policy information to the AMF. The AMF is implicitly subscribed in the PCF to be notified of changes in the policies.

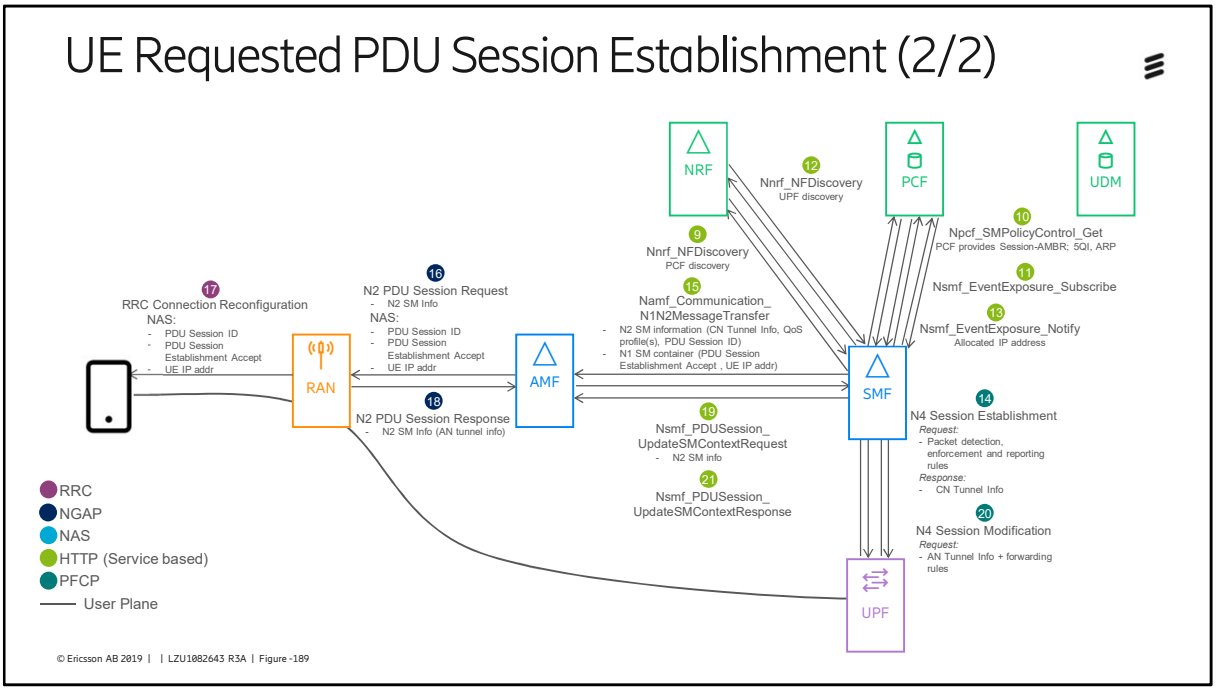
18. PCF to AMF: Namf_EventExposure_Subscribe
    The PCF may subscribe to events detected and triggered by the AMF. The PCF provides the list of event triggers to report.
    AMF to PCF: Namf_EventExposure_Subscribe response
    The AMF acknowledges the subscription from the PCF.
19. AMF to UE: Registration Accept
    The AMF sends a Registration Accept message to the UE indicating that the Registration Request has been accepted.
20. UE to AMF: Registration Complete
    The UE sends a Registration Complete message to the AMF to acknowledge the new 5G-GUTI.



This figure specifies a UE Requested PDU Session Establishment in the non-roaming case. In this example, the procedure is used to establish a *new* PDU session. The procedure assumes that the UE has already registered on the AMF, and therefore the AMF has already retrieved the user subscription data from UDM.

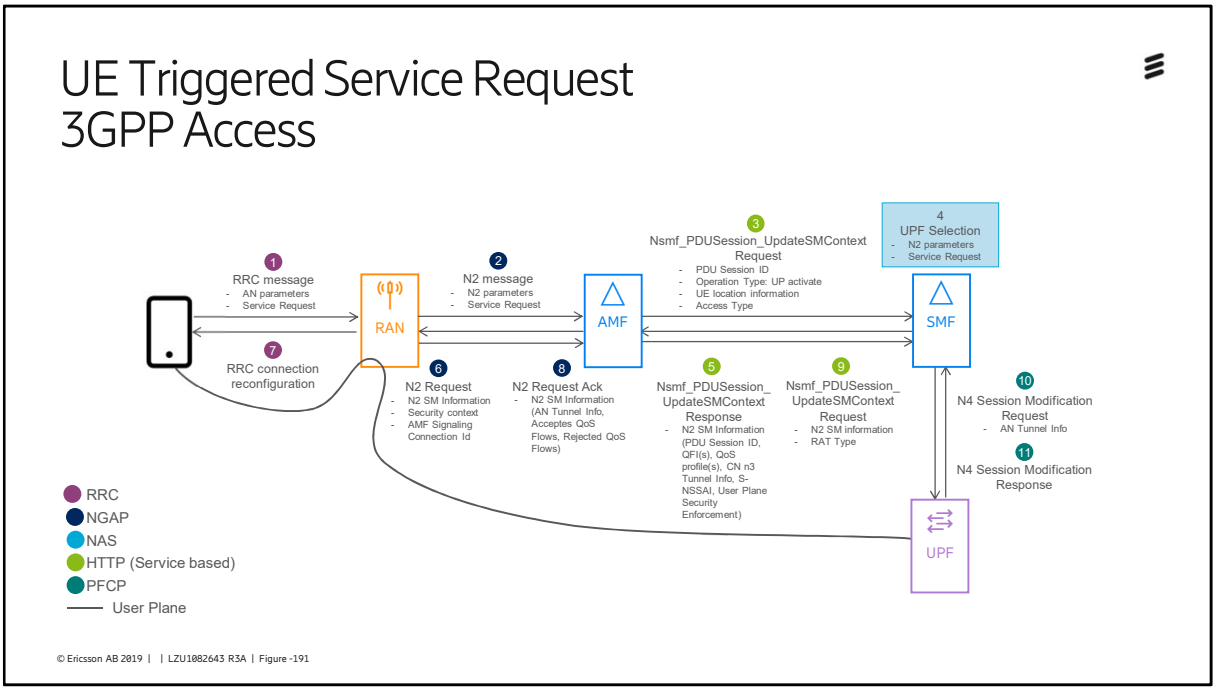
1. UE to AMF: NAS Message
   The UE initiates the UE Requested PDU Session Establishment procedure by the transmission of a NAS message containing a PDU Session Establishment Request within the N1 SM container. Since the PDU Session Establishment is a request to establish a new PDU Session, the Request Type indicates "Initial request". The UE includes the S-NSSAI from the Allowed NSSAI. The NAS message sent by the UE is encapsulated by the AN in a N2 message towards the AMF that should include User location information and Access Technology Type Information.
2. AMF to NRF: Nnrf_NFDiscovery_Resquest (SMF Selection)
   AMF queries the appropriate NRF including S-NSSAI, PLMN ID of the SUPI and DNN.
   The NRF provides e.g. FQDN or IP address, of a set of the discovered SMF instance(s) in an NF Discovery Response message.
3. AMF to SMF: Nsmf_PDUSession_CreateSMContext Request
   The AMF ID is the UE's GUAMI which uniquely identifies the AMF serving the UE. The AMF forwards the PDU Session ID together with the N1 SM container containing the PDU Session Establishment Request received from the UE.

4. SMF to NRF: Nnrf_NFDiscovery (UDM Discovery)
5. SMF to UDM: Nudm_UECM_Registration
   SMF registers with UDM.
6. SMF to UDM: Nudm_SDM_Get
   SMF retrieves the Session Management Subscription data. It includes the authorized PDU type(s), authorized SSC mode(s), default 5QI and ARP and subscribed Session-AMBR.
7. SMF to UDM: Nudm_SDM_Subscribe
   SMF subscribes to be notified when the subscription data is modified.
8. SMF to AMF: Nsmf_PDUSession_CreateSMContext Response
   The SMF creates an SM context and responds to the AMF by providing an SM Context Identifier.



9. SMF to NRF: Nnrf_NFDiscovery (PCF selection)
   Dynamic PCC is deployed, which means that SMF performs PCF selection.
10. SMF to PCF: Npcf_SMPolicyControl_Get
    The SMF performs a Session Management Policy Establishment procedure to establish a PDU Session with the PCF and get the default PCC Rules for the PDU Session.
11. PCF to SMF: Nsmf_EventExposure_Subscribe
    The PCF subscribes to the IP allocation/release event in the SMF.
12. SMF selects an SSC mode for the PDU Session. The SMF allocates an IP address/prefix for the PDU Session, and in case of PDU Type IPv6, also allocates an interface identifier to the UE for the UE to build its link-local address.
    SMF to NRF: Nnrf_NFDiscovery (UPF Selection)
    SMF selects a UPF for the session.
13. SMF to PCF: Nsmf_EventExposure_Notify
    SMF notifies the PCF (that has previously subscribed) with the allocated UE IP address/prefix.
14. SMF to UPF: N4 Session Establishment
    The SMF sends an N4 Session Establishment Request to the UPF and provides Packet detection, enforcement and reporting rules to be installed on the UPF for this PDU Session.
    The UPF acknowledges by sending an N4 Session Establishment Response. The CN Tunnel Info allocated by the UPF is provided to SMF in this step.

15. SMF to AMF: Namf_Communication_N1N2MessageTransfer
    The N2 SM information carries information that the AMF shall forward to the RAN, including:
    - The CN Tunnel Info corresponds to the Core Network address of the N3 tunnel corresponding to the PDU Session.
    - One or multiple QoS profiles and the corresponding QFIs can be provided to the RAN.
    - The PDU Session ID may be used by AN signaling with the UE to indicate to the UE the association between AN resources and a PDU Session for the UE.
    A PDU Session is associated to an S-NSSAI and a DNN.
    The N1 SM container contains the PDU Session Establishment Accept that the AMF shall provide to the UE.
    Multiple QoS Rules and QoS Profiles may be included in the PDU Session Establishment Accept within the N1 SM and in the N2 SM information.
    The Namf_Communication_N1N2MessageTransfer further contains the PDU Session ID and information allowing the AMF to know which access towards the UE to use.
16. AMF to RAN: N2 PDU Session Request
    The AMF sends the NAS message containing PDU Session ID and PDU Session Establishment Accept targeted to the UE and the N2 SM information received from the SMF within the N2 PDU Session Request to the RAN.
17. RAN to UE: RRC Connection reconfiguration
    The UE establishes the necessary RAN resources related to the QoS Rules for the PDU Session request.
    RAN allocates RAN N3 tunnel information for the PDU Session.
    RAN forwards the NAS message to the UE.
18. RAN to AMF: N2 PDU Session Response
19. AMF to SMF: Nsmf_PDUSession_UpdateSMContext
    The AMF forwards the N2 SM information received from (R)AN to the SMF.
20. SMF to UPF: N4 Session Modification
    The SMF provides AN Tunnel Info to the UPF as well as the corresponding forwarding rules.
    The UPF provides an N4 Session Modification Response to the SMF.
21. SMF to AMF: Nsmf_PDUSession_UpdateSMContext Response



The Service Request procedure is used by a UE in CM IDLE state or the 5GC to request the establishment of a secure connection to an AMF. The Service Request procedure is also used both when the UE is in CM-IDLE and in CM-CONNECTED to activate a User Plane connection for an established PDU Session.
The UE in CM-IDLE state initiates the Service Request procedure in order to send uplink signaling messages, user data, or as a response to a network paging request. After receiving the Service Request message, the AMF may perform authentication. After the establishment of the signaling connection to an AMF, the UE or network may send signaling messages, e.g. PDU Session establishment from UE to the SMF, via the AMF.
The Service Request procedure is used by a UE in CM-CONNECTED to request activate User Plane connection for PDU Sessions and to respond to a NAS Notification message from the AMF.

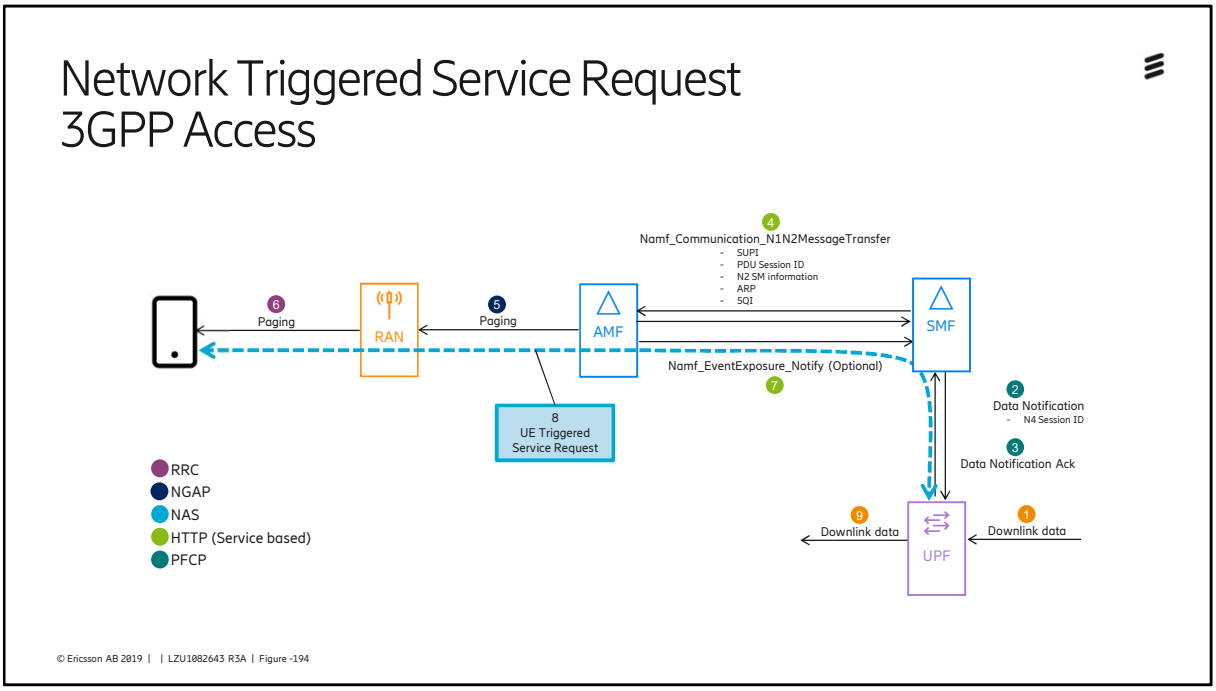
1. UE to RAN: RRC message
   For NG-RAN, the AN parameters include Selected PLMN ID and Establishment cause. The Establishment cause provides the reason for requesting the establishment of an RRC connection.
   The Service Request contains a list of PDU Sessions to be activated, security parameters and PDU Session status. The List Of PDU Sessions To Be Activated is provided by the UE when it wants to re-activate the PDU Session(s). If the Service Request is triggered for signaling only, the UE doesn't identify any PDU Sessions To Be Activated.

2. RAN to AMF: N2 Message
   For NG-RAN, the N2 parameters include the 5G-S-TMSI, Selected PLMN ID, Location information, RAT type and Establishment cause.

If the UE in CM-IDLE state triggered the Service Request to establish a signaling connection only, after successful establishment of the signaling connection the UE and the network can exchange NAS signaling and steps 3 to 5 and 9 to 11 are skipped.

3. AMF to SMF: Nsmf_PDUSession_UpdateSMContext Request
   If the Service Request message from the UE contained PDU Session(s) to be activated, a Nsmf_PDUSession_UpdateSMContext Request is invoked.
   The AMF determines the PDU Session(s) to be activated and sends an Nsmf_PDUSession_UpdateSMContext Request to SMF(s) associated with the PDU Session(s) with Operation Type set to "UP activate" to indicate establishment of user plane resources for the PDU Session(s).
4. UPF Selection
   Based on the location info received from the AMF, the SMF checks the UPF Selection Criteria and determines to accept the activation of the UP connection and continue using the current UPF(s).
5. SMF to AMF: Nsmf_PDUSession_UpdateSMContext Response
   The SMF generates N2 SM information and sends it the AMF to establish the user plane(s). The N2 SM information contains information that the AMF shall provide to the NG-RAN.
6. AMF to RAN: N2 Request
   If the UE triggered the Service Request while in CM-CONNECTED state, only N2 SM information received from SMF and MM NAS Service Accept are included in the N2 Request.
   For a UE that was in CM-IDLE state when the Service Request was triggered, the NG-RAN stores the Security Context, AMF Signaling Connection Id.
   If the Service Request is not triggered by the UE for a signaling connection only, RAN also stores QoS Information for the QoS Flows of the PDU Sessions that are activated and N3 Tunnel IDs in the UE RAN context and Handover Restriction List.
7. RAN to UE: RRC Connection Reconfiguration
   The NG-RAN performs RRC Connection Reconfiguration with the UE depending on the QoS Information for all the QoS Flows of the PDU Sessions whose UP connections are activated.
   After the User Plane radio resources are setup, the uplink data from the UE can now be forwarded to NG-RAN. The NG-RAN sends the uplink data to the UPF address and Tunnel ID provided in the step 5.
8. RAN to AMF: N2 Request Ack
   The message may include N2 SM information(s), e.g. AN Tunnel Info.

9. AMF to SMF: Nsmf_PDUSession_UpdateSMContext Request
   If the AMF received N2 SM information in step 8, then the AMF shall forward the N2 SM information to the relevant SMF per PDU Session ID.
10. SMF to UPF: N4 Session Modification Request
    The SMF sends an N4 Session Modification Request, providing AN Tunnel Info.
11. UPF to SMF: N4 Session Modification Response
    The old UPF acknowledges with an N4 Session Modification Response.



This procedure is used when the network needs to signal with a UE (e.g. N1 signaling to UE, Mobile-terminated SMS, User Plane connection activation for PDU Session(s) to deliver mobile terminating user data). If the UE is in CM-IDLE state or CM-CONNECTED state in 3GPP access, the network initiates a Network Triggered Service Request procedure. If the UE is in CM-IDLE state, the network sends a Paging Request to (R)AN/UE. The Paging Request triggers the UE Triggered Service Request procedure in the UE.

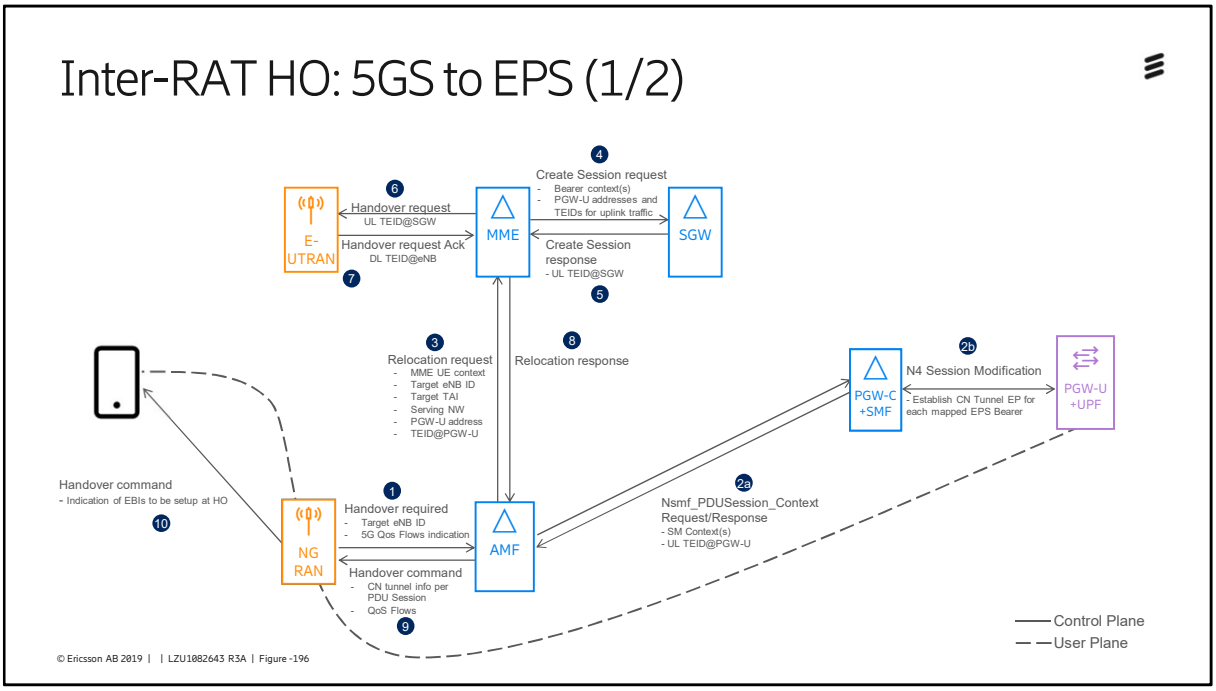
1. When a UPF receives downlink data for a PDU Session and there is no AN Tunnel Info stored in UPF for the PDU Session, based on the instruction from the SMF, the UPF may buffer the downlink data, or forward the downlink data to the SMF.
2. UPF → SMF: Data Notification
   On arrival of the first downlink data packet for any QoS Flow, the UPF shall send Data Notification message to the SMF, if the SMF has not previously notified the UPF to not send the Data Notification to the SMF. The message includes information to identify the QoS flow for the DL data packet.
   If the UPF receives downlink data packets for another QoS Flow in the same PDU Session, the UPF shall send another Data Notification message to the SMF.
3. SMF → UPF: Data Notification Ack

4. SMF → AMF: Namf_Communication_N1N2MessageTransfer
   The SMF determines the AMF and invokes the Namf_Communication_N1N2MessageTransfer to the AMF including the PDU Session ID.
   If the UE is in CM-IDLE state at the AMF, and the AMF is able to page the UE the AMF sends a Namf_Communication_N1N2MessageTransfer response to the SMF immediately with a cause "Attempting to reach UE" which indicates the SMF that the N2 SM information may be ignored by the AMF once the UE is reachable and the SMF may be asked to provide the N2 SM information again.
   If the UE is in CM-CONNECTED state at the AMF then the AMF sends a Namf_Communication_N1N2MessageTransfer response to the SMF immediately with a cause "N1/N2 transfer success"

If the UE is in CM_CONNECTED state in the access associated with the PDU Session ID received from the SMF, the user plane connection is activated for the PDU Session (see steps 6 – 11 of the UE Triggered Service Request procedure). The rest of this procedure is not applicable.
If the UE is in CM-IDLE state, the AMF may (based on local policy) decide to notify the UE.

5. AMF → RAN: Paging
   The AMF sends a Paging message to RAN node(s) belonging to the Registration Area(s) in which the UE is registered.
6. RAN → UE: Paging
   The NG-RAN node pages the UE.
7. AMF → SMF: Namf_EventExposure_Notify
   The AMF supervises the paging procedure with a timer. If the AMF receives no response from the UE to the Paging Request message, the AMF may apply further paging according to any applicable paging strategy. The AMF notifies the SMF if the UE is not reachable.
8. UE Triggered Service Request
   Upon reception of paging request for a PDU Session associated to 3GPP access, the UE shall initiate the *UE Triggered Service Request procedure* (see previous flow).
9. The UPF transmits the buffered downlink data toward UE via (R)AN node which performed the Service Request procedure.

Note: When the procedure is triggered by SMSF, PCF, or UDM, the SMF in the following figure should be replaced by SMSF, PCF or UDM.

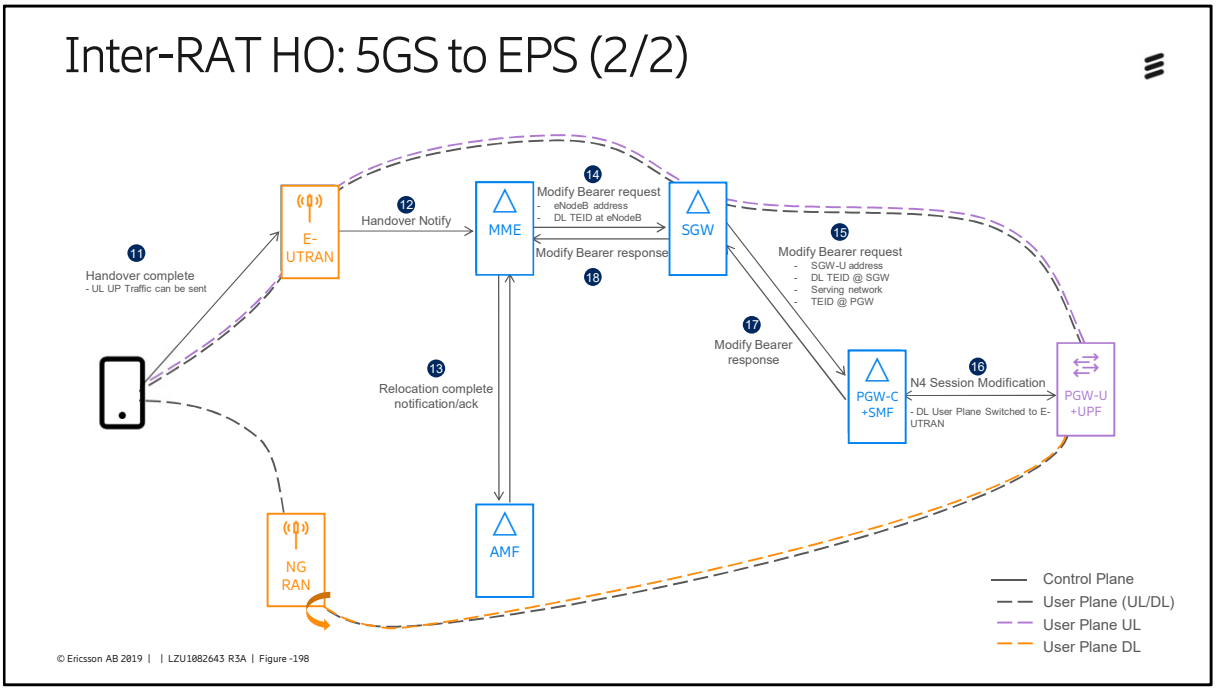


The N26 interface is used to provide seamless session continuity for single registration mode UE. This figure describes the handover procedure from 5GS to EPS when N26 is supported.

The procedure involves a handover to EPC and setup of default EPS bearer and dedicated bearers for GBR QoS Flows in EPC and re-activation, if required, of dedicated EPS bearers for non-GBR QoS Flows.

1. NG-RAN decides that the UE should be handed over to the E-UTRAN.
   NG-RAN to AMF: Handover required
   The NG-RAN sends a Handover Required (Target eNB ID, Source to Target Transparent Container, inter system handover indication) message to the AMF. NG-RAN indicates bearers corresponding to the 5G QoS Flows for data forwarding in Source to Target Transparent Container.
2. The AMF determines from the 'Target eNB Identifier' IE that the type of handover is Handover to E-UTRAN. The AMF selects an MME.
   AMF to PGW-C+SMF: Nsmf_PDUSession_ContextRequest/Response
   AMF requests the PGW-C+SMF to provide the SM Context for the PDU Session. The PGW-C+SMF send N4 Session modification to PGW-U+UPF to establish the CN tunnel for each EPS bearer and provide EPS Bearer Contexts to AMF. The PGW-U+UPF is ready to receive the uplink packet from E-UTRAN.

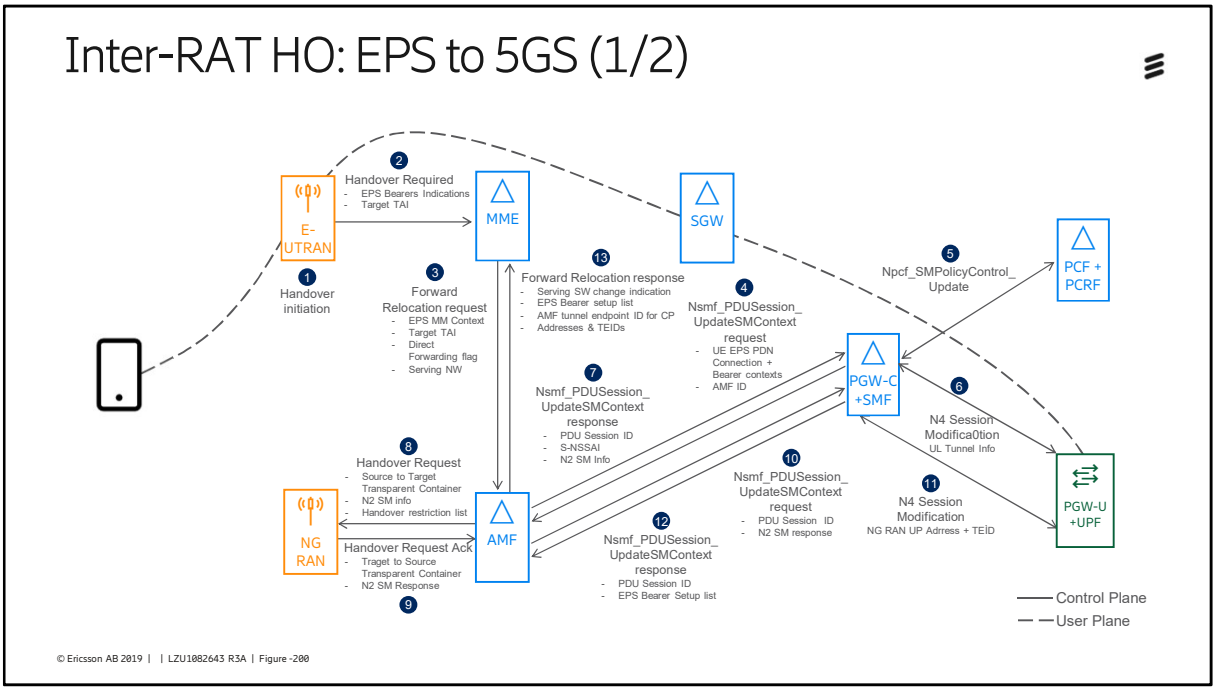
3. AMF to MME: Forward Relocation Request
   The MME UE context includes IMSI, ME Identity, UE security context, UE Network Capability, AMBR, Selected CN operator ID, APN restriction, Serving GW address and TEID for control signaling, and EPS Bearer context(s) including TEID(s) for the user plane bearers.
   The SGW address and TEID for both the control-plane or EPS bearers in the message are such that target MME selects a new SGW.
4. MME to SGW: Create Session request
   MME sends a Create Session Request with bearer context(s) with PDN GW addresses and TEIDs for uplink traffic to the SGW.
5. SGW to MME: Create Session response
   The target Serving GW allocates the S-GW addresses and TEIDs for the uplink traffic on S1-U, and sends a Create Session Response message back to the MME.
6. MME to E-UTRAN: Handover request
   This message creates the UE context in the target eNodeB, including information about the bearers, and the security context. For each EPS Bearer, the Bearers to Setup includes Serving GW address and uplink TEID for user plane, and EPS Bearer QoS.
7. E-UTRAN to MME: Handover request Ack
   The EPS Bearer Setup list includes a list of addresses and TEIDs allocated at the target eNodeB for downlink traffic (one TEID per bearer) and addresses and TEIDs for receiving forwarded data if necessary.
8. MME to AMF: Forward Relocation Response
   Includes information about the selected Serving GW
9. AMF to NG RAN: Handover command
10. NG RAN to UE: Handover command
    The source NG-RAN commands the UE to handover to the target access network by sending the HO Command. The UE correlates the ongoing QoS Flows with the indicated EPS Bearer IDs to be setup in the HO command.



11. UE to E-UTRAN: Handover complete
    After the UE has successfully synchronized to the target cell, it sends a Handover Complete message to the target eNodeB. Downlink packets forwarded from the source gNodeB can be sent to the UE in this example as indirect packet forwarding via PGW-U. Also, uplink packets can be sent from the UE, which are forwarded to the target Serving GW and on to the PGW-U+UPF.
12. E-UTRAN to MME: Handover notify
13. MME ←→ AMF: Relocation Complete Notification/Ack
    The AMF acknowledges MME with Relocation Complete Ack message. A timer in AMF is started to supervise when resources in the in NG-RAN and PGW-C+SMF shall be released.
14. MME to SGW: Modify Bearer Request
    The MME sends a Modify Bearer Request message to the target Serving GW for each PDN connection. The request contains eNodeB address and TEID allocated for S1-U downlink traffic.
15. SGW to PGW-C: Modify Bearer Request
    The SGW assigns addresses and TEIDs (one per bearer) for downlink traffic from the PDN GW, and sends a Modify Bearer Request per PDN connection to the PDN GW.

16. PGW-C+SMF to PGW-U+UPF: N4 Session Modification
    The PGW-C+SMF initiates a N4 Session Modification procedure towards the UPF+PGW-U to update the User Plane path, i.e. the downlink User Plane for the indicated PDU Session is switched to E-UTRAN. The PGW-C+SMF releases the resource of the CN tunnel for PDU Session in UPF+PGW-U.
17. PGW-C to SGW: Modify Bearer Response
    At this stage the User Plane path is established for the default bearer and the dedicated EPS bearers between the UE, target eNodeB, Serving GW and the PGW-U+UPF. The PGW-C+SMF uses the EPS QoS parameters as assigned for the dedicated EPS GBR bearers during the QoS flow establishment. PGW-C+SMF maps all the other IP flows to the default EPS bearer.
18. SGW to MME: Modify Bearer Response
    The Serving GW shall return a Modify Bearer Response (Serving GW address and TEID for uplink traffic) message to the MME as a response to a Modify Bearer Request message.

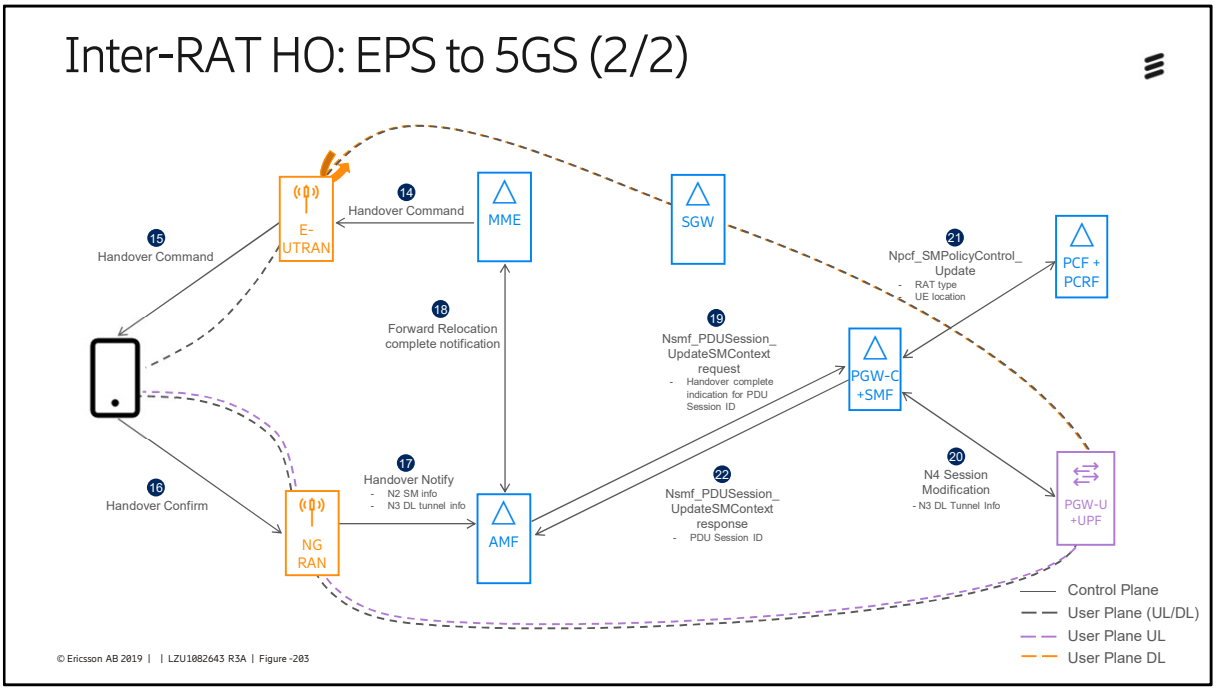
Finally, the UE initiates a Tracking Area Update. This includes the deregistration of the old AMF for 3GPP access from the HSS+UDM. Any registration associated with the non-3GPP access in the old AMF is not removed (i.e. an AMF that was serving the UE over both 3GPP and non-3GPP accesses does not consider the UE as deregistered over non 3GPP access and will remain registered and subscribed to subscription data updates in UDM).



1. The source eNB decides to initiate a handover.
2. eNB → MME: Handover Required
   The source eNodeB indicates which bearers are subject to data forwarding. Direct Forwarding Path Availability indicates whether direct forwarding is available from the source eNodeB to the target gNodeB. The target TAI is sent to MME to facilitate the selection of a suitable target AMF.
3. MME → AMF: Forward Relocation Request
   The AMF converts the received EPS MM Context into the 5GS MM Context. The MME UE context includes IMSI, ME Identity, UE security context, UE Network Capability, and EPS Bearer context(s). The MME EPS Bearer context(s) include for each EPS PDN connection the IP address and FQDN for the S5/S8 interface of the PGW-C+SMF and APN, and for each EPS bearer the IP address and CN Tunnel Info at the UPF+PGW-U for uplink traffic.
   The AMF queries the (PLMN level) NRF in serving PLMN by issuing the Nnrf_NFDiscovery_Request including the FQDN for the S5/S8 interface of the PGW-C+SMF, and the NRF provides the IP address or FQDN of the N11/N16 interface of the PGW-C+SMF.

4. AMF → PGW-C+SMF: Nsmf_PDUSession_UpdateSMContext
   AMF invokes an SM Context Update on the SMF identified by the PGW-C+SMF address, and includes a HO preparation indication (to avoid switching the UP path). The AMF ID is the UE's GUAMI which uniquely identifies the AMF serving the UE. This step is performed for each PDN Connection and the corresponding PGW-C+SMF address/ID in the UE context the AMF received in step 3. The SMF finds the corresponding PDU Session based on EPS Bearer Context(s).
5. SMF + PGW-C ↔ PCF + PCRF: Npcf_SMPolicyControl_Update
   If dynamic PCC is deployed, the SMF+ PGW-C may initiate Session Management Policy Modification towards the PCF + PCRF.
6. SMF + PGW-C ↔ UPF +PGW-U: N4 Session Modification
   The PGW-C+SMF may send N4 Session modification to PGW-U+UPF to establish the CN tunnel for PDU Session. The PGW-U+UPF is ready to receive the uplink packets from NG-RAN.
7. PGW-C + SMF → AMF: Nsmf_PDUSession_UpdateSMContext Response
   SMF includes mapping between QoS flows and EPS bearers as part of N2 SM Information container. If the Direct Forwarding Flag indicates indirect forwarding and there is no indirect data forwarding connectivity between source and target, the SMF shall further include a "Data forwarding not possible" indication in the N2 SM information container. NG-RAN can use the source to target transparent container and N2 SM Information container to determine which QoS flows have been proposed for forwarding and decide for which of those QoS flows it accepts the data forwarding or not. AMF stores an association of the PDU Session ID, S-NSSAI and the SMF ID.
8. AMF → NG-RAN: Handover request
9. NG-RAN → AMF: Handover Request Acknowledge
   The N2 SM Response contains PDU Session ID, list of accepted QFI(s) and AN Tunnel Info.
10. AMF → PGW-C + SMF: Nsmf_PDUSession_UpdateSMContext request
    An Update SM Context message is sent to the SMF for updating the N3 tunnel information. The N2 SM response contains a list of accepted QFI(s) and AN tunnel info. The SMF+PGW-C derives the QoS flows that should be mapped to the PDU Session.
11. SMF + PGW-C ↔ UPF + PGW-U: N4 Session Modification
    SMF performs preparations for N2 Handover by indicating N3 UP address and Tunnel ID of NG-RAN to the UPF if N2 Handover is accepted by NG-RAN and by indicating the mapping between the TEID where the UPF receives data forwarded by the source SGW and the QFI and N3 Tunnel Info for PDU Forwarding where the UPF is to forward such data.

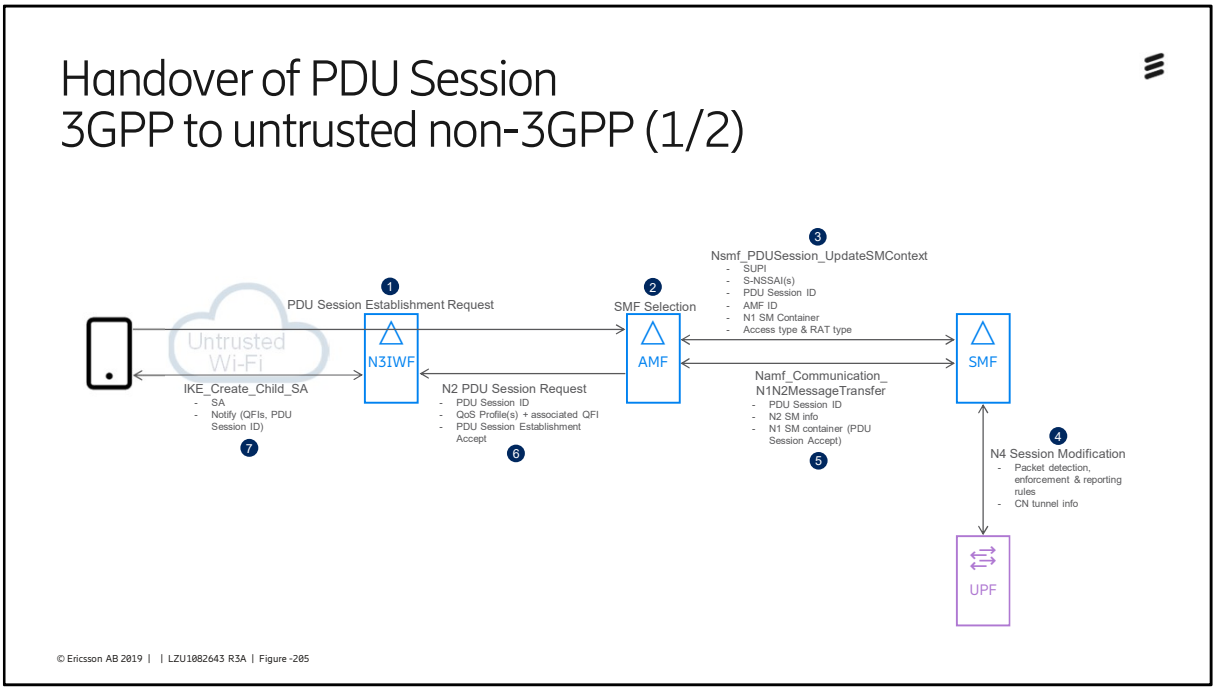
12. SMF + PGW-C → AMF: Nsmf_PDUSession_UpdateSMContext response
    This message is sent for each received Modify PDU Request message.
    The EPS Bearer Setup list is a list of EPS bearer Identifiers successfully handover to 5GC, which is generated based on the list of accepted QFI(s).
13. AMF → MME: Forward Relocation Response
    The EPS Bearer Setup list is the combination of EPS Bearer Setup list from different SMF+PGW-C(s).



14. MME → eNB: Handover Command
    The *Bearers subject to forwarding* includes a list of addresses and TEIDs allocated for forwarding. The *Bearers to Release* includes the list of bearers to be released.
15. eNB → UE: Handover Command
    The Handover Command is constructed using the Target to Source transparent container and is sent to the UE. Upon reception of this message the UE will remove any EPS bearers for which it did not receive the corresponding EPS radio bearers in the target cell.
16. UE → gNB: Handover Confirm
    The UE confirms the handover to NG-RAN. The UE moves from E-UTRAN and synchronizes with the target NG-RAN. The UE may resume the uplink transmission of user plane data only for those QFIs and Session IDs for which there are radio resources allocated in the NG-RAN.
17. gNB → AMF: Handover Notify
    NG-RAN notifies to the AMF that the UE is handed over to the NG-RAN. The notification message includes the N2 SM Information (N3 DL AN Tunnel Info).
18. AMF ↔ MME: Forward Relocation complete
    Then the AMF knows that the UE has arrived to the target side and informs the MME by sending a Forward Relocation Complete Notification message.

19. AMF → PGW-C + SMF: Nsmf_PDUSession_UpdateSMContext request
    Handover Complete is sent per each PDU Session to the corresponding SMF +PGW-C to indicate the success of the N2 Handover.
20. SMF + PGW-C → UPF + PGW-U: N4 Session Modification
    The SMF + PGW-C updates the UPF + PGW-U with the V-CN Tunnel Info, indicating that downlink User Plane for the indicated PDU Session is switched to NG-RAN.
21. SMF + PGW-C to PCF + PCRF: Npcf_SMPolicyControl_Update
    If PCC infrastructure is used, the SMF + PGW-C informs the PCF + PCRF about the change of, for example, the RAT type and UE location.
22. SMF + PGW-C → AMF: Nsmf_PDUSession_UpdateSMContext response
    SMF +PGW-C confirms reception of Handover Complete.

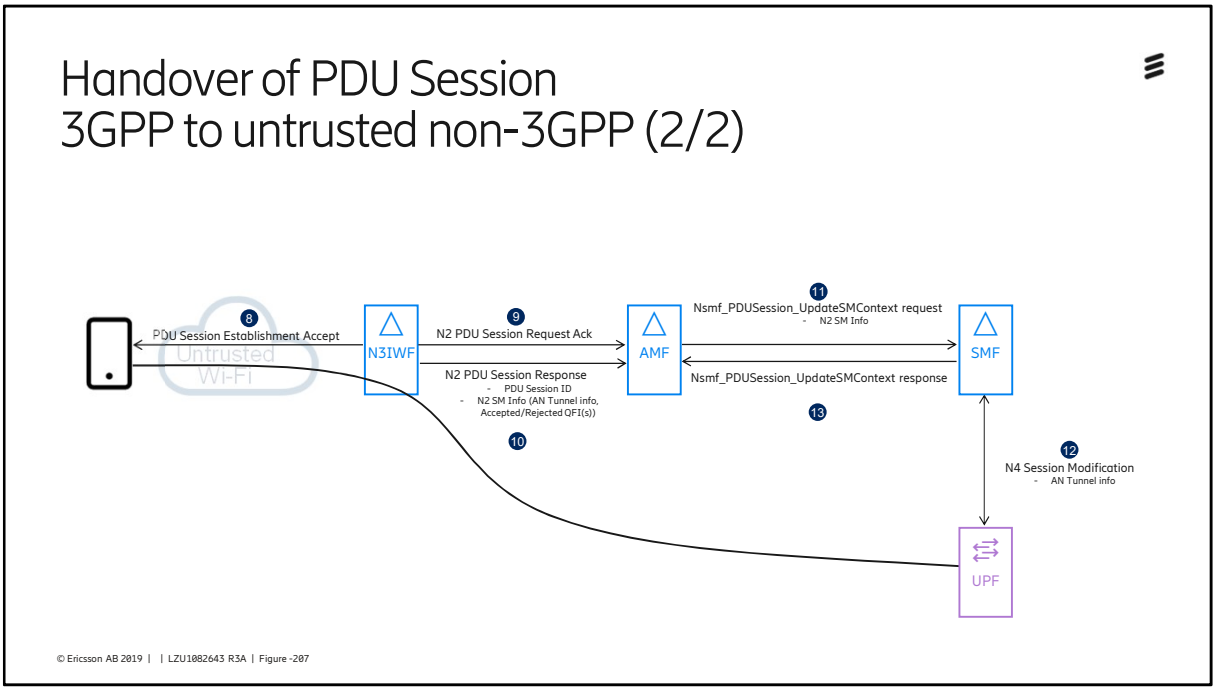
The UE performs the EPS to 5GS Mobility Registration Procedure to among other things perform cancel location of the UE in the MME and register the UE and serving AMF in the UDM.



In this figure it is specified how to hand over a UE from a source 3GPP access to a target untrusted non-3GPP access, and how a UE can handover a *PDU Session* from 3GPP access to untrusted non-3GPP access.
Initially, we assume that the UE is registered over 3GPP access.
We also assume that there are IPSec Security Associations for NAS Signaling in place between the UE and the N3IWF.

1. The UE sends a PDU Session Establishment Request message to the AMF. This message shall be sent to N3IWF via the IPsec SA for NAS signaling and the N3IWF shall transparently forward it to AMF in the 5GC.
2. The AMF uses the SMF ID (received from UDM during registration) to select an SMF. The S-NSSAI of the PDU Session is present in the Allowed NSSAI of the target access type, and the SMF-ID belongs to the HPLMN, so the PDU Session Establishment can continue.
3. AMF ↔ SMF: Nsmf_PDUSession_UpdateSMContext
   Since the AMF already has an association with an SMF for the PDU Session ID provided by the UE, the AMF invokes an Update SM Context request.
   The SMF identifies the existing PDU Session based on the PDU Session ID. The SMF updates the existing SM context and provides the representation of the updated SM context to the AMF in the response.
   Since the request type is “Existing PDU Session“, there is no secondary authentication performed by the SMF. The already selected PCF is used, and the SMF maintains the same IP address.

4. SMF ↔ UPF: N4 Session Modification
5. SMF → AMF: Nsmf_Communication_N1N2MessageTransfer
   The N2 SM information contains PDU Session ID, QFI(s), QoS Profile(s), CN Tunnel Info, S-NSSAI from the Allowed NSSAI, Session-AMBR, PDU Session Type and User Plane Policy Enforcement.
   The N1 SM container contains the PDU Session Establishment Accept that the AMF shall provide to the UE.
6. The AMF sends an N2 PDU Session Request message to N3IWF to establish the access resources for this PDU Session.
7. N3IWF ↔ UE: IKE_Create_Child_SA
   Based on its own policies and configuration, and based on the QoS profiles received in the previous step, the N3IWF determines the number of IPsec child SAs to establish and the QoS profiles associated with each IPsec child SA. In our case, the N3IWF decides to establish one IPsec child SA and associate all QoS profiles with this IPsec child SA. All QoS Flows of the PDU Session will consequently be transferred over one IPsec child SA.
   The N3IWF sends an IKE Create_Child_SA request according to the IKEv2 specification (RFC 7296) to establish the IPSec child SA for the PDU Session. This request shall include a 3GPP-specific Notify payload which contains
   - the QFI(s) associated with the child SA
   - the identity of the PDU Session associated with this child SA
   - optionally a DSCP value associated with the child SA



8. N3IWF → UE: PDU Session Establishment Accept
   N3IWF forwards the PDU Session Establishment Accept from step 6 to the UE, via the IPSec SA for NAS signaling.
9. N3IWF → AMF: N2 PDU Session Request Ack
10. N3IWF → AMF: N2 PDU Session Response
    The AN Tunnel Info corresponds to the Access Network address of the N3 tunnel corresponding to the PDU Session. If the (R)AN rejects QFI(s) the SMF is responsible of updating the QoS rules in the UE accordingly.
11. AMF → SMF: Nsmf_PDUSession_UpdateSMContext request
    The AMF forwards the N2 SM information received from (R)AN to the SMF.
    If a list of rejected QFI(s) is included in the N2 SM information, the SMF shall release the rejected QFI(s) associated QoS profiles.
12. SMF ↔ UPF: N4 Session Modification
    The SMF provides AN Tunnel Info to the UPF as well as the corresponding forwarding rules. Since the PDU Session Establishment Request was due to mobility between 3GPP and non-3GPP, the downlink data path is now switched towards the target access.
13. SMF → AMF: Nsmf_PDUSession_UpdateSMContext response

In the user-plane:

- When the UE has to transmit an UL PDU, the UE shall determine the QFI associated with the UL PDU (by using the QoS rules of the PDU Session), it shall encapsulate the UL PDU inside a GRE packet and shall forward the GRE packet to N3IWF via the IPsec child SA associated with this QFI. The header of the GRE packet carries the QFI associated with the UL PDU.

- When the N3IWF receives a DL PDU via N3, the N3IWF uses the QFI and the identity of the PDU Session in order to determine the IPsec child SA to use for sending the DL PDU over NWu. The N3IWF encapsulates the DL PDU inside a GRE packet and copies the QFI in the header of the GRE packet. The N3IWF may include also in the GRE header a Reflective QoS Indicator (RQI), which shall be used by the UE to enable reflective QoS.

Chapter Summary

On completion of this chapter, the participants are able to:

- Analyze the basic procedures for 5GC
  - Explain the Registration Procedures
  - Explore the Service Request Procedures
  - Examine the Session Management Procedures
  - Interpret the Handover Procedures

Student Notes

Course Summary

On completion of this course the participants are able to:

- Explain the basic conceptual network architecture and technology for the 5G Core
- List and explain Identifiers relevant for the 5GC
- List the interfaces and explain the signaling, protocols and service exchange between the network functions
- Analyze the basic procedures for 5GC

Student Notes

Acronyms & Abbreviations

(R)AN	(Radio) Access Network
3GPP	3rd Generation Partnership Project
5G-AN	5G Access Network
5GC	5G Core Network
5G-GUTI	5G Globally Unique Temporary Identifier
5GS	5G System
5G-S-TMSI	5G S-Temporary Mobile Subscription Identifier
5QI	5G QoS Identifier
AF	Application Function
AMF	Access and Mobility Management Function
ANDSF	Access Network Discovery and Selection Function
AS	Access Stratum
AUSF	Authentication Server Function
CDN	Content Delivery Network
CEE	Cloud Execution Environment
CN	Core Network
COMPA	Control Orchestration Management Policy Analytics
CP	Control Plane
CPE	Customer Premises/Provided Equipment
CUPS	CP/UP Split

Student Notes

Acronyms & Abbreviations

DC	Dual Connectivity
DCN	Dedicated Core Network
DECOR	Dedicated Core Network
DL	Downlink
DMBB	Dedicated MBB
DN	Data Network
DNAI	DN Access Identifier
DNN	Data Network Name
eDECOR	enhanced DECOR
EM	Element Management
EN-DC	E-UTRA-NR Dual Connectivity
EPC	Evolved Packet Core
EPS	Evolved Packet System
E-UTRA	Evolved Universal Terrestrial Radio Access
FQDN	Fully Qualified Domain Name
GBR	Guaranteed Bit Rate
GFBR	Guaranteed Flow Bit Rate
GMLC	Gateway Mobile Location Centre
GPSI	Generic Public Subscription Identifier
GTP	GPRS Tunneling Protocol
GUAMI	Globally Unique AMF Identifier

Student Notes

Acronyms & Abbreviations

HOT	Heat Orchestration Template
HR	Home Routed (roaming)
ICT	Information and Communication Technology
IMSI	IP Multimedia Subsystem
IMSI	International Mobile Subscriber Identity
IMT	International Mobile Telecommunications
IoT	Internet of Things
IPsec	Internet Protocol Security
ITU	International Telecommunication Union
LADN	Local Area Data Network
LBO	Local Break Out (roaming)
LCM	Life Cycle Management
LMF	Location Management Function
LRF	Location Retrieval Function
MANO	Management and Orchestration
MBB	Mobile BroadBand
MCC	Mobile Country Code
MCG	Master Cell Group
MFBR	Maximum Flow Bit Rate
MICO	Mobile Initiated Connection Only
MME	Mobility Management Entity
MN	Master Node

Student Notes

Acronyms & Abbreviations

MNC	Mobile Network Code
MOCN	Mobile Operator Core Network
MR-DC	Multi-RAT Dual Connectivity
MTC	Machine Type Communication
MVNO	Mobile Virtual Network Operator
N3IWF	Non-3GPP InterWorking Function
NAI	Network Access Identifier
NAS	Non-Access Stratum
NaaS	Network as a service
NE-DC	NR-E-UTRA Dual Connectivity
NEF	Network Exposure Function
NF	Network Function
NFV	Network Function Virtualization
NFVI	NFV Infrastructure
NGEN-DC	NG-RAN E-UTRA-NR Dual Connectivity
NGMN	Next Generation Mobile Networks
NR	New Radio
NRF	Network Repository Function
NSA	Non Stand-Alone
NSI ID	Network Slice Instance Identifier
NSSAI	Network Slice Selection Assistance Information
NSSF	Network Slice Selection Function

Student Notes

Acronyms & Abbreviations

NSSP	Network Slice Selection Policy
NWDAF	Network Data Analytics Function
OVF	Open Virtualization Format
PCF	Policy Control Function
PDU	Protocol Data Unit
PEI	Permanent Equipment Identifier
PER	Packet Error Rate
PFD	Packet Flow Description
PPD	Paging Policy Differentiation
PPI	Paging Policy Indicator
PSA	PDU Session Anchor
QFI	QoS Flow Identifier
QoE	Quality of Experience
RAT	Radio Access Technology
RFSP	RAT Frequency Selection Priority
RQA	Reflective QoS Attribute
RQI	Reflective QoS Indication
RRC	Radio Resource Control
SA NR	Standalone New Radio
SBA	Service Based Architecture
SBI	Service Based Interface
SCEF	Service Capability Exposure Function

Student Notes

Acronyms & Abbreviations

SCG	Secondary Cell Group
SD	Slice Differentiator
SDF	Service Data Flow
SDN	Software Defined Networks
SEAF	Security Anchor Functionality
SEPP	Security Edge Protection Proxy
SMF	Session Management Function
SN	Secondary Node
S-NSSAI	Single Network Slice Selection Assistance Information
SSC	Session and Service Continuity
SST	Slice/Service Type
SUCI	Subscription Concealed Identifier
SUPI	Subscription Permanent Identifier
TAU	Tracking Area Update
TOSCA	Topology and Orchestration Specification for Cloud Application
TTC	Time to Customer
TTM	Time to Market
UDC	User Data Consolidation
UDR	Unified Data Repository
UDSF	Unstructured Data Storage Function
UL	Uplink

Student Notes

Acronyms & Abbreviations

UL CL	Uplink Classifier
URLLC	Ultra-Reliable and Low Latency Communications
UPF	User Plane Function
URSP	UE Route Selection Policy
V2X	Vehicle to Anything
VIM	Virtualized Infrastructure Manager
VNF	Virtualized Network Function
VNFM	VNF Manager
YAML	Yet Another Markup Language
YANG	Yet Another Next Generation

Student Notes

Intentionally Blank

ericsson.com/ourportfolio/services/learning-services

Ericsson AB
Stockholm, Sweden
Telephone: +46 10 719 0000

www.ericsson.com/ourportfolio/services/learning-services

LZT1382060 Uae R3A

480233