Core Network

Architecture and Signaling Procedures

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Version 2.2.0, 2026-10-21

Table of Contents

Copyright and License . . . 5
Part I: GPRS Core . . . 6
1. Architecture and Specifications . . . 7
1.1. Network Elements . . . 7
1.2. Technical Specifications . . . 8
2. Protocol Stack . . . 11
2.1. GTPv1-C . . . 11
2.1.1. Technical Overview . . . 11
2.1.2. Packet Format . . . 12
2.1.3. Message Categories . . . 16
2.1.4. Error Handling . . . 22
2.1.5. References . . . 23
3. Functional Description and Information Flows . . . 25
3.1. PDP Context Activation Procedure . . . 25
3.1.1. Technical Overview . . . 25
3.1.2. Call Flow . . . 25
3.1.3. Step-by-Step Description . . . 26
3.1.4. Summary of Key Information Elements . . . 29
3.1.5. Possible Failures and Required Actions . . . 30
3.1.6. References . . . 31
3.2. PDP Context Deactivation Procedure . . . 33
3.2.1. Technical Overview . . . 33
3.2.2. Call Flow . . . 34
3.2.3. Step-by-Step Description . . . 34
3.2.4. Summary of Key Information Elements . . . 37
3.2.5. Possible Failures and Required Actions . . . 37
3.2.6. References . . . 39
Part II: Evolved Packet Core (EPC) . . . 40
4. Architecture and Specifications . . . 41
4.1. Network Elements . . . 41
4.2. Technical Specifications . . . 43
5. Protocol Stack . . . 46
5.1. S1AP (S1 Application Protocol) . . . 46
5.1.1. Technical Overview . . . 46
5.1.2. Message Format . . . 47
5.1.3. Message Categories . . . 48
5.1.4. References . . . 55
5.2. NAS (Non-Access Stratum) . . . 57
5.2.1. Technical Overview . . . 57
5.2.2. General Message Format . . . 57

5.2.3. Message Categories . . . 61
5.2.4. References . . . 65
5.3. GTPv2-C . . . 66
5.3.1. Technical Overview . . . 66
5.3.2. Packet Format . . . 66
5.3.3. Message Categories . . . 68
5.3.4. References . . . 73
5.3.5. Load and Overload Control . . . 74
5.4. PFCP (Packet Forwarding Control Protocol) . . . 78
5.4.1. Technical Overview . . . 78
5.4.2. Packet Format . . . 79
5.4.3. Message Categories . . . 81
5.4.4. References . . . 83
6. Functional Description and Information Flows . . . 85
6.1. Attach Procedure . . . 85
6.1.1. Technical Overview . . . 85
6.1.2. Call Flow . . . 85
6.1.3. Step-by-Step Description . . . 86
6.1.4. References . . . 88
6.2. Detach Procedure . . . 89
6.2.1. UE-Initiated Detach Procedure . . . 89
6.2.2. HSS-Initiated Detach Procedure . . . 92
6.3. Service Request Procedure . . . 95
6.3.1. UE-Initiated Service Request Procedure . . . 95
6.3.2. Network-Triggered Service Request Procedure . . . 98
6.4. Dedicated Bearer Activation Procedure . . . 101
6.4.1. Technical Overview . . . 101
6.4.2. Call Flow . . . 102
6.4.3. Step-by-Step Description . . . 102
6.4.4. Possible Failures and Required Actions . . . 105
6.4.5. References . . . 106
6.5. Bearer Modification Procedure . . . 107
6.5.1. P-GW-Initiated Bearer Modification Procedure . . . 107
6.5.2. HSS-Initiated Subscribed QoS Modification Procedure . . . 109
6.6. P-GW-Initiated Bearer Deactivation Procedure . . . 112
6.6.1. Technical Overview . . . 112
6.6.2. Call Flow . . . 113
6.6.3. Step-by-Step Description . . . 113
6.6.4. References . . . 115
6.7. Handover Procedure . . . 116
6.7.1. X2-Based Handover Procedure . . . 116

6.7.2. S1-Based Handover Procedure with MME Relocation . . . 123
6.7.3. S1-Based Handover Procedure without MME Relocation . . . 131
6.8. RADIUS Usage on the Gi/SGi Interface . . . 139
6.8.1. Technical Overview . . . 139
6.8.2. Call Flow . . . 140
6.8.3. Step-by-Step Description . . . 141
6.8.4. Possible Failures and Required Actions . . . 144
6.8.5. References . . . 145
6.9. Tracking Area Update Procedure . . . 145
6.9.1. Technical Overview . . . 145
6.9.2. Call Flow . . . 147
6.9.3. Step-by-Step Description . . . 148
6.9.4. Summary of Key Information Elements . . . 152
6.9.5. Possible Failures and Required Actions . . . 153
6.9.6. References . . . 154
Part III: 5G Core Network (5GC) . . . 156
7. Architecture and Specifications . . . 157
7.1. Service-Based Representation . . . 157
7.2. Reference Point Representation . . . 158
7.3. Network Functions . . . 159
7.4. Reference Points . . . 161
Glossary . . . 163

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The latest edition is published at https://amirsarebani81.github.io/core-network/, and its source is available at https://github.com/amirsarebani81/core-network.

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Part I: GPRS Core

This part describes the General Packet Radio Service (GPRS) core network: its network elements and the interfaces between them, the protocols that carry signaling between the network elements, and the signaling procedures that run over those protocols.

Chapter 1. Architecture and Specifications

The GPRS core network, which this book calls the GPRS Core, provides packet-switched connectivity to a mobile subscriber and is the direct predecessor of the Evolved Packet Core (EPC) architecture that Part II describes. This chapter describes the GPRS Core in Iu mode with Gn/Gp interfaces, based on the configuration that 3GPP TS 23.060 clause 5.4.0 shows in Figure 2 ("Overview of the GPRS Logical Architecture when based on Gn/Gp interfaces"), with the optional PCRF and the charging systems of the policy and charging control architecture added.

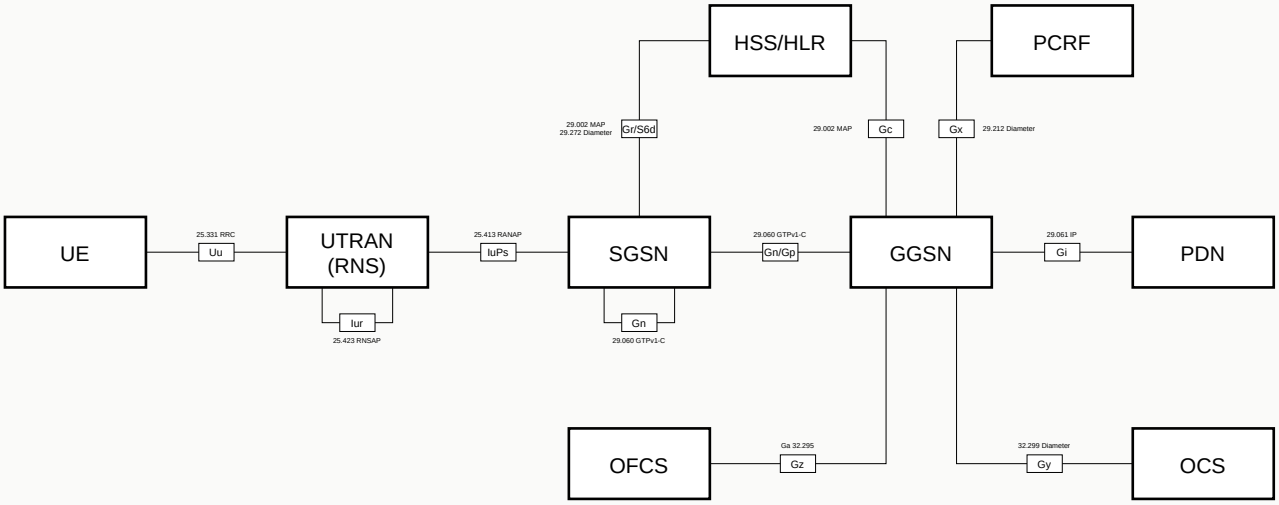


Figure 1. GPRS Core architecture

The figure above shows the path of packet-switched traffic from the UE, through the UTRAN and the two GPRS Support Nodes, to an external packet data network. The figure also shows the control-plane nodes that serve the GPRS Support Nodes: the HSS/HLR, which holds subscription data for the SGSN and the GGSN, the PCRF, which provides policy and charging control to the GGSN, and the OCS and the OFCS, which charge for the traffic that the GGSN carries. Each reference point in the figure carries the 3GPP specification and the protocol that it uses.

1.1. Network Elements

UE (User Equipment)

The UE is the subscriber's device, for example a mobile phone or a data modem, that connects to the UTRAN over the Uu radio interface. It is the endpoint for all mobility management, session management, and user-plane traffic.

UTRAN (Universal Terrestrial Radio Access Network)

The UTRAN is the Universal Mobile Telecommunications System (UMTS) radio access network, made up of Radio Network Subsystems (RNSs), each of which contains a Radio Network Controller (RNC) and the Node Bs that the RNC controls. It provides the Uu radio interface towards the UE and relays packet-switched signaling and user data to the SGSN over IuPs. Two RNCs interconnect over Iur, for example so that a Drift RNS can provide radio resources to the Serving RNS of a UE (TS 25.401 clause 6).

SGSN (Serving GPRS Support Node)

The SGSN is the node that serves the UE, handling mobility management, session management, and the forwarding of user data between the UTRAN and the GGSN. Unlike the Mobility Management Entity (MME) in the EPC, the SGSN usually carries both control-plane signaling and user-plane traffic, and it reaches the GGSN over Gn within the same Public Land Mobile Network (PLMN) or over Gp towards another PLMN. Two SGSNs also interconnect over Gn, for example to transfer the context of a UE when the serving SGSN changes.

GGSN (Gateway GPRS Support Node)

The GGSN is the gateway between the GPRS Core and the external packet data network. It anchors the Packet Data Protocol (PDP) address of the UE and routes packets between the SGSN over Gn/Gp and the PDN over Gi. The GGSN requests online credit control from the OCS over Gy and sends offline charging information to the OFCS over Gz (TS 23.203 clauses 5.2.4 and 5.2.5).

HSS/HLR (Home Subscriber Server/Home Location Register)

The HSS/HLR is the subscriber database of the GPRS Core. It stores subscription data, authentication data, and the identity of the SGSN currently serving each subscriber; the SGSN queries the HSS/HLR over Gr (S6d for an S4-SGSN) for authentication vectors and location updates, and the GGSN can query it over the optional Gc interface for the address of the serving SGSN.

PCRF (Policy and Charging Rules Function)

The PCRF is an optional policy and charging control element. It makes policy control decisions and flow-based charging control decisions, and it provides the GGSN with the resulting rules over Gx for enforcement.

OCS (Online Charging System)

The OCS is the real-time charging system for prepaid and quota-based services. It receives credit-control requests from the GGSN over Gy and grants or denies the quota for continued user-plane usage based on the available balance of the subscriber.

OFCS (Offline Charging System)

The OFCS is the postpaid charging system. It receives over Gz the Charging Data Records (CDRs) that the GGSN generates, and it forwards them to the billing domain without affecting the session of the subscriber in real time. In the GPRS Core, Gz is functionally equivalent to the Ga reference point (TS 32.240 clause 4.2.2 and TS 32.251 clause 4.2).

PDN (Packet Data Network)

The PDN is the external packet data network, for example the internet or a corporate intranet, that the UE obtains connectivity to, reached from the GGSN over Gi.

1.2. Technical Specifications

- **3GPP TS 23.007** *Restoration procedures*
- **3GPP TS 23.060** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile*

Telecommunications System (UMTS); General Packet Radio Service (GPRS); Service description; Stage 2

- **3GPP TS 23.203** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Policy and charging control architecture*
- **3GPP TS 23.246** *Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description*
- **3GPP TS 23.401** *LTE; General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access*
- **3GPP TS 24.008** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 5G; Mobile radio interface Layer 3 specification; Core network protocols; Stage 3*
- **3GPP TS 25.331** *Universal Mobile Telecommunications System (UMTS); Radio Resource Control (RRC); Protocol specification*
- **3GPP TS 25.401** *Universal Mobile Telecommunications System (UMTS); UTRAN overall description*
- **3GPP TS 25.410** *Universal Mobile Telecommunications System (UMTS); UTRAN Iu interface: General aspects and principles*
- **3GPP TS 25.413** *Universal Mobile Telecommunications System (UMTS); UTRAN Iu interface Radio Access Network Application Part (RANAP) signalling*
- **3GPP TS 25.423** *UTRAN Iur interface Radio Network Subsystem Application Part (RNSAP) signalling*
- **3GPP TS 29.002** *Mobile Application Part (MAP) specification*
- **3GPP TS 29.060** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); General Packet Radio Service (GPRS); GPRS Tunnelling Protocol (GTP) across the Gn and Gp interface*
- **3GPP TS 29.061** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 5G; Interworking between the Public Land Mobile Network (PLMN) supporting packet based services and Packet Data Networks (PDN)*
- **3GPP TS 29.212** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; Policy and Charging Control (PCC); Reference points*
- **3GPP TS 29.272** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; Evolved Packet System (EPS); Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on Diameter protocol*
- **3GPP TS 29.274** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; 3GPP Evolved Packet System (EPS); Evolved General Packet Radio Service (GPRS) Tunnelling Protocol for Control plane (GTPv2-C); Stage 3*
- **3GPP TS 29.281** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; General Packet Radio System (GPRS) Tunnelling Protocol User Plane (GTPv1-U)*
- **3GPP TS 32.240** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 5G; Telecommunication management; Charging management; Charging architecture and principles*
- **3GPP TS 32.251** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile*

Telecommunications System (UMTS); LTE; Telecommunication management; Charging management; Packet Switched (PS) domain charging

- **3GPP TS 32.295** *Telecommunication management; Charging management; Charging Data Record (CDR) transfer*
- **3GPP TS 32.299** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 5G; Telecommunication management; Charging management; Diameter charging applications*

Chapter 2. Protocol Stack

2.1. GTPv1-C

2.1.1. Technical Overview

The GPRS Tunnelling Protocol (GTP) is the protocol between the GPRS Support Nodes (GSNs) of the GPRS Core, and TS 29.060 defines both GTP for the control plane (GTP-C) and GTP for the user plane (GTP-U) (TS 29.060 clause 4.1). This section describes GTP version 1 for the control plane (GTPv1-C), which the SGSN and the GGSN use to create, modify, and delete the tunnels that carry the PDP contexts of a subscriber. TS 29.060 calls the subscriber's device the Mobile Station (MS); this section uses the term UE throughout, as the rest of the book does.

GTPv1-C applies over the Gn interface, between GSNs in the same PLMN, and over the Gp interface, between GSNs in different PLMNs (TS 29.060 clause 4.1). The Iu interface between the SGSN and the UTRAN carries only GTP-U, and on that interface the Radio Access Network Application Part (RANAP), together with the signaling part of GTP-U, performs the control function for the user plane. An MME can also use GTPv1-C towards a Gn/Gp SGSN, for roaming and for inter-access mobility as TS 23.401 Annex D specifies (TS 29.060 clause 4.1).

From Release 8 onwards, TS 29.281 is the normative specification of the user plane of GTP version 1 (GTPv1), and it supersedes the GTP-U provisions of TS 29.060 (TS 29.060 clause 1). TS 29.060 clause 6 still defines one header format for both GTP-C and GTP-U. Release 8 also removed the interworking between GTPv1 and GTP version 0 (GTPv0), so a GTPv1 entity of Release 8 or later can listen on the GTPv0 port 3386 or not; if it listens on that port, it should silently discard any GTPv0 message that it receives (TS 29.060 clause 4.2).

2.1.1.1. Transport

GTPv1-C runs over the User Datagram Protocol (UDP) and the Internet Protocol (IP), which together form the only path protocol that TS 29.060 clause 10.1 defines for GTP version 1. The control-plane protocol stack in TS 29.060 clause 8 (Figure 63) shows only GTP-C on top of this path protocol, and leaves the lower layers open.

Table 1. GTPv1-C protocol stack on the Gn and Gp interfaces

LAYER	PROTOCOL
Application	GTPv1-C (TS 29.060)
Transport	UDP (IETF RFC 768), destination port 2123 for a request message
Network	IP (IETF RFC 791)
Data link and physical	Not specified by TS 29.060

A GSN sends a GTPv1-C request message to the registered UDP destination port 2123 from a locally allocated source port. The peer GSN sends the response message from the destination port of the request to the source port of the request, and to the IP source address of the request (TS 29.060 clauses 10.1.1.1, 10.1.1.2, and 10.1.2.2). GTP-U request messages and encapsulated user data packets (T-PDUs) use the

registered GTP-U port 2152 instead (TS 29.060 clauses 10.1.1.1 and 10.1.1.3).

2.1.1.2. Paths and Tunnels

The GTP-C control-plane flow is logically associated with the GTP-U tunnels, but separate from them (TS 29.060 clause 8.1). Between each pair of GSNs there are one or more paths, and each path can carry one or more tunnels. A GSN can maintain a path with `Echo Request` and `Echo Response` messages, so that it detects a connectivity failure towards the peer GSN in a timely manner (TS 29.060 clause 8.1). How often a GSN sends `Echo Request` is implementation specific, but TS 29.060 clause 7.2.1 states that a GSN shall not send it more often than every 60 s on each path.

The `Echo Response` message carries the Restart Counter of the sending GSN in its Recovery information element (IE). The receiving GSN compares this value with the Restart Counter that it stored for the peer, and stores the received value if it has no stored value (TS 29.060 clause 7.2.2). A received value that is larger than the stored value, taking the integer roll-over into account, means that the peer has restarted, whereas a smaller value means a possible race condition, in which case the GSN discards the received value (TS 23.007 clause 18). When an SGSN detects that a GGSN has restarted, the SGSN considers all PDP contexts that use that GGSN as inactive, and a GGSN handles a restart of an SGSN in the same way (TS 29.060 clause 7.2.2).

2.1.1.3. Reliable Delivery

Because UDP does not guarantee delivery, a GSN starts the T3-RESPONSE timer when it sends a request message, and it retransmits the request if no response arrives before the timer expires, up to a total of N3-REQUESTS attempts (TS 29.060 clause 7.6). Both the T3-RESPONSE value and the N3-REQUESTS value are configurable per procedure. The GSN matches each response to its request through the Sequence Number in the header, which the responding GSN copies from the request, and it discards a duplicated response (TS 29.060 clauses 7.6 and 8.2).

A GSN also keeps a path counter, which it resets each time it receives a response on the path and increments each time T3-RESPONSE expires for a message on the path. When the counter exceeds N3-REQUESTS, the GSN considers the path down and notifies the upper layer, so that the upper layer can delete the PDP contexts that use the path (TS 29.060 clause 11.2).

The `SGSN Context Response` message is a special case, because the new SGSN answers it with an `SGSN Context Acknowledge` message that carries the same Sequence Number, unless the old SGSN rejected the `SGSN Context Request`. The old SGSN therefore applies the rules of a request message to an `SGSN Context Response` message for which it expects an `SGSN Context Acknowledge` message (TS 29.060 clause 7.6).

2.1.2. Packet Format

GTPv1-C uses the GTP header that TS 29.060 clause 6 defines for both GTP-C and GTP-U. The header has a mandatory part of 8 octets, followed by the optional `Sequence Number`, `N-PDU Number`, and `Next Extension Header Type` fields, which are all present whenever at least one of the `S`, `PN`, and `E` flags is set to 1. Because every GTPv1-C message sets the `S` flag to 1 (TS 29.060 clause 8.2), the GTPv1-C header is at least 12 octets long, and it grows by the length of any extension headers that follow it.

GTP version 2 for the control plane (GTPv2-C), which the EPC uses, has one header format with a Tunnel Endpoint Identifier (TEID) and one without (TS 29.274 clauses 5.1, 5.3, and 5.4). GTPv1-C, by contrast, has a single header format in which the `TEID` field is always present (TS 29.060 clause 6).

2.1.2.1. Header

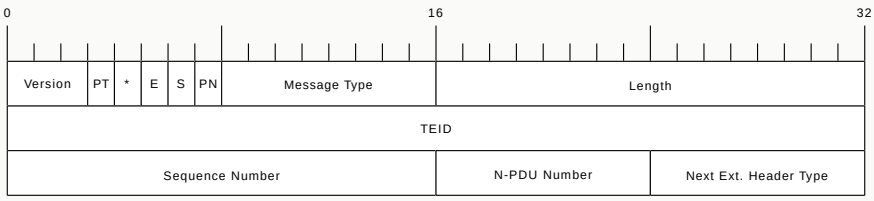


Figure 2. GTPv1-C header

`Version`

Bits 8 to 6 of octet 1. This field states the GTP version, and GTPv1-C sets it to decimal 1 (TS 29.060 clause 8.2).

`PT`

Bit 5 of octet 1. This is the Protocol Type flag, which distinguishes GTP (value 1) from the charging protocol GTP' (value 0), which TS 32.295 defines. GTPv1-C sets it to 1 (TS 29.060 clauses 6 and 8.2).

`*`

Bit 4 of octet 1. This bit is spare; the sender sets it to 0, and the receiver does not evaluate it (TS 29.060 clause 6, Figure 2).

`E`

Bit 3 of octet 1. This is the Extension Header flag; a value of 1 means that the `Next Extension Header Type` field is present and that the receiver interprets it, and a value of 0 means that the receiver does not interpret that field (TS 29.060 clause 6).

`S`

Bit 2 of octet 1. This is the Sequence Number flag, and GTPv1-C sets it to 1 (TS 29.060 clause 8.2).

`PN`

Bit 1 of octet 1. This is the N-PDU Number flag. GTPv1-C sets it to 0, and a GTP-C receiver does not return an error when this flag is set to 1 (TS 29.060 clause 8.2).

`Message Type`

Octet 2. This field states the message type, with a unique value for each GTPv1-C message. The tables in the Message Categories section below list these values (TS 29.060 clause 7.1, Table 1).

`Length`

Octets 3 to 4. This field states the length of the message in octets, excluding the mandatory first 8 octets

of the header. The `Sequence Number`, `N-PDU Number`, and `Next Extension Header Type` fields and any extension headers count as part of the length.

`TEID`

Octets 5 to 8. This field identifies the tunnel endpoint in the receiving GTP-C entity, and the sending entity sets it to the value that the receiving entity assigned. For a Tunnel Management message, the TEID identifies all PDP contexts with the same PDP address, or with the same pair of IPv4 and IPv6 addresses for PDP type IPv4v6, and the same Access Point Name (APN); for any other message, it identifies the UE and its context data (TS 29.060 clause 8.2).

`Sequence Number`

Octets 9 to 10. This field identifies a request message on the path, as a value from 0 to 65535, and the responding GSN copies it into the response. The receiver ignores this field in a message that has no response, which is the case for `Version Not Supported`, `RAN Information Relay`, and `Supported Extension Headers Notification` (TS 29.060 clause 8.2).

`N-PDU Number`

Octet 11. TS 29.060 clause 6 defines this field for the inter-SGSN Routeing Area Update procedure and some inter-system handover procedures, in which it coordinates the data transmission for the acknowledged mode of communication between the UE and the SGSN. GTPv1-C does not interpret this field (TS 29.060 clause 8.2).

`Next Extension Header Type`

Octet 12. This field states the type of the extension header that follows this field, and the value `0000 0000` means that no extension header follows (TS 29.060 clause 6, Figure 5).

The sending GSN sets the `TEID` field to all zeroes in each of the following cases (TS 29.060 clause 8.2):

- A `Create PDP Context Request` message, or a `Create MBMS Context Request` message for the Multimedia Broadcast Multicast Service (MBMS), when the GGSN has not yet assigned a TEID for the control plane to the SGSN for that UE.
- The `Echo Request`, `Echo Response`, `Version Not Supported`, and `Supported Extension Headers Notification` messages.
- The `Identification Request`, `Identification Response`, `SGSN Context Request`, and `Forward Relocation Request` messages.
- The `PDU Notification Request`, `MBMS Notification Request`, and `RAN Information Relay` messages, and every Location Management message.
- A `Relocation Cancel Request` message, unless the new SGSN has already assigned its TEID for the control plane to the old SGSN.
- An `MBMS Registration Request` message, while the successful assignment of the TEID for the control plane is not yet confirmed, and an `MBMS Session Start Request` message for an MBMS broadcast service.
- A response to a message that refers to a PDP context which the receiving GSN does not recognize; such

a response carries the Cause value "Non-existent" or "Context not found".

2.1.2.2. Extension Headers

When the E flag is set to 1, the `Next Extension Header Type` field in octet 12 of the header states the type of the first extension header. Each extension header consists of an `Extension Header Length` field, which states the length of the extension header in units of 4 octets, the extension header content, and a `Next Extension Header Type` field, which states the type of the next extension header, or 0 when no other extension header follows (TS 29.060 clause 6, Figure 3).

Bits 8 and 7 of an extension header type tell the receiver how to handle the extension header when the receiver does not know its type (TS 29.060 clause 6, Figure 4). A receiver that gets an unknown extension header marked as "comprehension not required" reads the `Next Extension Header Type` field of that extension header, which it locates through the `Extension Header Length` field. For an unknown extension header that is marked as "comprehension required", the receiver answers a request with the Cause value "unknown mandatory extension header", sends a `Supported Extension Headers Notification` message to the originator, and logs an error (TS 29.060 clause 6).

Table 2. GTPv1 extension header types

VALUE	EXTENSION HEADER	USE
`0000 0000`	No more extension headers	Ends the chain of extension headers.
`0000 0001`	MBMS support indication	An SGSN that supports MBMS adds it to `Create PDP Context Request`, `Update PDP Context Request`, `SGSN Context Request`, and `Forward Relocation Response` messages (TS 29.060 clause 6.1.4).
`0000 0010`	MS Info Change Reporting support indication	An SGSN that supports MS Info Change Reporting adds it to `Create PDP Context Request` and `Update PDP Context Request` messages, when operator policy permits location reporting to the GGSN operator (TS 29.060 clause 6.1.5).
`1100 0000`	PDCP PDU number	Carries the Packet Data Convergence Protocol (PDCP) sequence number of N-PDUs that are not yet acknowledged, for example at Serving Radio Network Subsystem (SRNS) relocation (TS 29.060 clause 6.1.1).
`1100 0001`	Suspend Request	At inter-SGSN handover, the new 2G SGSN adds it to an `SGSN Context Request` message after it receives a Suspend message from the Base Station Subsystem (BSS), when a UE that supports Dual Transfer Mode (DTM) has an ongoing circuit-switched call and moves to a cell that does not support DTM (TS 29.060 clause 6.1.2).
`1100 0010`	Suspend Response	The old SGSN adds it to the `SGSN Context Response` message that answers a Suspend Request (TS 29.060 clause 6.1.3).

TS 29.060 reserves the extension header types `0010 0000`, `0100 0000`, and `1000 0001` for GTP-U (TS 29.060 clause 6, Figure 5), and TS 29.281 defines them as the Service Class Indicator, UDP Port, and RAN Container extension headers (TS 29.281 clause 5.2.1, Figure 5.2.1-3).

2.1.2.3. Information Elements

The information elements of a GTPv1-C message follow the header, either in Type-Value (TV) or in Type-Length-Value (TLV) format (TS 29.060 clause 7.7.0). The most significant bit of the 1-octet `Type` field selects the format: a value of 0 means TV format, in which the type value alone determines the fixed length of the IE, and a value of 1 means TLV format, in which a 2-octet `Length` field follows the `Type` field. The `Length` field excludes the `Type` and `Length` fields themselves.

The sender sorts the IEs of a message in ascending order of their type values (TS 29.060 clause 7.7.0). A message carries at most one IE of each type, except for a list of IEs that can repeat, for example the PDP Context, Network layer Service Access Point Identifier (NSAPI), Tunnel Endpoint Identifier Data II, and Charging Characteristics IEs (TS 29.060 clause 8.2). Each message definition marks each of its IEs as Mandatory, Conditional, or Optional (TS 29.060 clause 7.1.1).

The difference between the two formats matters for error handling. A receiver skips an unknown TLV IE by its `Length` field, whereas after an unknown TV IE, which has no `Length` field, the receiver discards the rest of the message (TS 29.060 clause 11.1.9).

2.1.3. Message Categories

TS 29.060 clause 7 groups the GTPv1-C messages into six categories: Path Management Messages, Tunnel Management Messages, Location Management Messages, Mobility Management Messages, MBMS Messages, and MS Info Change Reporting Messages. Every GTPv1-C message applies over the Gn and Gp interfaces, so the tables below state the direction of each message instead of its interface. The `Type` column gives the decimal message type value from TS 29.060 clause 7.1, Table 1.

Table 1 also lists message types that only the charging protocol GTP' uses, such as `Node Alive Request` and `Data Record Transfer Request` (TS 32.295), and message types that only GTP-U uses, such as `Error Indication`, `End Marker`, and `G-PDU` (TS 29.281). The tables below leave these message types out.

2.1.3.1. Path Management Messages

Path management messages check that a peer GSN is alive and reachable, and report which GTP version and which extension headers a GSN supports. Any pair of GSNs, and a GSN and an RNC, can exchange these messages (TS 29.060 clause 7.2.0).

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`Echo Request`	1	GSN to GSN	Checks that the peer GSN is alive.
`Echo Response`	2	GSN to GSN	Confirms that the GSN is alive, and reports its Restart Counter in the Recovery IE.
`Version Not Supported`	3	GSN to GSN	Tells the sender of a message with an unsupported GTP version which latest version the receiving GSN supports. The message consists of the GTP header only.

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`Supported Extension Headers Notification`	31	GSN to GSN	Lists the extension headers that the GSN supports, after the GSN received an extension header that it was required to interpret but could not.

2.1.3.2. Tunnel Management Messages

Tunnel management messages create, modify, and delete the PDP contexts and their tunnels between the SGSN and the GGSN, and support the network-requested activation of a PDP context (TS 29.060 clause 7.3).

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`Create PDP Context Request`	16	SGSN to GGSN	Creates a PDP context in the GGSN, and the tunnel between the SGSN and the GGSN for that PDP context, during the PDP Context Activation procedure.
`Create PDP Context Response`	17	GGSN to SGSN	Reports whether the GGSN created the PDP context, and returns the End User Address, the negotiated Quality of Service (QoS), and the TEIDs and addresses of the GGSN.
`Update PDP Context Request`	18	SGSN to GGSN, or GGSN to SGSN	Changes the QoS or the path of an existing PDP context, for example during an inter-SGSN Routeing Area Update, during the PDP Context Modification procedure, or when the SGSN sets up Direct Tunnel. The GGSN can also send this message, for example to request the location of the UE.
`Update PDP Context Response`	19	GGSN to SGSN, or SGSN to GGSN	Reports the outcome of an `Update PDP Context Request`.
`Delete PDP Context Request`	20	SGSN to GGSN, or GGSN to SGSN	Deactivates a PDP context, or all PDP contexts of a PDN connection, during GPRS Detach or PDP context deactivation. This message takes precedence over any other Tunnel Management message in a collision.
`Delete PDP Context Response`	21	GGSN to SGSN, or SGSN to GGSN	Reports the outcome of a `Delete PDP Context Request`.
`Initiate PDP Context Activation Request`	22	GGSN to SGSN	Asks the SGSN to start the Secondary PDP Context Activation procedure, for network-requested bearer control.
`Initiate PDP Context Activation Response`	23	SGSN to GGSN	Reports whether the UE activated the secondary PDP context, rejected it, did not respond before timer T3385 expired, or was temporarily not reachable because of power saving.

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`PDU Notification Request`	27	GGSN to SGSN	Asks the SGSN to request the UE to activate a PDP context, during the Network-Requested PDP Context Activation procedure, after the GGSN received a T-PDU for a PDP address that has no PDP context.
`PDU Notification Response`	28	SGSN to GGSN	Reports whether the network-requested PDP context activation proceeds.
`PDU Notification Reject Request`	29	SGSN to GGSN	Reports that the network-requested PDP context activation proceeded but that the UE did not establish the PDP context, and states the reason.
`PDU Notification Reject Response`	30	GGSN to SGSN	Reports the outcome of a `PDU Notification Reject Request`.

TS 29.060 also lists the `Error Indication` message (type 26) among the Tunnel Management messages, but clause 7.3.7 refers to TS 29.281 for its specification, and Table 1 marks it as a GTP-U message only. A GSN sends the `Error Indication` message to the GTP-U port 2152 rather than to the GTP-C port (TS 29.060 clause 10.1.1.4).

2.1.3.3. Location Management Messages

Location management messages are optional. They support the Network-Requested PDP Context Activation procedure when the GGSN has no Signalling System No. 7 (SS7) Mobile Application Part (MAP) interface, the Gc interface, to the HLR. In this case, the GGSN exchanges GTPv1-C messages with a GTP-MAP protocol-converting GSN, which converts them to and from the MAP messages that it exchanges with the HLR (TS 29.060 clause 7.4.0).

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`Send Routeing Information for GPRS Request`	32	GGSN to protocol-converting GSN	Asks for the IP address of the SGSN that serves the UE, which the International Mobile Subscriber Identity (IMSI) of the UE identifies.
`Send Routeing Information for GPRS Response`	33	Protocol-converting GSN to GGSN	Reports whether the protocol-converting GSN accepted the request. Only an accepted response can carry the IP address of the serving SGSN, the MAP error code from the HLR, and the reason for which the Mobile station Not Reachable for GPRS (MNRG) flag is set.
`Failure Report Request`	34	GGSN to protocol-converting GSN	Asks the protocol-converting GSN to set the MNRG flag for the IMSI in the HLR.
`Failure Report Response`	35	Protocol-converting GSN to GGSN	Reports the outcome of a `Failure Report Request`.
`Note MS GPRS Present Request`	36	Protocol-converting GSN to GGSN	Tells the GGSN that the UE is reachable for GPRS again. The GGSN then clears the MNRG flag and stores the SGSN address from the request in each PDP context of the IMSI.

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`Note MS GPRS Present Response`	37	GGSN to protocol-converting GSN	Reports the outcome of a `Note MS GPRS Present Request`.

2.1.3.4. Mobility Management Messages

Mobility management messages transfer the data of a UE from the old SGSN to the new SGSN during the GPRS Attach and inter-SGSN Routeing Area Update procedures, and the new SGSN derives the address of the old SGSN from the old Routeing Area Identity (RAI) (TS 29.060 clause 7.5.0). The Forward Relocation and Relocation Cancel messages of this category also support the SRNS Relocation and packet-switched (PS) handover procedures (TS 29.060 clauses 7.5.6 to 7.5.10). The requirements of this category for an SGSN also apply to an MME that supports GTPv1-C for roaming and inter-access mobility towards a Gn/Gp SGSN (TS 29.060 clause 7.5.0).

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`Identification Request`	48	New SGSN to old SGSN	Asks for the IMSI of a UE that identified itself with a Packet Temporary Mobile Subscriber Identity (P-TMSI) at GPRS Attach, after the UE changed SGSN since it detached.
`Identification Response`	49	Old SGSN to new SGSN	Reports whether the old SGSN accepted the request. An accepted response carries the IMSI of the UE, and can also carry Authentication Triplet or Authentication Quintuplet IEs.
`SGSN Context Request`	50	New SGSN to old SGSN	Asks for the Mobility Management (MM) context and the PDP contexts of the UE.
`SGSN Context Response`	51	Old SGSN to new SGSN	Returns the MM context and the PDP contexts of the UE, or rejects the request.
`SGSN Context Acknowledge`	52	New SGSN to old SGSN	Confirms that the new SGSN received the PDP contexts and is ready to receive user data. The old SGSN starts to forward user data packets only after it receives this message.
`Forward Relocation Request`	53	Old SGSN to new SGSN	Carries the information that the new SGSN needs to perform SRNS Relocation with the target RNC, or PS handover with the target BSS.
`Forward Relocation Response`	54	New SGSN to old SGSN	Reports the outcome of a `Forward Relocation Request`. For SRNS Relocation and PS handover to Iu mode, it can carry the Radio Access Bearer (RAB) Setup Information and the UTRAN transparent container from the target RNC; for PS handover to A/Gb mode, it can carry the BSS Container.
`Forward Relocation Complete`	55	New SGSN to old SGSN	Tells the old SGSN that the SRNS Relocation or the PS handover finished successfully.
`Relocation Cancel Request`	56	Old SGSN to new SGSN	Cancels an SRNS Relocation or a PS handover, at the request of the source RNC or the source BSS.

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`Relocation Cancel Response`	57	New SGSN to old SGSN	Reports the outcome of a `Relocation Cancel Request`.
`Forward SRNS Context`	58	Old SGSN to new SGSN	Relays the RANAP Forward SRNS Context message, with one RAB Context IE for each RAB context, to the new SGSN, which forwards it to the target RNC, for a hard handover with a switch in the core network. The old SGSN also sends this message, with the PDU Numbers IE, during PS handover in the cases that TS 29.060 clause 7.5.13 lists.
`Forward Relocation Complete Acknowledge`	59	Old SGSN to new SGSN	Reports the outcome of a `Forward Relocation Complete`.
`Forward SRNS Context Acknowledge`	60	New SGSN to old SGSN	Reports the outcome of a `Forward SRNS Context`.
`UE Registration Query Request`	61	SGSN to MME	Asks an MME whether a UE is registered there, for circuit-switched and packet-switched coordination in shared UTRAN and GSM EDGE Radio Access Network (GERAN) access.
`UE Registration Query Response`	62	MME to SGSN	Reports whether the UE is registered in the MME, and with which core network operator.
`RAN Information Relay`	70	SGSN to SGSN or MME	Tunnels a RAN INFORMATION message, which the SGSN received from a BSS or an RNS, to the destination SGSN or MME.

TS 29.060 clause 7.6 treats `Forward Relocation Complete` and `Forward SRNS Context` as request messages, and `SGSN Context Acknowledge`, `Forward Relocation Complete Acknowledge`, and `Forward SRNS Context Acknowledge` as response messages, for the purpose of reliable delivery.

2.1.3.5. MBMS Messages

MBMS messages are control-plane messages between the SGSN and the GGSN that support MBMS in accordance with TS 23.246, and TS 29.060 divides them into UE-specific messages and service-specific messages (TS 29.060 clause 7.5A.0). The UE-specific messages create, update, and delete the MBMS UE context of one UE, and the service-specific messages register the SGSN for an MBMS service and control the MBMS Bearer Context and the sessions of that service, which the Broadcast Multicast Service Centre (BM-SC) triggers (TS 29.060 clauses 7.5A.1 and 7.5A.2).

Table 3. UE-specific MBMS messages

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`MBMS Notification Request`	96	GGSN to SGSN	Asks the SGSN to request the UE to activate an MBMS UE context, after the GGSN received an Internet Group Management Protocol (IGMP) or Multicast Listener Discovery (MLD) join message from the UE and the BM-SC authorized the request.

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`MBMS Notification Response`	97	SGSN to GGSN	Reports whether the MBMS context activation proceeds.
`MBMS Notification Reject Request`	98	SGSN to GGSN	Reports that the UE did not establish the MBMS UE context, for example because the UE rejected the activation or did not respond, and states the reason.
`MBMS Notification Reject Response`	99	GGSN to SGSN	Reports the outcome of an `MBMS Notification Reject Request`.
`Create MBMS Context Request`	100	SGSN to GGSN	Creates an MBMS UE context in the GGSN, and a GTP-C tunnel for it without a GTP-U tunnel, during the MBMS Context Activation procedure.
`Create MBMS Context Response`	101	GGSN to SGSN	Reports whether the GGSN created the MBMS UE context.
`Update MBMS Context Request`	102	SGSN to GGSN	Updates an MBMS UE context, for example during an inter-SGSN Routeing Area Update.
`Update MBMS Context Response`	103	GGSN to SGSN	Reports the outcome of an `Update MBMS Context Request`.
`Delete MBMS Context Request`	104	SGSN to GGSN, or GGSN to SGSN	Deletes an MBMS UE context, for example at GPRS Detach or after the UE sent an IGMP or MLD leave message.
`Delete MBMS Context Response`	105	GGSN to SGSN, or SGSN to GGSN	Reports the outcome of a `Delete MBMS Context Request`.

Table 4. Service-specific MBMS messages

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`MBMS Registration Request`	112	SGSN to GGSN	Registers the SGSN with the GGSN for an MBMS service, so that the SGSN receives the session attributes and data of that service, and creates an MBMS Bearer Context.
`MBMS Registration Response`	113	GGSN to SGSN	Reports the outcome of an `MBMS Registration Request`, and carries the Temporary Mobile Group Identity (TMGI) that the BM-SC allocated.
`MBMS De-Registration Request`	114	SGSN to GGSN, or GGSN to SGSN	From the SGSN, tells the GGSN that the SGSN no longer needs the session attributes and data of an MBMS service. From the GGSN, de-registers the SGSN as part of the BM-SC-initiated MBMS De-Registration procedure.
`MBMS De-Registration Response`	115	GGSN to SGSN, or SGSN to GGSN	Reports the outcome of an `MBMS De-Registration Request`.
`MBMS Session Start Request`	116	GGSN to SGSN	Asks the SGSN to set up the MBMS user-plane resources and the radio bearers of an MBMS session, when the BM-SC is ready to send data.

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`MBMS Session Start Response`	117	SGSN to GGSN	Reports the outcome of an `MBMS Session Start Request`.
`MBMS Session Stop Request`	118	GGSN to SGSN, or SGSN to GGSN	Releases the MBMS user-plane resources of a session when the BM-SC has no more data to send, or removes the SGSN from an MBMS broadcast service.
`MBMS Session Stop Response`	119	SGSN to GGSN, or GGSN to SGSN	Reports the outcome of an `MBMS Session Stop Request`.
`MBMS Session Update Request`	120	GGSN to SGSN	Changes the service area of an ongoing MBMS broadcast session.
`MBMS Session Update Response`	121	SGSN to GGSN	Reports the outcome of an `MBMS Session Update Request`.

2.1.3.6. MS Info Change Reporting Messages

These messages report changes in the location or the Closed Subscriber Group (CSG) information of a UE from the SGSN to the GGSN, after the GGSN requested such reports (TS 29.060 clause 7.5B.1.1). An SGSN indicates its support for location change reporting with the MS Info Change Reporting support indication extension header, and its support for CSG information change reporting with the CCRSI flag in the Extended Common Flags IE (TS 29.060 clause 7.5B.1.0).

MESSAGE	TYPE	DIRECTION	FUNCTIONALITY
`MS Info Change Notification Request`	128	SGSN to GGSN	Reports a change of the User Location Information (ULI) or of the User CSG Information (UCI) of the UE.
`MS Info Change Notification Response`	129	GGSN to SGSN	Acknowledges an `MS Info Change Notification Request`.

2.1.4. Error Handling

TS 29.060 clause 11.1 defines how a GSN handles a message with unknown, unforeseen, or erroneous content, and the GSN applies clauses 11.1.1 to 11.1.13 in decreasing order of priority. A message that the GSN "silently discards" is one that it discards without further processing; TS 29.060 clause 11.1 adds that the GSN should log the event and count the error in a statistics counter. For the purpose of these rules, the `Error Indication`, `Version Not Supported`, `RAN Information Relay`, `Supported Extension Headers Notification`, and `SGSN Context Acknowledge` messages count as response messages.

ERROR CONDITION	BEHAVIOR OF THE RECEIVING GSN	TS 29.060 CLAUSE
Unsupported GTP version	Returns a `Version Not Supported` message that carries the latest version it supports in the `Version` field, and discards the received message.	11.1.1
Message too short to contain the GTP header	Silently discards the message.	11.1.2

ERROR CONDITION	BEHAVIOR OF THE RECEIVING GSN	TS 29.060 CLAUSE
Length of a request inconsistent with the `Length` field	Returns a response with the Cause value "Invalid message format". For a response with the same error, it silently discards the message.	11.1.2
Unknown message type, or a message that the GSN does not expect, such as a response without an outstanding request	Silently discards the message.	11.1.3, 11.1.4
Mandatory IE missing from a request	Discards the request, and returns a response with the Cause value "Mandatory IE missing".	11.1.5
Mandatory IE with a value outside its defined range	Discards the request, and returns a response with the Cause value "Mandatory IE incorrect".	11.1.7
Unknown IE type	Ignores the IE: skips an unknown TLV IE by its `Length` field, and discards the rest of the message after an unknown TV IE. If the GSN cannot interpret the rest of the message because of the ignored IE, it discards the message, and for a request returns a response with the Cause value "Invalid message format".	11.1.9
IEs out of sequence	Discards the message, and for a request returns a response with the Cause value "Invalid message format".	11.1.10
Repeated IE where repetition is not specified	Handles the first occurrence of the IE, and ignores the repetitions.	11.1.12

2.1.5. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 29.060	• Clause 1 — Scope, and the relationship between TS 29.060 and TS 29.281 for the GTPv1 user plane • Clause 4.1 — General description, interfaces, and GTP-C and GTP-U roles • Clause 4.2 — Removal of GTPv1 to GTPv0 interworking • Clause 6 — GTP header, extension header format (Figure 3), handling of unknown extension headers (Figure 4), and extension header types (Figure 5) • Clause 6.1 — Extension headers • Clause 7.1 and Table 1 — Message types • Clause 7.1.1 — Presence requirements of IEs • Clause 7.2 — Path Management Messages • Clause 7.3 — Tunnel Management Messages • Clause 7.4 — Location Management Messages • Clause 7.5 — Mobility Management Messages • Clause 7.5A — MBMS Messages • Clause 7.5B.1 — MS Info Change Reporting Messages • Clause 7.6 — Reliable delivery of signalling messages • Clause 7.7.0 — IE encoding in TV and TLV format • Clause 8 — Control plane protocol stack (Figure 63), and usage of the GTP-C header • Clause 10.1 — UDP/IP path protocol, port numbers, and IP addresses • Clause 11 — Error handling and path failure
TS 29.281	• GTPv1 user plane, including the `Error Indication`, `End Marker`, and `G-PDU` messages • Clause 5.2.1 and Figure 5.2.1-3 — Extension header types that GTP-U uses
TS 29.274	• Clauses 5.1, 5.3, and 5.4 — GTPv2-C header formats with and without a TEID
TS 23.401	• Annex D — Roaming and inter-access mobility between Gn/Gp SGSNs and MMEs, for which an MME uses GTPv1-C (TS 29.060 clause 4.1)
TS 23.246	• MBMS architecture and procedures, in accordance with which the GTPv1-C MBMS messages are used (TS 29.060 clause 7.5A.0)
TS 32.295	• GTP' charging protocol, which uses the message types that TS 29.060 Table 1 marks for GTP' only
TS 23.007	• Clause 18 — GTP-C based restart procedures, including the comparison of a received Restart Counter with the stored value

Chapter 3. Functional Description and Information Flows

3.1. PDP Context Activation Procedure

3.1.1. Technical Overview

The PDP Context Activation procedure is the session management procedure that the UE starts to establish a PDP context with a GGSN in a GPRS core network with the Gn/Gp architecture (TS 23.060 clause 9.2.2.1). TS 24.008 calls the UE the MS; this chapter uses the term UE throughout. The procedure activates the default PDP context for a given PDP address and APN, and the UE activates any additional PDP context for the same PDP address and APN with the secondary PDP context activation procedure instead (TS 24.008 clause 6.1.3.1). The SGSN and the GGSN exchange the control-plane messages of the procedure over the Gn/Gp interface with GTPv1-C, which TS 29.060 defines. The PDP context provides IP or non-IP connectivity between the UE and the external PDN that the APN identifies. The procedure has these high-level effects:

On the UE

The UE starts the procedure with a Non-Access Stratum (NAS) Session Management (SM) message over the radio interface. The SM state of the UE moves from `PDP-INACTIVE` to `PDP-ACTIVE-PENDING` when the UE sends the request, and to `PDP-ACTIVE` when the UE receives the acceptance (TS 24.008 clause 6.1.3.1.1). The UE receives the allocated PDP address and the negotiated QoS.

On the SGSN

The SGSN validates the request against the PDP context subscription records of the subscriber, and selects a GGSN for the requested APN through a Domain Name System (DNS) interrogation (TS 23.060 clause 9.2.2.1 and Annex A). The SGSN then creates the PDP context in the GGSN over the Gn/Gp interface, and sets up the RAB with the RNC in Iu mode, or runs the packet flow context procedures with the BSS in A/Gb mode.

On the GGSN

The GGSN creates an entry in its PDP context table, generates a Charging ID, and allocates the PDP address (TS 23.060 clause 9.2.2.1). For authentication and authorization, the GGSN can interact with an external Authentication, Authorization, and Accounting (AAA) server through the Remote Authentication Dial-In User Service (RADIUS) over the Gi reference point (TS 29.061 clause 16), and with the PCRF over the Gx reference point (TS 29.212). The GGSN then routes PDP Protocol Data Units (PDUs) between the GPRS backbone and the external PDN.

3.1.2. Call Flow

The call flow shows the Iu mode variant of the procedure, which TS 23.060 clause 9.2.2.1 shows in Figure 64. Two parts of the call flow are optional: the external AAA or policy authorization at the GGSN, and the Update PDP Context exchange, which the SGSN starts for Direct Tunnel or after a QoS downgrade. The call flow omits the optional Invoke Trace step and the Customised Applications for Mobile network Enhanced Logic (CAMEL) procedures C1 and C2 of TS 23.060 clause 9.2.2.1, and it expands step 5 of Figure 64, Radio Access Bearer Setup, into the messages of the RAB Assignment procedure (TS 23.060 clause 12.7.4.1).

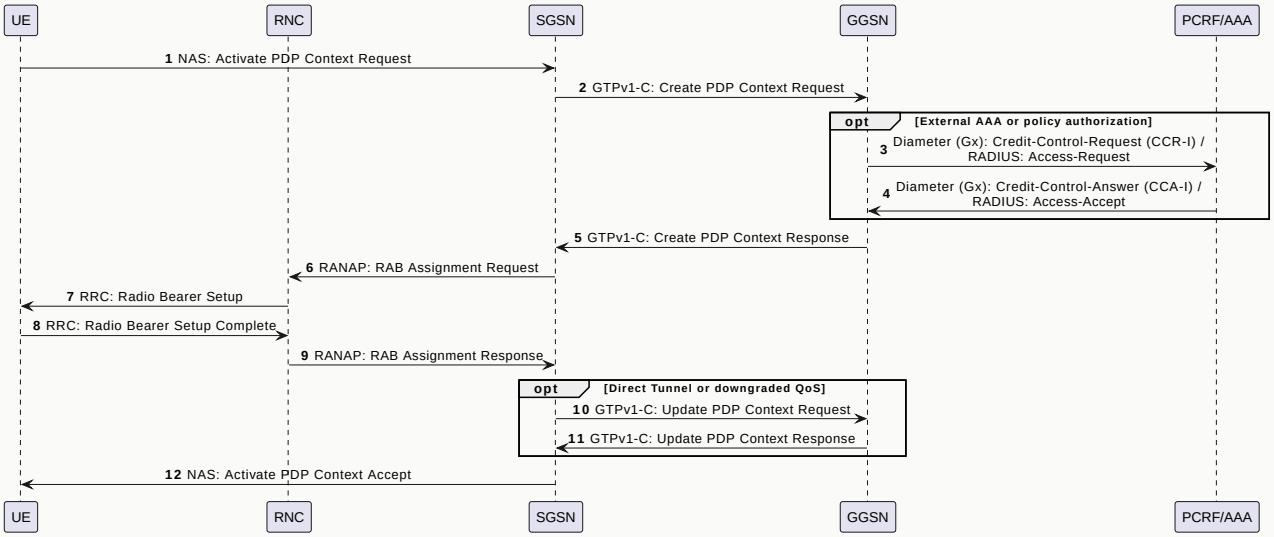


Figure 3. PDP context activation procedure call flow

3.1.3. Step-by-Step Description

1. The **UE** starts the activation by sending a NAS SM `Activate PDP Context Request` message (TS 24.008 clause 9.5.1) to the **SGSN** through the radio access network. When the UE sends this message, the UE enters the `PDP-ACTIVE-PENDING` state and starts timer T3380, whose value is 30 seconds (TS 24.008 Table 11.2c). The message carries the Transaction Identifier (TI), the Requested NSAPI, the Requested Logical Link Control (LLC) Service Access Point Identifier (SAPI), the Requested QoS, and the Requested PDP address. The Requested PDP address carries the PDP type number, for example IPv4, IPv6, IPv4v6, or non IP (TS 24.008 clause 10.5.6.4), and the UE leaves the address itself empty (TS 23.060 clause 9.2.2.1, step 1). The Requested QoS carries attributes such as the Traffic Class, the Maximum Bit Rate (MBR), the Guaranteed Bit Rate (GBR), the Delivery Order, the Residual Bit Error Rate, and the Transfer Delay (TS 24.008 clause 10.5.6.5). The message can also carry the APN, the Protocol Configuration Options (PCO), for example a request for DNS server or Proxy Call Session Control Function (P-CSCF) addresses (TS 24.008 clause 10.5.6.3), and the Request type, that is "initial request", "handover", or "emergency" (TS 24.008 clause 6.1.3.1.1).
2. The **SGSN** validates the request against the PDP context subscription records of the subscriber, and derives a GGSN address from the APN through a DNS interrogation according to the selection rules of TS 23.060 Annex A. If the SGSN cannot derive a GGSN address, or if the request is not valid according to Annex A, the SGSN rejects the activation (TS 23.060 clause 9.2.2.1, step 4). Otherwise, the SGSN sends a GTPv1-C `Create PDP Context Request` message (TS 29.060 clause 7.3.1) to the selected **GGSN** over the Gn/Gp interface. The mandatory IEs of the message are the TEID Data I, that is the SGSN TEID for downlink user-plane data, the NSAPI, the SGSN Address for signalling, the SGSN Address for user traffic, and the Quality of Service Profile. Under the conditions that TS 29.060 Table 5 states, the message also carries the IMSI, the Selection mode, the TEID Control Plane, that is the SGSN TEID for control-plane messages, the End User Address, which holds the PDP type and an empty PDP address for dynamic allocation, the APN, the Mobile Station International Subscriber Directory Number (MSISDN), the Charging Characteristics, and the IMEI(SV), which holds the International Mobile Equipment Identity (IMEI) or the International Mobile Equipment Identity and Software Version Number (IMEISV) of the UE. Optional IEs include the RAI, the PCO, the Radio Access Technology (RAT) Type, for example UTRAN, and

the User Location Information, which holds the Cell Global Identification (CGI), the Service Area Identifier (SAI), or the RAI of the UE (TS 29.060 clause 7.7.51).

3. When the **GGSN** receives the request, the GGSN can perform external authorization and policy control before the GGSN answers. If the GGSN acts as the Policy and Charging Enforcement Function (PCEF) of dynamic Policy and Charging Control (PCC), the GGSN sends a Diameter `Credit-Control-Request` (CCR) message with the `CC-Request-Type` Attribute-Value Pair (AVP) set to `INITIAL_REQUEST` to the **PCRF** over the Gx reference point (TS 29.212 clause 4.5.1). This message carries the user identity in the `Subscription-Id` AVP, the IMEI(SV) in the `User-Equipment-Info` AVP, the `IP-CAN-Type` AVP set to `3GPP-GPRS` (TS 29.212 clause 5.3.27), the APN in the `Called-Station-Id` AVP, and the UE IPv4 address or IPv6 prefix in the `Framed-IP-Address` or `Framed-IPv6-Prefix` AVP. For GPRS access, the message also carries the requested QoS in the `QoS-Information` AVP, the location of the UE, and the SGSN address (TS 29.212 clauses A.3.1 and A.3.3.1). If the APN requires authentication by an external AAA server, the GGSN sends a RADIUS `Access-Request` message to an external **AAA** server over the Gi reference point (TS 29.061 clause 16.3.1). This message carries the `User-Name` attribute, the `User-Password` attribute when the user authenticates with the Password Authentication Protocol (PAP) or the `CHAP-Password` attribute when the user authenticates with the Challenge Handshake Authentication Protocol (CHAP), the `NAS-IP-Address` attribute, which holds the GGSN IPv4 address, or the `NAS-Identifier` attribute, which holds the GGSN hostname, and the `Called-Station-Id` attribute, which holds the APN (TS 29.061 clause 16.4.1, Table 1).
4. The **PCRF** returns a Diameter `Credit-Control-Answer` (CCA) message to the **GGSN** over the Gx reference point, or the external **AAA** server returns a RADIUS `Access-Accept` message to the GGSN over the Gi reference point. In the CCA message, the PCRF can provide PCC rules in the `Charging-Rule-Install` AVP, event triggers in the `Event-Trigger` AVP, and the authorized QoS in the `QoS-Information` AVP (TS 29.212 clauses 4.5.2, 4.5.3, 4.5.5, and 5.6.3); a successful answer carries the `Result-Code` AVP set to `DIAMETER_SUCCESS` (2001) (IETF RFC 6733 section 7.1.2). In the `Access-Accept` message, the AAA server can provide the UE IPv4 address in the `Framed-IP-Address` attribute, the IPv6 prefix in the `Framed-IPv6-Prefix` attribute, and the DNS server addresses in the `MS-Primary-DNS-Server` and `MS-Secondary-DNS-Server` attributes or in the `3GPP-IPv6-DNS-Servers` sub-attribute (TS 29.061 clause 16.4.2).
5. The **GGSN** creates an entry in its PDP context table, generates a Charging ID, and allocates a PDP address according to the selected PDP type (TS 23.060 clause 9.2.2.1, step 4). The GGSN then returns a GTPv1-C `Create PDP Context Response` message (TS 29.060 clause 7.3.2) to the **SGSN** over the Gn/Gp interface. On success, the message carries the Cause, set to "Request accepted" (128), the TEID Data I, that is the GGSN TEID for uplink user-plane data, the TEID Control Plane, that is the GGSN TEID for control-plane messages, the Charging ID, the End User Address, which holds the allocated PDP address, the GGSN Address for Control Plane, the GGSN Address for user traffic, and the Quality of Service Profile. Under the conditions and options of TS 29.060 Table 6, the message can also carry the Reordering required IE, the NSAPI, the PCO, the Bearer Control Mode (BCM), and the APN Restriction. The PCO carries the BCM and optional PDP parameters for the UE (TS 23.060 clause 9.2.2.1, step 4), for example the DNS server and P-CSCF addresses that the UE requested (TS 24.008 clause 10.5.6.3). When the GGSN indicates the BCM in the PCO, the GGSN also includes the Bearer Control Mode IE with the same value (TS 29.060 clause 7.3.2).
6. When the **SGSN** receives the accepted response, the SGSN re-verifies the negotiated QoS against the subscribed QoS profile (TS 23.060 clause 9.2.2.1, step 4) and starts the radio resource setup. In Iu mode,

the SGSN sends a RANAP `RAB Assignment Request` message (TS 25.413 clause 9.1.3) to the **RNC** over the IuPs interface; in A/Gb mode, the SGSN can instead run the BSS packet flow context procedures with the BSS (TS 23.060 clause 9.2.2.1, step 7). For each RAB to set up, the message carries the RAB ID, which contains the NSAPI of the PDP context (TS 25.413 clause 9.2.1.2), and the RAB Parameters, which hold the RAB attributes such as the Traffic Class, the Maximum Bit Rate, the Guaranteed Bit Rate, and the Allocation/Retention Priority (TS 25.413 clause 9.2.1.3). The message also carries the Transport Layer Address and the Iu Transport Association, that is the GTP TEID for uplink data (TS 25.413 clauses 8.2.2, 9.2.2.1, and 9.2.2.2). These two IEs identify the user plane of the SGSN, or the user plane of the GGSN when the SGSN uses Direct Tunnel (TS 23.060 clause 12.7.4.1).

7. The **RNC** sets up the radio bearers for the RAB and sends a Radio Resource Control (RRC) `Radio Bearer Setup` message (TS 25.331 clause 10.2.33) to the **UE** over the Uu interface. The message carries the RRC transaction identifier and the RAB information to setup list. For each RAB, this list carries the RAB info, which contains the RAB identity and the Core Network (CN) domain identity, and the RB information to setup list. For each Radio Bearer (RB), the RB information to setup contains the RB identity, the Radio Link Control (RLC) info, the RB mapping info, and optionally the PDCP info (TS 25.331 clauses 10.3.4.8, 10.3.4.10, and 10.3.4.20).
8. The **UE** configures the radio bearers and returns an RRC `Radio Bearer Setup Complete` message (TS 25.331 clause 10.2.34) to the **RNC** over the Uu interface. The message carries the RRC transaction identifier.
9. The **RNC** returns a RANAP `RAB Assignment Response` message (TS 25.413 clause 9.1.4) to the **SGSN** over the IuPs interface. For each RAB that the RNC set up, the message carries the RAB ID, the Transport Layer Address, that is the RNC user-plane address, and the Iu Transport Association, that is the RNC TEID for downlink data (TS 25.413 clause 8.2.2).
10. If the SGSN established Direct Tunnel during the RAB setup, the **SGSN** sends a GTPv1-C `Update PDP Context Request` message (TS 29.060 clause 7.3.3) to the **GGSN** over the Gn/Gp interface. If the QoS attributes were downgraded during the RAB setup, the SGSN can send the same message to inform the GGSN of the downgraded QoS attributes (TS 23.060 clause 9.2.2.1, step 8). For Direct Tunnel, the message carries the RNC address for user plane, the RNC TEID for downlink data, the No QoS negotiation indication, and the Direct Tunnel Indicator (DTI) (TS 23.060 clause 9.2.2.1, step 8); the DTI is a bit of the Direct Tunnel Flags IE (TS 29.060 clause 7.7.81). In both cases, the SGSN sets the No QoS negotiation indication, which tells the GGSN to accept the QoS attributes without negotiation (TS 23.060 clause 9.2.2.1, step 8). The mandatory IEs of the message are the TEID Data I, the NSAPI, the SGSN Address for Control Plane, the SGSN Address for User Traffic, and the Quality of Service Profile (TS 29.060 Table 7).
11. The **GGSN** updates the PDP context and returns a GTPv1-C `Update PDP Context Response` message (TS 29.060 clause 7.3.4) to the **SGSN** over the Gn/Gp interface, with the Cause set to "Request accepted" (128). With Direct Tunnel, the GGSN updates the address for user plane and the TEID for downlink data to those of the RNC (TS 23.060 clause 12.7.4.1), and the GGSN does not change its own allocated user-plane TEID and IP address in the response (TS 29.060 clause 7.3.3). Under the conditions of TS 29.060 Table 9, the message also carries the TEID Data I, the TEID Control Plane, the Charging ID, the GGSN Address for Control Plane, the GGSN Address for User Traffic, and the Quality of Service Profile. The GGSN does not include a PCO in this response when the No QoS negotiation indication is set (TS 23.060

clause 9.2.2.1, step 8).

12. The **SGSN** inserts the NSAPI and the GGSN address in its PDP context, selects the Radio Priority and the Packet Flow Identifier based on the negotiated QoS, and sends a NAS SM `Activate PDP Context Accept` message (TS 24.008 clause 9.5.2) to the **UE** (TS 23.060 clause 9.2.2.1, step 9). The message carries the TI, the Negotiated LLC SAPI, the Negotiated QoS, and the Radio priority. The message can also carry the PDP address, which holds the PDP type number and the allocated address, the PCO, the Packet Flow Identifier, and an SM cause, for example #50 "PDP type IPv4 only allowed" when the network grants a single address type for an IPv4v6 request (TS 24.008 clause 6.1.3.1). The PCO carries the BCM (TS 23.060 clause 9.2.2.1, step 9) and can carry the DNS server and P-CSCF addresses (TS 24.008 clause 10.5.6.3). If the message carries no BCM, the UE applies the Bearer Control Mode `MS_Only` (TS 23.060 clause 9.2.2.1, step 9). When the UE receives this message, the UE stops timer T3380 and enters the `PDP-ACTIVE` state (TS 24.008 clause 6.1.3.1.1). The SGSN can now route PDP PDUs between the GGSN and the UE.

3.1.4. Summary of Key Information Elements

The following table summarizes the key IEs of the main messages of the procedure, grouped by protocol.

PROTOCOL	MESSAGE	KEY IES
NAS SM (TS 24.008)	`Activate PDP Context Request`	TI, Requested NSAPI, Requested LLC SAPI, Requested QoS, Requested PDP address (PDP type number), APN, PCO, Request type
NAS SM (TS 24.008)	`Activate PDP Context Accept`	TI, Negotiated LLC SAPI, Negotiated QoS, Radio priority, PDP address, PCO, Packet Flow Identifier, SM cause
GTPv1-C (TS 29.060)	`Create PDP Context Request`	IMSI, TEID Data I, TEID Control Plane, NSAPI, End User Address, APN, Quality of Service Profile, PCO, SGSN Address for signalling, SGSN Address for user traffic
GTPv1-C (TS 29.060)	`Create PDP Context Response`	Cause ("Request accepted", 128), TEID Data I, TEID Control Plane, Charging ID, End User Address, PCO, GGSN Address for Control Plane, GGSN Address for user traffic, Quality of Service Profile
GTPv1-C (TS 29.060)	`Update PDP Context Request`	TEID Data I, NSAPI, SGSN Address for Control Plane, SGSN Address for User Traffic, Quality of Service Profile, Direct Tunnel Flags (with the DTI)
Diameter over Gx (TS 29.212)	`Credit-Control-Request` (CCR-I)	`CC-Request-Type` (`INITIAL_REQUEST`), `Subscription-Id`, `Called-Station-Id` (APN), `IP-CAN-Type` (`3GPP-GPRS`), `QoS-Information`
Diameter over Gx (TS 29.212)	`Credit-Control-Answer` (CCA-I)	`Result-Code` (`DIAMETER_SUCCESS`), `Charging-Rule-Install`, `QoS-Information`, `Event-Trigger`
RADIUS over Gi (TS 29.061)	`Access-Request`	`User-Name`, `User-Password` or `CHAP-Password`, `NAS-IP-Address` or `NAS-Identifier`, `Called-Station-Id` (APN)
RANAP (TS 25.413)	`RAB Assignment Request`	RAB ID, RAB Parameters, Transport Layer Address, Iu Transport Association (GTP TEID)

3.1.5. Possible Failures and Required Actions

The GTPv1-C Cause values in this section come from TS 29.060 clause 7.7.1, Table 38, and the mapping from GTPv1-C Cause values to NAS SM Cause values comes from TS 29.060 Annex B, Table B.1. Where Table B.1 lists more than one SM Cause value for a GTPv1-C Cause value, the SGSN can send any of them, as an implementation choice (TS 29.060 Table B.1, NOTE 3). When the UE receives an `Activate PDP Context Reject` message, the UE stops timer T3380 and enters or remains in the `PDP-INACTIVE` state (TS 24.008 clause 6.1.3.1.3.1).

External authentication failure or APN access denial

During steps 3 and 4, the external AAA server can reject the authentication of the user with an `Access-Reject` message, and the GGSN then rejects the request with GTP Cause #209, "User authentication failed" (TS 29.061 clause 16.1 and TS 29.060 clause 7.3.2). The GGSN uses GTP Cause #222, "APN access denied – no subscription", when the APN requires a subscription that the subscriber does not have. GTP Cause #209 maps to SM Cause #29, "User authentication failed", and GTP Cause #222 maps to SM Cause #33, "Requested service option not subscribed", or to SM Cause #27, "Missing or unknown APN". The nodes then act as follows:

1. The GGSN returns a `Create PDP Context Response` message with GTP Cause #209 or #222 to the SGSN.
2. The SGSN sends an `Activate PDP Context Reject` message with the mapped SM Cause, #29, #33, or #27, to the UE.
3. The UE stops timer T3380 and enters the `PDP-INACTIVE` state.
4. If the reject message carries a Back-off timer value IE with a value that is neither zero nor deactivated, the UE starts a back-off timer for the combination of the PLMN and the APN, and does not send another `Activate PDP Context Request` message for the same APN in the PLMN until the back-off timer expires. If the value indicates that the timer is deactivated, the UE does not send that message until the UE is switched off or the Subscriber Identity Module (SIM) or Universal Subscriber Identity Module (USIM) is removed; if the value is zero, the UE can send that message again (TS 24.008 clause 6.1.3.1.3.3). Without that IE, after SM Cause #27 or #33 the UE applies a back-off timer with the configured SM_RetryWaitTime value when the UE is registered in its Home PLMN (HPLMN) or in a PLMN in the Equivalent HPLMN (EHPLMN) list. Otherwise, or when no SM_RetryWaitTime value is configured, the UE applies the default value of 12 minutes. After SM Cause #29 without that IE, TS 24.008 leaves the start of a back-off timer unspecified.

GGSN resource exhaustion or dynamic address occupation

The GGSN can lack the resources to accept the `Create PDP Context Request` message of step 2. In this case, the GGSN uses GTP Cause #199, "No resources available", GTP Cause #211, "All dynamic PDP addresses are occupied", or GTP Cause #212, "No memory is available" (TS 29.060 clause 7.3.2). GTP Cause #211 maps to SM Cause #26, "Insufficient resources", and GTP Causes #199 and #212 each map to SM Cause #26 or to SM Cause #34, "Service option temporarily out of order". The nodes then act as follows:

1. The GGSN returns a `Create PDP Context Response` message with GTP Cause #199, #211, or #212 to

the SGSN.

2. The SGSN sends an `Activate PDP Context Reject` message with SM Cause #26 or #34 to the UE. With SM Cause #26, the SGSN can include a Back-off timer value IE, which carries a value for timer T3396, unless the request type was "emergency" (TS 24.008 clause 6.1.3.1.3.1).
3. The UE stops timer T3380 and enters the `PDP-INACTIVE` state.
4. If the UE receives SM Cause #26 with a Back-off timer value that is neither zero nor deactivated, the UE starts timer T3396. Until timer T3396 expires or stops, the UE does not send another `Activate PDP Context Request`, `Activate Secondary PDP Context Request`, or `Modify PDP Context Request` message for the same APN, except for the cases that TS 24.008 clause 6.1.3.3 identifies. The UE can still start a PDP context activation for emergency bearer services while timer T3396 runs (TS 24.008 clause 6.1.3.1.3.2).

Unknown APN or APN restriction conflict

If the SGSN cannot derive a GGSN address for the requested APN, the SGSN rejects the activation without any GTPv1-C exchange (TS 23.060 clause 9.2.2.1, step 4). The GGSN uses GTP Cause #219, "Missing or unknown APN", for example when the GGSN does not support the APN (TS 29.060 clause 7.3.2). The GGSN checks the Maximum APN Restriction that the SGSN sent against the APN Restriction of the new PDP context, and rejects the request on a conflict (TS 23.060 clause 9.2.2.1, step 4). GTP Cause #223, "APN Restriction type incompatibility with currently active PDP Contexts", indicates that the GGSN did not create the PDP context because the PDP context would break the coexistence rules of TS 23.060 clause 15.4 (TS 29.060 clause 7.7.1). GTP Cause #219 maps to SM Cause #27, "Missing or unknown APN", and GTP Cause #223 maps to SM Cause #112, "APN restriction value incompatible with active PDP context". The nodes then act as follows:

1. The SGSN detects the failure itself, or the GGSN returns a `Create PDP Context Response` message with GTP Cause #219 or #223 to the SGSN.
2. The SGSN sends an `Activate PDP Context Reject` message to the UE, with SM Cause #27 or #112 when the GGSN rejected the request.
3. The UE stops timer T3380 and enters the `PDP-INACTIVE` state.
4. After SM Cause #27, the UE applies the back-off behavior of the first failure case in this section, per combination of PLMN and APN. After a PLMN change, the UE can send a new `Activate PDP Context Request` message for the same APN in the new PLMN if no back-off timer runs, and none is deactivated, for that combination (TS 24.008 clause 6.1.3.1.3.3).

3.1.6. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.060	• Clause 9.2.2.1 — PDP Context Activation Procedure for A/Gb mode and Iu mode, and Figures 63 and 64 • Clause 9.2.2.1A — PDP Context Activation Procedure using S4, for comparison • Clause 12.7.4.1 — RAB Assignment Procedure Using Gn/Gp • Clause 15.4 — APN Restriction and the coexistence of PDP contexts • Annex A — APN and GGSN selection
TS 24.008	• Clause 6.1.3.1 — PDP context activation, including the successful (6.1.3.1.1) and unsuccessful (6.1.3.1.3) cases initiated by the MS • Clauses 9.5.1, 9.5.2, and 9.5.3 — `Activate PDP Context Request`, `Activate PDP Context Accept`, and `Activate PDP Context Reject` message contents • Clauses 10.5.6.3, 10.5.6.4, and 10.5.6.5 — Protocol configuration options IE, Packet data protocol address IE, and Quality of service IE • Clause 10.5.6.6 and Table 10.5.157 — SM cause IE; clause 10.5.6.6a — SM cause 2 IE, which the `Activate PDP Context Accept` message uses • Clause 11.2.3 and Table 11.2c — SM timers T3380 and T3396 on the MS side
TS 29.060	• Clauses 7.3.1 and 7.3.2 — `Create PDP Context Request` and `Create PDP Context Response` message contents (Tables 5 and 6) • Clauses 7.3.3 and 7.3.4 — `Update PDP Context Request` and `Update PDP Context Response` message contents (Tables 7 and 9) • Clause 7.7.1 and Table 38 — Cause IE values • Clause 7.7.81 — Direct Tunnel Flags IE • Annex B (normative), Table B.1 — Mapping from Gn/Gp Cause values to NAS SM Cause values
TS 29.061	• Clause 16.1 — RADIUS authentication and authorization, including the handling of `Access-Reject` • Clause 16.3.1 — RADIUS authentication and accounting message flows for the IP PDP type • Clauses 16.4.1 and 16.4.2 — `Access-Request` and `Access-Accept` attributes (Tables 1 and 2)
TS 25.413	• Clause 8.2 — RAB Assignment procedure • Clauses 9.1.3 and 9.1.4 — `RAB Assignment Request` and `RAB Assignment Response` message contents • Clauses 9.2.1.2, 9.2.1.3, 9.2.2.1, and 9.2.2.2 — RAB ID, RAB Parameters, Transport Layer Address, and Iu Transport Association IEs
TS 25.331	• Clauses 10.2.33 and 10.2.34 — `Radio Bearer Setup` and `Radio Bearer Setup Complete` message contents • Clauses 10.3.4.8, 10.3.4.10, and 10.3.4.20 — RAB info, RAB information for setup, and RB information to setup IEs

SPECIFICATION	CLAUSES AND COVERAGE
TS 29.212	• Clause 4.5.1 — Request for PCC rules at IP-CAN session establishment • Clauses 4.5.2, 4.5.3, and 4.5.5 — Provisioning of PCC rules, of event triggers, and of authorized QoS • Clause 5.3.27 — IP-CAN-Type AVP • Clauses 5.6.2 and 5.6.3 — CC-Request and CC-Answer command formats • Clauses A.3.1 and A.3.3.1 — GPRS-specific aspects of the request for PCC rules and of the provisioning of authorized QoS per IP-CAN bearer
IETF RFC 6733	• Section 7.1.2 — `DIAMETER_SUCCESS` (2001) result code

3.2. PDP Context Deactivation Procedure

3.2.1. Technical Overview

The PDP Context Deactivation procedure is the session management procedure that terminates an established PDP context between the UE and the GGSN in a GPRS core network with the Gn/Gp architecture (TS 23.060 clause 9.2.4). TS 24.008 calls the UE the MS; this chapter uses the term UE throughout. The UE, the SGSN, or the GGSN can start the procedure (TS 23.060 clauses 9.2.4.1, 9.2.4.2, and 9.2.4.3). When the HLR requests the detach of a UE that has PDP contexts for emergency services, the SGSN also starts the procedure for each PDP context of the UE that is not for emergency services (TS 24.008 clause 6.1.3.4.2). The procedure releases the control-plane and user-plane tunnels of GTP over the Gn/Gp interface, releases the radio resources of the PDP context, updates or terminates the associated PCC session over the Gx reference point, stops the accounting of the PDP context over the Gi reference point, and releases a dynamically allocated PDP address. In Iu mode, the SGSN releases the RAB over the IuPs interface with the RAB Assignment procedure, and in A/Gb mode, the SGSN can instead run the packet flow context procedures with the BSS (TS 23.060 clause 9.2.4.1, steps 5 and 6). The procedure has these high-level effects:

On the UE

The SM state of the UE moves from `PDP-ACTIVE` to `PDP-INACTIVE-PENDING` when the UE sends the deactivation request (TS 24.008 clause 6.1.3.4.1), and to `PDP-INACTIVE`, in which no PDP context exists, when the deactivation completes (TS 24.008 clause 6.1.2.1). In Iu mode, the network releases the RAB of the PDP context, and in A/Gb mode, the UE and the network release the logical link locally if no other PDP context uses the logical link (TS 24.008 clause 6.1.3.4.1). After a successful deactivation, the UE releases the NSAPI and the TI of the PDP context, and can assign them to another PDP context (TS 24.008 clause 6.1.3.4).

On the SGSN

The SGSN removes the PDP context from its session tables, tells the RNC or the BSS to release the associated radio resources, and deletes the GTP tunnels with the GGSN over the Gn/Gp interface (TS 23.060 clause 9.2.4.1).

On the GGSN

The GGSN removes its PDP context record and the bindings of the user-plane TEIDs of the PDP context,

and stops the accounting collection over the RADIUS or Diameter. The GGSN notifies the PCRF of the termination of the PDP context, or of the termination of the IP Connectivity Access Network (IP-CAN) session when the PDP context is the last PDP context of the IP-CAN session (TS 29.212 Annex A.3.4 and A.3.5). If the UE used a dynamic PDP address that the GGSN allocated, and the PDP context is the last PDP context associated with this PDP address, the GGSN releases the PDP address and makes the address available to other UEs (TS 23.060 clause 9.2.4.1, step 3).

3.2.2. Call Flow

The call flow shows the UE-initiated variant of the procedure in Iu mode, which TS 23.060 clause 9.2.4.1 shows in Figure 75; Figure 74 shows the same procedure in A/Gb mode. TS 23.060 shows the SGSN-initiated variant in Figure 76 (clause 9.2.4.2) and the GGSN-initiated variant in Figure 77 (clause 9.2.4.3). Three parts of the call flow are optional: the Diameter exchange over the Gx reference point, which the GGSN runs only as the PCEF of dynamic PCC; the RADIUS accounting stop over the Gi reference point, which the GGSN runs only if the GGSN sent a RADIUS `Accounting-Request` (START) message for the PDP context (TS 29.061 clause 16.3.1); and the RAB release, which the SGSN runs only if a RAB exists for the PDP context (TS 23.060 clause 9.2.4.1, step 5). The figure shows the RADIUS `Accounting-Response` message after the `Delete PDP Context Response` message because the GGSN does not wait for the `Accounting-Response` message before the GGSN replies to the SGSN (TS 29.061 clause 16.3.1). The call flow omits the CAMEL procedure C1 of TS 23.060 clause 9.2.4.1, and it expands step 5 of Figure 75, Radio Access Bearer Release, into the messages of the RAB Assignment procedure.

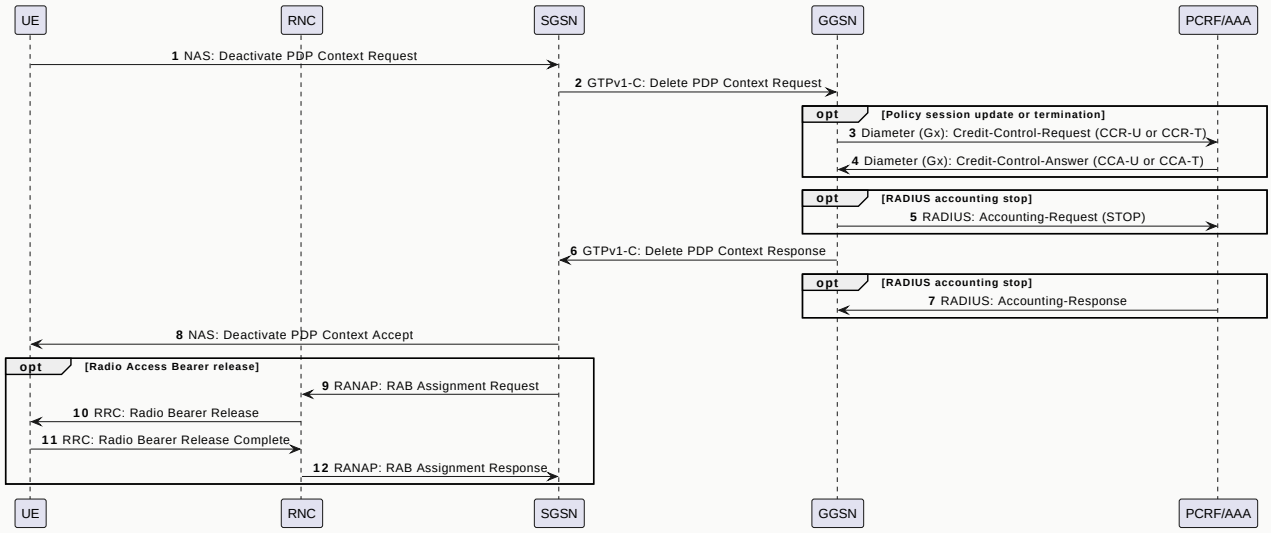


Figure 4. PDP context deactivation procedure call flow

3.2.3. Step-by-Step Description

1. The **UE** starts the deactivation by sending a NAS SM `Deactivate PDP Context Request` message (TS 24.008 clause 9.5.14) to the **SGSN** through the radio access network. When the UE sends this message, the UE enters the `PDP-INACTIVE-PENDING` state and starts timer T3390 (TS 24.008 clause 6.1.3.4.1), whose value is 8 seconds (TS 24.008 Table 11.2c). The message identifies the PDP context by its TI and carries an SM cause, for example #36 "regular deactivation", #37 "QoS not accepted", or #25 "LLC or SNDCP failure (A/Gb mode only)" (TS 24.008 clause 6.1.3.4.1). If the UE deactivates all active PDP contexts that

share the same PDP address and APN, the UE includes the Tear down indicator IE; the UE then deactivates the other PDP contexts locally, without peer-to-peer signaling (TS 24.008 clause 6.1.3.4). The UE also includes the Tear down indicator IE when the UE deactivates the PDP context that the PDP Context Activation procedure created (TS 23.060 clause 9.2.4.1, step 1), and a UE that supports S1 mode always includes the IE when the UE deactivates the default PDP context (TS 24.008 clause 6.1.3.4). The message can also carry the PCO (TS 24.008 clause 9.5.14.2).

2. The **SGSN** checks the TI and sends a GTPv1-C `Delete PDP Context Request` message (TS 29.060 clause 7.3.5) to the **GGSN** over the Gn/Gp interface. The message tells the GGSN to release the control-plane and user-plane GTP tunnels of the PDP context that the NSAPI identifies. The GTP header carries the GGSN TEID for control-plane messages. The NSAPI is the only mandatory IE (TS 29.060 Table 11). The SGSN copies the Teardown Ind IE from the `Deactivate PDP Context Request` message if the UE included it, and sets the Teardown Ind to "1" when the PDP context is the last PDP context of the PDN connection; with the Teardown Ind set to "1", the GGSN tears down all PDP contexts that share the PDN connection. The SGSN copies the PCO transparently from the `Deactivate PDP Context Request` message, includes the User Location Information, which holds the CGI or the SAI of the UE, together with the ULI Timestamp, which records when the SGSN acquired the User Location Information, and includes the MS Time Zone if the MS Time Zone changed since the SGSN last reported it. If the SGSN sends the message because of a network problem, the SGSN includes the Cause IE, for example "Network Failure" (TS 29.060 clause 7.3.5).

3. When the **GGSN** receives the request, and the GGSN acts as the PCEF of dynamic PCC, the GGSN sends a Diameter `Credit-Control-Request` (CCR) message to the **PCRF** over the Gx reference point. The content of the message depends on whether other PDP contexts of the IP-CAN session stay active, because in GPRS an IP-CAN session ends only when the last PDP context of the IP-CAN session ends (TS 29.212 Annex A.3.5). If other PDP contexts stay active, the GGSN sends a CCR-U message, that is a CCR message with the `CC-Request-Type` AVP set to `UPDATE_REQUEST` (2), and reports the PCC rules of the PDP context as inactive in the `Charging-Rule-Report` AVP; when the PCRF performs the bearer binding, the GGSN also includes the `Bearer-Identifier` AVP and the `Bearer-Operation` AVP set to `TERMINATION` (TS 29.212 clause 4.5.6 and Annex A.3.4). If the PDP context is the last PDP context of the IP-CAN session, the GGSN sends a CCR-T message, that is a CCR message with the `CC-Request-Type` AVP set to `TERMINATION_REQUEST` (3) (TS 29.212 clause 4.5.7 and Annex A.3.5), which can carry the reason for the termination in the `Termination-Cause` AVP, for example `DIAMETER_LOGOUT` (1) (IETF RFC 6733 section 8.15). Both messages identify the Gx session by the `Session-Id` AVP and carry the `CC-Request-Number` AVP. If the GGSN and the PCRF support the RAN-NAS-Cause feature, the GGSN includes the location of the UE in the `3GPP-User-Location-Info` AVP and the time zone of the UE in the `3GPP-MS-TimeZone` AVP, if available (TS 29.212 clauses 4.5.6 and 4.5.7). The GGSN also delivers the User Location Information and the UE Time Zone to the PCRF when the PCRF requested them (TS 23.060 clause 9.2.4.1, step 3).

4. The **PCRF** acknowledges the request with a Diameter `Credit-Control-Answer` (CCA) message to the **GGSN** over the Gx reference point. The message carries the `Result-Code` AVP set to `DIAMETER_SUCCESS` (2001) (IETF RFC 6733 section 7.1.2), the `CC-Request-Type` AVP with the same value as in the request, and the `CC-Request-Number` AVP. In reply to a CCR-U message, the PCRF can make a new policy decision and, when the PCRF performs the bearer binding, move the PCC rules of the terminated PDP context to a remaining PDP context; the GGSN removes the PCC rules that the PCRF does not move (TS 29.212 Annex A.3.4). In reply to a CCR-T message, the PCRF only acknowledges the request, and the CCR-T and CCA-T

exchange ends the Diameter Credit Control session of the IP-CAN session (TS 29.212 clause 4.5.7).

5. If the GGSN sent an `Accounting-Request` (START) message for the PDP context, the **GGSN** sends a RADIUS `Accounting-Request` (STOP) message to the external **AAA** server over the Gi reference point (TS 29.061 clauses 16.3.1 and 16.4.4). The GGSN can send one `Accounting-Request` (STOP) message for each PDP context, primary or secondary, and the message carries the final usage counters of the PDP context, for example the `Acct-Input-Octets`, `Acct-Output-Octets`, and `Acct-Session-Time` attributes. When the PDP context is the last PDP context of the IP-CAN session, the GGSN includes the 3GPP Vendor-Specific sub-attribute `3GPP-Session-Stop-Indicator`; the AAA server does not consider the IP-CAN session terminated until the AAA server receives this sub-attribute (TS 29.061 clause 16.2).

6. The **GGSN** removes the PDP context from its session tables, releases the bindings of the user-plane GTP-U TEIDs, and releases the dynamic PDP address if the PDP context is the last PDP context associated with this PDP address (TS 23.060 clause 9.2.4.1, step 3). The GGSN then returns a GTPv1-C `Delete PDP Context Response` message (TS 29.060 clause 7.3.6) to the **SGSN** over the Gn/Gp interface. If the GGSN sent an `Accounting-Request` (STOP) message, the GGSN sends the response at once, without waiting for the RADIUS `Accounting-Response` message (TS 29.061 clause 16.3.1). The GTP header carries the SGSN TEID for control-plane messages. The message carries the Cause, set to "Request accepted" (128), or to "Non-existent" (192) when the GGSN received the request for a PDP context that does not exist; in the second case, the GTP header carries the TEID value zero (TS 29.060 clause 7.3.6). The message can also carry the PCO (TS 29.060 Table 12). The User Location Information, the ULI Timestamp, and the MS Time Zone appear in this message only when the SGSN sends the response in the GGSN-initiated variant of the procedure (TS 29.060 clause 7.3.6).

7. If the GGSN sent an `Accounting-Request` (STOP) message, the external **AAA** server acknowledges the message with a RADIUS `Accounting-Response` message to the **GGSN** over the Gi reference point. If the AAA server assigned the IP address of the UE, the AAA server can make the address available for assignment again after the AAA server receives an `Accounting-Request` (STOP) message for every PDP context of the IP-CAN session (TS 29.061 clause 16.2).

8. When the **SGSN** receives the response, the SGSN removes the PDP context from its session database and sends a NAS SM `Deactivate PDP Context Accept` message (TS 24.008 clause 9.5.15) to the **UE** (TS 23.060 clause 9.2.4.1, step 4). The message carries the TI, and can carry the PCO, which the SGSN copies transparently from the `Delete PDP Context Response` message (TS 29.060 clause 7.3.6). When the UE receives this message, the UE stops timer T3390 (TS 24.008 clause 6.1.3.4.1) and enters the `PDP-INACTIVE` state for the PDP context that the TI identifies (TS 24.008 clause 6.1.2.1).

9. In Iu mode, the SGSN releases the access stratum resources of the PDP context with the RAB Assignment procedure, if a RAB exists for the PDP context (TS 23.060 clause 9.2.4.1, step 5). The **SGSN** sends a RANAP `RAB Assignment Request` message to the **RNC** over the IuPs interface, with the RAB to release in the RABs To Be Released List IE (TS 25.413 clause 8.2). For each RAB, the message carries the RAB ID, which contains the NSAPI of the PDP context (TS 25.413 clause 9.2.1.2), and the Cause (TS 25.413 clause 9.2.1.4), which is typically "Normal Release" (83) for a regular deactivation.

10. The **RNC** releases the radio bearers of the RAB and sends an RRC `Radio Bearer Release` message (TS 25.331 clause 10.2.30) to the **UE** over the Uu interface. The message tells the UE to release the RLC and PDCP entities of the radio bearers. The message carries the RRC transaction identifier and the RB information to release list, which holds the RB identity of each radio bearer to release, and can carry the

RAB information to reconfigure list.

11. The **UE** releases the radio bearers and returns an RRC `Radio Bearer Release Complete` message (TS 25.331 clause 10.2.31) to the **RNC** over the Uu interface, to confirm that the UE released the radio resources. The message carries the RRC transaction identifier.
12. The **RNC** releases its local resources and returns a RANAP `RAB Assignment Response` message to the **SGSN** over the IuPs interface. The message carries the RAB ID of each released RAB in the RABs Released List IE, which confirms that the RNC released the transport resources of the PDP context (TS 25.413 clause 8.2).

3.2.4. Summary of Key Information Elements

The following table summarizes the key IEs of the main messages of the procedure, grouped by protocol.

PROTOCOL	MESSAGE	KEY IES
NAS SM (TS 24.008)	`Deactivate PDP Context Request`	TI, SM cause, Tear down indicator, PCO
NAS SM (TS 24.008)	`Deactivate PDP Context Accept`	TI, PCO
GTPv1-C (TS 29.060)	`Delete PDP Context Request`	TEID Control Plane (GTP header), NSAPI, Teardown Ind, PCO, User Location Information (CGI or SAI), ULI Timestamp, MS Time Zone, Cause
GTPv1-C (TS 29.060)	`Delete PDP Context Response`	Cause ("Request accepted", 128, or "Non-existent", 192), TEID Control Plane (GTP header), PCO
Diameter over Gx (TS 29.212)	`Credit-Control-Request` (CCR-U or CCR-T)	`Session-Id`, `CC-Request-Type` (`UPDATE_REQUEST`, 2, or `TERMINATION_REQUEST`, 3), `CC-Request-Number`, `Charging-Rule-Report` (CCR-U), `Bearer-Identifier` and `Bearer-Operation` (CCR-U), `Termination-Cause` (CCR-T), `3GPP-User-Location-Info`, `3GPP-MS-TimeZone`
Diameter over Gx (TS 29.212)	`Credit-Control-Answer` (CCA-U or CCA-T)	`Session-Id`, `Result-Code` (`DIAMETER_SUCCESS`, 2001), `CC-Request-Type`, `CC-Request-Number`
RADIUS over Gi (TS 29.061)	`Accounting-Request` (STOP)	`Acct-Status-Type` (Stop), `Acct-Session-Id`, `Acct-Input-Octets`, `Acct-Output-Octets`, `Acct-Session-Time`, `3GPP-Session-Stop-Indicator` (last PDP context of the IP-CAN session)
RANAP (TS 25.413)	`RAB Assignment Request`	RABs To Be Released List: RAB ID, Cause
RANAP (TS 25.413)	`RAB Assignment Response`	RABs Released List: RAB ID
RRC (TS 25.331)	`Radio Bearer Release`	RRC transaction identifier, RB information to release list (RB identity), RAB information to reconfigure list

3.2.5. Possible Failures and Required Actions

The abnormal cases in this section come from TS 24.008 clause 6.1.3.4.3, the GTPv1-C Cause values come from TS 29.060 clause 7.7.1, Table 38, and the mapping from GTPv1-C Cause values to NAS SM Cause values comes from TS 29.060 Annex B, Table B.3.

Expiry of timer T3390 or T3395

The node that starts the deactivation starts a supervision timer when the node sends the `Deactivate PDP Context Request` message: the UE starts timer T3390, and the network starts timer T3395 (TS 24.008 clauses 6.1.3.4.1 and 6.1.3.4.2). Both timers have a value of 8 seconds (TS 24.008 Tables 11.2c and 11.2d). If the `Deactivate PDP Context Accept` message does not arrive before the timer expires, the node retransmits the request and restarts the timer, up to four times, so that the node sends the request five times in total. The nodes then act as follows:

1. On each of the first four expiries, the node that started the deactivation retransmits the `Deactivate PDP Context Request` message and restarts timer T3390 or T3395.
2. On the fifth expiry of timer T3390, the UE releases all resources that the UE allocated for the PDP context and erases the data of the PDP context.
3. On the fifth expiry of timer T3395, the network erases the data of the PDP context for that UE.

Collision of UE-initiated and network-initiated deactivation

The UE and the network can each send a `Deactivate PDP Context Request` message before either node receives the request of the other node. In this case, the UE and the network each reply with a `Deactivate PDP Context Accept` message, the UE stops timer T3390, and the network stops timer T3395 (TS 24.008 clause 6.1.3.4.3).

Network-initiated deactivation with reactivation requested

The GGSN or the SGSN can deactivate a PDP context and request that the UE re-establish the connectivity to the same APN at once. When the SGSN determines that a gateway relocation is desirable for the Selected IP Traffic Offload (SIPTO) function, the SGSN deactivates the PDN connection with the "reactivation requested" cause, and the UE then typically re-establishes the PDN connection to the same APN (TS 23.060 clause 9.2.4.2). The GGSN requests the reactivation with GTP Cause #6, "Reactivation Requested" (TS 29.060 clause 7.7.1, Table 38), and tears down all PDP contexts of the same PDN connection at the same time (TS 29.060 clause 7.3.5). In the GGSN-initiated variant, the nodes act as follows:

1. The GGSN sends a `Delete PDP Context Request` message to the SGSN with the Cause set to #6, "Reactivation Requested", and the Teardown Ind set to "1" (TS 29.060 clause 7.3.5).
2. If the SGSN supports the Cause IE in this message, the SGSN maps GTP Cause #6 to SM Cause #39, "Reactivation requested", in the `Deactivate PDP Context Request` message that the SGSN sends to the UE (TS 29.060 clause 7.3.5 and Table B.3).
3. When the UE receives SM Cause #39 for a PDP context that the UE activated with an APN, the UE stops timer T3396 if timer T3396 runs for that APN, and returns a `Deactivate PDP Context Accept` message. The UE then typically starts a new UE-initiated PDP Context Activation procedure for the same APN to restore the data connectivity, and also reactivates the other PDP contexts that the UE activated and that the network released in the same deactivation (TS 24.008 clause 6.1.3.4.2).

3.2.6. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.060	• Clause 9.2.4 — Deactivation Procedures • Clause 9.2.4.1 and Figures 74 and 75 — MS Initiated PDP Context Deactivation Procedure for A/Gb mode and Iu mode • Clause 9.2.4.2 and Figure 76 — SGSN-initiated PDP Context Deactivation Procedure • Clause 9.2.4.3 and Figure 77 — GGSN-initiated PDP Context Deactivation Procedure
TS 24.008	• Clause 6.1.2.1 — Session management states in the MS, including `PDP-INACTIVE` and `PDP-INACTIVE-PENDING` • Clause 6.1.3.4 — PDP context deactivation procedure • Clauses 6.1.3.4.1 and 6.1.3.4.2 — PDP context deactivation initiated by the MS and by the network • Clause 6.1.3.4.3 — Abnormal cases: expiry of timers T3390 and T3395, and collision of deactivation requests • Clauses 9.5.14 and 9.5.15 — `Deactivate PDP Context Request` and `Deactivate PDP Context Accept` message contents • Clause 10.5.6.6 and Table 10.5.157 — SM cause IE • Clause 11.2.3, Tables 11.2c and 11.2d — SM timers T3390 and T3396 on the MS side, and T3395 on the network side
TS 29.060	• Clauses 7.3.5 and 7.3.6 — `Delete PDP Context Request` and `Delete PDP Context Response` message contents (Tables 11 and 12) • Clause 7.7.1 and Table 38 — Cause IE values, including #6, #128, and #192 • Annex B (normative), Table B.3 — Mapping from Gn/Gp Cause values in a request message from the GGSN to NAS SM Cause values
TS 29.061	• Clause 16.2 — RADIUS accounting, including `Accounting-Request` (STOP) and the Session Stop Indicator • Clause 16.3.1 and Figure 22 — RADIUS message flow for PDP type IP, including the deactivation • Clause 16.4.4 — Attributes of the `Accounting-Request` (STOP) message
TS 25.413	• Clause 8.2 — RAB Assignment procedure, including the release of RABs • Clauses 9.2.1.2 and 9.2.1.4 — RAB ID and Cause IEs
TS 25.331	• Clauses 10.2.30 and 10.2.31 — `Radio Bearer Release` and `Radio Bearer Release Complete` message contents
TS 29.212	• Clause 4.5.6 — Indication of IP-CAN Bearer Termination Implications over the Gx reference point • Clause 4.5.7 — Indication of IP-CAN Session Termination over the Gx reference point • Annex A.3.4 and A.3.5 — Indication of IP-CAN bearer termination and IP-CAN session termination for the 3GPP-GPRS IP-CAN • Clauses 5.6.2 and 5.6.3 — CC-Request and CC-Answer command formats
IETF RFC 6733	• Section 7.1.2 — `DIAMETER_SUCCESS` (2001) result code • Section 8.15 — `Termination-Cause` AVP, including `DIAMETER_LOGOUT` (1)

Part II: Evolved Packet Core (EPC)

This part describes the Evolved Packet Core (EPC) with Control and User Plane Separation (CUPS): its network elements and the interfaces between them, the protocols that carry signaling between the network elements, and the signaling procedures that run over those protocols.

Chapter 4. Architecture and Specifications

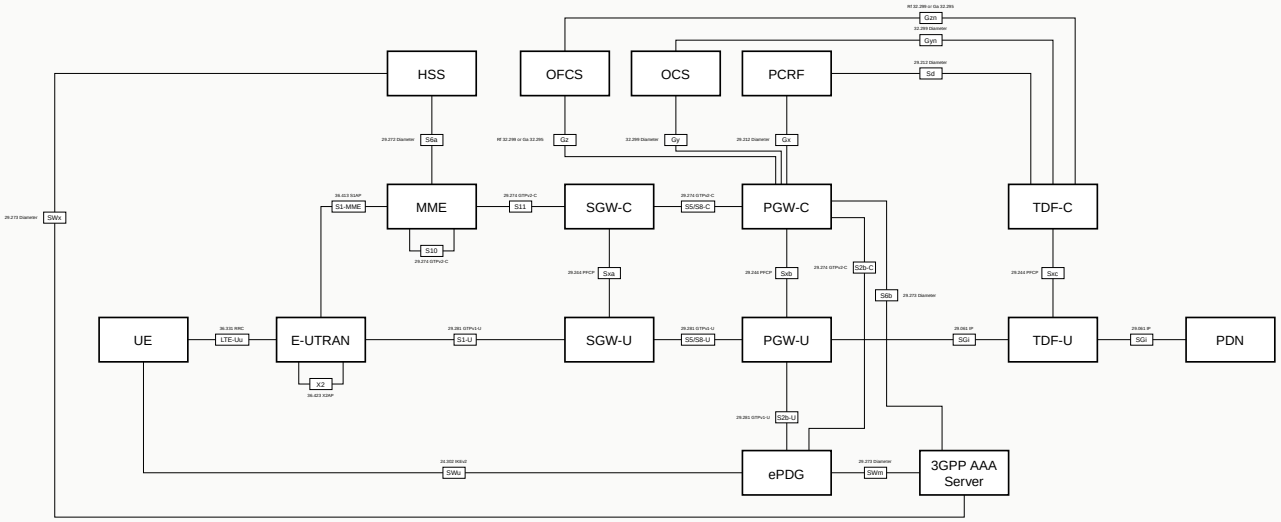


Figure 5. EPC architecture

The figure above shows the network elements of the EPC, the core network of the Evolved Packet System (EPS), and the reference points between them, and it labels each reference point with the 3GPP specification and the protocol that the reference point uses.

4.1. Network Elements

UE (User Equipment)

The UE is the subscriber's device, for example a smartphone or an Internet of Things (IoT) module, that attaches to the network over the radio interface. It is the endpoint for all mobility management, session management, and user-plane traffic. The UE reaches the E-UTRAN over LTE-Uu, and over an untrusted non-3GPP access network, such as public Wi-Fi, the UE reaches the ePDG over SWu (TS 23.402 clause 4.2.2).

E-UTRAN (Evolved Universal Terrestrial Radio Access Network)

The E-UTRAN is the Long Term Evolution (LTE) radio access network, made up of E-UTRAN Node Bs (eNodeBs). It provides the radio interface towards the UE over LTE-Uu, relays control-plane signaling to the MME over S1-MME, and relays user-plane traffic to the SGW-U over S1-U. Neighboring eNodeBs interconnect over X2, for example to prepare a handover.

MME (Mobility Management Entity)

The MME is the control-plane node of the EPC, handling UE authentication, mobility management, tracking area management, paging, and bearer session signaling. The MME carries no user-plane traffic itself and relies on the SGW-C for session establishment towards the user plane. Two MMEs exchange the context of a UE over S10 when the serving MME changes.

HSS (Home Subscriber Server)

The HSS is the master subscriber database of the EPC. It stores subscription profiles, authentication data, and the identity of the MME currently serving each subscriber, and the MME queries the HSS over

S6a for authentication vectors and location updates. The 3GPP AAA Server retrieves the authentication data and the subscription data for non-3GPP access from the HSS over SWx (TS 23.402 clause 4.2.2).

SGW-C (Serving Gateway - Control Plane)

The SGW-C is the control-plane function of the Serving Gateway. It terminates S11 signaling from the MME and translates this signaling into Packet Forwarding Control Protocol (PFCP) rules that configure the SGW-U, without handling any user data itself.

SGW-U (Serving Gateway - User Plane)

The SGW-U is the user-plane function of the Serving Gateway. It forwards the Internet Protocol (IP) packets of the user between the eNodeB and the PGW-U according to the forwarding rules that the SGW-C provisions over Sxa, and it acts as the local mobility anchor for inter-eNodeB handovers.

PGW-C (PDN Gateway - Control Plane)

The PGW-C is the control-plane function of the PDN Gateway, handling session establishment, IP address allocation, and Quality of Service (QoS) and policy signaling. It then provisions the PGW-U with the corresponding PFCP rules.

PCRF (Policy and Charging Rules Function)

The PCRF is the policy control node of the EPC. It derives QoS, charging, and traffic-detection rules from subscriber and service policies, and it provisions the PGW-C with these rules over Gx and the TDF-C with application detection and control (ADC) rules over Sd for enforcement in the user plane.

OCS (Online Charging System)

The OCS is the real-time charging system for prepaid and quota-based services. It receives credit-control requests from the PGW-C over Gy and from the TDF-C over Gyn, and it authorizes or denies continued user-plane usage based on the subscriber’s available balance.

OFCS (Offline Charging System)

The OFCS is the offline, postpaid charging system of the EPC. It collects offline charging information from the PGW-C over Gz and from the TDF-C over Gzn, which are functionally equivalent to the Rf or the Ga reference point (TS 32.240 clause 4.2.2), for billing purposes, without affecting the subscriber’s session in real time.

PGW-U (PDN Gateway - User Plane)

The PGW-U is the user-plane function of the PDN Gateway. It routes user traffic between the SGW-U and the TDF-U, enforcing the QoS, charging, and packet-filtering rules that the PGW-C provisions over Sxb.

3GPP AAA Server

The 3GPP AAA Server is the Authentication, Authorization, and Accounting (AAA) server for non-3GPP access. When the UE connects through an untrusted non-3GPP access network, the 3GPP AAA Server authenticates the UE through the ePDG over SWm, with the authentication data that it retrieves from the HSS over SWx, and it supplies the PGW-C with the required authorization data over S6b (TS 23.402 clause 4.2.2).

ePDG (evolved Packet Data Gateway)

The ePDG is the security gateway for untrusted non-3GPP access, such as public Wi-Fi. It terminates the IPsec tunnel that the UE establishes over SWu, relays the authentication of the UE to the 3GPP AAA Server over SWm, and relays control-plane signaling to the PGW-C over S2b-C and user-plane traffic to the PGW-U over S2b-U.

TDF-C (Traffic Detection Function - Control Plane)

The TDF-C is the control-plane function of the Traffic Detection Function, handling traffic-detection and application-control policy signaling. It receives ADC rules from the PCRF over Sd, it reports usage to the OCS over Gyn and to the OFCS over Gzn, and it provisions the TDF-U with the corresponding PFCP rules over Sxc (TS 23.214 clauses 4.2.3 and 5.3.1).

TDF-U (Traffic Detection Function - User Plane)

The TDF-U is the user-plane function of the Traffic Detection Function. Sitting inline between the PGW-U and the external PDN, it performs deep packet inspection and traffic detection on user traffic according to the rules that the TDF-C provisions over Sxc.

PDN (Packet Data Network)

The PDN is the external packet data network, for example the internet, that the UE obtains connectivity to, reached from the TDF-U over SGi.

4.2. Technical Specifications

- **3GPP TS 22.278** *LTE; Service requirements for the Evolved Packet System (EPS)*
- **3GPP TS 23.203** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Policy and charging control architecture*
- **3GPP TS 23.214** *Universal Mobile Telecommunications System (UMTS); LTE; Architecture enhancements for control and user plane separation of EPC nodes*
- **3GPP TS 23.228** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; IP Multimedia Subsystem (IMS); Stage 2*
- **3GPP TS 23.401** *LTE; General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access*
- **3GPP TS 23.402** *Universal Mobile Telecommunications System (UMTS); LTE; Architecture enhancements for non-3GPP accesses*
- **3GPP TS 24.008** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 5G; Mobile radio interface Layer 3 specification; Core network protocols; Stage 3*
- **3GPP TS 24.301** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3*
- **3GPP TS 24.302** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; Access to the 3GPP Evolved Packet Core (EPC) via non-3GPP access networks; Stage 3*

- **3GPP TS 29.061** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 5G; Interworking between the Public Land Mobile Network (PLMN) supporting packet based services and Packet Data Networks (PDN)*
- **3GPP TS 29.212** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; Policy and Charging Control (PCC); Reference points*
- **3GPP TS 29.213** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 5G; Policy and charging control signalling flows and Quality of Service (QoS) parameter mapping*
- **3GPP TS 29.214** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; Policy and charging control over Rx reference point*
- **3GPP TS 29.244** *LTE; 5G; Interface between the Control Plane and the User Plane nodes*
- **3GPP TS 29.272** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; Evolved Packet System (EPS); Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on Diameter protocol*
- **3GPP TS 29.273** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; Evolved Packet System (EPS); 3GPP EPS AAA interfaces*
- **3GPP TS 29.274** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; 3GPP Evolved Packet System (EPS); Evolved General Packet Radio Service (GPRS) Tunnelling Protocol for Control plane (GTPv2-C); Stage 3*
- **3GPP TS 29.281** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; General Packet Radio System (GPRS) Tunnelling Protocol User Plane (GTPv1-U)*
- **3GPP TS 29.303** *Universal Mobile Telecommunications System (UMTS); LTE; 5G; Domain Name System Procedures; Stage 3*
- **3GPP TS 32.240** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 5G; Telecommunication management; Charging management; Charging architecture and principles*
- **3GPP TS 32.295** *Telecommunication management; Charging management; Charging Data Record (CDR) transfer*
- **3GPP TS 32.298** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 5G; Telecommunication management; Charging management; Charging Data Record (CDR) parameter description*
- **3GPP TS 32.299** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 5G; Telecommunication management; Charging management; Diameter charging applications*
- **3GPP TS 33.401** *Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 3GPP System Architecture Evolution (SAE); Security architecture*
- **3GPP TS 36.331** *LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification*
- **3GPP TS 36.401** *LTE; Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Architecture description*

- **3GPP TS 36.413** *LTE; Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 Application Protocol (S1AP)*
- **3GPP TS 36.423** *LTE; Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 Application Protocol (X2AP)*
- **ETSI TS 103 653-1** *Core Network and Interoperability Testing (INT); VoLTE/ViLTE interoperability test description over 4G/early 5G in physical/virtual environments; (3GPP Release 15); Part 1: Test Purposes (TP) and Protocol Implementation Conformance Statement (PICS) for VoLTE/ViLTE interoperability*
- **ETSI TS 103 653-2** *Core Network and Interoperability Testing (INT); VoLTE/ViLTE interoperability test description over 4G/early 5G in physical/virtual environments; (3GPP Release 15); Part 2: Test Descriptions for VoLTE/ViLTE interoperability*

Chapter 5. Protocol Stack

5.1. S1AP (S1 Application Protocol)

5.1.1. Technical Overview

The S1 Application Protocol (S1AP) is the radio network layer signaling protocol of the S1-MME interface between the E-UTRAN and the MME, a scope that TS 36.413 clause 1 defines. S1AP carries UE mobility and session control, and it relays Non-Access Stratum (NAS) messages between the UE and the MME without inspecting their content.

S1AP consists of Elementary Procedures (EPs), where an EP is a unit of interaction between an eNodeB and the MME that comprises an initiating message and, for a Class 1 EP, a response message. TS 36.413 clause 3.1 defines two EP classes:

Class 1

An EP with a response, which reports a successful outcome, an unsuccessful outcome, or both outcomes for different requests within the same message.

Class 2

An EP without a response; the network always considers a Class 2 EP successful.

An eNodeB and the MME can run several EPs independently of each other, in parallel, unless a specific EP description restricts this independence.

S1AP provides two groups of services, a grouping that TS 36.413 clause 5 defines:

Non-UE-associated services

These are services related to the whole S1 interface instance between an eNodeB and the MME, for example S1 Setup or Reset.

UE-associated services

These are services related to one UE, over a UE-associated logical S1-connection that TS 36.413 clause 3.1 defines and that can exist before the eNodeB establishes the S1 UE context. This connection uses the MME UE S1AP ID and the eNB UE S1AP ID to identify the UE at the MME and at the eNodeB.

S1AP runs over the Stream Control Transmission Protocol (SCTP), which provides in-sequence delivery of S1AP messages and notifies S1AP if the signaling connection breaks. TS 36.413 clause 6 defines this transport requirement; TS 36.410 defines the S1 transport network layer in detail.

Unlike NAS, PFCP, and the GPRS Tunnelling Protocol (GTP), S1AP does not encode its messages with a fixed-position byte header. S1AP messages use the Packed Encoding Rules (PER) of Abstract Syntax Notation One (ASN.1), as defined in ITU-T Recommendation X.691, so a message’s on-the-wire layout depends on the abstract syntax of its information elements rather than on fixed octet positions. The Message Format section below describes the message structure at the ASN.1 level instead of a byte-position diagram.

5.1.2. Message Format

5.1.2.1. Elementary Procedure Structure

TS 36.413 clause 9.3.2 defines the `S1AP-ELEMENTARY-PROCEDURE` ASN.1 class, which every S1AP EP conforms to:

```
S1AP-ELEMENTARY-PROCEDURE ::= CLASS {
    &InitiatingMessage             ,
    &SuccessfulOutcome              OPTIONAL,
    &UnsuccessfulOutcome            OPTIONAL,
    &procedureCode      ProcedureCode  UNIQUE,
    &criticality        Criticality    DEFAULT ignore
}
```

`InitiatingMessage`

This is the message that starts the EP, and every EP defines it.

`SuccessfulOutcome`

This is the response message for a successful outcome, and only a Class 1 EP defines it.

`UnsuccessfulOutcome`

This is the response message for an unsuccessful outcome, and only a Class 1 EP that supports an explicit failure response defines it.

`procedureCode`

This is a value that uniquely identifies the EP, for example the value assigned to the Handover Preparation procedure or the E-RAB Setup procedure.

`criticality`

This is the default criticality of the EP itself, used when an S1AP node does not comprehend the procedure code.

5.1.2.2. S1AP-PDU

TS 36.413 clause 9.3.3 defines the top-level S1AP-PDU as a CHOICE between three message classes:

```
S1AP-PDU ::= CHOICE {
    initiatingMessage   InitiatingMessage,
    successfulOutcome   SuccessfulOutcome,
    unsuccessfulOutcome UnsuccessfulOutcome,
    ...
}

InitiatingMessage ::= SEQUENCE {
    procedureCode   S1AP-ELEMENTARY-PROCEDURE.&procedureCode,
    criticality     S1AP-ELEMENTARY-PROCEDURE.&criticality,
    value           S1AP-ELEMENTARY-PROCEDURE.&InitiatingMessage
```

```
}
```

`SuccessfulOutcome` and `UnsuccessfulOutcome` follow the same `procedureCode/criticality/value` structure as `InitiatingMessage`.

`procedureCode`

This field identifies which EP the message belongs to, for example E-RAB Setup or Path Switch Request.

`criticality`

This field states how a receiving node handles the message if it does not comprehend the EP, and the Criticality Values table below lists the possible values.

`value`

This field carries the message-specific information elements (IEs) for this EP and outcome, for example the IEs of an E-RAB SETUP REQUEST message.

5.1.2.3. Criticality Values

Each IE or IE group within a message can carry its own criticality information, independent of the criticality of the EP itself. TS 36.413 clause 10.3.2 defines these values.

VALUE	MEANING
`reject`	The receiving node rejects the entire procedure if it does not comprehend the IE or IE group.
`notify`	The receiving node ignores the IE or IE group if it does not comprehend it, and notifies the sender.
`ignore`	The receiving node ignores the IE or IE group if it does not comprehend it, without notifying the sender.

5.1.3. Message Categories

5.1.3.1. E-RAB Management Messages

These messages assign, modify, and release the E-UTRAN Radio Access Bearers (E-RABs) and their Data Radio Bearers for a UE.

MESSAGE	FUNCTIONALITY	DIRECTION
`E-RAB Setup Request`	Asks the eNodeB to assign Uu and S1 resources and set up Data Radio Bearers for one or more E-RABs.	MME → eNodeB
`E-RAB Setup Response`	Reports the E-RABs successfully set up and the E-RABs that failed to be set up.	eNodeB → MME
`E-RAB Modify Request`	Asks the eNodeB to modify one or more already established E-RABs for a UE.	MME → eNodeB
`E-RAB Modify Response`	Reports the E-RABs successfully modified and the E-RABs that failed to be modified.	eNodeB → MME

MESSAGE	FUNCTIONALITY	DIRECTION
`E-RAB Release Command`	Asks the eNodeB to release one or more established E-RABs for a UE.	MME → eNodeB
`E-RAB Release Response`	Reports the E-RABs successfully released and the E-RABs that failed to be released.	eNodeB → MME
`E-RAB Release Indication`	Tells the MME that the eNodeB released one or more E-RABs on its own initiative.	eNodeB → MME
`E-RAB Modification Indication`	Asks the MME to accept a modification of one or more established E-RABs that the eNodeB initiated, for example a new downlink transport address.	eNodeB → MME
`E-RAB Modification Confirm`	Reports the E-RABs successfully modified, the E-RABs that failed to be modified, and the E-RABs to be released, for an `E-RAB Modification Indication` message.	MME → eNodeB

5.1.3.2. Context Management Messages

These messages establish, modify, suspend, resume, and release a UE's context at the eNodeB and the MME, and transfer UE information between them.

MESSAGE	FUNCTIONALITY	DIRECTION
`Initial Context Setup Request`	Establishes the initial UE context in the eNodeB, sets up the default IP connectivity, and optionally sets up one or more E-RABs.	MME → eNodeB
`Initial Context Setup Response`	Reports that the eNodeB established the initial UE context.	eNodeB → MME
`Initial Context Setup Failure`	Reports that the eNodeB could not establish the initial UE context.	eNodeB → MME
`UE Context Release Request`	Asks the MME to release the UE-associated logical S1-connection for an E-UTRAN generated reason, for example user inactivity.	eNodeB → MME
`UE Context Release Command`	Orders the release of the UE-associated logical S1-connection, for example after a completed handover.	MME → eNodeB
`UE Context Release Complete`	Confirms that the eNodeB released all signaling and user-plane transport resources for the UE.	eNodeB → MME
`UE Context Modification Request`	Asks the eNodeB to partly modify the established UE context, for example the Security Key or the UE Aggregate Maximum Bit Rate.	MME → eNodeB
`UE Context Modification Response`	Confirms that the eNodeB applied the requested UE context modification.	eNodeB → MME
`UE Context Modification Failure`	Reports that the eNodeB could not apply the requested UE context modification.	eNodeB → MME
`UE Radio Capability Match Request`	Asks the eNodeB to derive whether the UE radio capabilities are compatible with the network configuration for voice continuity.	MME → eNodeB
`UE Radio Capability Match Response`	Returns the Voice Support Match Indicator that a `UE Radio Capability Match Request` message asked for.	eNodeB → MME
`UE Context Modification Indication`	Asks the MME to verify Closed Subscriber Group (CSG) membership for the established UE context.	eNodeB → MME
`UE Context Modification Confirm`	Returns the CSG membership verification result for a `UE Context Modification Indication` message.	MME → eNodeB

MESSAGE	FUNCTIONALITY	DIRECTION
`UE Context Suspend Request`	Asks the MME to suspend the UE context, the UE-associated logical S1-connection, and the related bearer contexts.	eNodeB → MME
`UE Context Suspend Response`	Confirms that the MME suspended the UE context.	MME → eNodeB
`UE Context Resume Request`	Tells the MME that the UE resumed its suspended Radio Resource Control (RRC) connection, and asks the MME to resume the UE context.	eNodeB → MME
`UE Context Resume Response`	Confirms that the MME resumed the UE context.	MME → eNodeB
`UE Context Resume Failure`	Reports that the MME could not resume at least one suspended E-RAB, and releases the UE-associated logical S1-connection.	MME → eNodeB
`Connection Establishment Indication`	Completes the establishment of the UE-associated logical S1-connection, and can trigger the eNodeB to obtain and report the UE radio capability.	MME → eNodeB
`Retrieve UE Information`	Asks the MME for the UE information of a Narrowband Internet of Things (NB-IoT) UE that uses Control Plane Cellular Internet of Things (CIoT) EPS Optimisation.	eNodeB → MME
`UE Information Transfer`	Sends the requested UE information, for example QoS parameters and UE radio capability, to the eNodeB.	MME → eNodeB
`eNB CP Relocation Indication`	Asks the MME to authenticate a UE's re-establishment request for an NB-IoT UE that uses Control Plane CIoT EPS Optimisation.	eNodeB → MME
`MME CP Relocation Indication`	Tells the eNodeB that the UE's connection is to be relocated to another eNodeB.	MME → eNodeB

5.1.3.3. Handover Signalling Messages

These messages prepare, execute, confirm, and cancel a handover of a UE between eNodeBs or between radio access technologies, and transfer Packet Data Convergence Protocol (PDCP) status between the source and the target eNodeB.

MESSAGE	FUNCTIONALITY	DIRECTION
`Handover Required`	Starts the Handover Preparation procedure. The source eNodeB requests preparation of resources at the target side via the EPC.	eNodeB → MME
`Handover Command`	Reports that the MME accepted the handover, and carries the target-side transparent container for the UE.	MME → eNodeB
`Handover Preparation Failure`	Reports that the handover preparation failed.	MME → eNodeB
`Handover Request`	Asks the target eNodeB to reserve resources for the handover of a UE.	MME → eNodeB
`Handover Request Acknowledge`	Reports that the target eNodeB reserved the requested resources.	eNodeB → MME
`Handover Failure`	Reports that the target eNodeB could not reserve the requested resources.	eNodeB → MME
`Handover Notify`	Tells the MME that the UE arrived at the target cell and the S1 handover completed successfully.	eNodeB → MME
`Path Switch Request`	Establishes a UE-associated signaling connection to the EPC, and requests the switch of a downlink GTP tunnel to a new endpoint.	eNodeB → MME

MESSAGE	FUNCTIONALITY	DIRECTION
`Path Switch Request Acknowledge`	Reports that the EPC switched the downlink path for at least one requested E-RAB.	MME → eNodeB
`Path Switch Request Failure`	Reports that the EPC failed to switch the downlink path for every requested E-RAB.	MME → eNodeB
`Handover Cancel`	Asks the EPC to cancel an ongoing handover preparation or an already prepared handover.	eNodeB → MME
`Handover Cancel Acknowledge`	Confirms that the EPC released the resources of the cancelled handover.	MME → eNodeB
`eNB Status Transfer`	Transfers the uplink and downlink PDCP Sequence Number (PDCP-SN) and Hyper Frame Number (HFN) status from the source eNodeB to the target eNodeB via the MME.	eNodeB → MME
`MME Status Transfer`	Forwards the PDCP-SN and HFN status that an `eNB Status Transfer` message carried to the target eNodeB.	MME → eNodeB
`Handover Success`	Tells the source eNodeB, during a Dual Active Protocol Stack (DAPS) handover, that the UE successfully accessed the target eNodeB.	MME → eNodeB
`eNB Early Status Transfer`	Transfers, during a DAPS handover, the COUNT of the first downlink Service Data Unit (SDU) that the source eNodeB forwards to the target eNodeB.	eNodeB → MME
`MME Early Status Transfer`	Forwards the COUNT that an `eNB Early Status Transfer` message carried to the target eNodeB.	MME → eNodeB

5.1.3.4. Paging Messages

MESSAGE	FUNCTIONALITY	DIRECTION
`Paging`	Asks the eNodeB to page a UE in the cells of the tracking areas listed in the message.	MME → eNodeB

5.1.3.5. NAS Transport Messages

These messages carry NAS signaling, opaque to the eNodeB, between the UE and the MME over the S1 interface. TS 36.413 clause 8.6.1 defines this scope.

MESSAGE	FUNCTIONALITY	DIRECTION
`Initial UE Message`	Forwards the UE's first uplink NAS message to the MME, and can establish the UE-associated logical S1-connection.	eNodeB → MME
`Downlink NAS Transport`	Forwards a NAS message from the MME to the UE.	MME → eNodeB
`Uplink NAS Transport`	Forwards a NAS message from the UE to the MME, over an existing UE-associated logical S1-connection.	eNodeB → MME
`NAS Non Delivery Indication`	Reports that the eNodeB could not deliver, or decided not to start delivering, a NAS message to the UE.	eNodeB → MME
`NAS Delivery Indication`	Reports that the eNodeB successfully delivered a downlink NAS message to the UE, when the MME requested this indication.	eNodeB → MME

MESSAGE	FUNCTIONALITY	DIRECTION
`Reroute NAS Request`	Asks the eNodeB to reroute an `Initial UE Message` message to the MME of the indicated Dedicated Core Network (DCN).	MME → eNodeB

5.1.3.6. Management Messages

These messages initialize the S1 interface, exchange interoperability data, report unrecoverable errors, and manage MME overload.

MESSAGE	FUNCTIONALITY	DIRECTION
`Reset`	Initializes or re-initializes the E-UTRAN, or part of the E-UTRAN S1AP UE-related contexts, after a failure at the sending node.	Both
`Reset Acknowledge`	Confirms that the receiving node released the S1 resources and UE associations indicated in a `Reset` message.	Both
`Error Indication`	Reports a detected error in an incoming message, when no dedicated failure message exists to report it.	Both
`S1 Setup Request`	Starts the S1 Setup procedure, the first S1AP procedure after the transport network layer association becomes operational.	eNodeB → MME
`S1 Setup Response`	Reports that the MME accepted the S1 Setup Request, and exchanges application-level configuration data.	MME → eNodeB
`S1 Setup Failure`	Reports that the MME rejected the S1 Setup Request.	MME → eNodeB
`eNB Configuration Update`	Updates application-level configuration data that the eNodeB and the MME need to interoperate on the S1 interface.	eNodeB → MME
`eNB Configuration Update Acknowledge`	Confirms that the MME updated the configuration data.	MME → eNodeB
`eNB Configuration Update Failure`	Reports that the MME rejected the configuration update.	MME → eNodeB
`MME Configuration Update`	Updates application-level configuration data that the eNodeB needs to interoperate with the MME.	MME → eNodeB
`MME Configuration Update Acknowledge`	Confirms that the eNodeB updated the configuration data.	eNodeB → MME
`MME Configuration Update Failure`	Reports that the eNodeB rejected the configuration update.	eNodeB → MME
`Overload Start`	Tells the eNodeB to reduce the signaling load it sends towards the concerned MME.	MME → eNodeB
`Overload Stop`	Tells the eNodeB that the overload situation at the MME ended, and normal operation can resume.	MME → eNodeB

5.1.3.7. S1 CDMA2000 Tunnelling Messages

These messages tunnel CDMA2000 signaling, opaque to the eNodeB, between the UE and the CDMA2000 radio access technology over the S1 interface.

MESSAGE	FUNCTIONALITY	DIRECTION
`Downlink S1 CDMA2000 Tunnelling`	Forwards a CDMA2000 message from the MME to the UE, through the eNodeB.	MME → eNodeB
`Uplink S1 CDMA2000 Tunnelling`	Forwards a CDMA2000 message from the UE to the MME, through the eNodeB.	eNodeB → MME

5.1.3.8. UE Capability Info Indication Messages

MESSAGE	FUNCTIONALITY	DIRECTION
`UE Capability Info Indication`	Provides UE capability-related information, received from the UE, to the MME.	eNodeB → MME

5.1.3.9. Trace Messages

These messages control a trace session or a Minimization of Drive Tests (MDT) session for a UE, as specified in TS 32.422.

MESSAGE	FUNCTIONALITY	DIRECTION
`Trace Start`	Asks the eNodeB to start a trace function, and optionally an MDT session, for a UE.	MME → eNodeB
`Trace Failure Indication`	Reports that a `Trace Start` or `Deactivate Trace` procedure failed because of an interaction with a handover.	eNodeB → MME
`Deactivate Trace`	Asks the eNodeB to stop the trace session identified by the given trace reference.	MME → eNodeB
`Cell Traffic Trace`	Sends the allocated Trace Recording Session Reference and Trace Reference to the MME.	eNodeB → MME

5.1.3.10. Location Reporting Messages

MESSAGE	FUNCTIONALITY	DIRECTION
`Location Reporting Control`	Asks the eNodeB to report the UE's current location, for example on every serving-cell change.	MME → eNodeB
`Location Report Failure Indication`	Reports that a `Location Reporting Control` procedure failed because of an interaction with a handover.	eNodeB → MME
`Location Report`	Provides the UE's current location to the MME.	eNodeB → MME

5.1.3.11. Warning Message Transmission Messages

These messages start, replace, and cancel the broadcast of Public Warning System (PWS) messages, and report the eNodeB's PWS status to the MME.

MESSAGE	FUNCTIONALITY	DIRECTION
`Write-Replace Warning Request`	Starts, or replaces, the broadcast of a warning message in the indicated warning area.	MME → eNodeB

MESSAGE	FUNCTIONALITY	DIRECTION
`Write-Replace Warning Response`	Reports the area(s) where the eNodeB is broadcasting the warning message.	eNodeB → MME
`Kill Request`	Asks the eNodeB to cancel an already ongoing broadcast of a warning message.	MME → eNodeB
`Kill Response`	Reports the area(s) where the eNodeB stopped the warning message broadcast.	eNodeB → MME
`PWS Restart Indication`	Tells the MME that PWS information for some or all cells of the eNodeB is available for reloading from the Cell Broadcast Centre (CBC).	eNodeB → MME
`PWS Failure Indication`	Tells the MME that an ongoing PWS operation for one or more cells of the eNodeB has failed.	eNodeB → MME

5.1.3.12. Direct Information Transfer Messages

These messages transfer RAN Information Management (RIM) information, in unacknowledged mode, between an eNodeB and a peer RAN node via the core network. The MME does not interpret the transferred information.

MESSAGE	FUNCTIONALITY	DIRECTION
`eNB Direct Information Transfer`	Transfers RAN information from the eNodeB to the MME.	eNodeB → MME
`MME Direct Information Transfer`	Transfers RAN information from the MME to the eNodeB.	MME → eNodeB

5.1.3.13. Configuration Transfer Messages

These messages transfer Self-Organizing Network (SON) configuration information, in unacknowledged mode, between an eNodeB and a peer RAN node via the core network.

MESSAGE	FUNCTIONALITY	DIRECTION
`eNB Configuration Transfer`	Transfers RAN configuration information from the eNodeB to the MME.	eNodeB → MME
`MME Configuration Transfer`	Transfers RAN configuration information from the MME to the eNodeB.	MME → eNodeB

5.1.3.14. LPPa Transport Messages

These messages carry LTE Positioning Protocol Annex (LPPa) signaling between an eNodeB and the Evolved Serving Mobile Location Centre (E-SMLC), relayed transparently by the MME, as specified in TS 36.455.

MESSAGE	FUNCTIONALITY	DIRECTION
`Downlink UE Associated LPPa Transport`	Forwards a UE-associated LPPa message from the MME to the eNodeB, for example to support Enhanced Cell-ID (E-CID) or Uplink Time Difference Of Arrival (UTDOA) positioning of that UE.	MME → eNodeB
`Uplink UE Associated LPPa Transport`	Forwards a UE-associated LPPa message from the eNodeB to the MME.	eNodeB → MME

MESSAGE	FUNCTIONALITY	DIRECTION
`Downlink Non UE Associated LPPa Transport`	Forwards a non-UE-associated LPPa message from the MME to the eNodeB, for example to obtain Observed Time Difference Of Arrival (OTDOA) assistance data.	MME → eNodeB
`Uplink Non UE Associated LPPa Transport`	Forwards a non-UE-associated LPPa message from the eNodeB to the MME.	eNodeB → MME

5.1.3.15. Secondary RAT Data Usage Report Messages

MESSAGE	FUNCTIONALITY	DIRECTION
`Secondary RAT Data Usage Report`	Reports the resources used on a secondary Radio Access Technology (RAT), for example New Radio (NR) resources during E-UTRA-NR Dual Connectivity (EN-DC) operation.	eNodeB → MME

5.1.3.16. UE Radio Capability ID Mapping Messages

MESSAGE	FUNCTIONALITY	DIRECTION
`UE Radio Capability ID Mapping Request`	Asks the MME for the UE radio capability information that maps to a given UE Radio Capability ID.	eNodeB → MME
`UE Radio Capability ID Mapping Response`	Returns the UE radio capability information that a `UE Radio Capability ID Mapping Request` message asked for.	MME → eNodeB

5.1.4. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 36.413	• Clause 1 — Scope • Clause 3.1 — Definitions, covering Elementary Procedures and EP classes, and the UE-associated logical S1-connection • Clause 5 — S1AP services • Clause 6 — Services expected from the signaling transport • Clause 8.1 — List of S1AP Elementary procedures (Table 1: Class 1 procedures, Table 2: Class 2 procedures) • Clause 8.2 — E-RAB Management procedures • Clause 8.3 — Context Management procedures • Clause 8.4 — Handover Signalling • Clause 8.5 — Paging • Clause 8.6 — NAS transport • Clause 8.7 — Management procedures • Clause 8.8 — S1 CDMA2000 Tunnelling Procedures • Clause 8.9 — UE Capability Info Indication • Clause 8.10 — Trace Procedures • Clause 8.11 — Location Reporting Procedures • Clause 8.12 — Warning Message Transmission Procedures • Clause 8.13 — eNB Direct Information Transfer • Clause 8.14 — MME Direct Information Transfer • Clause 8.15 — eNB Configuration Transfer • Clause 8.16 — MME Configuration Transfer • Clause 8.17 — LPPa transport • Clause 8.18 — Secondary RAT Data Usage Report • Clause 8.19 — UE Radio Capability ID Mapping • Clause 9.3.2 — Elementary Procedure definitions, covering the `S1AP-ELEMENTARY-PROCEDURE` class • Clause 9.3.3 — PDU Definitions, covering the `S1AP-PDU` choice and the `InitiatingMessage`, `SuccessfulOutcome`, and `UnsuccessfulOutcome` types • Clause 10.3.2 — Criticality information
ITU-T X.691	ASN.1 encoding rules: Specification of PER, used to encode S1AP messages
TS 36.410	E-UTRAN; S1 general aspects and principles: defines the S1 transport network layer
TS 32.422	Subscriber and equipment trace; Trace control and configuration management: defines the trace and MDT sessions that the Trace Messages control
TS 36.455	LPPa, the protocol relayed transparently between the eNodeB and the E-SMLC by the LPPa Transport messages

5.2. NAS (Non-Access Stratum)

5.2.1. Technical Overview

The NAS protocol forms the highest stratum of the control plane between the UE and the MME at the LTE-Uu radio interface, a scope that TS 24.301 clause 4.1 defines. Between the UE and the MME, the E-UTRAN carries each NAS message transparently, and the S1AP chapter describes the S1AP messages that carry NAS messages over S1-MME.

NAS comprises two protocols: the EPS Mobility Management (EMM) protocol and the EPS Session Management (ESM) protocol. The EMM protocol supports the mobility of the UE, which includes registering the UE with the network and tracking its location, and it also carries the procedures that control NAS security. The ESM protocol establishes, modifies, and releases the PDN connections and the EPS bearer contexts of the UE.

The network can activate a default EPS bearer context during the attach procedure, when the UE requests PDN connectivity in its attach request, because an EMM message can carry an ESM message in an information element. In that case, the UE and the network run the attach procedure and the default EPS bearer context activation procedure in parallel, and TS 24.301 clause 4.2 defines this linkage between EMM and ESM.

NAS security protects both EMM and ESM messages with integrity protection and ciphering, once the UE and the MME take an EPS security context into use. Ciphering is an operator option, and an operator that does not use ciphering configures the MME to always select the null ciphering algorithm, EPS Encryption Algorithm 0 (EEA0). TS 24.301 clause 4.4 defines NAS security, and the Security Header Type field, which the General Message Format section below describes, states which protection a given NAS message carries.

5.2.2. General Message Format

Every NAS message except the `Service Request` message is a standard Layer 3 message as TS 24.007 defines it, and NAS arranges each of these messages either as a plain NAS message or as a security protected NAS message. TS 24.301 clause 9.1 defines both organizations.

5.2.2.1. Plain NAS Message

A plain NAS message carries a Protocol Discriminator, a Security Header Type or an EPS Bearer Identity, a Procedure Transaction Identity in an ESM message only, a Message Type, and zero or more other IEs. An EMM message and an ESM message use a different header layout, because only an ESM message carries an EPS Bearer Identity and a Procedure Transaction Identity.

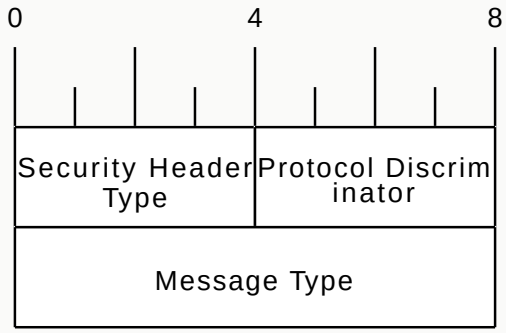


Figure 6. NAS header for a plain EMM message

`Protocol Discriminator`

Bits 1 to 4 of octet 1. This field states which NAS protocol the message belongs to, EMM or ESM, and TS 24.301 clause 9.2 refers to TS 24.007 for its coding.

`Security Header Type`

Bits 5 to 8 of octet 1 of an EMM message. This field states whether the message is a plain NAS message or a security protected NAS message, and which protection a security protected NAS message carries. TS 24.301 clause 9.3.1 defines this field, and the Security Header Type Values table below lists its values.

`Message Type`

Octet 2. This field states the message type, with a unique value for each EMM or ESM message, and TS 24.301 clause 9.8 defines the value for each message type.

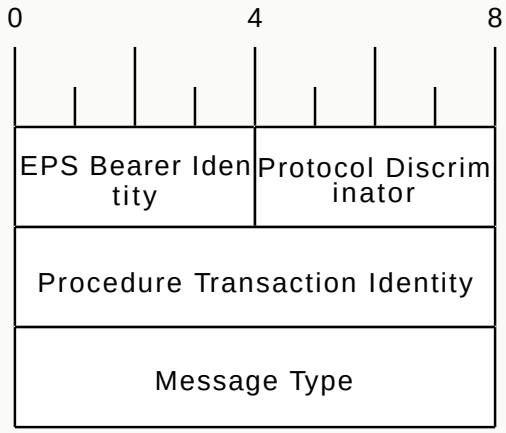


Figure 7. NAS header for a plain ESM message

`EPS Bearer Identity`

Bits 5 to 8 of octet 1 of an ESM message. This field identifies the EPS bearer context that the message applies to, or carries the value 0 when no EPS bearer identity is assigned. TS 24.301 clause 9.3.2 defines this field.

`Procedure Transaction Identity`

Octet 1a of an ESM message. This field identifies the ESM procedure transaction that the message belongs to, so that the UE and the MME can match a response to its request. TS 24.301 clause 9.4 defines this field.

5.2.2.2. Security Protected NAS Message

After the UE and the MME establish the secure exchange of NAS messages, the UE and the MME send every NAS message, apart from the `Service Request` message, in a security protected NAS message. The `Service Request` message is also integrity protected, but it carries its own security header, with Security Header Type `1100`, a key set identifier, a short sequence number, and a short Message Authentication Code, as TS 24.301 clause 8.2.25 defines. A security protected NAS message places a Message Authentication Code and a Sequence Number in front of a complete plain NAS message, which can be either an EMM message or an ESM message. The Protocol Discriminator of the security protected NAS message itself always states EMM, as TS 24.301 clause 9.2 defines.

Before the secure exchange of NAS messages exists, the UE and the MME can send a small set of EMM messages without integrity protection, for example `Identity Request`, `Authentication Request`, and `Attach Request`. The only ESM message that the UE can send without integrity protection is a `PDN Connectivity Request` message that the UE carries in an `Attach Request` message before NAS security is activated. TS 24.301 clauses 4.4.4.2 and 4.4.4.3 list these messages.

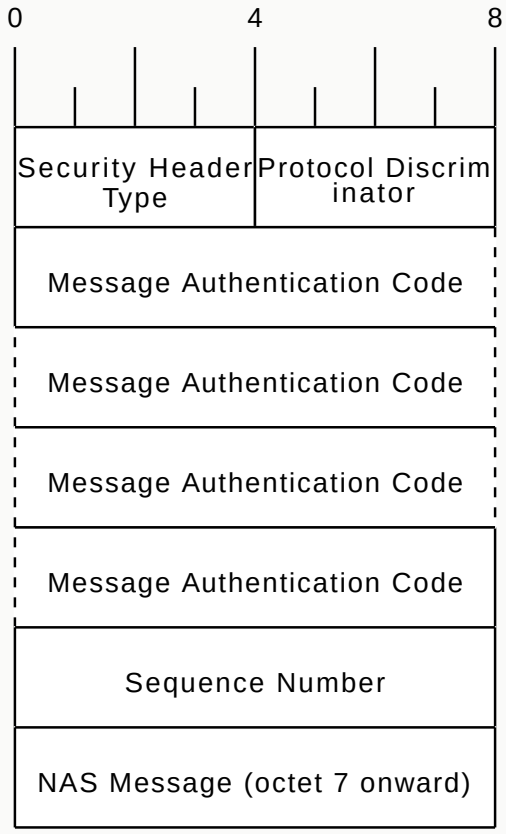


Figure 8. NAS header for a security protected NAS message

`Message Authentication Code`

Octets 2 to 5. This field carries the integrity protection value for the message, which the sender calculates over the Sequence Number and the NAS Message fields. TS 24.301 clause 9.5 defines this field, and clause 4.4.3.3 defines its calculation.

`Sequence Number`

Octet 6. This field carries the eight least significant bits of the NAS COUNT of the sending entity, and the receiving entity uses the NAS COUNT to protect against replayed messages. TS 24.301 clauses 4.4.3 and 9.6 define this field.

`NAS Message`

Octet 7 onward. This field carries the complete plain NAS message that the Plain NAS Message section above describes. TS 24.301 clause 9.7 defines this field.

5.2.2.3. Security Header Type Values

VALUE	MEANING
`0000`	Plain NAS message, not security protected.

VALUE	MEANING
0001	Integrity protected.
0010	Integrity protected and ciphered.
0011	Integrity protected with a new EPS security context. Only the Security Mode Command message can use this value.
0100	Integrity protected and ciphered with a new EPS security context. Only the Security Mode Complete message can use this value.
0101	Integrity protected and partially ciphered NAS message. Only the Control Plane Service Request message can use this value.
1100	Security header for the Service Request message, which is not a standard Layer 3 message.
1101 to 1111	Not used in this version of the protocol. A receiving entity interprets these values as 1100.

All other values are reserved. TS 24.301 clause 9.3.1 (Table 9.3.1) defines these values.

5.2.3. Message Categories

TS 24.301 clause 8.2 defines the EMM messages, and clause 8.3 defines the ESM messages. The tables below group these messages by function, and state which entity sends each message.

5.2.3.1. EMM: Attach and Detach Messages

MESSAGE	FUNCTIONALITY	DIRECTION
Attach Request	Starts the attach procedure, and carries the identity of the UE, the UE network capability, and an ESM message container.	UE → MME
Attach Accept	Reports that the network accepted the attach request, and carries the tracking area identity (TAI) list and an ESM message container. The message can also carry a new Globally Unique Temporary UE Identity (GUTI).	MME → UE
Attach Complete	Responds to an Attach Accept message.	UE → MME
Attach Reject	Reports that the network rejected the attach request, and states the reason.	MME → UE
Detach Request	Requests the release of the EMM context. Either the UE or the MME sends this message.	Both
Detach Accept	Reports that the detach procedure completed. Either the UE or the MME sends this message.	Both

5.2.3.2. EMM: Tracking Area Update Messages

MESSAGE	FUNCTIONALITY	DIRECTION
Tracking Area Update Request	Starts the tracking area updating procedure, for example after the UE enters a tracking area outside its current TAI list.	UE → MME
Tracking Area Update Accept	Reports that the network accepted the tracking area update, and carries EMM data such as an updated GUTI or TAI list.	MME → UE

MESSAGE	FUNCTIONALITY	DIRECTION
`Tracking Area Update Complete`	Responds to a `Tracking Area Update Accept` message that changed the GUTI or assigned a new Temporary Mobile Subscriber Identity (TMSI).	UE → MME
`Tracking Area Update Reject`	Reports that the network rejected the tracking area update, and states the reason.	MME → UE

5.2.3.3. EMM: Service Request Messages

MESSAGE	FUNCTIONALITY	DIRECTION
`Service Request`	Requests the establishment of a NAS signaling connection and of the radio and S1 bearers. This message does not follow the structure of a standard Layer 3 message.	UE → MME
`Extended Service Request`	Starts a circuit-switched (CS) fallback or 1xCS fallback call, or responds to a mobile-terminated CS fallback request. The UE also uses this message for packet services when it needs to provide information that a `Service Request` message cannot carry.	UE → MME
`Control Plane Service Request`	Starts the service request procedure for a UE that uses control plane CIoT EPS optimization, and can carry an `ESM Data Transport` message.	UE → MME
`Service Reject`	Reports that the network rejected the service request procedure.	MME → UE
`Service Accept`	Reports that the network accepted a `Service Request`, an `Extended Service Request`, or a `Control Plane Service Request` message.	MME → UE

5.2.3.4. EMM: Security Messages

MESSAGE	FUNCTIONALITY	DIRECTION
`Authentication Request`	Starts authentication of the UE identity, and carries the NAS key set identifier and the random challenge (RAND) and authentication token (AUTN) parameters.	MME → UE
`Authentication Response`	Carries the authentication response that the UE calculated.	UE → MME
`Authentication Reject`	Reports that the authentication procedure failed, and instructs the UE to abort all EMM activities.	MME → UE
`Authentication Failure`	Reports that the UE could not authenticate the network, for example because of a synchronization failure.	UE → MME
`Identity Request`	Requests the UE to provide a specified identity, for example its International Mobile Subscriber Identity (IMSI).	MME → UE
`Identity Response`	Carries the identity that an `Identity Request` message requested.	UE → MME
`Security Mode Command`	Establishes NAS signaling security, and states the selected integrity and ciphering algorithms.	MME → UE
`Security Mode Complete`	Responds to a `Security Mode Command` message that the UE accepted.	UE → MME
`Security Mode Reject`	Reports that the UE rejected a `Security Mode Command` message.	UE → MME
`GUTI Reallocation Command`	Assigns a new GUTI to the UE, and optionally a new TAI list.	MME → UE

MESSAGE	FUNCTIONALITY	DIRECTION
`GUTI Reallocation Complete`	Reports that the UE applied the GUTI that a `GUTI Reallocation Command` message assigned.	UE → MME

5.2.3.5. EMM: NAS Transport and Status Messages

MESSAGE	FUNCTIONALITY	DIRECTION
`Downlink NAS Transport`	Carries a Short Message Service (SMS) message in encapsulated format from the network to the UE.	MME → UE
`Uplink NAS Transport`	Carries an SMS message in encapsulated format from the UE to the network.	UE → MME
`Downlink Generic NAS Transport`	Carries an application message in encapsulated format from the network to the UE.	MME → UE
`Uplink Generic NAS Transport`	Carries an application message in encapsulated format from the UE to the network.	UE → MME
`CS Service Notification`	Informs the UE about a paging request with a CS call indicator that the MME received over the SGs interface, while a NAS signaling connection already exists for the UE.	MME → UE
`EMM Status`	Reports an EMM error condition, for example an unexpected message type. Either the UE or the MME sends this message.	Both
`EMM Information`	Sends EMM information to the UE while an EMM context exists, for example the network name or the local time zone.	MME → UE

5.2.3.6. ESM: Default and Dedicated Bearer Context Messages

MESSAGE	FUNCTIONALITY	DIRECTION
`Activate Default EPS Bearer Context Request`	Requests the UE to activate a default EPS bearer context.	MME → UE
`Activate Default EPS Bearer Context Accept`	Acknowledges that the UE activated the default EPS bearer context.	UE → MME
`Activate Default EPS Bearer Context Reject`	Reports that the UE rejected activation of the default EPS bearer context.	UE → MME
`Activate Dedicated EPS Bearer Context Request`	Requests the UE to activate a dedicated EPS bearer context that uses the same PDN address and access point name (APN) as an active default EPS bearer context.	MME → UE
`Activate Dedicated EPS Bearer Context Accept`	Acknowledges that the UE activated the dedicated EPS bearer context.	UE → MME
`Activate Dedicated EPS Bearer Context Reject`	Reports that the UE rejected activation of the dedicated EPS bearer context.	UE → MME
`Modify EPS Bearer Context Request`	Requests the UE to modify an active EPS bearer context, for example its QoS or its traffic flow template (TFT).	MME → UE
`Modify EPS Bearer Context Accept`	Acknowledges that the UE modified the active EPS bearer context.	UE → MME
`Modify EPS Bearer Context Reject`	Reports that the UE rejected the modification of an active EPS bearer context.	UE → MME

MESSAGE	FUNCTIONALITY	DIRECTION
`Deactivate EPS Bearer Context Request`	Requests the UE to deactivate an active EPS bearer context, and states the reason.	MME → UE
`Deactivate EPS Bearer Context Accept`	Acknowledges that the UE deactivated the EPS bearer context.	UE → MME

5.2.3.7. ESM: PDN Connectivity Messages

MESSAGE	FUNCTIONALITY	DIRECTION
`PDN Connectivity Request`	Starts the establishment of a PDN connection, and states the requested PDN type and, optionally, the APN.	UE → MME
`PDN Connectivity Reject`	Reports that the network rejected the establishment of the PDN connection, and states the reason.	MME → UE
`PDN Disconnect Request`	Starts the release of an existing PDN connection.	UE → MME
`PDN Disconnect Reject`	Reports that the network rejected the release of the PDN connection.	MME → UE

5.2.3.8. ESM: Bearer Resource Messages

MESSAGE	FUNCTIONALITY	DIRECTION
`Bearer Resource Allocation Request`	Requests the network to allocate a dedicated bearer resource, for example for a new IP flow.	UE → MME
`Bearer Resource Allocation Reject`	Reports that the network rejected a `Bearer Resource Allocation Request` message.	MME → UE
`Bearer Resource Modification Request`	Requests the network to modify or release a dedicated bearer resource.	UE → MME
`Bearer Resource Modification Reject`	Reports that the network rejected a `Bearer Resource Modification Request` message.	MME → UE

5.2.3.9. ESM: ESM Information, Status, and Transport Messages

MESSAGE	FUNCTIONALITY	DIRECTION
`ESM Information Request`	Requests the UE to provide ESM information, that is, protocol configuration options, the APN, or both. The MME sends this message only after NAS security is set up, and only when the UE set the ESM information transfer flag in its `PDN Connectivity Request` message, as TS 24.301 clause 6.6.1.2.2 defines.	MME → UE
`ESM Information Response`	Carries the ESM information that an `ESM Information Request` message requested.	UE → MME
`ESM Status`	Reports the status of an EPS bearer context or an ESM error condition. Either the UE or the MME sends this message.	Both
`ESM Dummy Message`	Fills the ESM message container of an attach procedure in which the UE does not request a PDN connection. Either the UE or the MME sends this message.	Both

MESSAGE	FUNCTIONALITY	DIRECTION
`Notification`	Informs the UE about an event that is relevant for the upper layers, for example a cancelled Single Radio Voice Call Continuity (SRVCC) handover after which the UE needs to re-establish its IP Multimedia Subsystem (IMS) session.	MME → UE
`Remote UE Report`	Reports that a remote UE connected to or disconnected from a UE that acts as a Proximity-based Services (ProSe) UE-to-network relay.	UE → MME
`Remote UE Report Response`	Acknowledges receipt of a `Remote UE Report` message.	MME → UE
`ESM Data Transport`	Carries user data in encapsulated format, for a UE that uses control plane CIoT EPS optimization. Either the UE or the MME sends this message.	Both

TS 24.301 clause 8.3.17 describes the `Modify EPS Bearer Context Reject` message as sent "by the UE or the network", but the Direction entry of the same clause states "UE to network", and only the UE rejects a modification in the procedure of clause 6.4.3.4. This document follows the Direction entry.

5.2.4. References

SPECIFICATION	CLAUSES AND COVERAGE

TS 24.301	• Clause 4.1 — Overview of the NAS
	• Clause 4.2 — Linkage between the protocols for EPS mobility management and EPS session management
	• Clause 4.4 — NAS security, covering:
	  ◦ 4.4.3 NAS COUNT and replay protection
	  ◦ 4.4.3.3 integrity protection and verification
	  ◦ 4.4.4.2 and 4.4.4.3 messages accepted without integrity protection
	• Clause 6.4.3.4 — EPS bearer context modification not accepted by the UE
	• Clause 6.6.1.2.2 — ESM information request initiated by the network
	• Clause 8.2 — EPS mobility management messages
	• Clause 8.2.25 — Service request
	• Clause 8.3 — EPS session management messages
	• Clause 9.1 — General message format
	• Clause 9.2 — Protocol discriminator
	• Clause 9.3 — Security header type and EPS bearer identity
	• Clause 9.4 — Procedure transaction identity
	• Clause 9.5 — Message authentication code
	• Clause 9.6 — Sequence number
	• Clause 9.7 — NAS message
	• Clause 9.8 — Message type

5.3. GTPv2-C

5.3.1. Technical Overview

GTP version 2 for the control plane (GTPv2-C) is the control-plane signaling protocol of the EPC, and network nodes use it to create, modify, and delete GTP tunnels and EPS bearers, and to exchange mobility management information.

GTPv2-C runs over the User Datagram Protocol (UDP), on port 2123, and because UDP does not guarantee delivery, a GTPv2-C entity retransmits a request message if it does not receive a response before a timer expires.

GTPv2-C messages fall into eight categories: Path Management Messages, Tunnel Management Messages, Mobility Management Messages, CS Fallback and SRVCC related messages, Non-3GPP access related messages, Restoration and Recovery messages, Trace Management Messages, and MBMS Messages. The Message Categories section below lists the messages in each category.

GTPv2-C applies over the S3, S4, S5, S8, S10, S11, S16, Sv, S101, S121, Sm, Sn, S2a, and S2b interfaces.

A GTPv2-C message can carry a second, piggybacked GTPv2-C message inside the same IP/UDP packet, to avoid an extra signaling round trip; the network uses piggybacking for two message pairs, a `Create Session Response` that carries a piggybacked `Create Bearer Request` and a `Create Bearer Response` that carries a piggybacked `Modify Bearer Request`. The network uses these combinations during the E-UTRAN Initial Attach procedure, a handover from non-3GPP access to E-UTRAN, and the UE-requested PDN connectivity procedure.

5.3.2. Packet Format

Control Plane GTP uses a variable-length header, with a length that is always a multiple of 4 octets, and GTPv2-C defines two header formats.

5.3.2.1. Header Without a Tunnel Endpoint Identifier

The `Echo Request`, `Echo Response`, and `Version Not Supported Indication` messages use the header without a Tunnel Endpoint Identifier (TEID), which is 8 octets long.

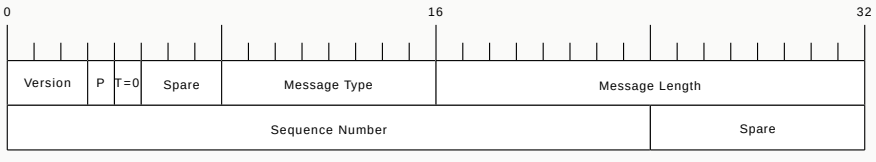


Figure 9. GTPv2-C header without a TEID

`Version`

Bits 8 to 6 of octet 1. This field states the GTP version, and GTPv2-C sets it to decimal 2.

`P`

Bit 5 of octet 1. This is the Piggybacking flag; a value of 0 means the message carries no piggybacked message.

`T`

Bit 4 of octet 1. This is the TEID flag; a value of 0 means the header carries no TEID field.

`Message Type`

Octet 2. This field states the message type, with a unique value for each GTPv2-C message.

`Message Length`

Octets 3 to 4. This field states the length of the message in octets, excluding the first 4 octets of the header.

`Sequence Number`

Octets 5 to 7. This field identifies the request or response, and a node uses it to match a response to its request and to detect retransmissions.

5.3.2.2. Header With a Tunnel Endpoint Identifier

Apart from the Echo and Version Not Supported Indication messages, every GTPv2-C message uses the header with a TEID, which is 12 octets long.

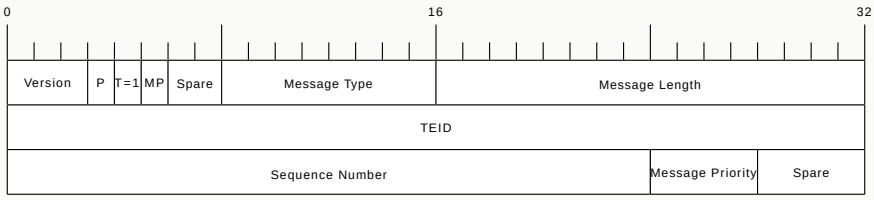


Figure 10. GTPv2-C header with a TEID

`TEID`

Octets 5 to 8. This field identifies a tunnel endpoint in the receiving entity of GTP for the control plane (GTP-C), and the sending entity sets it to the value that the receiving entity provided.

`MP`

Bit 3 of octet 1. This is the Message Priority flag; a value of 1 means octet 12 carries a valid `Message Priority` value. The Load and Overload Control section below describes how a node uses this flag.

`Message Priority`

Bits 8 to 5 of octet 12. This field states the relative priority of the message, as a value from 0 to 15, where 0 is the highest priority and 15 is the lowest, and it is valid only when the `MP` flag is set to 1.

5.3.3. Message Categories

5.3.3.1. Path Management Messages

Path management messages check that a GTPv2-C peer is alive and reachable.

MESSAGE	FUNCTIONALITY	INTERFACES
`Echo Request`	Checks that a peer GTP-C node is alive, and carries the sender's Restart Counter.	All GTPv2-C interfaces.
`Echo Response`	Confirms that the node is alive, and reports its own Restart Counter and the features it supports.	All GTPv2-C interfaces.
`Version Not Supported Indication`	Tells the sender of an unsupported-version message which GTP version the receiving node supports.	All GTPv2-C interfaces.

5.3.3.2. Tunnel Management Messages

Tunnel management messages create, modify, and delete GTP tunnels and EPS bearers, and carry other session-level signaling between the MME or the Serving GPRS Support Node (SGSN), the SGW-C, and the PGW-C.

MESSAGE	FUNCTIONALITY	INTERFACES
`Create Session Request`	Creates a new PDN connection and its default EPS bearer.	S11, S4, S5, S8, S2a, S2b.
`Create Session Response`	Reports the outcome of a `Create Session Request`, and returns the allocated addresses and bearer parameters.	S11, S4, S5, S8, S2a, S2b.
`Create Bearer Request`	Creates one or more dedicated EPS bearers for an existing PDN connection.	S11, S4, S5, S8, S2a, S2b.
`Create Bearer Response`	Reports the outcome of a `Create Bearer Request`.	S11, S4, S5, S8, S2a, S2b.
`Bearer Resource Command`	Forwards a UE request for a new bearer resource or a change to an existing one, for example a QoS change or an IP flow mobility update.	S11, S4, S5, S8, S2a, S2b.
`Bearer Resource Failure Indication`	Reports that the network could not honor a `Bearer Resource Command`.	S11, S4, S5, S8, S2a, S2b.
`Modify Bearer Request`	Updates the parameters of an existing EPS bearer, for example the eNodeB's downlink address after a handover or a service request.	S11, S5, S8.
`Modify Bearer Response`	Reports the outcome of a `Modify Bearer Request`.	S11, S4, S5, S8, S2b.
`Delete Session Request`	Deletes a PDN connection and its EPS bearers.	S11, S4, S5, S8, S2a, S2b.
`Delete Bearer Request`	Deletes one or more dedicated EPS bearers, without deleting the whole PDN connection.	S11, S4, S5, S8, S2a, S2b.
`Delete Session Response`	Reports the outcome of a `Delete Session Request`.	S11, S4, S5, S8, S2a, S2b.
`Delete Bearer Response`	Reports the outcome of a `Delete Bearer Request`.	S11, S4, S5, S8, S2a, S2b.

MESSAGE	FUNCTIONALITY	INTERFACES
`Downlink Data Notification`	Tells the MME/SGSN that the SGW-C received downlink data, or downlink signaling, for a UE in idle mode, to start paging.	S11, S4.
`Downlink Data Notification Acknowledge`	Confirms that the MME/SGSN accepted a `Downlink Data Notification` and attempts to reach the UE.	S11, S4.
`Downlink Data Notification Failure Indication`	Tells the SGW-C that a paging attempt failed, for example because the UE did not respond.	S11, S4.
`Delete Indirect Data Forwarding Tunnel Request`	Tells the SGW-C to release an indirect data-forwarding tunnel that a handover procedure set up.	S11, S4.
`Delete Indirect Data Forwarding Tunnel Response`	Reports the outcome of a `Delete Indirect Data Forwarding Tunnel Request`.	S11, S4.
`Modify Bearer Command`	Asks the PGW-C to apply a subscribed QoS change that the HSS pushed down for a UE's default bearer.	S11, S4, S5, S8, S2a, S2b.
`Modify Bearer Failure Indication`	Reports that the PGW-C could not apply the QoS change requested in a `Modify Bearer Command`.	S11, S4, S5, S8, S2a, S2b.
`Update Bearer Request`	Changes the QoS or the TFT of an existing EPS bearer, at the request of the PGW-C or the PCRF.	S11, S4, S5, S8, S2a, S2b.
`Update Bearer Response`	Reports the outcome of an `Update Bearer Request`.	S11, S4, S5, S8, S2a, S2b.
`Delete Bearer Command`	Asks the SGW-C/PGW-C to deactivate one or more dedicated EPS bearers, without deleting the PDN connection.	S11, S4, S5, S8.
`Delete Bearer Failure Indication`	Reports that the PGW-C could not deactivate the bearers requested in a `Delete Bearer Command`.	S11, S4, S5, S8.
`Create Indirect Data Forwarding Tunnel Request`	Sets up an indirect data-forwarding tunnel at the SGW-C, to forward buffered downlink data during a handover.	S11, S4.
`Create Indirect Data Forwarding Tunnel Response`	Reports the outcome of a `Create Indirect Data Forwarding Tunnel Request`.	S11, S4.
`Release Access Bearers Request`	Asks the SGW-C to release the radio and S1-U (or Iu) user-plane bearers for a UE that enters idle mode, while keeping the PDN connection.	S11, S4.
`Release Access Bearers Response`	Reports the outcome of a `Release Access Bearers Request`.	S11, S4.
`Stop Paging Indication`	Tells the MME/SGSN to stop paging a UE, for example because the network already reached it another way.	S11, S4.
`Modify Access Bearers Request`	Updates only the eNodeB's user-plane addresses at the SGW-C for a UE's bearers, without involving the PGW-C.	S11.
`Modify Access Bearers Response`	Reports the outcome of a `Modify Access Bearers Request`.	S11.

MESSAGE	FUNCTIONALITY	INTERFACES
`Remote UE Report Notification`	Tells the SGW-C/PGW-C that a remote UE, reached through a ProSe UE-to-Network Relay, connected or disconnected.	S11, S5, S8.
`Remote UE Report Acknowledge`	Reports the outcome of a `Remote UE Report Notification`.	S11, S5, S8.

5.3.3.3. Mobility Management Messages

Mobility management messages transfer a UE's mobility management and bearer context between the old and the new serving node during a handover, a relocation, or a Tracking/Routing Area Update. Some of these messages coordinate Idle mode Signalling Reduction (ISR), a feature that keeps a UE registered on an MME and an SGSN at the same time, so the network can page the UE without knowing which of the two it is camped on. These messages also apply to the EPS to 5G System (5GS) handover and idle-mode mobility procedures, where the peer node is an Access and Mobility Management Function (AMF), over the N26 interface.

MESSAGE	FUNCTIONALITY	INTERFACES
`Forward Relocation Request`	Asks the target node to prepare resources for a handover or a relocation, and carries the UE's mobility management and bearer context.	S10, S3, S16, N26.
`Forward Relocation Response`	Reports whether the target node accepted the relocation, and which bearers it set up.	S10, S3, S16, N26.
`Forward Relocation Complete Notification`	Tells the source node that the handover finished successfully.	S10, S3, S16, N26.
`Forward Relocation Complete Acknowledge`	Reports the outcome of a `Forward Relocation Complete Notification`.	S10, S3, S16, N26.
`Context Request`	Asks the old serving node for a UE's mobility management and bearer context, during a Tracking/Routing Area Update or an idle-mode inter-system mobility procedure.	S3, S16, S10, N26.
`Context Response`	Returns the requested mobility management and bearer context, or rejects the request.	S3, S16, S10, N26.
`Context Acknowledge`	Confirms that the new node accepted the context that a `Context Response` transferred.	S3, S16, S10, N26.
`Identification Request`	Asks the old serving node to resolve a UE's temporary identity to its IMSI.	S3, S16, S10, N26.
`Identification Response`	Returns the UE's IMSI, and its mobility management context if authentication already succeeded.	S3, S16, S10, N26.
`Forward Access Context Notification`	Forwards a UE's radio access network context, for example a Radio Network Controller (RNC) or an eNodeB context, to the target node during a relocation.	S16, S10.

MESSAGE	FUNCTIONALITY	INTERFACES
`Forward Access Context Acknowledge`	Reports the outcome of a `Forward Access Context Notification`.	S16, S10.
`Detach Notification`	Tells an ISR-associated MME or SGSN to also detach the UE, or to only deactivate ISR for it.	S3.
`Detach Acknowledge`	Reports the outcome of a `Detach Notification`.	S3.
`Change Notification Request`	Reports a change in a UE's location or CSG membership to the SGW-C, for location-dependent charging.	S11, S4, S5, S8.
`Change Notification Response`	Reports the outcome of a `Change Notification Request`.	S11, S4, S5, S8.
`Relocation Cancel Request`	Tells the target node to abandon the resources it prepared for a handover or a relocation that the source node cancelled.	S3, S10, S16, N26.
`Relocation Cancel Response`	Reports the outcome of a `Relocation Cancel Request`.	S3, S10, S16, N26.
`Configuration Transfer Tunnel`	Carries an opaque radio configuration container between a source and a target radio node, relayed transparently through the core network.	S10, N26.
`RAN Information Relay`	Relays radio access network information between core-network nodes, on behalf of their radio access network nodes.	S3, S16.
`ISR Status Indication`	Tells an ISR-associated MME or SGSN to deactivate ISR, to page the UE, or to stop paging it.	S3.
`UE Registration Query Request`	Asks a candidate MME whether a given UE is registered there, to coordinate CS and packet-switched (PS) service in a shared radio access network.	S3.
`UE Registration Query Response`	Reports whether the UE is registered in the queried MME, and with which core network operator.	S3.

5.3.3.4. CS Fallback and SRVCC Related Messages

These messages support CS Fallback and SRVCC: they suspend and resume a UE's non-Guaranteed Bit Rate (non-GBR) bearers around a move to the CS domain, and coordinate paging and activity reporting between an MME and an ISR-associated SGSN.

MESSAGE	FUNCTIONALITY	INTERFACES
`Suspend Notification`	Tells the SGW-C/PGW-C to suspend a UE's non-GBR bearers, because the UE moved to the CS domain.	S3, S4, S5, S8, S11, S16.
`Suspend Acknowledge`	Reports the outcome of a `Suspend Notification`.	S3, S4, S5, S8, S11, S16.
`Resume Notification`	Tells the SGW-C/PGW-C to resume a UE's suspended bearers, because the UE returned to the PS domain.	S11, S4, S5, S8.
`Resume Acknowledge`	Reports the outcome of a `Resume Notification`.	S11, S4, S5, S8.

MESSAGE	FUNCTIONALITY	INTERFACES
`CS Paging Indication`	Relays a CS domain paging request from the MME to an ISR-associated SGSN.	S3.
`Alert MME Notification`	Asks an ISR-associated SGSN to notify the MME the next time it detects activity from the UE.	S3.
`Alert MME Acknowledge`	Reports the outcome of an `Alert MME Notification`.	S3.
`UE Activity Notification`	Tells the MME that an ISR-associated SGSN detected activity from the UE.	S3.
`UE Activity Acknowledge`	Reports the outcome of a `UE Activity Notification`.	S3.

5.3.3.5. Non-3GPP Access Related Messages

These messages set up an indirect data-forwarding tunnel at the SGW-C for a handover between E-UTRAN and CDMA2000 High Rate Packet Data (HRPD) access.

MESSAGE	FUNCTIONALITY	INTERFACES
`Create Forwarding Tunnel Request`	Asks the SGW-C to set up an indirect data-forwarding tunnel for a handover from E-UTRAN to CDMA2000 HRPD access.	S11.
`Create Forwarding Tunnel Response`	Reports the outcome of a `Create Forwarding Tunnel Request`.	S11.

5.3.3.6. Restoration and Recovery Messages

These messages let GTP-C nodes recover gracefully from a peer's partial fault or restart, by deleting or re-associating the affected PDN connections. TS 23.007 defines the restoration and recovery procedures that use these messages.

MESSAGE	FUNCTIONALITY	INTERFACES
`Delete PDN Connection Set Request`	Tells a peer node that reports a partial fault to delete the PDN connections associated with the affected control-plane identifier.	S2a, S2b, S5, S8, S11.
`Delete PDN Connection Set Response`	Reports the outcome of a `Delete PDN Connection Set Request`.	S2a, S2b, S5, S8, S11.
`Update PDN Connection Set Request`	Tells the PGW-C which control-plane node now serves a PDN connection's SGW-C or MME, after an MME change that did not change the SGW-C.	S5, S8.
`Update PDN Connection Set Response`	Reports the outcome of an `Update PDN Connection Set Request`.	S5, S8.
`PGW Restart Notification`	Tells the MME/SGSN that the PGW-C serving a UE's PDN connections has restarted or failed.	S11, S4.
`PGW Restart Notification Acknowledge`	Confirms that the MME/SGSN deleted the PDN connections that a `PGW Restart Notification` reported.	S11, S4.

MESSAGE	FUNCTIONALITY	INTERFACES
`PGW Downlink Triggering Notification`	Asks the SGW-C to restore the user-plane path for a UE, after the SGW-C lost its bearer context but the PGW-C still has downlink data or signaling to deliver.	S5, S8, S11, S4.
`PGW Downlink Triggering Acknowledge`	Reports the outcome of a `PGW Downlink Triggering Notification`.	S5, S8, S11, S4.

5.3.3.7. Trace Management Messages

These messages start and stop a protocol-level signaling trace for a subscriber, across the control-plane nodes that serve the subscriber's session.

MESSAGE	FUNCTIONALITY	INTERFACES
`Trace Session Activation`	Activates signaling trace recording for a subscriber's session.	S11, S4, S5, S8, S2a, S2b.
`Trace Session Deactivation`	Deactivates a previously activated signaling trace.	S11, S4, S5, S8, S2a, S2b.

5.3.3.8. MBMS Messages

These messages let the Multimedia Broadcast Multicast Service (MBMS) Gateway control a broadcast or multicast session at the MME/SGSN.

MESSAGE	FUNCTIONALITY	INTERFACES
`MBMS Session Start Request`	Asks the MME/SGSN to start an MBMS session, and carries its QoS, service area, and multicast distribution parameters.	Sm, Sn.
`MBMS Session Start Response`	Reports the outcome of an `MBMS Session Start Request`.	Sm, Sn.
`MBMS Session Update Request`	Updates the parameters of an ongoing MBMS session, for example its service area.	Sm, Sn.
`MBMS Session Update Response`	Reports the outcome of an `MBMS Session Update Request`.	Sm, Sn.
`MBMS Session Stop Request`	Ends an MBMS session.	Sm, Sn.
`MBMS Session Stop Response`	Reports the outcome of an `MBMS Session Stop Request`.	Sm, Sn.

5.3.4. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 29.274	• Clause 4.2 — GTPv2-C protocol stack and interfaces • Clause 4.3 — Transmission order and bit definitions • Clause 5.1 — General header format • Clause 5.3 — Header for the Echo and Version Not Supported Indication messages • Clause 5.4 — EPC specific GTP-C header • Clause 5.5 — Usage of the GTPv2-C header, including the `MP` flag and the `Message Priority` field • Clause 6 — GTP-C message types and message formats • Clause 7 — GTP-C messages, covering: ◦ 7.1 Path Management Messages ◦ 7.2 Tunnel Management Messages ◦ 7.3 Mobility Management Messages ◦ 7.4 CS Fallback and SRVCC related messages ◦ 7.5 Non-3GPP access related messages ◦ 7.9 Restoration and Recovery ◦ 7.12 Trace Management Messages ◦ 7.13 MBMS Messages

5.3.5. Load and Overload Control

5.3.5.1. Technical Overview

GTPv2-C load control and GTPv2-C overload control are optional, complementary features that manage signaling traffic between EPC control-plane nodes and help keep the network stable.

Load control is a preventive mechanism: a node uses it to balance the distribution of new sessions across its peers before an overload condition occurs.

Overload control is a reactive mechanism: a node uses it to reduce incoming signaling traffic after the node already operates over its capacity.

An operator can support load control and overload control independently of each other, based on operator policy. Each node piggybacks its `Load Control Information` (LCI) or `Overload Control Information` (OCI) onto existing GTP-C request and response messages, a method that avoids extra signaling traffic and keeps the computation and transfer of this control information from adding significant load to the sending node or to its peers.

Overload control still lets the network give preferential treatment to emergency services traffic and to enhanced Multimedia Priority Service (eMPS) traffic.

Load control and overload control apply over the S11, S4, S5, S8, S2a, and S2b interfaces.

5.3.5.2. Load Control Procedure

Load control lets a node, typically the SGW-C or the PGW-C, advertise its operating status to a peer, for example the MME, the SGSN, the Trusted WLAN Access Network (TWAN), or the ePDG. The peer uses this status to balance the distribution of new sessions.

The node includes an `LCI` IE in its GTP-C messages. The `LCI` IE carries the following parameters:

`Load Control Sequence Number`
: This number sequences the LCI updates, letting the receiving node identify the most recent load information.

`Load Metric`
: This parameter states the current load level, as a percentage from 0 to 100, where 100 means the node operates at maximum load.

`List of APN and Relative Capacity` **(PGW-C only)**
: This list states the load status for a specific APN, and the PGW-C includes it when it does not distribute its resources evenly across its APNs.

Load control operates at two levels:

Node Level
: This level advertises the load of the entire node, helping distribute sessions evenly across a cluster of gateways.

APN Level
: This level advertises the load for a specific APN and applies when a PGW-C allocates a separate resource pool to each APN, stopping the network from selecting a node for a new session on an APN whose resources are exhausted, even when the node has spare capacity overall.

5.3.5.3. Overload Control Procedure

Overload control activates when a node operates over its nominal capacity and its performance degrades, and the overloaded node instructs its peers to reduce the rate of Request messages that they send to it.

The node includes an `OCI` IE in its GTP-C messages. The `OCI` IE carries the following parameters:

`Overload Control Sequence Number`
: This number differentiates between OCI instances, letting the receiving node collate reports that arrive out of order.

`Overload Reduction Metric`
: This parameter states the traffic reduction that the sender requests from the receiver, as a percentage from 0 to 100, where a value of 0 means the overload condition ended.

`Period of Validity`

This parameter states how long the overload condition stays valid, and when this timer expires without a new OCI, the receiving node considers the overload condition ended.

`List of APNs` **(PGW-C only)**

This list states the APNs that are in overload, for example because of a shortage in the IP address pool.

A node reduces traffic toward an overloaded peer through the following mechanisms:

Message Throttling

The reacting node reduces the number of initial messages that it sends to the overloaded peer, in proportion to the Overload Reduction Metric, but does not throttle a triggered request or a response message, because doing so would cause the sender to retransmit the corresponding request message.

"Loss" Throttling Algorithm

This is the mandatory default throttling algorithm for overload control, under which the node discards a fraction of the initial messages, in proportion to the requested traffic reduction. A typical implementation generates a random number for each candidate message and discards the message when the number falls within the requested reduction percentage.

Self-Protection

As a fallback when peer throttling does not reduce the load enough, an overloaded node can still reject incoming requests, with a cause value such as `GTP-C Entity Congestion` or `APN congestion`.

5.3.5.4. Message Prioritization during Overload

Emergency services traffic and eMPS traffic keep the highest priority, and, depending on regional and national requirements and on operator policy, the network exempts this traffic from throttling for as long as it can achieve the requested traffic reduction without throttling it.

For other traffic, an overloaded node can prioritize messages for throttling in the following ways.

Prioritization Based on Procedures

The node groups GTPv2-C procedures into four categories and gives a lower preference to throttle to the messages of a higher-priority category.

Prioritization Based on Session Parameters

The node can further prioritize messages within a category, based on session parameters such as the APN, the QoS Class Identifier (QCI), the Allocation and Retention Priority (ARP), or the Low Access Priority Indicator (LAPI).

Prioritization Based on the Message Priority

The node can prioritize messages based on the relative `Message Priority` that the sending node signals in the GTPv2-C header, through the `MP` flag and the `Message Priority` field.

The procedure categories, from the highest priority to the lowest, are:

1. UE session mobility, for example a `Create Session Request` and a `Modify Bearer Request` with the handover indication bit set. Throttling these messages can cause the loss of a PDN connection or the interruption of a service.
2. Release of a PDN connection or bearer resources, for example a `Delete Session Request` and a `Delete Bearer Request`. These messages free node resources, so the node gives them a lower preference to throttle.
3. Other session management procedures, for example a `Modify Bearer Request` without the handover indication bit set, and a `Change Notification`.
4. Requests for a new PDN connection or new bearer resources, for example a `Create Session Request` for a new PDN connection, and a `Create Bearer Request`. The node gives the highest preference to throttle these messages, because it denies new services before it drops existing ones.

5.3.5.5. Implementation Requirements and Enforcement

Peer Discovery

A node decides whether to use load control and overload control, based on local configuration and operator policy, and this decision applies separately to internal interfaces and to roaming interfaces.

Homogeneity

Operators need to support these features consistently across all nodes in the network, because partial support can cause unfair load distribution: supporting nodes throttle their traffic, while non-supporting nodes keep overwhelming the target node.

Direct Enforcement

A node enforces load control and overload control for peers that it directly contacts, based on the metrics that those peers report.

Remote Enforcement

A node also enforces control for entities that it does not directly contact, for example an MME that signals to a PGW-C through an SGW-C. In this case, the source node enforces control based on the maximum reduction metric that any node in the signaling path reports, whether that node is the target or an intermediate node.

Interaction with the PGW-C Back-Off Timer

For a given APN, a PGW-C uses either APN-level overload control or the PGW back-off timer mechanism, never both mechanisms at the same time.

5.3.5.6. Messages Carrying Load and Overload Control Information

A node includes the `LCI` IE and the `OCI` IE in a wide range of session management messages, including:

- `Create Session Request` and `Create Session Response`.

- `Modify Bearer Request` and `Modify Bearer Response`.
- `Delete Session Request` and `Delete Session Response`.
- `Create Bearer Request/Response`, `Update Bearer Request/Response`, and `Delete Bearer Request/Response`.
- `Downlink Data Notification`.
- `Bearer Resource Command` and `Bearer Resource Failure Indication`.

5.3.5.7. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 4.3.7.1a — GTP-C signalling based Load and Overload Control • Clause 4.3.7.1a.1 — Load control • Clause 4.3.7.1a.2 — Overload control • Clause 4.3.7.5 — APN congestion control and the PGW back-off timer
TS 29.274	• Clauses 5.4 and 5.5 — the `MP` flag and the `Message Priority` field • Clauses 8.111 to 8.115 — the Overload Control Information, Load Control Information, Metric, Sequence Number, and APN and Relative Capacity Information Elements • Clauses 12.1 to 12.3 — the GTP-C load and overload control mechanism, including message throttling in clause 12.3.9 and enforcement in clause 12.3.10 • Annex D — the GTP-C interfaces that do not support these features, and example implementations of the "Loss" algorithm and of overload control enforcement between remote GTP-C entities
TS 29.244	Clauses 6.2.3 and 6.2.4 (the parallel load and overload control mechanism over the Packet Forwarding Control Protocol, PFCP).
TS 29.213	Annexes G and K (the equivalent load and overload control mechanism over Diameter).

5.4. PFCP (Packet Forwarding Control Protocol)

5.4.1. Technical Overview

PFCP is the protocol on the interface between a control plane (CP) function and a user plane (UP) function. In the EPC, the CP functions are the SGW-C, the PGW-C, and the TDF-C, and the UP functions are the SGW-U, the PGW-U, and the TDF-U.

PFCP applies over the Sxa, Sxb, and Sxc reference points and the combined Sxa/Sxb reference point of the EPC, and over the N4 and N4mb reference points of the 5G System. TS 29.244 clause 1 defines this scope, together with the CP functions and the UP functions.

A CP function controls the packet processing in a UP function by establishing PFCP sessions and by provisioning rules in each PFCP session. Each Packet Detection Rule (PDR) contains Packet Detection Information (PDI), the match fields against which the UP function matches incoming packets, and a PDR can be associated with one or more Forwarding Action Rules (FARs) and with zero or more QoS Enforcement Rules (QERs) and Usage Reporting Rules (URRs). A FAR that buffers packets references a Buffering Action

Rule (BAR), which the CP function creates at the level of the PFCP session. TS 29.244 clause 5.2.1 defines this packet forwarding model.

PFCP runs over UDP, and a request message uses the registered UDP destination port 8805. Because UDP does not guarantee delivery, a PFCP entity retransmits a request message when it does not receive a response before timer T1 expires, until the number of retransmissions reaches N1. TS 29.244 clause 4.2 defines the UDP port numbers, and clause 6.4 defines the retransmission rules.

PFCP messages fall into two groups, node related messages and session related messages, and TS 29.244 Table 7.3-1 assigns every message to one of these groups. A node related message applies to a PFCP entity or to the PFCP association as a whole, and carries no Session Endpoint Identifier (SEID); the Session Set messages belong to this group, although they act on a set of PFCP sessions. A session related message applies to an individual PFCP session, and carries an SEID that identifies that PFCP session at the receiving entity.

5.4.2. Packet Format

PFCP uses a variable-length header with a length that is always a multiple of 4 octets, and PFCP defines one header format for node related messages and one for session related messages. TS 29.244 clause 7.2.2 defines both header formats.

5.4.2.1. Header for Node Related Messages

Every node related message, for example `PFCP Heartbeat Request` or `PFCP Association Setup Request`, uses the header without an SEID, which is 8 octets long. TS 29.244 clause 7.2.2.2 defines this header.

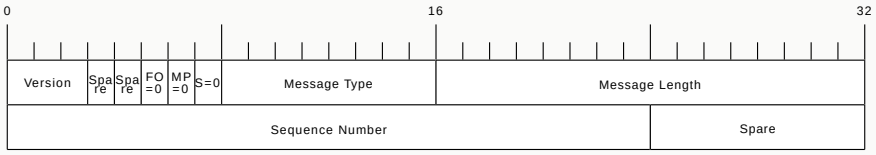


Figure 11. PFCP header for a node related message

`Version`

Bits 8 to 6 of octet 1. This field states the PFCP version, and the current version of PFCP sets it to decimal 1, as TS 29.244 clause 7.2.2.4.1 defines.

`FO`

Bit 3 of octet 1. This is the Follow On flag, and a node related message always sets it to 0, because PFCP does not allow node related messages to be bundled in one UDP/IP packet (TS 29.244 clause 6.5).

`MP`

Bit 2 of octet 1. This is the Message Priority flag, and a node related message always sets it to 0, because the header without an SEID has no `Message Priority` field.

`S`

Bit 1 of octet 1. This is the SEID flag; a value of 0 means that the header carries no SEID field, and every node related message sets this flag to 0.

`Message Type`

Octet 2. This field states the message type, with a unique value for each PFCP message, and TS 29.244 Table 7.3-1 lists these values.

`Message Length`

Octets 3 to 4. This field states the length of the message in octets, excluding the first 4 octets of the header, so the count includes the SEID, if present, and the `Sequence Number`.

`Sequence Number`

Octets 5 to 7. This field identifies the request or response, and a PFCP entity uses it to match a response to its request and to detect retransmissions. A receiver ignores this field in a `PFCP Version Not Supported Response` message.

5.4.2.2. Header for Session Related Messages

Every session related message, for example `PFCP Session Establishment Request`, uses the header with an SEID, which is 16 octets long and sets the `S` flag to 1. TS 29.244 clause 7.2.2.3 defines this header, and clause 7.2.2.4 defines how a PFCP entity uses the fields of both headers.

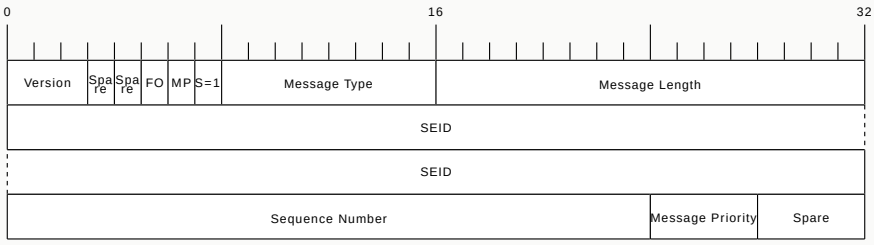


Figure 12. PFCP header for a session related message

`FO`

Bit 3 of octet 1. This is the Follow On flag; a value of 1 means that another PFCP message follows in the same UDP/IP packet. A CP function and a UP function can bundle session related messages in this way only when both functions indicated support for PFCP message bundling during the PFCP association setup or update procedure (TS 29.244 clause 6.5).

`MP`

Bit 2 of octet 1. This is the Message Priority flag; a value of 1 means that octet 16 carries a valid `Message Priority` value.

`SEID`

Octets 5 to 12. This field identifies the PFCP session at the receiving entity. The sending entity sets this

field to the SEID value that the receiving entity provided, or to 0 when the SEID of the peer is not yet available, for example in a `PFCP Session Establishment Request` message.

`Sequence Number`

Octets 13 to 15. This field identifies the request or response, in the same way as in the header for node related messages.

`Message Priority`

Bits 8 to 5 of octet 16. This field states the relative priority of the message, as a value from 0 to 15, where 0 is the highest priority and 15 is the lowest, and it is valid only when the `MP` flag is set to 1.

5.4.3. Message Categories

TS 29.244 Table 7.3-1 lists every PFCP message and the reference points that each message applies to. The tables below group these messages by function.

5.4.3.1. Heartbeat and Version Messages

Heartbeat messages check that a peer PFCP entity is alive. The `PFCP Version Not Supported Response` message reports that the receiving entity does not support the PFCP version of a request.

MESSAGE	FUNCTIONALITY	APPLICABILITY
`PFCP Heartbeat Request`	Checks that a peer PFCP entity is alive, and carries the Recovery Time Stamp of the sender.	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Heartbeat Response`	Responds to a `PFCP Heartbeat Request` message, and carries the Recovery Time Stamp of the responding PFCP entity.	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Version Not Supported Response`	Carries only a PFCP header, in which the Version field states the highest PFCP version that the sending entity supports.	Sxa, Sxb, Sxc, N4, N4mb.

5.4.3.2. Association Messages

Association messages set up, update, and release the PFCP association between a CP function and a UP function. A CP function uses the resources of a UP function, for example to establish PFCP sessions, only after the two functions set up a PFCP association.

MESSAGE	FUNCTIONALITY	APPLICABILITY
`PFCP Association Setup Request`	Sets up a PFCP association, and carries the Node ID, the Recovery Time Stamp, and the supported features of the sender.	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Association Setup Response`	Reports the outcome of a `PFCP Association Setup Request` message.	Sxa, Sxb, Sxc, N4, N4mb.

MESSAGE	FUNCTIONALITY	APPLICABILITY
`PFCP Association Update Request`	Modifies an existing PFCP association, for example to update the supported features or the available resources of the UP function.	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Association Update Response`	Reports the outcome of a `PFCP Association Update Request` message.	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Association Release Request`	Terminates an existing PFCP association. The CP function and the UP function then delete the PFCP sessions of that association locally.	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Association Release Response`	Reports the outcome of a `PFCP Association Release Request` message.	Sxa, Sxb, Sxc, N4, N4mb.

5.4.3.3. PFD Management and Node Report Messages

PFD Management messages provision Packet Flow Descriptions (PFDs) in the UP function for application detection. Node Report messages let the UP function report information that does not relate to a specific PFCP session.

MESSAGE	FUNCTIONALITY	APPLICABILITY
`PFCP PFD Management Request`	Provisions PFDs in the UP function for one or more application identifiers.	Sxb, Sxc, N4.
`PFCP PFD Management Response`	Reports the outcome of a `PFCP PFD Management Request` message.	Sxb, Sxc, N4.
`PFCP Node Report Request`	Reports information that does not relate to a specific PFCP session to the CP function, for example a user plane path failure that affects all PFCP sessions towards a remote peer of GTP for the user plane (GTP-U).	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Node Report Response`	Reports the outcome of a `PFCP Node Report Request` message.	Sxa, Sxb, Sxc, N4, N4mb.

5.4.3.4. Session Set Messages

Session Set messages act on a set of PFCP sessions in one exchange, instead of on every affected PFCP session individually.

MESSAGE	FUNCTIONALITY	APPLICABILITY
`PFCP Session Set Deletion Request`	Requests the peer to delete the PFCP sessions that a partial failure affected. Either the CP function or the UP function sends this message.	Sxa, Sxb, N4.
`PFCP Session Set Deletion Response`	Reports the outcome of a `PFCP Session Set Deletion Request` message.	Sxa, Sxb, N4.

MESSAGE	FUNCTIONALITY	APPLICABILITY
`PFCP Session Set Modification Request`	Requests the UP function to send subsequent `PFCP Session Report Request` messages for a set of PFCP sessions to an alternative PGW-C, for example when a partial PGW-C failure affects those PFCP sessions.	Sxb, N4.
`PFCP Session Set Modification Response`	Reports the outcome of a `PFCP Session Set Modification Request` message.	Sxb, N4.

5.4.3.5. Session Establishment and Deletion Messages

These messages create and remove a PFCP session, together with the rules that the CP function provisioned in that PFCP session.

MESSAGE	FUNCTIONALITY	APPLICABILITY
`PFCP Session Establishment Request`	Creates a PFCP session in the UP function, and provisions its initial PDRs, FARs, QERs, URRs, and BAR.	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Session Establishment Response`	Reports the outcome of a `PFCP Session Establishment Request` message, and carries the SEID that the UP function allocated.	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Session Deletion Request`	Deletes an existing PFCP session, together with all its rules.	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Session Deletion Response`	Reports the outcome of a `PFCP Session Deletion Request` message, and can carry a final usage report.	Sxa, Sxb, Sxc, N4, N4mb.

5.4.3.6. Session Modification and Report Messages

These messages update an existing PFCP session, and let the UP function report an event that relates to an individual PFCP session to the CP function.

MESSAGE	FUNCTIONALITY	APPLICABILITY
`PFCP Session Modification Request`	Adds, modifies, or removes the PDRs, FARs, QERs, URRs, or BAR of an existing PFCP session.	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Session Modification Response`	Reports the outcome of a `PFCP Session Modification Request` message, and can carry a usage report for the affected rules.	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Session Report Request`	Reports an event of a PFCP session to the CP function, for example a usage report or the arrival of downlink data for a UE that is in idle mode.	Sxa, Sxb, Sxc, N4, N4mb.
`PFCP Session Report Response`	Reports the outcome of a `PFCP Session Report Request` message.	Sxa, Sxb, Sxc, N4, N4mb.

5.4.4. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 29.244	• Clause 1 — Scope and applicable reference points • Clause 4.2 — UDP header and port numbers • Clause 5.2.1 — Packet forwarding model, covering PDR, FAR, QER, URR, and BAR • Clause 6.2 — PFCP node related procedures, covering heartbeat, PFD management, association, and node report • Clause 6.4 — Reliable delivery of PFCP messages • Clause 6.5 — PFCP messages bundling • Clause 7.2.2 — Message header, covering: ◦ 7.2.2.2 the header for node related messages ◦ 7.2.2.3 the header for session related messages ◦ 7.2.2.4 the usage of the PFCP header • Clause 7.3 — Message types (Table 7.3-1) • Clause 7.4 — PFCP node related messages, covering: ◦ 7.4.4.7 PFCP Version Not Supported Response ◦ 7.4.6 PFCP Session Set Deletion ◦ 7.4.7 PFCP Session Set Modification • Clause 7.5 — PFCP session related messages

Chapter 6. Functional Description and Information Flows

6.1. Attach Procedure

6.1.1. Technical Overview

The Attach procedure registers a UE with the network, a registration the UE needs before it can use services that require it.

The procedure establishes an EMM context in the MME and, in most cases, a default EPS bearer that gives the UE always-on IP connectivity.

The procedure moves the UE from the EMM-DEREGISTERED state to the EMM-REGISTERED state, and during the procedure the network authenticates the UE, sets up security, and allocates an IP address to the UE.

6.1.2. Call Flow

The call flow has four phases: Identification and Security, Location Update and Session Creation, Radio Bearer Setup, and Attach Completion.

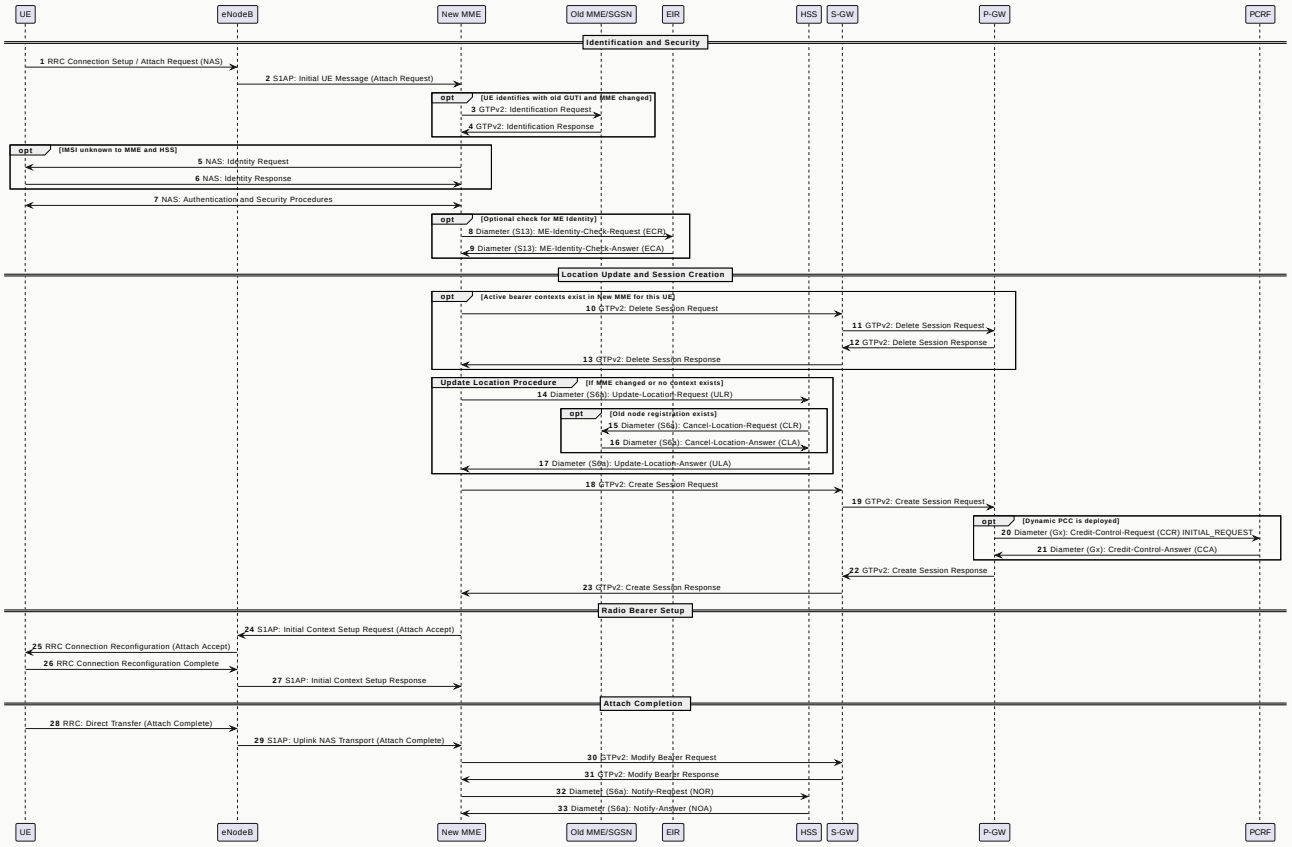


Figure 13. Attach procedure call flow

6.1.3. Step-by-Step Description

1. The **UE** sends an `Attach Request` message to the **eNodeB**, carrying this NAS message inside the RRC connection establishment procedure. The message carries the IMSI or the old GUTI, the old GUTI type, and the last visited TAI, which helps the MME allocate a TAI list, as well as the UE Core Network Capability, an ESM message container with a PDN Connectivity Request, the Key Set Identifier for the Access Security Management Entity (KSI_ASME), the NAS sequence number, and the NAS Message Authentication Code (NAS-MAC).
2. On receiving the Attach Request, the **eNodeB** derives the target MME address from the old Globally Unique MME Identifier (GUMMEI), or, if no association exists, selects a new MME, and forwards the NAS message to the **New MME** over the S1-MME interface, inside an S1AP `Initial UE Message`. This message carries the NAS Protocol Data Unit (NAS-PDU) with the Attach Request, the Selected Network, the TAI, and the E-UTRAN Cell Global Identifier (ECGI), as well as the S-Temporary Mobile Subscriber Identity (S-TMSI), the GUMMEI, and the RRC establishment cause.
3. If the UE identified itself with an old GUTI and the MME changed since the last detach, the **New MME** derives the address of the previous serving node from the old GUTI and sends a GTP version 2 (GTPv2) `Identification Request` message to the **Old MME/SGSN**, to retrieve the IMSI and the Mobility Management (MM) context from that node. This message carries the old GUTI and the complete Attach Request message.
4. The **Old MME/SGSN** verifies the Attach Request message, using the NAS-MAC or the Packet Temporary Mobile Subscriber Identity (P-TMSI) signature, and responds with a GTPv2 `Identification Response` message that, if the integrity check succeeds, carries the IMSI, the MM Context, and the Cause.
5. If the IMSI is unknown to both the new and the old serving nodes, the **New MME** sends a NAS `Identity Request` message to the **UE**, carrying the identity type IMSI, to ask the UE for its permanent identity.
6. The **UE** responds with a NAS `Identity Response` message that carries its IMSI, letting the New MME proceed with authentication and with subscription retrieval from the HSS.
7. The **New MME** and the **UE** then perform the Authentication and Security Procedures, carrying the RAND, the AUTN, the Authentication Response (RES), the selected NAS algorithms, the Key Set Identifier for E-UTRAN (eKSI), the UE Security Capability, and the NAS-MAC. These procedures activate integrity protection and NAS ciphering, establish a secure NAS connection, and confirm the legitimacy of the UE and the network.
8. The **New MME** can check the Mobile Equipment (ME) identity with the **Equipment Identity Register (EIR)** by sending a Diameter `ME-Identity-Check-Request` (ECR) message over the S13 interface, carrying the ME Identity, that is the International Mobile Equipment Identity and Software Version Number (IMEISV), and the IMSI, to confirm that the equipment is not stolen or unauthorized.
9. The **EIR** responds with a Diameter `ME-Identity-Check-Answer` (ECA) message that carries a Result-Code, stating the status of the ME, for example whitelisted or blacklisted, and the New MME decides whether to continue or reject the Attach procedure based on this result.
10. If the **New MME** holds active bearer contexts for this UE from a previous session that was not properly detached, it releases the stale user-plane resources by sending a GTPv2 `Delete Session Request` message to the **S-GW (Serving Gateway)**, carrying the Linked EPS Bearer Identity (LBI).

11. The **S-GW** forwards the GTPv2 `Delete Session Request` message, carrying the LBI, to the **P-GW (PDN Gateway)** to complete the session release, and, if the network deploys a PCRF, the P-GW also starts an IP Connectivity Access Network (IP-CAN) Session Termination procedure.
12. The **P-GW** acknowledges the deletion by returning a GTPv2 `Delete Session Response` message that carries a Cause to the **S-GW**.
13. The **S-GW** returns the GTPv2 `Delete Session Response` message, carrying a Cause, to the **New MME**, confirming that the old session contexts are removed.
14. To register itself as the serving node and retrieve the subscription data, the **New MME** sends a Diameter `Update-Location-Request` (ULR) message to the **HSS** over the S6a interface. The message carries the MME Identity, the IMSI, the IMEISV, the MME Capabilities, and the ULR-Flags, including the Initial-Attach-Indicator, through which the New MME indicates an initial attach.
15. If a registration exists for an old MME or SGSN, the **HSS** instructs that node to remove its MM and bearer contexts for the UE by sending a Diameter `Cancel-Location-Request` (CLR) message to the **Old MME/SGSN**, carrying the IMSI and the Cancellation Type.
16. The **Old MME/SGSN** removes the contexts and returns a Diameter `Cancel-Location-Answer` (CLA) message, carrying the IMSI, to the **HSS**.
17. The **HSS** acknowledges the location update by sending a Diameter `Update-Location-Answer` (ULA) message to the **New MME**, carrying the IMSI, the ULA-Flags, and the Subscription Data, including the PDN subscription contexts, the QoS profile, and the APN Aggregate Maximum Bit Rate (APN-AMBR), covering the authorized APNs.
18. The **New MME** selects an S-GW and sends it a GTPv2 `Create Session Request` message to establish the default EPS bearer, carrying the IMSI, the Mobile Station International Subscriber Directory Number (MSISDN), the MME TEID for the control plane, the PDN GW address, the APN, the RAT type, the Default EPS Bearer QoS, and the EPS Bearer Identity.
19. The **S-GW** creates an entry in its EPS bearer table and forwards the GTPv2 `Create Session Request` message to the P-GW that the MME indicated, carrying the IMSI, the APN, its own Serving GW Address and TEID for the user plane, the SGW TEID for the control plane, the RAT type, the Default EPS Bearer QoS, and the EPS Bearer Identity.
20. If the network deploys dynamic Policy and Charging Control (PCC), the **P-GW**, acting as the Policy and Charging Enforcement Function (PCEF), retrieves the PCC rules for the new IP-CAN session by sending a Diameter `Credit-Control-Request` (CCR) message to the **PCRF** over the Gx interface. The message carries the CC-Request-Type INITIAL_REQUEST, the Subscription-Id, that is the IMSI, the Called-Station-Id, that is the APN, the IP-CAN-Type, the RAT-Type, the Default-EPS-Bearer-QoS, and the APN-AMBR.
21. The **PCRF** determines the policy and returns a Diameter `Credit-Control-Answer` (CCA) message to the **P-GW**, carrying the PCC rules, the authorized QoS information, and the Event-Trigger, for the P-GW to enforce.
22. The **P-GW** creates an EPS bearer context and returns a GTPv2 `Create Session Response` message to the **S-GW**, carrying its own Address and TEID for the user plane, its TEID for the control plane, the PDN Type, the allocated PDN Address, that is the UE IP address, the EPS Bearer Identity, the QoS, and the Charging Id.

23. The **S-GW** returns the GTPv2 `Create Session Response` message to the **New MME**, carrying the PDN Type, the PDN Address, the Serving GW address and TEID for the user plane, the SGW TEID for the control plane, the EPS Bearer Identity, the EPS Bearer QoS, and the P-GW TEID for uplink traffic.
24. To establish the UE context in the Radio Access Network (RAN) and request the setup of the radio bearers and the S1-U bearers, the **New MME** sends an S1AP `Initial Context Setup Request` message to the **eNodeB**, carrying the MME UE S1AP ID, the UE Aggregate Maximum Bitrate, the E-RAB To Be Setup List, with the EPS Bearer QoS, the SGW TEID, and the SGW Address, and the NAS-PDU with the `Attach Accept` message.
25. The **eNodeB** sets up the radio bearer by sending an RRC `Connection Reconfiguration` message to the **UE**, carrying the EPS Radio Bearer Identity and the NAS-PDU with the Attach Accept, and the UE stores its assigned IP address and QoS parameters.
26. The **UE** completes the radio reconfiguration and returns an RRC `Connection Reconfiguration Complete` message, carrying the RRC Transaction Identifier, to the **eNodeB**, confirming that the radio bearers are set up.
27. The **eNodeB** sends an S1AP `Initial Context Setup Response` message to the **New MME**, carrying the eNB UE S1AP ID, the MME UE S1AP ID, and the E-RAB Setup List, with the eNodeB Address and the eNodeB TEID for downlink traffic.
28. The **UE** sends an RRC `Direct Transfer` message to the **eNodeB** that carries the NAS `Attach Complete` message, with the EPS Bearer Identity, the NAS sequence number, and the NAS-MAC, indicating that the UE processed the network's attach acceptance.
29. The **eNodeB** forwards the Attach Complete message to the **New MME** inside an S1AP `Uplink NAS Transport` message, carrying the MME UE S1AP ID, the eNB UE S1AP ID, and the NAS-PDU.
30. When the **New MME** receives both the Initial Context Setup Response and the Attach Complete message, it informs the S-GW of the eNodeB's downlink tunnel information, so that data can flow, by sending a GTPv2 `Modify Bearer Request` message to the **S-GW**, carrying the EPS Bearer Identity, the eNodeB address, the eNodeB TEID, the RAT type, and the Handover Indication.
31. The **S-GW** acknowledges with a GTPv2 `Modify Bearer Response` message, carrying the EPS Bearer Identity and the Cause, to the **New MME**, and can now deliver any downlink data that it buffered to the UE.
32. For non-emergency services, the **New MME** notifies the HSS of the established PDN connection, so that the HSS can store the P-GW identity and the APN, by sending a Diameter `Notify-Request` (NOR) message to the **HSS**, carrying the IMSI, the Terminal Information, the PDN GW Address, and the APN.
33. The **HSS** stores the information and returns a Diameter `Notify-Answer` (NOA) message, carrying a Result-Code, to the **New MME**, completing the Attach procedure.

6.1.4. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 5.3.2.1 — Attach procedure • Clause 4.3.19 — node resolution • Figure 5.3.2.1-1
TS 24.301	• Clause 5.5.1 — Attach procedure • Clause 5.1.3 — EMM states • Clause 6.5.1 — UE requested PDN connectivity • Table 8.2.4.1
TS 29.274	• Clause 7.2.1 — Create Session • Clause 7.2.9 — Delete Session • Clause 7.3.5 — Context Request • Clause 7.3.8 — Identification Request • Clause 7.2.7 — Modify Bearer
TS 29.272	• Clause 5.2.1.1 — Update Location • Clause 7.2.3 — ULR • Clause 7.2.4 — ULA • The S6a interface definitions
TS 29.212 / TS 29.213	The Gx CCR/CCA procedures and the overall PCC architecture.
TS 36.413	• Clause 8.3.1 — Initial Context Setup • Clause 8.6.2 — Initial UE Message • Clause 9.1.4 — S1AP message content

6.2. Detach Procedure

6.2.1. UE-Initiated Detach Procedure

6.2.1.1. Technical Overview

The UE-initiated Detach procedure lets a UE inform the network that it no longer needs access to the EPS, and it deactivates all active EPS bearer contexts, including the default bearer.

The procedure removes the UE's mobility management and security contexts from the MME and from the UE, moving the UE to the EMM-DEREGISTERED state.

Across the S1, S11, and S5/S8 interfaces, the EPC releases all associated user-plane and control-plane resources.

6.2.1.2. Call Flow

The call flow has three phases: Detach Request, Resource Deactivation, and Detach Acceptance and S1

Release.

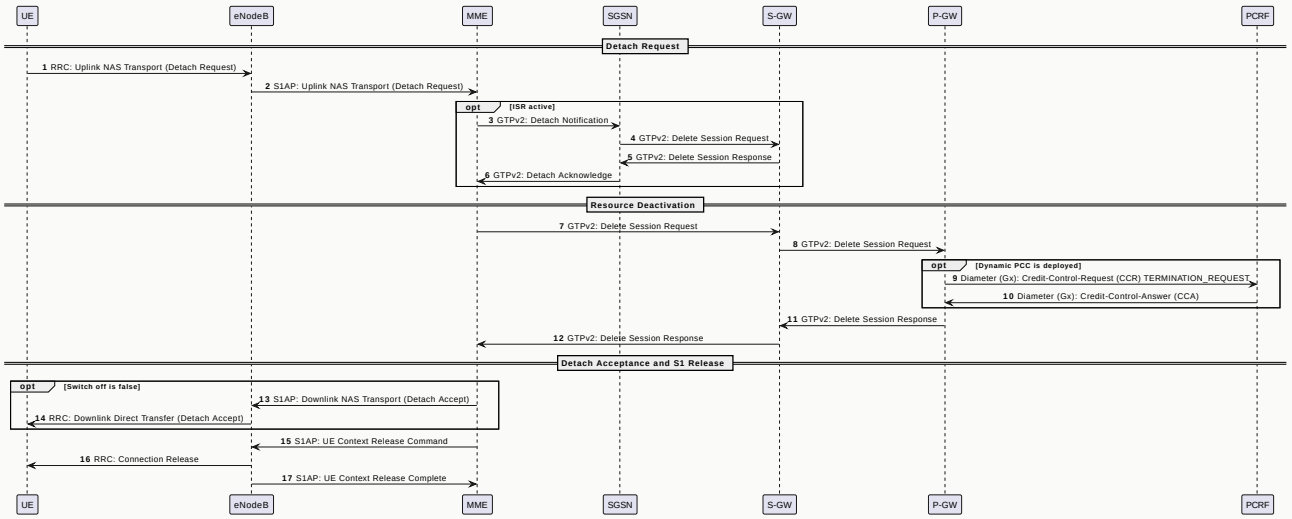


Figure 14. UE-initiated detach procedure call flow

6.2.1.3. Step-by-Step Description

1. The **UE** sends a `Detach Request` message to the **eNodeB**, carrying this NAS message inside an RRC message; if the UE was in ECM-IDLE mode, this message triggers the establishment of a NAS signaling connection. The message carries the GUTI, the Detach type, which shows the kind of detach, for example EPS detach or combined EPS/IMSI detach, the Switch off indicator, which shows whether the UE is powering down, and the NAS key set identifier, that is the eKSI.
2. The **eNodeB** forwards the NAS message to the **MME** inside an S1AP `Uplink NAS Transport` message, including the User Location Information of the serving cell, that is the ECGI and the TAI, and the NAS-PDU.
3. If ISR is active for the UE, the **MME** sends a GTPv2 `Detach Notification` message to the associated **SGSN** to detach the UE from GSM EDGE Radio Access Network (GERAN) and Universal Terrestrial Radio Access Network (UTRAN) access as well. The message carries a Cause value set to "Complete Detach" and the Detach Type.
4. On receiving the Detach Notification, the **SGSN** deactivates the UE's active Packet Data Protocol (PDP) contexts and sends a GTPv2 `Delete Session Request` message to the **S-GW**. The message carries the LBI, the User Location Information, that is the Cell Global Identification (CGI) and the Service Area Identifier (SAI), and the UE Time Zone.
5. The **S-GW** acknowledges the deletion of the SGSN-related bearer contexts by returning a GTPv2 `Delete Session Response` message, carrying a Cause, to the **SGSN**.
6. The **SGSN** confirms the completion of its local detach procedure by sending a GTPv2 `Detach Acknowledge` message, carrying a Cause, to the **MME**.
7. To deactivate all active EPS bearers, the **MME** sends a GTPv2 `Delete Session Request` message to the **S-GW** for each PDN connection, carrying the LBI, the User Location Information, that is the ECGI, the Secondary RAT usage data, and the UE Time Zone. If ISR was active, the S-GW does not release its control-plane TEID until it receives this message.

8. For each PDN connection that the procedure releases, the **S-GW** sends a GTPv2 `Delete Session Request` message to the **P-GW**, telling the P-GW to delete all bearers for that PDN connection. The message carries the LBI, the User Location Information, and the Secondary RAT usage data.
9. If the network deploys dynamic PCC, the **P-GW** starts an IP-CAN Session Termination procedure with the **PCRF**, using Diameter, letting the PCRF release the policy and charging rules for the session. The Diameter message carries a CC-Request-Type set to TERMINATION_REQUEST and the Used-Service-Unit, for usage monitoring reporting.
10. The **P-GW** acknowledges the session deletion by returning a GTPv2 `Delete Session Response` message to the **S-GW**, carrying a Cause and the APN Rate Control Status.
11. The **S-GW** releases the UE's context information and forwards the acknowledgement to the **MME** with a GTPv2 `Delete Session Response` message, carrying a Cause and the APN Rate Control Status.
12. If the UE indicated that Switch off is false in the Detach Request, the **MME** sends a NAS `Detach Accept` message to the **eNodeB** inside an S1AP `Downlink NAS Transport` message, carrying the NAS-PDU and the MME UE S1AP ID.
13. The **eNodeB** delivers the Detach Accept message to the **UE** over the radio interface, and the UE stops timer T3421 on receiving it.
14. The **MME** starts the release of the S1-MME signaling connection by sending an S1AP `UE Context Release Command` message to the **eNodeB**, carrying the UE S1AP IDs and a Cause set to "Detach".
15. The **eNodeB** sends an RRC `Connection Release` message to the **UE** and deletes the UE's RAN context after the UE acknowledges it.
16. The **eNodeB** confirms the release of the S1 connection and the user-plane resources by sending an S1AP `UE Context Release Complete` message to the **MME**, carrying the MME UE S1AP ID, the eNB UE S1AP ID, and the User Location Information.

6.2.1.4. Possible Failures and Required Actions

Authentication failure during S1 establishment

When the UE is in ECM-IDLE mode, it first needs to set up the S1 connection to send the Detach Request, and the MME can start authentication at that point. If authentication fails, the UE receives a NAS `Authentication Reject` message, stops the Detach procedure, stops all related EMM timers, for example T3421, and enters the EMM-DEREGISTERED state. The MME can deactivate all non-emergency bearers and mark the UE as detached.

Detach through an unauthorized CSG cell

The UE can send a Detach Request, without the Switch off indicator, while connected to a CSG cell for which its subscription has expired. In this case, the MME responds with EMM Cause #25, "Not authorized for this CSG", and starts a network-initiated detach procedure. The UE removes the CSG ID from its Allowed CSG list and, if needed, performs a new Public Land Mobile Network (PLMN) selection.

T3421 timer expiry

The UE can send a Detach Request, without the Switch off indicator, and not receive a Detach Accept

message before timer T3421 expires. In this case, the UE retransmits the Detach Request message, up to four times, and on the fifth expiry stops the signaling procedure, performs a local detach, and enters the EMM-DEREGISTERED state.

6.2.1.5. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 5.3.8.1 — Detach procedure • Clause 5.3.8.2.1 — UE-initiated detach • Clause 5.3.5 — ISR
TS 24.301	• Clause 5.5.2.1 — Detach procedure • Clause 5.5.2.2.1 — UE-initiated detach, general • Clause 5.5.2.2.2 — UE-initiated detach procedure • Clause 8.2.11 — Detach Request message content
TS 29.274	• Clause 7.2.9.1 — Delete Session Request • Clause 7.2.10.1 — Delete Session Response • Clause 7.3.12 — Detach Notification/Acknowledge
TS 29.213	Clause 4.2.2.1 (IP-CAN Session Termination).
TS 36.413	• Clause 8.3.3 — UE Context Release • Clause 9.1.4.6 — UE Context Release Command • Clause 9.1.4.7 — UE Context Release Complete

6.2.2. HSS-Initiated Detach Procedure

6.2.2.1. Technical Overview

The HSS-initiated Detach procedure lets the HSS remove a subscriber’s MM context and EPS bearer contexts from the network; the HSS, not the UE, triggers this procedure.

The HSS starts the procedure for operator-determined reasons, for example a subscription withdrawal, a profile change that no longer allows PS services, or a Core Network access restriction.

The procedure removes the contexts from the MME and, if the network deploys an SGSN for the subscriber, from the SGSN as well.

The procedure moves the UE to the EMM-DEREGISTERED state and releases all active PDN connections and their EPS bearers, and the MME, the S-GW, and the P-GW remove the subscriber’s session information.

6.2.2.2. Call Flow

The call flow has four phases: Cancellation at the MME, UE Notification, Resource Release, and Detach Acknowledgement and S1 Release.

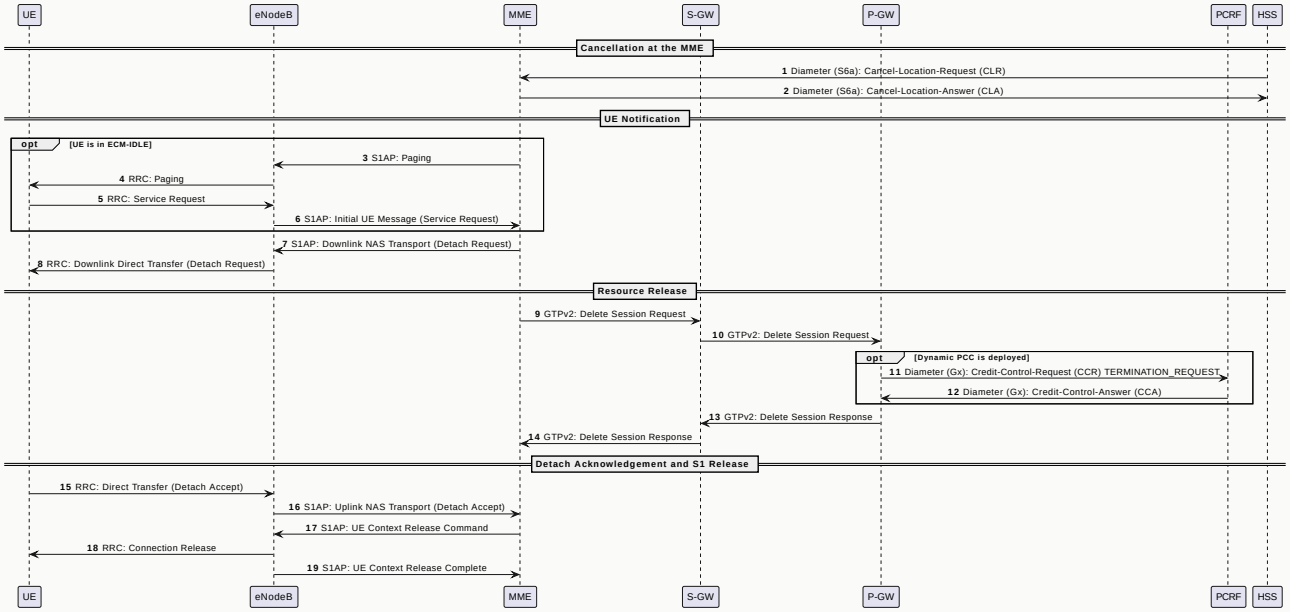


Figure 15. HSS-initiated detach procedure call flow

6.2.2.3. Step-by-Step Description

1. The **HSS** starts the procedure by sending a Diameter `Cancel-Location-Request` (CLR) message to the **MME**, asking the MME to delete the subscriber's MM context and EPS bearer contexts. The message carries the IMSI, the Cancellation-Type, for example "Subscription Withdrawal", and, optionally, the CLR-Flags, including a Reattach-Required indicator.
2. The **MME** verifies the IMSI and confirms that it accepted the cancellation by returning a Diameter `Cancel-Location-Answer` (CLA) message to the **HSS**, carrying a Result-Code and the Supported-Features.
3. If the UE is in ECM-IDLE mode, the **MME** starts the Paging procedure by sending an S1AP `Paging` message to the **eNodeB**, carrying the UE Identity Index Value, the Paging Discontinuous Reception (DRX) cycle, and the S-TMSI, and the eNodeB pages the **UE** over the radio interface with an RRC `Paging` message.
4. The **UE** responds to the page with an RRC `Service Request` message to the **eNodeB**, which forwards the request to the **MME** inside an S1AP `Initial UE Message`, carrying the Service Request; this exchange establishes a NAS signaling connection.
5. The **MME** sends a NAS `Detach Request` message to the **eNodeB** inside an S1AP `Downlink NAS Transport` message, carrying the Detach type, which shows whether the UE needs to reattach, and an EMM cause, for example cause #2, "IMSI unknown in HSS". The eNodeB delivers the Detach Request to the **UE** inside an RRC `Downlink Direct Transfer` message, telling the UE that the network detached it.
6. To deactivate the associated EPS bearers, the **MME** sends a GTPv2 `Delete Session Request` message to the **S-GW** for each active PDN connection, carrying the LBI, the User Location Information, that is the ECGI, and, if policy permits, the NAS Release Cause.
7. For each PDN connection that the procedure releases, the **S-GW** forwards the GTPv2 `Delete Session Request` message to the **P-GW**, carrying the LBI, the User Location Information, and the Indication Flags, with the Operation Indication flag set.

8. If the network deploys dynamic PCC, the **P-GW** starts an IP-CAN Session Termination procedure with the **PCRF** by sending a Diameter `Credit-Control-Request` (CCR) message to report the final usage, carrying a CC-Request-Type set to TERMINATION_REQUEST, the Subscription-Id, and the Used-Service-Unit.
9. The **PCRF** acknowledges the termination by returning a Diameter `Credit-Control-Answer` (CCA) message, carrying a Result-Code, to the **P-GW**, letting the P-GW release the session's policy and charging resources.
10. The **P-GW** acknowledges the deletion by returning a GTPv2 `Delete Session Response` message to the **S-GW**, carrying a Cause set to "Request Accepted" and the APN Rate Control Status.
11. The **S-GW** releases its local context for the UE and returns a GTPv2 `Delete Session Response` message to the **MME**, carrying a Cause and the Recovery counter.
12. The **UE** acknowledges the Detach Request with a NAS `Detach Accept` message to the **eNodeB** inside an RRC `Direct Transfer` message, and the eNodeB forwards it to the **MME** inside an S1AP `Uplink NAS Transport` message, carrying the NAS-PDU and the User Location Information.
13. When the **MME** receives both the Detach Accept and the Delete Session Response, it starts the release of the S1-MME signaling connection by sending an S1AP `UE Context Release Command` message to the **eNodeB**, carrying the UE S1AP IDs and a Cause set to "Detach".
14. The **eNodeB** sends an RRC `Connection Release` message to the **UE** and deletes the UE's RAN context after the UE acknowledges it.
15. The **eNodeB** confirms the release of the S1 connection by sending an S1AP `UE Context Release Complete` message to the **MME**, carrying the MME UE S1AP ID and the eNB UE S1AP ID.

6.2.2.4. Possible Failures and Required Actions

T3422 timer expiry

The MME sends the Detach Request and starts timer T3422, with a default value of 6 seconds. If the MME does not receive a Detach Accept message before the timer expires, it retransmits the Detach Request, up to four times, and on the fifth expiry stops the signaling procedure and enters the EMM-DEREGISTERED state for the UE.

Detach in a forbidden satellite E-UTRAN area

In a network that uses satellite E-UTRAN access, the MME can determine that the UE is in a location where the PLMN cannot operate. In this case, the MME sends the Detach Request with EMM Cause #78, "PLMN not allowed to operate at the present UE location", and the UE enters the EMM-DEREGISTERED.LIMITED-SERVICE state and searches for a new suitable cell.

Detach procedure collision

The UE can start a UE-initiated Detach procedure, for example due to power off, while an HSS-initiated Detach procedure is in progress at the MME, sending a Detach Request with the Switch off indicator before the MME completes the HSS-initiated procedure. In this case, the MME considers both Detach procedures complete at the same time.

6.2.2.5. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 5.3.8.4 — HSS-initiated detach • Clause 5.3.5 — S1 release • Clause 5.10.3 — satellite E-UTRAN access restrictions
TS 24.301	• Clause 5.5.2.3 — Network-initiated detach procedure • Clause 8.2.11 — Detach Request message content • Clause 9.9.3.7 — Detach type
TS 29.272	• Clause 5.2.1.2 — Cancel Location procedure • Clause 7.2.7 — CLR command • Clause 7.3.24 — Cancellation-Type values
TS 29.274	• Clause 7.2.9.1 — Delete Session Request • Clause 7.2.10.1 — Delete Session Response • Clause 8.4 — Cause values
TS 29.213	Clause 4.2.2.1 (IP-CAN Session Termination).
TS 36.413	• Clause 8.3.3 — UE Context Release • Clause 9.1.4.6 — UE Context Release Command • Clause 9.1.4.7 — UE Context Release Complete

6.3. Service Request Procedure

6.3.1. UE-Initiated Service Request Procedure

6.3.1.1. Technical Overview

The UE-initiated Service Request procedure lets a UE in ECM-IDLE mode establish a NAS signaling connection with the network, and the UE starts the procedure when it has pending uplink user data or pending uplink signaling.

The procedure establishes the radio bearers and the S1 user-plane bearers for the UE’s active EPS bearers, moving the UE from ECM-IDLE mode to ECM-CONNECTED mode.

The procedure also synchronizes the EPS bearer contexts between the UE and the MME.

6.3.1.2. Call Flow

The call flow has three phases: Service Request, Radio Bearer Setup, and Path Switch and Data Delivery.

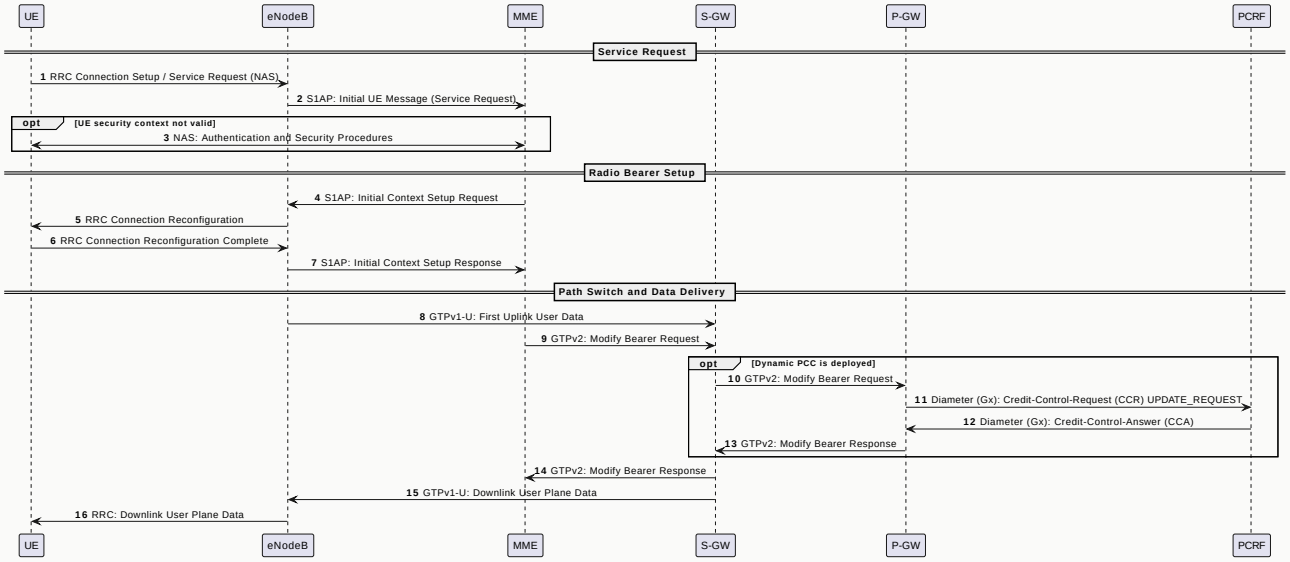


Figure 16. UE-initiated service request procedure call flow

6.3.1.3. Step-by-Step Description

1. The **UE** sends a `Service Request` message to the **eNodeB**, carrying this NAS message inside the RRC connection establishment procedure. The message carries the Key Set Identifier (KSI), the NAS sequence number, and the NAS-MAC.
2. The **eNodeB** forwards the NAS message to the **MME** inside an S1AP `Initial UE Message`, which establishes the UE-associated logical S1 connection. The message carries the NAS-PDU, the S-TMSI, the TAI and the ECGI of the serving cell, and the RRC establishment cause, for example "mo-Data" or "mo-Signalling".
3. If the UE's security context is missing or no longer valid, the **MME** and the **UE** perform the Authentication and Security Procedures, carrying the RAND, the AUTN, and the selected NAS security algorithms, and activating NAS integrity protection and ciphering.
4. The **MME** sends an S1AP `Initial Context Setup Request` message to the **eNodeB**, providing it with the security context and the Serving GW address for the uplink. The message carries the MME UE S1AP ID, the eNB UE S1AP ID, the E-RAB To Be Setup List, with the S1-U S-GW Fully Qualified Tunnel Endpoint Identifier (F-TEID) and the QoS parameters, the UE Aggregate Maximum Bit Rate, and the Security Context.
5. The **eNodeB** sets up the radio bearer by sending an RRC `Connection Reconfiguration` message to the **UE**, establishing the data radio bearers for the requested E-RABs.
6. The **UE** completes the radio reconfiguration and returns an RRC `Connection Reconfiguration Complete` message to the **eNodeB**, after which the UE is ready to send user data.
7. The **eNodeB** sends an S1AP `Initial Context Setup Response` message to the **MME**, providing it with the eNodeB's downlink tunnel information. The message carries the eNB UE S1AP ID, the MME UE S1AP ID, and the E-RAB Setup List, with the S1-U eNodeB F-TEID for the downlink.
8. Once the radio bearer setup completes, the **eNodeB** can forward uplink user-plane packets to the **S-GW**, using the S-GW F-TEID from step 4.

9. To update the user-plane path with the eNodeB's downlink F-TEID, the **MME** sends a GTPv2 `Modify Bearer Request` message to the **S-GW** for each PDN connection, carrying the Bearer Contexts to be modified, that is the EPS Bearer Identity (EBI) and the S1-U eNodeB F-TEID, the User Location Information, and the RAT type.
10. If the network deploys dynamic PCC, the **S-GW** forwards the GTPv2 `Modify Bearer Request` message to the **P-GW**. The P-GW then starts a Diameter `Credit-Control-Request/ Credit-Control-Answer` (Update) exchange with the **PCRF** over the Gx interface, carrying the CC-Request-Type set to UPDATE_REQUEST, the 3GPP-User-Location-Info, and the RAT-Type, before returning a GTPv2 `Modify Bearer Response` message to the S-GW.
11. Whether or not the network deployed dynamic PCC, the **S-GW** returns a GTPv2 `Modify Bearer Response` message to the **MME**, carrying a Cause set to "Request Accepted" and the S-GW F-TEID for the control plane.
12. Using the downlink F-TEID from step 7, the **S-GW** delivers buffered or newly arrived downlink user data to the **eNodeB**, which delivers the data to the **UE** over the radio interface.

6.3.1.4. Possible Failures and Required Actions

Authentication failure

If the UE fails the authentication check that the MME starts during the Service Request procedure, the MME sends a NAS `Authentication Reject` message, with EMM Cause #3, "Illegal UE", or EMM Cause #6, "Illegal ME". The UE then stops the procedure, considers its Universal Subscriber Identity Module (USIM) or Subscriber Identity Module (SIM) invalid for EPS services, and enters the EMM-DEREGISTERED state.

MME congestion

If the MME is overloaded and cannot process the Service Request, it sends a NAS `Service Reject` message, with EMM Cause #22, "Congestion", and a value for timer T3346. The UE starts timer T3346 and does not start a new Service Request of the same category until the timer expires.

E-UTRAN resource allocation failure

If the eNodeB cannot admit one or more E-RABs because radio resources are not available, it returns an S1AP `Initial Context Setup Failure` message, with S1AP Cause "Radio resources not available". The MME maps this internally to GTP Cause #73, "No resources available", and, if it rejects the UE, can map it further to NAS EMM Cause #26, "Insufficient resources". The MME locally deactivates the EPS bearer contexts that failed to establish, while the UE stays in its current state and can start timer T3346.

6.3.1.5. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 5.3.4.1 — Service Request procedure • Clause 5.3.4.2 — Abnormal cases • Clause 4.3.7.4.2 — Congestion control

SPECIFICATION	CLAUSES AND COVERAGE
TS 24.301	• Clause 5.6.1 — Service Request procedure • Clause 8.2.24 — Service Reject message content • Clause 8.2.25 — Service Request message content • Clause 9.9.3.9 — EMM cause
TS 36.413	• Clause 8.2.1 — Initial Context Setup • Clause 8.6.2.1 — Initial UE Message • Clause 9.1.4.1 — Initial Context Setup Request
TS 29.274	• Clause 7.2.7 — Modify Bearer Request/Response • Clause 8.4 — Cause values
TS 29.213	Clause 4.3.1.1 (PCC rule update procedures).

6.3.2. Network-Triggered Service Request Procedure

6.3.2.1. Technical Overview

The Network-Triggered Service Request procedure moves a UE from ECM-IDLE mode to ECM-CONNECTED mode when the EPC has downlink user data or downlink signaling to deliver. The S-GW starts the procedure when it receives a downlink packet for a UE that has no active S1 user-plane connection.

The procedure establishes the radio bearers and the S1 bearers for the UE, synchronizes the EPS bearer contexts between the UE and the MME, and delivers the buffered downlink data to the UE.

6.3.2.2. Call Flow

The call flow has four phases: Downlink Data Notification, Paging and Service Request, Radio Bearer Setup, and Path Switch and Data Delivery.

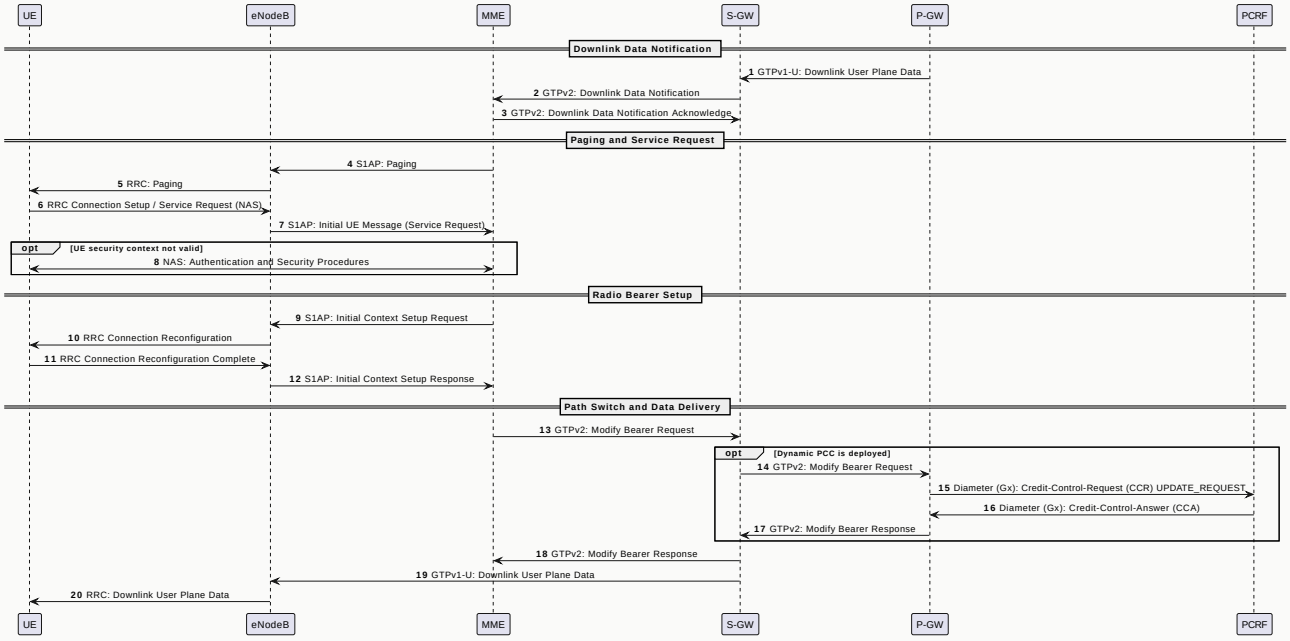


Figure 17. Network-triggered service request procedure call flow

6.3.2.3. Step-by-Step Description

1. The **P-GW** forwards a downlink PDU to the **S-GW** over the S5/S8 interface. Because the UE is in ECM-IDLE mode, the S-GW has no S1-U tunnel, that is no eNodeB F-TEID, for this UE, and it buffers the incoming data.
2. The **S-GW** identifies the MME that serves the UE and sends it a GTPv2 `Downlink Data Notification` (DDN) message to start the paging process. The message carries the ARP, derived from the bearer on which the data arrived, and the EBI.
3. The **MME** acknowledges the DDN message by returning a GTPv2 `Downlink Data Notification Acknowledge` message to the **S-GW**, carrying a Cause set to "Request Accepted" to confirm that the MME attempts to reach the UE.
4. The **MME** sends an S1AP `Paging` message to every eNodeB in the UE's registered Tracking Area List. The message carries the UE Identity Index Value, for calculating the paging frame, the UE Paging ID, that is the S-TMSI, the Paging DRX cycle, and the List of TAIs.
5. During the UE's paging occasion, the **eNodeB** broadcasts the paging indication over the radio interface by sending an RRC `Paging` message to the **UE**.
6. The **UE** matches its S-TMSI in the Paging message and starts the RRC connection establishment procedure, sending a `Service Request` message to the **eNodeB** inside this procedure. The message carries the Protocol Discriminator, the NAS KSI, the NAS sequence number, and the NAS-MAC.
7. The **eNodeB** forwards the NAS message to the **MME** inside an S1AP `Initial UE Message`.
8. If the UE's security context is missing or no longer valid, the **MME** and the **UE** perform the Authentication and Security Procedures, carrying the RAND, the AUTN, and the selected NAS security algorithms.
9. The **MME** sends an S1AP `Initial Context Setup Request` message to the **eNodeB** to establish the S1-U

connection and the radio bearers, carrying the MME UE S1AP ID, the E-RAB To Be Setup List, with the S-GW F-TEIDs for the uplink, the UE Aggregate Maximum Bit Rate, and the Security Context.

10. The **eNodeB** sends an RRC `Connection Reconfiguration` message to the **UE** to activate the data radio bearers for the requested EPS bearers, allocating the radio resources for the user-plane traffic.
11. The **eNodeB** confirms the successful setup of the radio and S1 bearers by returning an S1AP `Initial Context Setup Response` message to the **MME**, carrying the eNB UE S1AP ID, the MME UE S1AP ID, and the E-RAB Setup List, with the eNodeB F-TEIDs for the downlink.
12. To provide the eNodeB's downlink F-TEID and show that the UE is reachable, the **MME** sends a GTPv2 `Modify Bearer Request` message to the **S-GW** for each PDN connection. The message carries the Bearer Contexts to be modified, that is the EBI and the S1-U eNodeB F-TEID for the downlink, the User Location Information, and the RAT type.
13. If the network deploys dynamic PCC, for example for location reporting or RAT change reporting, the **S-GW** forwards the GTPv2 `Modify Bearer Request` message to the **P-GW**. The P-GW then starts a Diameter `Credit-Control-Request`/ `Credit-Control-Answer` (Update) exchange with the **PCRF** over the Gx interface, carrying the CC-Request-Type set to UPDATE_REQUEST, the 3GPP-User-Location-Info, and the RAT-Type, before returning a GTPv2 `Modify Bearer Response` message to the S-GW.
14. Whether or not the network deployed dynamic PCC, the **S-GW** updates its bearer contexts and returns a GTPv2 `Modify Bearer Response` message to the **MME**, carrying a Cause set to "Request Accepted" and the S-GW F-TEID for the control plane.
15. Using the downlink F-TEID from step 11, the **S-GW** transmits the buffered downlink packets to the **eNodeB**, which delivers the data to the **UE** over the radio interface.

6.3.2.4. Possible Failures and Required Actions

Paging failure, UE not responding

If the MME completes its paging repetition strategy and receives no Service Request from the UE, it sends a GTPv2 `Downlink Data Notification Reject` message to the S-GW, with Cause #87, "UE not responding", and the S-GW deletes all buffered packets for the UE. Based on operator policy, the MME can also start a Dedicated Bearer Deactivation procedure for any preserved Guaranteed Bit Rate (GBR) bearers.

Resource allocation rejection by eNodeB

If the eNodeB cannot allocate radio resources for some or all bearers during the Initial Context Setup because of congestion, it returns an S1AP `Initial Context Setup Failure` message, with S1AP Cause "Radio resources not available". The MME maps this internally to GTP Cause #73, "No resources available", and, if it rejects the UE, can map it further to NAS EMM Cause #26, "Insufficient resources". The MME can locally deactivate the EPS bearer contexts that failed to establish, while the UE stays in its current state and the NAS layer can start back-off timer T3346.

MME-triggered congestion control

If the MME receives a Service Request in response to paging but is too overloaded to establish the user-plane radio bearers, it sends a NAS `Service Reject` message, with EMM Cause #22, "Congestion", and a

value for timer T3346. The UE aborts the procedure, enters the EMM-REGISTERED state, and starts timer T3346, while the MME notifies the S-GW of the failure so that the S-GW discards the buffered data.

6.3.2.5. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 5.3.4.1 — Service Request procedure • Clause 5.3.4.3 — Network-triggered Service Request • Clause 5.3.4.2 — Abnormal cases
TS 24.301	• Clause 5.6.1 — Service Request procedure • Clause 5.6.2 — Paging procedure • Clause 8.2.24 — Service Reject message content • Clause 9.9.3.9 — EMM cause
TS 29.274	• Clause 7.2.7 — Modify Bearer Request/Response • Clause 7.2.11 — Downlink Data Notification • Table 8.4-1 — Cause values • Annex C — Cause mapping
TS 29.272	Annex A (Mapping between S6a and NAS causes).
TS 36.413	• Clause 8.2.1 — Initial Context Setup • Clause 9.1.6 — Paging • Clause 9.2.1.3 — S1AP Cause values

6.4. Dedicated Bearer Activation Procedure

6.4.1. Technical Overview

The network starts the Dedicated Bearer Activation procedure to establish an additional EPS bearer for an IP-CAN session. A dedicated bearer never exists on its own: the network always links it, through the LBI, to the default bearer that the UE already holds for that IP-CAN session. The new bearer has specific QoS characteristics, for example a GBR or a non-GBR profile, together with a TFT.

PCC usually triggers the procedure when the PCRF detects a service data flow (SDF) that needs prioritized treatment, for example IMS Voice over LTE (VoLTE) voice media with the QCI set to 1.

The procedure establishes end-to-end user-plane resources that map the traffic matching the packet filters of the TFT to dedicated radio tunnels and dedicated network tunnels. If the UE is in ECM-CONNECTED mode, the network establishes these resources immediately over the existing S1 signaling connection. If the UE is in ECM-IDLE mode, the MME first pages the UE and waits for a NAS `Service Request` message, because the eNodeB needs an active S1 and RRC connection before it can set up the new Data Radio Bearer (DRB). The procedure has these high-level effects:

On the UE

The UE establishes a new DRB, associates the DRB with the assigned EBI, and stores the uplink packet filters in its TFT to enforce the correct uplink bearer binding.

On the EPC

The nodes establish logical GTP-U tunnels: one tunnel connects the eNodeB and the S-GW over the S1-U interface, while the other connects the S-GW and the P-GW over the S5/S8 interface. The user-plane nodes, that is the PGW-U and the SGW-U, allocate new Fully Qualified Tunnel Endpoint Identifiers (F-TEIDs) to route the downlink data and the uplink data. All nodes obey the authorized QoS parameters, that is the QCI, the ARP, the GBR, and the Maximum Bit Rate (MBR).

6.4.2. Call Flow

The call flow has six phases: Gx Policy Provisioning, GTPv2 Bearer Resource Allocation, Paging and Service Request, E-UTRAN Resource Establishment and NAS Signaling, GTPv2 Tunnel Confirmation, and Gx Enforcement Reporting.

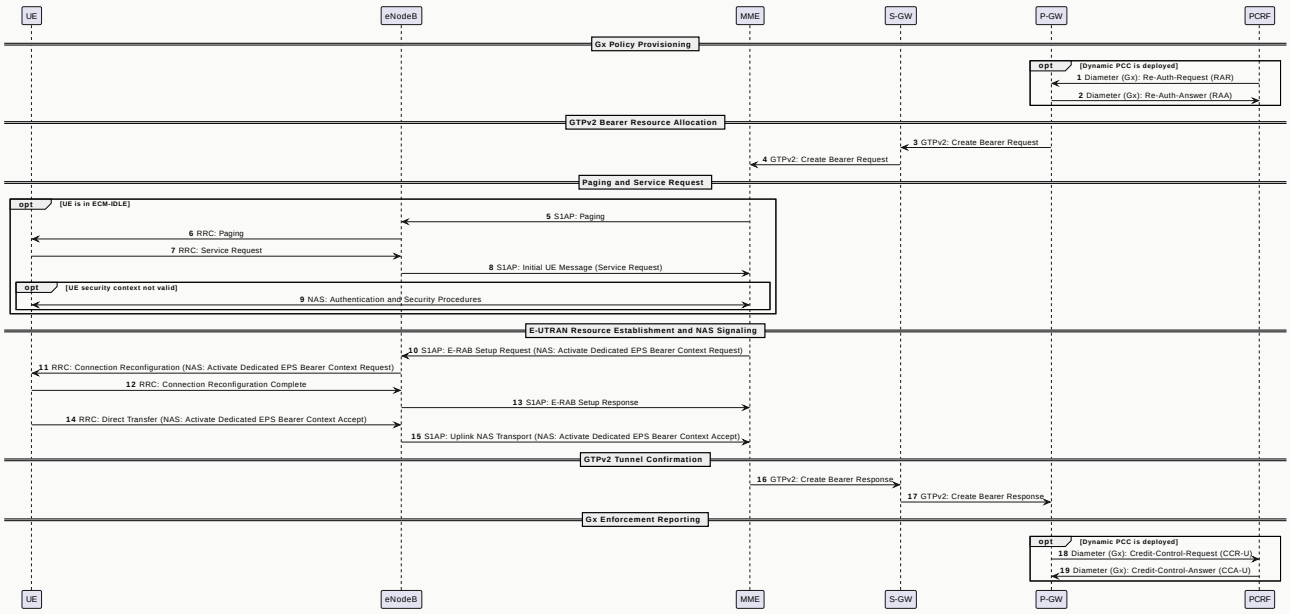


Figure 18. Dedicated bearer activation procedure call flow

6.4.3. Step-by-Step Description

1. If the network deploys dynamic PCC, the **PCRF** starts the IP-CAN session modification by sending a Diameter `Re-Auth-Request` (RAR) message over the Gx interface to the PCEF, which is collocated in the **P-GW**. The message installs new PCC rules and provisions the authorized QoS profile and the packet filters for the SDF. The message carries these Attribute-Value Pairs (AVPs): the `Session-Id`, the `Auth-Application-Id`, set to the vendor-specific Gx Application ID `16777238`, the `Re-Auth-Request-Type`, set to `AUTHORIZE_ONLY`, and the `Event-Trigger`, set to request user location reporting, if the PCRF needs this report. The message also carries the `Charging-Rule-Install` AVP, which encapsulates the `Charging-Rule-Definition` AVP containing the `Charging-Rule-Name`, the `Flow-Information` with the IP 5-tuple filters, and the `QoS-Information` that defines the target QCI, the ARP, the GBR, and the MBR.

2. The **P-GW** acknowledges the policy provisioning request by returning a Diameter `Re-Auth-Answer` (RAA) message to the **PCRF**. This message confirms that the PCEF received the PCC rule installation command and will continue with the bearer mapping and with the access network signaling. The message carries the `Session-Id`, the `Origin-Host`, the `Origin-Realm`, and the `Result-Code`, set to `DIAMETER_SUCCESS`. This result code shows that the transaction routing and the command parsing were successful.
3. The **P-GW** maps the received PCC rules to a dedicated bearer context and sends a GTPv2-C `Create Bearer Request` message to the **S-GW** over the S5/S8 control-plane interface to start the tunnel allocation. The message establishes the downlink S5/S8-U user-plane path at the S-GW and carries these IEs: the IMSI, the Procedure Transaction Identity (PTI), set to "no procedure transaction identity assigned" unless the P-GW correlates a UE-requested modification, the LBI, which identifies the associated default bearer, and the Protocol Configuration Options (PCO), which carry application-level parameters. The message also carries the Bearer Contexts grouped IE, which contains the EPS Bearer ID, set to `0` for a new allocation, the Bearer TFT with the packet filters, the S5/8-U P-GW F-TEID, which contains the uplink IP address and the uplink TEID for user data that the PGW-U allocates, the Bearer Level QoS, which defines the QCI, the ARP, the GBR, and the MBR, and the Charging Id.
4. After processing the request of the P-GW, the **S-GW** reserves local downlink user-plane resources on the S5/S8-U interface and forwards the GTPv2 `Create Bearer Request` message to the **MME** over the S11 interface. The message carries the IMSI, the LBI, the PTI, the PCO, and the Bearer Contexts grouped IE, which contains the EPS Bearer ID, set to `0`, the Bearer TFT, the S1-U S-GW F-TEID, which contains the SGW-U IP address and the downlink TEID that the S-GW allocates for downlink user-plane data, the S5/8-U P-GW F-TEID, and the Bearer Level QoS.
5. If the UE is in ECM-IDLE mode when the **MME** receives the Create Bearer Request, the MME buffers the request and pages the UE before it continues the dedicated bearer signaling. The MME sends an S1AP `Paging` message to every **eNodeB** in the UE's registered Tracking Area List, carrying the UE Identity Index Value, for calculating the paging frame, the UE Paging ID, that is the S-TMSI, the Paging DRX cycle, and the List of TAIs.
6. The **eNodeB** broadcasts the paging indication over the radio interface, during the UE's paging occasion. The eNodeB sends an RRC `Paging` message to the **UE**.
7. The **UE** matches its S-TMSI in the Paging message and starts the RRC connection establishment procedure, sending a NAS `Service Request` message to the **eNodeB** inside this procedure. The message carries the Protocol Discriminator, the NAS KSI, the NAS sequence number, and the NAS-MAC.
8. The **eNodeB** forwards the NAS message to the **MME** inside an S1AP `Initial UE Message`, which completes the UE's transition to ECM-CONNECTED mode.
9. The UE's security context can be missing or no longer valid. In this case, the **MME** and the **UE** perform the Authentication and Security Mode Control procedures, carrying the RAND, the AUTN, and the selected NAS security algorithms, before the MME resumes the buffered dedicated bearer signaling.
10. The **MME** selects an unassigned EBI from its pool, that is a value from 5 to 15 because the network reserves values 0 to 4, and builds an S1AP `E-RAB Setup Request` message, which the MME sends to the **eNodeB** to trigger the resource allocation at the eNodeB and to encapsulate the NAS message for the UE. The MME starts the session management guard timer T3485 when it sends this message. The message requests the eNodeB to assign Uu radio resources and S1-U uplink transport resources, and

carries the Message Type, the MME UE S1AP ID, the eNB UE S1AP ID, the UE Aggregate Maximum Bit Rate (UE-AMBR), and the E-RAB to Be Setup List grouped IE. Each item of this list contains the allocated E-RAB ID, that is the EBI, the E-RAB Level QoS Parameters, that is the QCI, the ARP, and the GBR and MBR limits, the Transport Layer Address, that is the S1-U S-GW IP address, the GTP-TEID, that is the S1-U S-GW downlink TEID for the user plane, and a NAS-PDU that encapsulates the NAS `Activate Dedicated EPS Bearer Context Request` message.

11. After receiving the S1AP `E-RAB Setup Request` message, the **eNodeB** maps the QoS parameters to the Radio Bearer QoS and sends an RRC `Connection Reconfiguration` message to the **UE** over the Uu air interface. The message establishes a new DRB and configures the physical layer parameters, the Medium Access Control (MAC) layer parameters, and the Radio Link Control (RLC) layer parameters. The message carries the `rrc-TransactionIdentifier` and the `radioResourceConfigDedicated` container, which includes the `drb-ToAddModList` with the assigned DRB identity, the EBI, the `rlc-Config`, and the `logicalChannelConfig`. The message also carries the `dedicatedInfoNASList`, which contains the NAS `Activate Dedicated EPS Bearer Context Request` message. This NAS sub-layer message carries the EPS bearer identity, the LBI, the PTI, the EPS QoS, which excludes the ARP parameter, the TFT, and the PCO.

12. The **UE** processes the reconfiguration parameters, activates the dedicated DRB, binds the DRB to the new dedicated ESM bearer context, and returns an RRC `Connection Reconfiguration Complete` message to the **eNodeB** over the air interface. This message confirms that the UE reconfigured its radio parameters and established the new radio bearer, and carries the `rrc-TransactionIdentifier` and the `rrcConnectionReconfigurationComplete-r8` field.

13. The **eNodeB** sends an S1AP `E-RAB Setup Response` message to the **MME** over the S1-MME interface to confirm the successful access-stratum bearer establishment, delivering the uplink S1-U transport path information that the eNodeB allocates. The message carries the Message Type, the MME UE S1AP ID, the eNB UE S1AP ID, and the E-RAB Setup List grouped IE, which contains the E-RAB ID, the Transport Layer Address, that is the eNodeB downlink user-plane IP address, and the downlink GTP-TEID, that is the eNodeB downlink TEID for the user plane. If the network uses Dual Connectivity, the message also carries the ID of the Primary SCG Cell (PSCell), that is the primary cell of the Secondary Cell Group (SCG).

14. At the same time as the radio acknowledgement, or immediately after it, the NAS layer of the **UE** builds the ESM response and encapsulates this response in an RRC `Direct Transfer` message, which the UE sends to the **eNodeB** over the control-plane signaling connection. The message delivers the NAS ESM session acceptance and carries the `rrc-TransactionIdentifier` and the `dedicatedInfoNASList`, which contains the NAS `Activate Dedicated EPS Bearer Context Accept` message. This NAS message includes the Protocol discriminator, the EPS bearer identity, the PTI, and optional PCO elements.

15. The **eNodeB** extracts the encapsulated NAS-PDU from the RRC message and forwards the NAS-PDU without changes to the **MME**, inside an S1AP `Uplink NAS Transport` message that completes the control-plane ESM signaling link between the UE and the MME. The message carries the Message Type, the MME UE S1AP ID, the eNB UE S1AP ID, the NAS-PDU with the `Activate Dedicated EPS Bearer Context Accept` message, the ECGI, and the TAI of the serving cell.

16. When the **MME** receives both the S1AP `E-RAB Setup Response` message of step 13 and the `Uplink NAS Transport` message with the NAS Accept of step 15, the MME stops timer T3485, moves the bearer context to the `BEARER CONTEXT ACTIVE` state, and acknowledges the bearer activation by sending a GTPv2 `Create Bearer Response` message to the **S-GW** over the S11 interface. The message transmits the

downlink transport parameters of the eNodeB to the S-GW and carries the Bearer Contexts grouped IE, which contains the EPS Bearer ID, the Cause, set to "Request accepted" to show success, the F-TEID, that is the eNodeB downlink IP address and the downlink user-plane S1-U TEID, and the User Location Information (ULI) with the ECGI and the TAI.

17. The **S-GW** matches the downlink transport parameters from the MME with its S5/S8 user-plane parameters and sends a GTPv2 `Create Bearer Response` message to the **P-GW** over the S5/S8 control-plane interface, which completes the end-to-end user-plane tunnel establishment. The message carries the Bearer Contexts grouped IE, which contains the EPS Bearer ID, the Cause, the S5/8-U S-GW F-TEID, that is the downlink IP address and the downlink user-plane S5/S8-U TEID that the SGW-U allocates, the ULI with the ECGI and the TAI, and, optionally, the Secondary RAT Usage Data Report.
18. If a policy provisioning step triggered the procedure, the **P-GW**, in its PCEF role, reports the enforcement outcome of the installed PCC rules to the **PCRF** by sending a Diameter `Credit-Control-Request` (CCR) message with the CC-Request-Type set to UPDATE_REQUEST. The message confirms that the access network activated the requested QoS policy, and carries the `Session-Id`, the `CC-Request-Type`, set to `UPDATE_REQUEST`, the `CC-Request-Number`, the `Event-Trigger`, set to `SUCCESSFUL_RESOURCE_ALLOCATION`, and the `Charging-Rule-Report`, which contains the `Charging-Rule-Name` and the `PCC-Rule-Status`, set to `ACTIVE`. The message also carries the `Access-Network-Charging-Identifier-Gx`, which carries the charging ID of the dedicated bearer to bind the bearer to the charging records, and the `3GPP-User-Location-Info`.
19. The **PCRF** acknowledges the rule activation report and closes the dynamic policy modification transaction by sending a Diameter `Credit-Control-Answer` (CCA) message to the **P-GW**. This message completes the PCRF-initiated IP-CAN Session Modification procedure and permits the start of the user-plane traffic forwarding. The message carries the `Session-Id`, the `Origin-Host`, the `Origin-Realm`, and the `Result-Code`, set to `DIAMETER_SUCCESS`.

6.4.4. Possible Failures and Required Actions

Radio resource allocation rejection by the eNodeB

The eNodeB can lack the cell capacity or the GBR hardware channels to admit the QoS that the E-RAB Setup Request demands, for example the guaranteed bit rate of a QCI 1 VoLTE bearer during a busy hour. In this case, the eNodeB returns an S1AP `E-RAB Setup Response` message that lists the bearer in the E-RAB Failed to Setup List, with S1AP Cause #20, "Radio resources not available". The MME stops timer T3485, leaves the bearer context in the `BEARER CONTEXT INACTIVE` state, and reports the failure to the S-GW with a GTPv2 `Create Bearer Response` message that carries GTP Cause #89, "Service denied". The S-GW relays this response to the P-GW, which, if the network deploys dynamic PCC, reports the enforcement failure to the PCRF over Gx with a `Charging-Rule-Report` that carries a `Rule-Failure-Code`.

TFT validation failure at the UE

The UE's NAS layer can find a semantic or a syntactical error in the packet filters of the received TFT, for example a filter that conflicts with an existing precedence value. In this case, the UE returns a NAS `Activate Dedicated EPS Bearer Context Reject` message, inside an S1AP `Uplink NAS Transport` message, with ESM Cause #45, "syntactical errors in packet filter(s)", or ESM Cause #41, "semantic error in the TFT operation". The MME stops timer T3485, releases the radio resources that the eNodeB already reserved with an S1AP `E-RAB Release Command` message, and reports the rejection to the S-GW with a GTPv2 `Create`

`Bearer Response` message that carries the matching GTP Cause, #77, "Syntactic errors in packet filter(s)", or #74, "Semantic error in the TFT operation". The bearer context stays in the `BEARER CONTEXT INACTIVE` state at the UE and at the network.

Paging timeout

The UE can be unreachable, for example because it is out of coverage or has a depleted battery, and does not respond to the S1AP `Paging` message before the MME's paging repetition strategy completes. In this case, the MME cancels the buffered dedicated bearer signaling and sends a GTPv2 `Create Bearer Response` message to the S-GW with GTP Cause #87, "UE not responding", or, when extended idle-mode DRX applies, GTP Cause #123, "UE is temporarily not reachable due to power saving", and sets the "Pending Network Initiated PDN Connection Signalling" flag for the UE. The P-GW retries the dedicated bearer activation after it learns that the UE is reachable again, for example from a later `Modify Bearer Request` message.

6.4.5. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401 (v18.5.0)	• Clause 5.4.1 — Dedicated bearer activation, and Figure 5.4.1-1 • Clauses 4.7.2 and 4.7.3 — The EPS bearer with GTP-based S5/S8, and bearer level QoS parameters • Clause 5.3.4.3 — Network-triggered Service Request, for the paging case
TS 24.301 (v18.6.0)	• Clause 6.4.2 — Dedicated EPS bearer context activation procedure, and Figure 6.4.2.2.1 • Clauses 8.3.1 and 8.3.3 — Activate dedicated EPS bearer context accept and Activate dedicated EPS bearer context request message definitions • Clause 5.6.2 — Paging procedure • Table 9.9.4.4 — ESM cause values
TS 29.274 (v18.6.0)	• Clause 7.2.3 — Create Bearer Request, and Tables 7.2.3-1 and 7.2.3-2 • Clause 7.2.4 — Create Bearer Response • Table 8.4-1 — Cause values
TS 29.212 (v18.0.0)	• Clause 4.5.2 — PCC Rule Provisioning • Clauses 5.6.1 and 5.6.2 — Gx Application messages, including the RAR/RAA and CCR/CCA message syntax
TS 36.413 (v18.1.0)	• Clause 8.2 — E-RAB Management Procedures, that is E-RAB Setup Request and E-RAB Setup Response • Clauses 9.1.3.1 and 9.1.3.2 — E-RAB SETUP REQUEST and E-RAB SETUP RESPONSE message content tables • Clause 9.1.6 — Paging • Clause 9.2.1.3 — S1AP Cause values
TS 24.007	Clause 11.2.3.1.5 (EPS bearer identity value range).

6.5. Bearer Modification Procedure

6.5.1. P-GW-Initiated Bearer Modification Procedure

6.5.1.1. Technical Overview

The P-GW-initiated Bearer Modification procedure updates the parameters of an active default or dedicated EPS bearer, and the P-GW starts the procedure.

The procedure changes the QoS of the bearer, that is the QCI, the GBR, the MBR, and the ARP, and it can also update the TFT, the APN-AMBR, and the PCO.

The procedure keeps the radio and core network resources aligned with the PCC rules that the PCRF authorizes, reconfiguring the DRB at the UE and updating the EPS bearer contexts at the P-GW, the S-GW, and the MME.

6.5.1.2. Call Flow

The call flow has four phases: Policy Decision, Bearer Modification Request, Radio Bearer Modification, and Bearer Modification Acknowledgement.

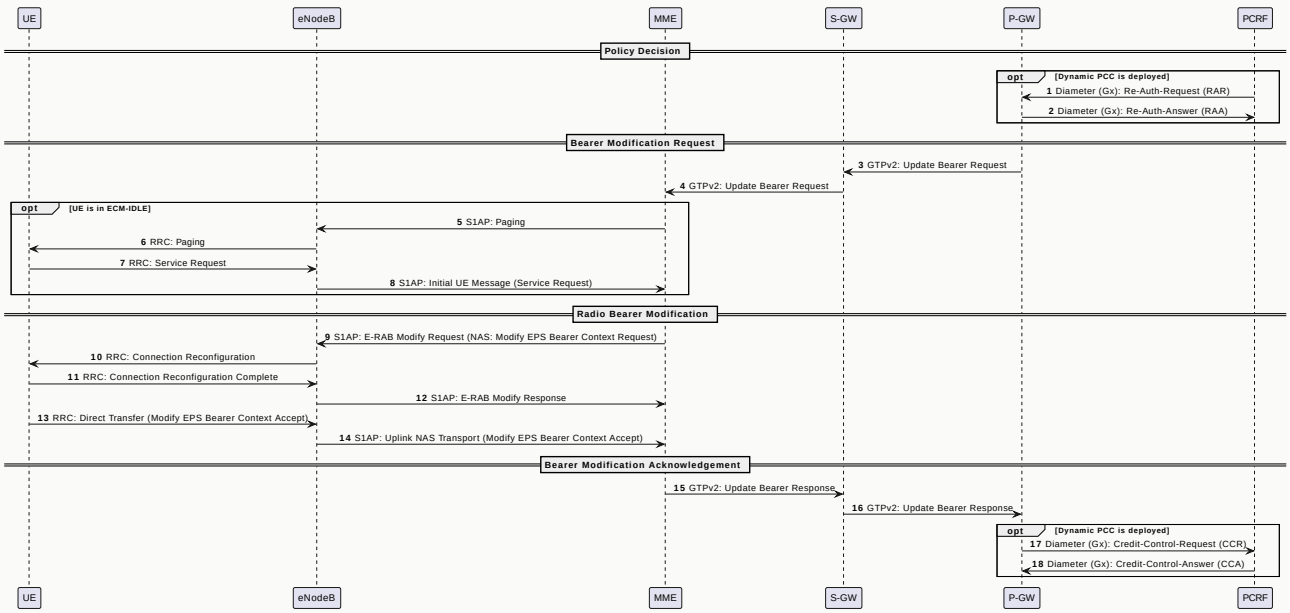


Figure 19. P-GW-initiated bearer modification procedure call flow

6.5.1.3. Step-by-Step Description

1. If the network deploys dynamic PCC, the **PCRF** starts the procedure by sending a Diameter `Re-Auth-Request` (RAR) message to the **P-GW** over the Gx interface, to provision new PCC rules, and the **P-GW** returns a Diameter `Re-Auth-Answer` (RAA) message to acknowledge the new policy decision.
2. The **P-GW** derives the new EPS Bearer QoS from the PCC rules and sends a GTPv2 `Update Bearer Request` message to the **S-GW**, carrying the PTI, the EBI, the EPS Bearer QoS, the APN-AMBR, and the TFT.

3. The **S-GW** forwards the GTPv2 `Update Bearer Request` message to the **MME**, without changes.
4. If the UE is in ECM-IDLE mode, the **MME** pages the UE, unless the procedure only changes the ARP, by sending an S1AP `Paging` message to the **eNodeB**, which pages the **UE** over the radio interface with an RRC `Paging` message. The UE responds with an RRC `Service Request` message to the eNodeB, and the eNodeB forwards the request to the MME inside an S1AP `Initial UE Message`.
5. The **MME** builds a NAS `Modify EPS Bearer Context Request` message and sends it to the **eNodeB** inside an S1AP `E-RAB Modify Request` message, carrying the E-RAB ID, the E-RAB Level QoS Parameters, the NAS-PDU, and, if the APN-AMBR changed, the UE-AMBR.
6. The **eNodeB** maps the new EPS Bearer QoS to the Radio Bearer QoS and sends an RRC `Connection Reconfiguration` message to the **UE**, carrying the Radio Bearer QoS and the Session Management Request, that is the NAS `Modify EPS Bearer Context Request` message.
7. The **UE** reconfigures its radio resources and returns an RRC `Connection Reconfiguration Complete` message to the **eNodeB**.
8. The **eNodeB** confirms the successful radio bearer modification by returning an S1AP `E-RAB Modify Response` message to the **MME**, carrying the E-RAB ID and, if the network uses Dual Connectivity, the PSCell ID.
9. The **UE** accepts the new EPS bearer context by sending a NAS `Modify EPS Bearer Context Accept` message, inside an RRC `Direct Transfer` message, to the **eNodeB**, which forwards it to the **MME** inside an S1AP `Uplink NAS Transport` message.
10. When the **MME** receives both the S1AP and the NAS acknowledgements, it sends a GTPv2 `Update Bearer Response` message to the **S-GW**, carrying the EBI, a Cause set to "Request Accepted", the ULI, that is the ECGI, and the PSCell ID.
11. The **S-GW** forwards the GTPv2 `Update Bearer Response` message to the **P-GW** over the S5/S8 interface, carrying the EBI and the ULI.
12. If the network deploys dynamic PCC, the **P-GW** confirms the enforcement of the PCC rules to the **PCRF** by sending a Diameter `Credit-Control-Request` (CCR) message to provide the provisioning acknowledgement, and the PCRF returns a Diameter `Credit-Control-Answer` (CCA) message, concluding the IP-CAN Session Modification procedure.

6.5.1.4. Possible Failures and Required Actions

Radio resource allocation rejection by eNodeB

If the eNodeB cannot meet the requested QoS, for example because of congestion or a lack of GBR capacity, it returns an S1AP `E-RAB Modify Response` message, with the bearer in the E-RAB Failed to Modify List and S1AP Cause #20, "Radio resources not available". The MME reports the failure to the S-GW and the P-GW with a GTPv2 `Update Bearer Response` message, with GTP Cause #89, "Service denied", and the P-GW informs the PCRF that the network cannot enforce the PCC decision.

NAS syntactical error in the TFT

If the UE's NAS layer finds a syntax error in the packet filters of the modification request, the UE returns a NAS `Modify EPS Bearer Context Reject` message to the MME, with ESM Cause #45, "syntactical error in

the TFT operation". The MME stops timer T3486 and sends a GTPv2 `Update Bearer Response` message to the S-GW, with GTP Cause #77, "Syntactic errors in packet filter(s)", and, if it detects a mismatch, can start a procedure to re-align the bearer context.

UE temporarily not reachable

When the MME tries to modify a bearer for a UE in ECM-IDLE mode with Extended Discontinuous Reception (eDRX) active, the UE can fail to respond to paging before the paging timer expires. In this case, the MME sends a GTPv2 `Update Bearer Response` message to the S-GW, with GTP Cause #123, "UE is temporarily not reachable due to power saving", and sets the "Pending Network Initiated PDN Connection Signalling" flag for the UE. The P-GW retries the procedure after it receives an indication that the UE is reachable, for example in a later `Modify Bearer Request` message.

6.5.1.5. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 5.4.2.1 — PGW-initiated bearer modification without bearer QoS update • Clause 5.4.3 — Bearer modification with bearer QoS update • Figures 5.4.2.1-1 and 5.4.3-1
TS 24.301	• Clause 6.4.3 — Modification of EPS bearer context • Clause 8.3.18 — Modify EPS Bearer Context Request/Accept/Reject message content • Table 9.9.4.4 — ESM cause values • Annex B
TS 29.274	• Clauses 7.2.15 and 7.2.16 — Update Bearer Request/Response • Clause 8.4 — Cause values • Tables 7.2.15-1 and 8.4-1 • Annex C — Cause mapping
TS 29.272	Annex A (Mapping between S6a, Gx, and NAS/S1AP cause values).
TS 36.413	• Clause 8.2.2 — E-RAB Modify procedure • Clause 9.1.3.3 — E-RAB Modify Response • Clause 9.2.1.3 — S1AP Cause values
TS 29.213	Clause 4.3.2 (IP-CAN Session Modification).

6.5.2. HSS-Initiated Subscribed QoS Modification Procedure

6.5.2.1. Technical Overview

The HSS-initiated Subscribed QoS Modification procedure updates the QoS of an active EPS bearer after a change in the subscriber’s subscription data at the HSS, and the HSS starts the procedure.

The procedure changes the Subscribed UE Aggregate Maximum Bit Rate (Subscribed-UE-AMBR), the Subscribed APN-AMBR, or the QCI and the ARP of the default bearer.

The procedure synchronizes the UE's radio and session management contexts with the new subscription parameters across the MME, the S-GW, and the P-GW, keeping the bearer compliant with the PCC rules.

6.5.2.2. Call Flow

The call flow has three phases: Subscription Update, Bearer Modification Command, and, if the QCI, the ARP, or the APN-AMBR changed, Bearer Modification Request and Bearer Modification Acknowledgement.

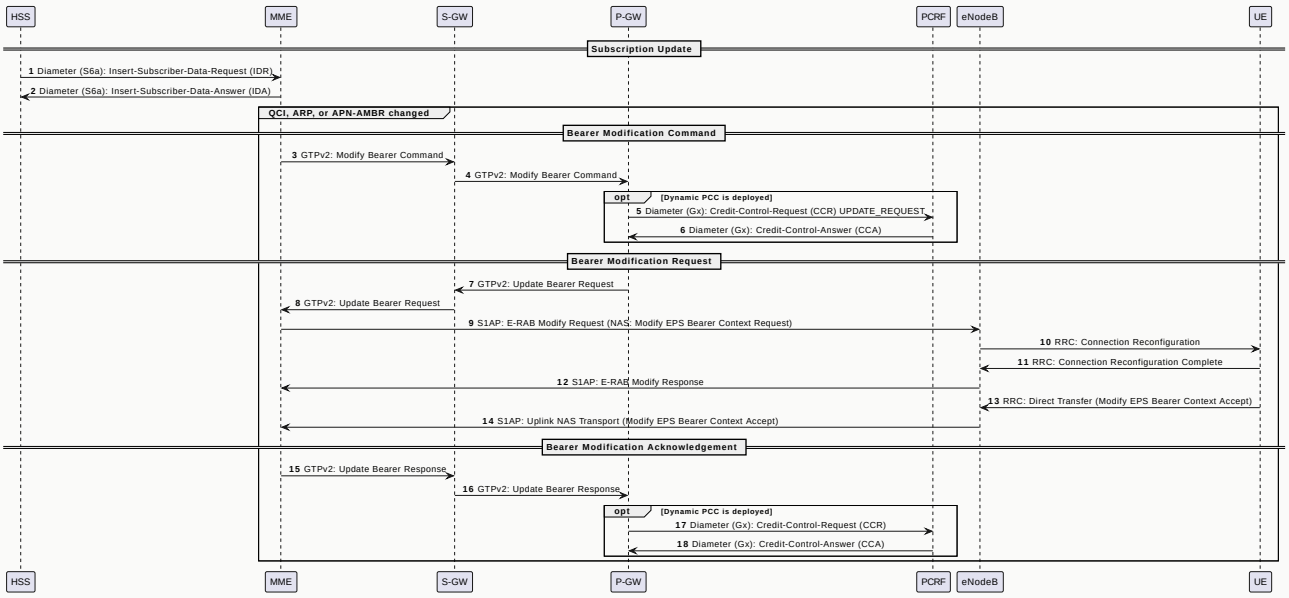


Figure 20. HSS-initiated subscribed QoS modification procedure call flow

6.5.2.3. Step-by-Step Description

1. After an administrative change to the subscription, the **HSS** starts the procedure by sending a Diameter `Insert-Subscriber-Data-Request` (IDR) message to the **MME**, carrying the IMSI and the Subscription-Data, that is the new Subscribed-UE-AMBR, APN-AMBR, QCI, or ARP.
2. The **MME** updates its local UE context with the new subscription data and returns a Diameter `Insert-Subscriber-Data-Answer` (IDA) message to the **HSS**, carrying a Result-Code set to DIAMETER_SUCCESS.
3. If the new subscription data affects an active PDN connection, for example a changed QCI or APN-AMBR, the **MME** sends a GTPv2 `Modify Bearer Command` message to the **S-GW**, carrying the EBI of the default bearer, the Bearer Level QoS, and the APN-AMBR.
4. The **S-GW** forwards the GTPv2 `Modify Bearer Command` message to the **P-GW**, carrying the EBI, the Bearer Level QoS, and the APN-AMBR.
5. If the network deploys dynamic PCC, the **P-GW** reports the updated subscribed QoS to the **PCRF** by sending a Diameter `Credit-Control-Request` (CCR) message over the Gx interface, with the CC-Request-Type set to UPDATE_REQUEST, carrying the Subscription-Id, the QoS-Information, and the APN-Aggregate-Max-Bitrate.
6. The **PCRF** authorizes the modification, adjusting the parameters based on local policy if needed, and returns a Diameter `Credit-Control-Answer` (CCA) message to the **P-GW**, carrying a Result-Code, the QoS-Information, and the APN-Aggregate-Max-Bitrate.

7. To update the bearer context, the **P-GW** sends a GTPv2 `Update Bearer Request` message to the **S-GW**, carrying the EBI, the Bearer Level QoS, the TFT, and the APN-AMBR.
8. The **S-GW** forwards the GTPv2 `Update Bearer Request` message to the **MME**, without changes.
9. The **MME** builds a NAS `Modify EPS Bearer Context Request` message and sends it to the **eNodeB** inside an S1AP `E-RAB Modify Request` message, carrying the E-RAB ID, the E-RAB Level QoS Parameters, the NAS-PDU, and the UE-AMBR.
10. The **eNodeB** reconfigures the radio bearer by sending an RRC `Connection Reconfiguration` message to the **UE**, carrying the Radio Bearer QoS and the Session Management Request.
11. The **UE** confirms the successful reconfiguration of its radio resources by returning an RRC `Connection Reconfiguration Complete` message to the **eNodeB**.
12. The **eNodeB** informs the MME of the outcome of the resource modification by returning an S1AP `E-RAB Modify Response` message to the **MME**, carrying the E-RAB ID and a Cause set to "Request Accepted".
13. The **UE** accepts the new EPS bearer context by sending a NAS `Modify EPS Bearer Context Accept` message, carrying the EBI, inside an RRC `Direct Transfer` message, to the **eNodeB**, which forwards it to the **MME** inside an S1AP `Uplink NAS Transport` message.
14. When the **MME** receives both the eNodeB and the UE acknowledgements, it sends a GTPv2 `Update Bearer Response` message to the **S-GW**, carrying the EBI, a Cause set to "Request Accepted", and the ULI.
15. The **S-GW** forwards the GTPv2 `Update Bearer Response` message to the **P-GW**, carrying the EBI, the Cause, and the ULI.
16. If the network deploys dynamic PCC, the **P-GW** confirms the enforcement of the authorized QoS to the **PCRF** by sending a Diameter `Credit-Control-Request` (CCR) message, with the Event-Trigger set to SUCCESSFUL_RESOURCE_ALLOCATION, and the PCRF returns a Diameter `Credit-Control-Answer` (CCA) message to acknowledge the final status.

6.5.2.4. Possible Failures and Required Actions

HSS registration rejection

If the MME sends an Update Location for a subscriber unknown to the HSS, the HSS returns a Diameter Result-Code DIAMETER_ERROR_USER_UNKNOWN (5001). When the HSS returns this error during an Update Location, the MME rejects the UE’s Attach or Tracking Area Update request, with EMM Cause #2, "IMSI unknown in HSS", whereas when it returns this error during an Insert Subscriber Data procedure for an active UE, the MME locally detaches the UE and removes its context.

Radio resource allocation rejection by eNodeB

If the eNodeB cannot provide the requested GBR or QCI because of congestion, it returns an S1AP Cause #20, "Radio resources not available", or a cause of "Not supported QCI Value". The MME maps this to GTPv2 Cause #89, "Service denied", or GTPv2 Cause #90, "No resources available", in the `Update Bearer Response` message to the P-GW, which informs the PCRF that the modification failed and, if the modification is mandatory, can delete the affected bearer.

NAS syntactical error in the TFT

If the UE's NAS layer finds a syntax error in the packet filters of the modification request, the UE returns a NAS `Modify EPS Bearer Context Reject` message, with ESM Cause #45, "syntactical error in the TFT operation", which maps to GTPv2 Cause #77, "Syntactic errors in packet filter(s)". The MME stops timer T3486, aborts the procedure, and can start a procedure to re-align the bearer context between the EPC and the UE.

6.5.2.5. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 5.3.9.2 — Subscribed QoS modification • Clause 5.4.2.1 — PGW-initiated bearer modification without bearer QoS update • Clause 5.4.2.2 — Bearer modification with bearer QoS update procedures using GTP • Figure 5.4.2.2-1
TS 24.301	• Clauses 6.4.3.2, 6.4.3.3, and 6.4.3.4 — Network-requested EPS bearer context modification • Table 9.9.4.4 — ESM cause values
TS 29.272	• Clause 5.2.2.1 — Insert Subscriber Data procedure • Clause 7.2.9 — IDR/IDA commands • Tables 5.2.2.1.1/1 and A.1
TS 29.274	• Clause 7.2.14 — Modify Bearer Command • Clauses 7.2.15 and 7.2.16 — Update Bearer Request/Response • Tables 7.2.14.1-1 and 8.4-1
TS 36.413	• Clause 8.2.2 — E-RAB Modify procedure • Clause 9.1.3.3 — E-RAB Modify Response • Clause 9.2.1.3 — S1AP Cause values
TS 29.213	• Clause 4.3.2 — IP-CAN Session Modification • Clause 7.4.1.2.2.2 — QoS negotiation at Subscribed QoS modification

6.6. P-GW-Initiated Bearer Deactivation Procedure

6.6.1. Technical Overview

The EPC starts the P-GW-initiated Bearer Deactivation procedure to deactivate an active EPS bearer context. The procedure can also disconnect a UE from a PDN, in which case it deactivates all bearer contexts of that PDN connection.

Three events can trigger the procedure: a local QoS policy in the P-GW, the expiry of an inactivity timer for specific PDN types such as emergency services, or an explicit policy enforcement action from the PCRF.

The procedure tears down dedicated or default user-plane resources, releasing them on the radio interface and on the logical network tunnels, and at the same time synchronizes the session management states in

all involved nodes. The procedure has these high-level effects:

On the UE

The UE releases the designated DRB and deletes the related TFT filters, moving the ESM state of the bearer to `BEARER CONTEXT INACTIVE`. If the deactivated bearer is the default bearer of a PDN connection, the UE deletes all associated dedicated bearers as well, and when the network does not support EMM-REGISTERED without PDN connectivity, the UE also starts a local detach or an explicit detach.

On the EPC

The eNodeB (Evolved Node B) deallocates the radio resources and the S1-U uplink transport resources, while the S-GW and the P-GW delete their user-plane contexts, for example the F-TEIDs, and stop the packet count and the packet forwarding for the deactivated bearer. When the network deploys dynamic PCC, the PCEF in the P-GW reports the successful enforcement outcome to the PCRF, which closes the dynamic session.

6.6.2. Call Flow

The call flow has five phases: Gx Policy Provisioning, GTPv2 Bearer Resource Release, E-UTRAN Resource Release and NAS Signaling, GTPv2 Tunnel Confirmation, and Gx Enforcement Reporting.

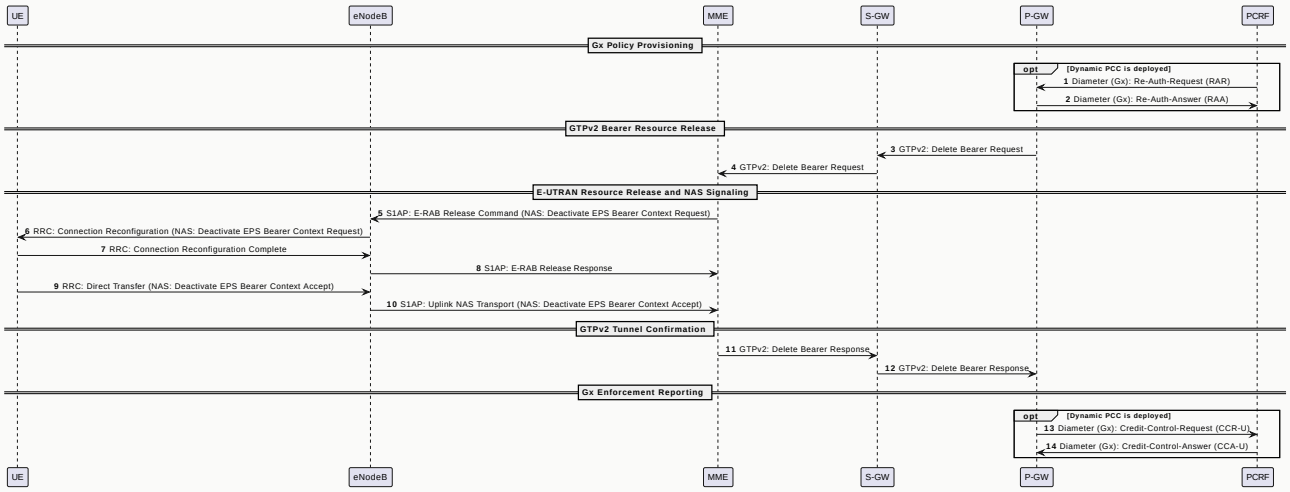


Figure 21. P-GW-initiated bearer deactivation procedure call flow

6.6.3. Step-by-Step Description

1. If the network deploys dynamic PCC, the **PCRF** triggers the bearer deactivation by sending a Diameter `Re-Auth-Request` (RAR) message over the Gx interface to the PCEF, which is collocated in the **P-GW**. The message removes authorized PCC rules and instructs the PCEF to delete the specific SDF filters of the bearer that the network deactivates. The message carries these AVPs: the `Session-Id`, the `Auth-Application-Id`, set to the vendor-specific Gx Application ID `16777238`, the `Re-Auth-Request-Type`, set to `AUTHORIZE_ONLY`, and the `Charging-Rule-Remove`. The `Charging-Rule-Remove` AVP encapsulates the `Charging-Rule-Name` or the `Charging-Rule-Base-Name`, which identify the rules to deactivate.
2. The **P-GW** acknowledges the policy modification command by returning a Diameter `Re-Auth-Answer`

(RAA) message to the **PCRF**. This message shows that the PCEF accepted the rule removal request and starts the bearer deactivation on the access network. The message carries the `Session-Id`, the `Origin-Host`, the `Origin-Realm`, and the `Result-Code`, set to `DIAMETER_SUCCESS`, to confirm a successful transaction.

3. The **P-GW** maps the removed PCC rules to the related bearer context and sends a GTPv2-C `Delete Bearer Request` message to the **S-GW** over the S5/S8 interface. The message starts the deallocation of the downlink S5/S8-U transport parameters and identifies the bearer that the network deactivates. The message carries these IEs: the EPS Bearer IDs, which identify the specific dedicated bearer to delete, or the LBI, if the network deactivates the complete PDN connection, the PTI, which correlates the message with a UE-initiated modification if applicable, and the Cause. The Cause IE carries the specific release trigger, for example "Regular deactivation" or "RAT changed from 3GPP to Non-3GPP".
4. After processing the request of the P-GW, the **S-GW** starts the release of its local S5/S8-U user-plane tunnel resources and forwards the GTPv2 `Delete Bearer Request` message to the **MME** over the S11 interface. The message prompts the MME to start the E-UTRAN resource release and the NAS signaling to the UE, and carries the EPS Bearer IDs with the target EBI, the PTI, and the Cause.
5. To terminate the logical S1-U connection and the radio resources of the bearer, the **MME** starts the S1AP E-RAB Release procedure and sends an S1AP `E-RAB Release Command` message to the **eNodeB**. The message instructs the eNodeB to release the radio resources on the Uu interface and the uplink user-plane tunnels on the S1-U interface, and carries the MME UE S1AP ID, the eNB UE S1AP ID, and the E-RAB To Be Released List, which contains the E-RAB To Be Released Item with the target E-RAB ID and the Cause. The message also carries a NAS-PDU, which encapsulates the NAS `Deactivate EPS Bearer Context Request` message. The embedded NAS ESM message carries the EPS bearer identity, the PTI, and the ESM cause, for example ESM Cause #36, "regular deactivation", or ESM Cause #39, "reactivation requested".
6. The **eNodeB** maps the received S1AP E-RAB release information to the radio bearer parameters and sends an RRC `Connection Reconfiguration` message to the **UE** over the Uu interface. The message requests the UE to release the physical layer resources, the MAC layer resources, and the RLC layer resources of the designated DRB, and carries the `rrc-TransactionIdentifier` and the `radioResourceConfigDedicated` container. This container carries the `drb-ToReleaseList` with the assigned DRB identity to release. The message also carries the `dedicatedInfoNASList`, which contains the NAS `Deactivate EPS Bearer Context Request` message.
7. The **UE** tears down the physical radio resources, removes the uplink packet filters in its TFT that match the deactivated EPS bearer, and returns an RRC `Connection Reconfiguration Complete` message to the **eNodeB** over the air interface. The message carries the `rrc-TransactionIdentifier` and confirms that the UE reconfigured the radio sub-layers.
8. After confirming the successful deallocation of the S1-U tunnel endpoints and of the Uu interface radio resources, the **eNodeB** sends an S1AP `E-RAB Release Response` message to the **MME** over the S1-MME interface. The message carries the MME UE S1AP ID, the eNB UE S1AP ID, and the E-RAB Release List, which encloses the E-RAB Release Item with the E-RAB ID, together with the User Location Information with the ECGI and the TAI of the serving cell. If the network releases secondary RAT resources, the message also carries the Secondary RAT Usage Report List.
9. The NAS layer of the **UE** builds the ESM response that acknowledges the bearer context deactivation

and encapsulates this response in an RRC `Direct Transfer` message, which the UE sends to the **eNodeB** over the control-plane signaling link. The message carries the `rrc-TransactionIdentifier` and the `dedicatedInfoNASList`, which contains the NAS `Deactivate EPS Bearer Context Accept` message. This NAS message contains the Protocol discriminator, the EPS bearer identity, and the PTI.

10. The **eNodeB** extracts the encapsulated NAS-PDU from the RRC `Direct Transfer` message and forwards the NAS-PDU without changes to the **MME**, inside an S1AP `Uplink NAS Transport` message that delivers the final ESM confirmation from the UE to the core network. The message carries the Message Type, the MME UE S1AP ID, the eNB UE S1AP ID, the NAS-PDU with the `Deactivate EPS Bearer Context Accept` message, the ECGI, and the TAI of the serving cell.
11. When the **MME** receives both the S1AP `E-RAB Release Response` message of step 8 and the `Uplink NAS Transport` message with the NAS Accept of step 10, the MME deletes the local bearer context and acknowledges the bearer deactivation to the **S-GW** with a GTPv2 `Delete Bearer Response` message over the S11 interface. The message carries the Cause, set to "Request accepted", the EPS Bearer ID, which is grouped in the Bearer Contexts IE, the ULI with the ECGI and the TAI, and the RAN/NAS Cause, which indicates the release cause of the access network. If the data is available, the message also carries the Secondary RAT Usage Data Report.
12. After processing the response of the MME, the **S-GW** deallocates its downlink user-plane tunnel resources, that is the S1-U F-TEID, and its uplink S5/S8-U tunnel resources, and forwards the GTPv2 `Delete Bearer Response` message to the **P-GW** over the S5/S8 interface. This message confirms the end-to-end deactivation of the user-plane resources in the EPC and carries the Cause, the EPS Bearer ID, which is grouped in the Bearer Contexts IE, the ULI, and the Secondary RAT Usage Data Report.
13. If dynamic policy rules triggered the bearer deactivation, the PCEF in the **P-GW** reports the successful enforcement of the PCC rule removal to the **PCRF** by sending a Diameter `Credit-Control-Request` (CCR) message with the CC-Request-Type set to UPDATE_REQUEST. The message synchronizes the session state of the PCRF with the actual state of the core network and reports the charging identifiers and the location information. The message carries the `Session-Id`, the `CC-Request-Type`, set to `UPDATE_REQUEST`, the `CC-Request-Number`, and the `Charging-Rule-Report`, which contains the `Charging-Rule-Name` and the `PCC-Rule-Status`, set to `INACTIVE`. The message also carries the `Access-Network-Charging-Identifier-Gx`, the `RAN-NAS-Release-Cause`, and the `3GPP-User-Location-Info`.
14. The **PCRF** acknowledges the rule deactivation report of the PCEF and closes the policy modification transaction by sending a Diameter `Credit-Control-Answer` (CCA) message to the **P-GW**. The message carries the `Session-Id`, the `Origin-Host`, the `Origin-Realm`, and the `Result-Code`, set to `DIAMETER_SUCCESS`.

6.6.4. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401 (v18.5.0)	• Clause 5.4.4.1 — PDN GW initiated bearer deactivation, and Figure 5.4.4.1-1 • Clause 4.7.2.2 — The EPS bearer with GTP-based S5/S8
TS 24.301 (v18.6.0)	• Clause 6.4.4.2 — EPS bearer context deactivation initiated by the network, and Figure 6.4.4.2.1 • Clauses 8.3.11 and 8.3.12 — Deactivate EPS bearer context accept and Deactivate EPS bearer context request message definitions

SPECIFICATION	CLAUSES AND COVERAGE
TS 29.274 (v18.6.0)	• Clause 7.2.9.2 — Delete Bearer Request, and Tables 7.2.9.2-1 and 7.2.9.2-2 • Clause 7.2.10.2 — Delete Bearer Response, and Tables 7.2.10.2-1 and 7.2.10.2-2
TS 29.212 (v18.0.0)	• Clause 4.5.7 — Bearer deactivation • Clauses 5.6.2 and 5.6.4 — CC-Request (CCR) Command and Re-Auth-Request (RAR) Command Gx message formats
TS 36.413 (v18.1.0)	• Clause 8.2.3 — E-RAB Release procedure • Clauses 9.1.3.5 and 9.1.3.6 — E-RAB RELEASE COMMAND and E-RAB RELEASE RESPONSE message functional contents

6.7. Handover Procedure

6.7.1. X2-Based Handover Procedure

6.7.1.1. Technical Overview

The X2-based handover procedure moves a UE in ECM-CONNECTED mode from a source eNodeB to a target eNodeB over the X2 reference point between the two eNodeBs. The MME doesn't change in this procedure, and the procedure relies on an S1-MME connection between the MME and both the source and the target eNodeB (TS 23.401 clause 5.5.1.1.1). TS 23.401 defines two variants of the procedure. In the X2-based handover without S-GW relocation, the S-GW that already serves the UE continues to serve it (TS 23.401 clause 5.5.1.1.2). In the X2-based handover with S-GW relocation, the MME decides to relocate the S-GW and selects a new S-GW with the S-GW selection function of TS 23.401 clause 4.3.8.2 (TS 23.401 clause 5.5.1.1.3). The S-GW relocation affects only the handover completion phase, and the handover preparation and execution phases are identical in both variants (TS 23.401 clause 5.5.1.1.1). If the target eNodeB has no IP connectivity to the source S-GW, the network uses the S1-based handover instead of the X2-based handover with S-GW relocation (TS 23.401 clause 5.5.1.1.3).

The procedure has these high-level effects on the network elements:

On the UE

The UE stays in the RRC_CONNECTED state and in the EMM-REGISTERED state, and switches its radio connection from the source cell to the target cell. It applies the radio configuration of the target cell and derives a new KeNB from the Next hop Chaining Counter (NCC) that it receives in the handover command (TS 33.401 clause 7.2.8.4.4). The UE doesn't attach again, but it starts a Tracking Area Update when one of the TAU triggers applies (TS 23.401 clause 5.5.1.1.2, step 8).

On the source eNodeB

The source eNodeB decides on the handover, prepares the target eNodeB with the X2 Application Protocol (X2AP), forwards downlink and, optionally, uplink packets to the target eNodeB, and transfers the PDCP-SN and HFN status of the E-RABs to the target eNodeB (TS 23.401 clause 5.5.1.1.1, and TS 36.423 clause 8.2.2). It derives the KeNB* for the target cell and sends it with the NCC to the target eNodeB, which uses the KeNB* directly as the KeNB of the Access Stratum (AS) security with the UE (TS

33.401 clause 7.2.8.4.2). It releases the radio and control-plane resources of the UE when the target eNodeB sends the X2AP `UE Context Release` message (TS 36.423 clause 8.2.3).

On the target eNodeB

The target eNodeB performs admission control for the requested E-RABs, builds the handover command for the UE, receives the forwarded data, and asks the MME to switch the downlink path of the E-RABs with the S1AP `Path Switch Request` message. It stores the fresh pair of Next Hop (NH) parameter and NCC that the MME returns, for use in the next handover (TS 33.401 clause 7.2.8.4.2).

On the MME

The MME verifies the CSG membership of the UE when the target cell is a CSG cell or a hybrid cell and updates the User CSG Information. It then switches the downlink user-plane path at the S-GW over S11, or relocates the S-GW, and computes a fresh {NH, NCC} pair for the target eNodeB (TS 23.401 clause 5.5.1.1.2, step 1b, and TS 33.401 clause 7.2.8.4.2).

On the S-GW

Without S-GW relocation, the S-GW switches the downlink path of the S1-U bearers from the source eNodeB to the target eNodeB and sends one or more GTP-U end marker packets on the old path. With S-GW relocation, the target S-GW establishes the S5/S8 bearers towards the P-GW, and the source S-GW forwards the end marker packets that the P-GW sends on the old path to the source eNodeB (TS 23.401 clauses 5.5.1.1.2 and 5.5.1.1.3).

On the P-GW

The P-GW remains the anchor of the PDN connection on SGi. With S-GW relocation, the P-GW switches the downlink path to the target S-GW and sends one or more end marker packets on the old path to the source S-GW (TS 23.401 clause 5.5.1.1.3, step 3).

6.7.1.2. Call Flow

The call flow has three phases: Handover Preparation and Execution, Path Switch, and Resource Release. In the figure, the source S-GW is the S-GW that serves the UE before the handover, and it continues to serve the UE when the S-GW isn’t relocated.

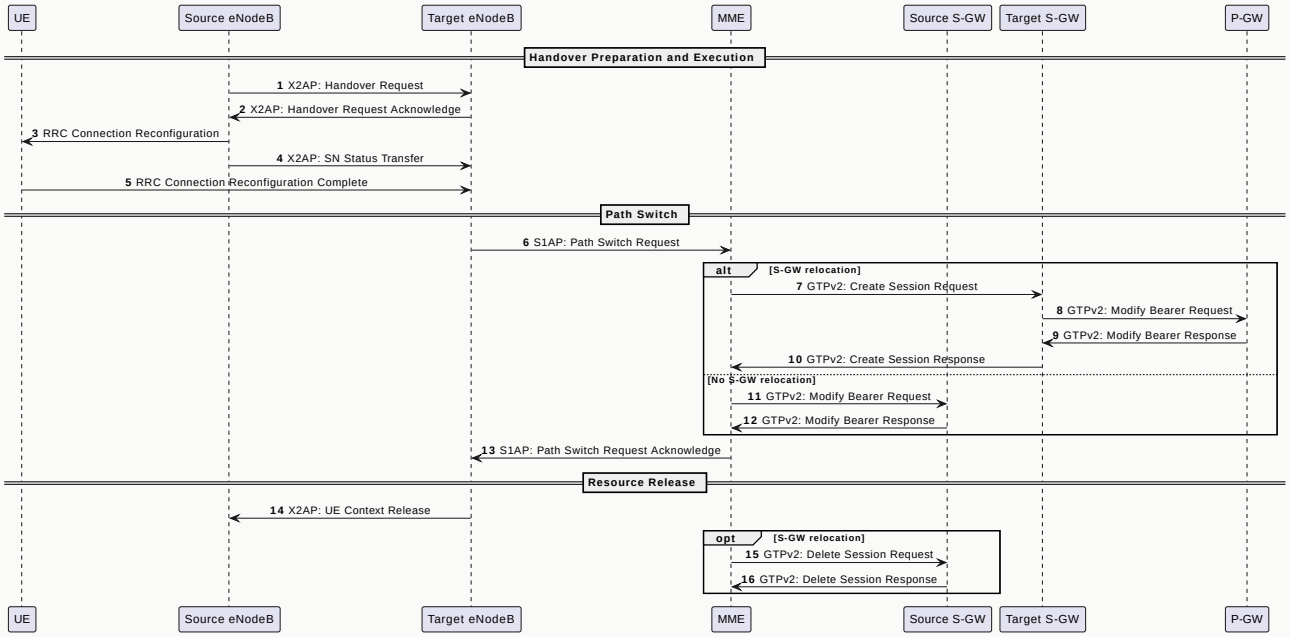


Figure 22. X2-based handover procedure call flow

6.7.1.3. Step-by-Step Description

1. The **source eNodeB** decides on an X2-based handover from the measurement reports of the UE and sends an X2AP `Handover Request` message to the **target eNodeB** to prepare resources for the UE. The message carries the Old eNB UE X2AP ID, the Cause, for example "Handover Desirable for Radio Reasons", the Target Cell ID (ECGI), and the GUMMEI. It also carries the UE Context Information, with the MME UE S1AP ID, the UE Security Capabilities, the AS Security Information with the KeNB* and the NCC, the UE-AMBR, the E-RABs To Be Setup List, with the E-RAB ID, the E-RAB Level QoS Parameters, such as the QCI and the ARP, and the S-GW UL GTP Tunnel Endpoint of each E-RAB, and the RRC Context with the RRC `HandoverPreparationInformation` message (TS 36.423 clause 9.1.1.1, and TS 33.401 clause 7.2.8.4.2).

2. The **target eNodeB** performs admission control for the requested E-RABs and returns an X2AP `Handover Request Acknowledge` message to the **source eNodeB**. The message carries the Old eNB UE X2AP ID, the New eNB UE X2AP ID, the E-RABs Admitted List, with the E-RAB ID and the GTP tunnel endpoints for data forwarding, the E-RABs Not Admitted List, and the Target eNB To Source eNB Transparent Container. The container holds the RRC `HandoverCommand` message (TS 36.423 clause 9.1.1.2), which in turn holds the `RRCConnectionReconfiguration` message that the target eNodeB has prepared for the UE.

3. The **source eNodeB** forwards the handover command of the target eNodeB to the **UE** in an RRC `RRCConnectionReconfiguration` message over the radio interface. The message carries the `mobilityControlInfo` field, with the target physical cell identity, the carrier frequency, timer T304, the new Cell Radio Network Temporary Identifier (C-RNTI), and, optionally, a dedicated random access preamble, together with the `radioResourceConfigDedicated` field and the `securityConfigHO` field, with the security algorithm configuration and the NCC (TS 36.331 clause 6.2.2). The UE leaves the source cell, derives the new KeNB from the received NCC (TS 33.401 clause 7.2.8.4.4), and accesses the target cell.

4. To preserve the packet sequence, the **source eNodeB** sends an X2AP `SN Status Transfer` message to the **target eNodeB**. The message carries the Old eNB UE X2AP ID, the New eNB UE X2AP ID, and the E-

RABs Subject To Status Transfer List, with the E-RAB ID, the Receive Status Of UL PDCP SDUs, the UL COUNT Value, and the DL COUNT Value of each E-RAB, where a COUNT value consists of the PDCP-SN and the HFN (TS 36.423 clause 9.1.1.4).

5. After the **UE** has synchronized to the target cell, it sends an RRC `RRCConnectionReconfigurationComplete` message to the **target eNodeB**, carrying the RRC Transaction Identifier (TS 36.331 clause 6.2.2). From this point, the target eNodeB can deliver the forwarded downlink data to the UE and send the uplink data of the UE towards the S-GW.
6. The **target eNodeB** informs the **MME** that the UE has changed cell by sending an S1AP `Path Switch Request` message over S1-MME (TS 23.401 clause 5.5.1.1.2, step 1b). The message carries the eNB UE S1AP ID, the E-RAB To Be Switched in Downlink List, with the E-RAB ID, the transport layer address, and the GTP-TEID of the target eNodeB for each E-RAB, the Source MME UE S1AP ID, the E-UTRAN CGI, the TAI, and the UE Security Capabilities. For a CSG cell or a hybrid cell, the message also carries the CSG Id, the Cell Access Mode, and the CSG Membership Status (TS 36.413 clause 9.1.5.8).
7. If the MME relocates the S-GW, the **MME** sends a GTPv2 `Create Session Request` message to the **target S-GW** over S11, one message for each PDN connection whose default bearer the target eNodeB has accepted (TS 23.401 clause 5.5.1.1.3, step 2). The message carries the IMSI, the Sender F-TEID for Control Plane, the PGW S5/S8 Address for Control Plane, the RAT Type, the Serving Network, the User Location Information, and the Bearer Contexts to be created, with the EBI, the S1-U eNodeB F-TEID of the target eNodeB, and the S5/S8-U PGW F-TEID. The Indication Flags IE carries the Operation Indication flag set to 1 (TS 29.274 clause 7.2.1). The target S-GW allocates one S1-U uplink TEID for each bearer.
8. If the S-GW is relocated, the **target S-GW** allocates the downlink TEIDs for the traffic from the P-GW and sends a GTPv2 `Modify Bearer Request` message to the **P-GW** over S5/S8, one message for each PDN connection (TS 23.401 clause 5.5.1.1.3, step 3). The message carries the Sender F-TEID for Control Plane of the target S-GW, the Bearer Contexts to be modified, with the EBI and the S5/8-U SGW F-TEID, and, when the MME has provided it, the User Location Information (TS 29.274 clause 7.2.7).
9. If the S-GW is relocated, the **P-GW** updates its context, switches the downlink path to the target S-GW, and returns a GTPv2 `Modify Bearer Response` message to the **target S-GW**. The message carries the Cause set to "Request accepted" (16), the MSISDN, if the P-GW has stored it, the Bearer Contexts modified, with the Charging ID of each bearer, and, when applicable, the Change Reporting Action (TS 29.274 clauses 7.2.8 and 8.4). Immediately after switching the path, the P-GW sends one or more end marker packets on the old path, and the source S-GW forwards these packets to the source eNodeB (TS 23.401 clause 5.5.1.1.3, step 3).
10. If the S-GW is relocated, the **target S-GW** returns a GTPv2 `Create Session Response` message to the **MME** over S11. The message carries the Cause set to "Request accepted" (16), the Sender F-TEID for Control Plane of the target S-GW, and the Bearer Contexts created, with the EBI, the Cause, and the S1-U SGW F-TEID for the uplink traffic of each bearer (TS 29.274 clause 7.2.2). The MME starts the timer that supervises the release of the source S-GW in step 15 (TS 23.401 clause 5.5.1.1.3, step 4).
11. If the S-GW isn't relocated, the **MME** sends a GTPv2 `Modify Bearer Request` message to the **S-GW** that serves the UE over S11, one message for each PDN connection whose default bearer the target eNodeB has accepted (TS 23.401 clause 5.5.1.1.2, step 2). The message carries the Bearer Contexts to be modified, with the EBI and the S1 eNodeB F-TEID of the target eNodeB. It also carries the User Location

Information, if the P-GW has requested location change reporting and the location has changed, and the User CSG Information, if the P-GW has requested it and the information has changed. Because neither the MME nor the S-GW changes, the message doesn't carry the Sender F-TEID for Control Plane (TS 29.274 clause 7.2.7).

12. If the S-GW isn't relocated, the **S-GW** starts sending downlink packets to the target eNodeB and returns a GTPv2 `Modify Bearer Response` message to the **MME**. The message carries the Cause set to "Request accepted" (16) and the Bearer Contexts modified, with the EBI, the Cause, and the S1-U SGW F-TEID of each bearer, and, when applicable, the Change Reporting Action (TS 29.274 clause 7.2.8). Immediately after switching the path, the S-GW sends one or more end marker packets on the old path to assist the reordering function in the target eNodeB (TS 23.401 clause 5.5.1.1.2, steps 4 and 5).
13. The **MME** confirms the path switch by returning an S1AP `Path Switch Request Acknowledge` message to the **target eNodeB**. The message carries the MME UE S1AP ID, the eNB UE S1AP ID, and the Security Context, with one fresh {NH, NCC} pair that the MME computes after it has increased its locally kept NCC by one (TS 33.401 clause 7.2.8.4.2). It carries the UE-AMBR if the value has changed and the E-RAB To Be Switched in Uplink List, with the S-GW transport layer address and GTP-TEID of each E-RAB, if the uplink tunnel endpoints have changed. If some bearers failed in the core network, the message carries the E-RAB To Be Released List (TS 36.413 clauses 8.4.4.2 and 9.1.5.9, and TS 23.401 clause 5.5.1.1.2, step 6).
14. The **target eNodeB** informs the **source eNodeB** that the handover has succeeded by sending an X2AP `UE Context Release` message, which carries the Old eNB UE X2AP ID and the New eNB UE X2AP ID. The source eNodeB then releases the radio and control-plane resources of the UE. The target eNodeB sends this message only after it has received the `Path Switch Request Acknowledge` message, and any ongoing data forwarding can continue after the release (TS 36.300 clause 10.1.2.1.1, steps 17 and 18, TS 36.423 clause 8.2.3, and TS 23.401 clause 5.5.1.1.2, step 7).
15. If the S-GW is relocated, the **MME** releases the bearers in the **source S-GW** when the timer of step 10 expires, by sending a GTPv2 `Delete Session Request` message over S11. The message carries the Indication Flags, with the Operation Indication flag not set, so that the source S-GW doesn't start a deletion towards the P-GW, and with the Scope Indication flag set to 1, together with the User Location Information. The message carries a Cause only when it also deactivates ISR, with the value "ISR deactivation" (TS 23.401 clause 5.5.1.1.3, step 7, and TS 29.274 clause 7.2.9.1).
16. The **source S-GW** releases the bearer resources of the UE and returns a GTPv2 `Delete Session Response` message to the **MME** over S11, with the Cause set to "Request accepted" (16) (TS 29.274 clause 7.2.10).

After the handover, the UE starts a Tracking Area Update procedure when one of the TAU triggers applies, and the MME then performs only a subset of the procedure because the UE is in ECM-CONNECTED mode (TS 23.401 clauses 5.5.1.1.2 and 5.5.1.1.3, step 8).

6.7.1.4. Summary of Key Information Elements

The following table summarizes the key IEs of the main messages of the procedure, grouped by protocol.

PROTOCOL	MESSAGE	KEY IES
X2AP (TS 36.423)	`Handover Request`	Old eNB UE X2AP ID, Cause, Target Cell ID (ECGI), GUMMEI, UE Context Information: MME UE S1AP ID, UE Security Capabilities, AS Security Information (KeNB*, NCC), UE-AMBR, E-RABs To Be Setup List, RRC Context
X2AP (TS 36.423)	`Handover Request Acknowledge`	Old eNB UE X2AP ID, New eNB UE X2AP ID, E-RABs Admitted List (forwarding GTP tunnel endpoints), E-RABs Not Admitted List, Target eNB To Source eNB Transparent Container
X2AP (TS 36.423)	`SN Status Transfer`	Old eNB UE X2AP ID, New eNB UE X2AP ID, E-RABs Subject To Status Transfer List: E-RAB ID, Receive Status Of UL PDCP SDUs, UL COUNT Value, DL COUNT Value
X2AP (TS 36.423)	`UE Context Release`	Old eNB UE X2AP ID, New eNB UE X2AP ID
S1AP (TS 36.413)	`Path Switch Request`	eNB UE S1AP ID, E-RAB To Be Switched in Downlink List (transport layer address, GTP-TEID), Source MME UE S1AP ID, E-UTRAN CGI, TAI, UE Security Capabilities
S1AP (TS 36.413)	`Path Switch Request Acknowledge`	MME UE S1AP ID, eNB UE S1AP ID, Security Context ({NH, NCC}), UE-AMBR, E-RAB To Be Switched in Uplink List (S-GW transport layer address, GTP-TEID), E-RAB To Be Released List
GTPv2-C (TS 29.274)	`Create Session Request` (S-GW relocation)	IMSI, Sender F-TEID for Control Plane, PGW S5/S8 Address for Control Plane, RAT Type, ULI, Bearer Contexts to be created (EBI, S1-U eNodeB F-TEID), Indication Flags (Operation Indication)
GTPv2-C (TS 29.274)	`Create Session Response` (S-GW relocation)	Cause ("Request accepted", 16), Sender F-TEID for Control Plane, Bearer Contexts created (EBI, Cause, S1-U SGW F-TEID)
GTPv2-C (TS 29.274)	`Modify Bearer Request`	Bearer Contexts to be modified (EBI, S1 eNodeB F-TEID on S11, S5/8-U SGW F-TEID on S5/S8), ULI, Sender F-TEID for Control Plane (S5/S8 with S-GW relocation)
GTPv2-C (TS 29.274)	`Modify Bearer Response`	Cause ("Request accepted", 16), Bearer Contexts modified (EBI, Cause, S1-U SGW F-TEID on S11, Charging ID on S5/S8)

6.7.1.5. Possible Failures and Required Actions

Admission control rejection by the target eNodeB

If the target eNodeB doesn't admit at least one non-GBR E-RAB, or another failure occurs during the handover preparation, the target eNodeB sends an X2AP `Handover Preparation Failure` message to the source eNodeB with an appropriate Cause (TS 36.423 clause 8.2.1.3), for example "No Radio Resources Available in Target Cell" or "Cell not Available" (TS 36.423 clause 9.2.6). The handover doesn't take place, and the UE stays in the source cell. The source eNodeB can choose another target cell or start an S1-based handover, which TS 23.401 clause 5.5.1.2.2, step 1, lists as a response to an error indication from the target eNodeB after an unsuccessful X2-based handover.

Path switch rejection by the EPC

If none of the default EPS bearers has been switched successfully in the core network, or if the target eNodeB hasn't accepted any of them, the MME sends an S1AP `Path Switch Request Failure` message to the target eNodeB (TS 23.401 clause 5.5.1.1.2, step 6). Causes in the core network include a target S-GW

that rejects the `Create Session Request` message, for example with GTP Cause #73, "No resources available" (TS 29.274 clause 8.4), and a `Path Switch Request` message without the CSG Membership Status IE from a hybrid cell whose CSG differs from that of the source cell (TS 36.413 clause 8.4.4.4). The message carries a Cause IE (TS 36.413 clause 9.1.5.10), for example "Unknown or already allocated MME UE S1AP ID" (TS 36.413 clause 9.2.1.3). The target eNodeB decides its subsequent actions (TS 36.413 clause 8.4.4.3). The MME detaches the UE explicitly with the MME-initiated detach procedure of TS 23.401 clause 5.3.8.3. Because the UE is in ECM-CONNECTED mode, the MME sends a NAS `Detach Request` message to the UE, releases the bearers in the S-GW with GTPv2 `Delete Session Request` messages, and finally releases the signaling connection. If the MME sets the Detach Type to require a re-attach, the UE attaches again at the end of the detach (TS 23.401 clause 5.3.8.3, steps 1, 2, and 12).

Handover failure at the target cell

If the UE fails to synchronize to the target cell before timer T304 expires, for example because of interference or a failed random access, the UE detects a handover failure (TS 36.331 clause 5.3.5.6). The UE reverts to the configuration of the source cell and starts the RRC connection re-establishment procedure, with the `reestablishmentCause` set to `handoverFailure` (TS 36.331 clause 5.3.7.4). The source eNodeB and the UE keep part of the UE context, for example the C-RNTI, so that the UE can return after a handover failure (TS 36.300 clause 10.1.2.1.0). The source eNodeB releases this context only when it receives the X2AP `UE Context Release` message (TS 36.300 clause 10.1.2.1.1, step 18). An eNodeB that finds a context matching the identity of the UE, including an eNodeB that has admitted the UE in an earlier handover preparation, indicates to the UE that the connection can be resumed (TS 36.300 clause 10.1.6). If the re-establishment fails, for example because timer T311 expires or the network rejects the request, the UE leaves the RRC_CONNECTED state with the release cause "RRC connection failure" (TS 36.331 clauses 5.3.7.6 and 5.3.7.8). The NAS layer then recovers the NAS signaling connection with a Tracking Area Update when no uplink signaling or user data is pending (TS 24.301 clause 5.5.3.2.2, case i), or with a Service Request when user data is pending (TS 24.301 clause 5.6.1.1).

6.7.1.6. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 5.5.1.1.1 — X2-based handover, general • Clause 5.5.1.1.2 — X2-based handover without Serving GW relocation • Clause 5.5.1.1.3 — X2-based handover with Serving GW relocation • Clause 5.3.8.3 — MME-initiated detach procedure
TS 36.423	• Clauses 8.2.1, 8.2.2, and 8.2.3 — Handover Preparation, SN Status Transfer, and UE Context Release procedures • Clauses 9.1.1.1 to 9.1.1.5 — HANDOVER REQUEST, HANDOVER REQUEST ACKNOWLEDGE, HANDOVER PREPARATION FAILURE, SN STATUS TRANSFER, and UE CONTEXT RELEASE message contents • Clause 9.2.6 — Cause

SPECIFICATION	CLAUSES AND COVERAGE
TS 36.413	• Clause 8.4.4 — Path Switch Request procedure • Clauses 9.1.5.8, 9.1.5.9, and 9.1.5.10 — PATH SWITCH REQUEST, PATH SWITCH REQUEST ACKNOWLEDGE, and PATH SWITCH REQUEST FAILURE message contents • Clause 9.2.1.3 — Cause
TS 29.274	• Clauses 7.2.1 and 7.2.2 — Create Session Request/Response • Clauses 7.2.7 and 7.2.8 — Modify Bearer Request/Response • Clauses 7.2.9 and 7.2.10 — Delete Session Request/Response • Table 8.4-1 — Cause values • Annex C — Cause mapping
TS 33.401	• Clause 7.2.8.4.2 — Key derivation in X2-handover • Clause 7.2.8.4.4 — UE handling of the NCC in a handover
TS 36.300	• Clause 10.1.2.1 — Intra-E-UTRAN handover, C-plane and U-plane handling • Clause 10.1.2.2 — Path switch and end marker packets • Clause 10.1.6 — Radio link failure
TS 36.331	• Clause 5.3.5.6 — T304 expiry (handover failure) • Clause 5.3.7 — RRC connection re-establishment • Clause 6.2.2 — RRCConnectionReconfiguration and RRCConnectionReconfigurationComplete message contents
TS 24.301	• Clause 5.5.3.2.2 — Tracking area updating procedure initiation • Clause 5.6.1.1 — Service request procedure

6.7.2. S1-Based Handover Procedure with MME Relocation

6.7.2.1. Technical Overview

The S1-based handover procedure moves a UE in ECM-CONNECTED mode from a source eNodeB to a target eNodeB through the EPC, over S1-MME, when the X2-based handover can't be used (TS 23.401 clause 5.5.1.2.1). The source eNodeB can start the procedure, for example, because it has no X2 connectivity to the target eNodeB, because the target eNodeB has returned an error indication after an unsuccessful X2-based handover, or because of dynamic information that the source eNodeB has learned (TS 23.401 clause 5.5.1.2.2, step 1). The MME prepares the target radio and transport resources before the source eNodeB commands the UE to change cell.

The S1-based handover can relocate the MME, the S-GW, or both. The source MME selects the target MME, and TS 23.401 recommends that the MME isn't relocated during an inter-eNodeB handover unless the UE leaves the MME pool area that serves it. The target MME then determines whether the S-GW needs to be relocated, and if so selects the target S-GW (TS 23.401 clause 5.5.1.2.1). This section describes the procedure with MME relocation, in which the source MME and the target MME exchange the UE context over S10, both with and without S-GW relocation. The procedure without MME relocation is described in S1-Based Handover Procedure without MME Relocation.

The procedure has these high-level effects on the network elements:

On the UE

The UE stays in the ECM-CONNECTED state and in the EMM-REGISTERED state while it switches its radio connection from the source cell to the target cell. It applies the radio configuration of the target cell and derives a new KeNB from the NCC that it receives in the handover command (TS 33.401 clause 7.2.8.4.4).

On the source eNodeB

The source eNodeB starts the handover with the S1AP `Handover Required` message, decides which E-RABs are subject to data forwarding, and forwards downlink and, optionally, uplink data either directly to the target eNodeB or indirectly through the source and target S-GWs. It transfers the PDCP-SN and HFN status of the E-RABs and releases its resources when the source MME sends the S1AP `UE Context Release Command` message (TS 23.401 clause 5.5.1.2.1 and clause 5.5.1.2.2, steps 10 and 19).

On the target eNodeB

The target eNodeB performs admission control for the requested E-RABs, allocates the radio resources, builds the handover command for the UE, receives the forwarded data, and starts serving the user traffic when the UE has arrived in the target cell (TS 23.401 clause 5.5.1.2.2).

On the source MME and the target MME

The source MME computes a fresh {NH, NCC} pair and sends it, together with the rest of the UE context, to the target MME over S10. The target MME passes the {NH, NCC} pair to the target eNodeB, manages the bearers in the S-GW over S11, and switches the downlink user-plane path to the target eNodeB (TS 33.401 clause 7.2.8.4.3, and TS 23.401 clause 5.5.1.2.2).

On the S-GW

The S-GW allocates the uplink and downlink GTP-U tunnel endpoints. With S-GW relocation, the target S-GW establishes the S5/S8 bearers towards the P-GW, and the source S-GW forwards the end marker packets of the P-GW to the source eNodeB (TS 23.401 clause 5.5.1.2.2, step 16).

On the P-GW

The P-GW remains the anchor of the PDN connection on SGi. With S-GW relocation, the P-GW switches the downlink path to the target S-GW and sends one or more end marker packets on the old path (TS 23.401 clause 5.5.1.2.2, step 16).

6.7.2.2. Call Flow

The call flow has four phases: Handover Preparation, Handover Execution, Handover Completion, and Resource Release. When the S-GW isn't relocated, the source S-GW also acts as the target S-GW in the figure (TS 23.401 clause 5.5.1.2.2, NOTE 2).

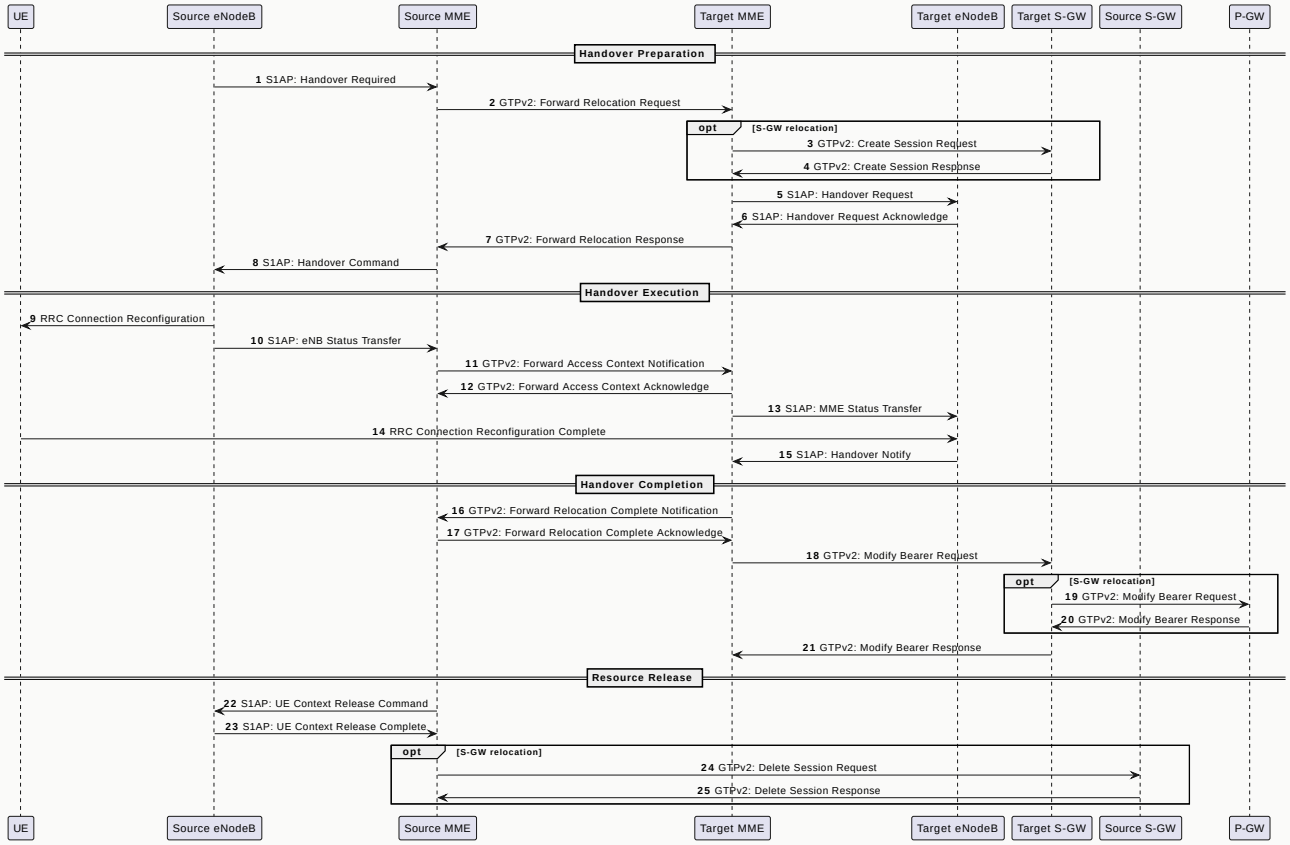


Figure 23. S1-based handover procedure with MME relocation call flow

6.7.2.3. Step-by-Step Description

1. The **source eNodeB** decides on an S1-based handover and sends an S1AP `Handover Required` message to the **source MME** over S1-MME. The message carries the MME UE S1AP ID, the eNB UE S1AP ID, the Handover Type set to "IntraLTE", the Cause, for example "Handover desirable for radio reasons", the Target ID, with the Global eNB ID of the target eNodeB and the selected TAI, the Direct Forwarding Path Availability, and the Source to Target Transparent Container (TS 36.413 clauses 9.1.5.1 and 9.2.1.6). For a handover within E-UTRAN, the container is the Source eNB to Target eNB Transparent Container, with the RRC Container, the E-RABs Information List, which marks the E-RABs that the source eNodeB proposes for downlink forwarding, the Target Cell ID (ECGI), the Subscriber Profile ID for RAT/Frequency priority, and the UE History Information (TS 36.413 clause 9.2.1.7). The container also carries the AS ciphering and integrity algorithms of the source cell (TS 33.401 clause 7.2.8.4.3).
2. The **source MME** selects the target MME and sends a GTPv2 `Forward Relocation Request` message to the **target MME** over S10 (TS 23.401 clause 5.5.1.2.2, step 3). On receiving the `Handover Required` message, the source MME has increased its locally kept NCC by one and computed a fresh NH (TS 33.401 clause 7.2.8.4.3). The message carries the IMSI, the Sender’s F-TEID for Control Plane, the Target Identification, the SGW S11/S4 IP Address and TEID for Control Plane, the S1-AP Cause, which holds the cause that the source eNodeB has sent, and the E-UTRAN Transparent Container, which holds the Source to Target Transparent Container. It also carries the MME/SGSN/AMF UE MM Context, with the EPS security context, that is the KASME, its eKSI, and the fresh {NH, NCC} pair, and the UE Network Capability, and the MME/SGSN/AMF UE EPS PDN Connections, with the APN, the PGW S5/S8 IP Address for Control Plane, and the bearer contexts, with the EBI, the Bearer Level QoS, the SGW S1/S4/S12 IP

Address and TEID for user plane, and the PGW S5/S8 IP Address and TEID for user plane (TS 29.274 clause 7.3.1, and TS 33.401 clause 7.2.8.4.3).

3. If the target MME relocates the S-GW, the **target MME** sends a GTPv2 `Create Session Request` message to the **target S-GW** over S11, one message for each PDN connection (TS 23.401 clause 5.5.1.2.2, step 4). The message carries the IMSI, the Sender F-TEID for Control Plane of the target MME, the PGW S5/S8 Address for Control Plane, the RAT Type, the Serving Network, the Indication Flags, and the Bearer Contexts to be created, with the EBI, the Bearer Level QoS, and the S5/S8-U PGW F-TEID (TS 29.274 clause 7.2.1). Unlike the X2-based handover, the message doesn't carry the User Location Information, which the target MME sends later in the `Modify Bearer Request` message (TS 29.274 clause 7.2.1, and TS 23.401 clause 5.5.1.2.2, steps 4 and 15).
4. If the S-GW is relocated, the **target S-GW** allocates one S1-U uplink TEID for each bearer and returns a GTPv2 `Create Session Response` message to the **target MME** over S11. The message carries the Cause set to "Request accepted" (16), the Sender F-TEID for Control Plane of the target S-GW, and the Bearer Contexts created, with the EBI, the Cause, and the S1-U SGW F-TEID of each bearer (TS 29.274 clause 7.2.2).
5. The **target MME** sends an S1AP `Handover Request` message to the **target eNodeB** to create the UE context there (TS 23.401 clause 5.5.1.2.2, step 5). The message carries the MME UE S1AP ID, the Handover Type set to "IntraLTE", the Cause, the UE-AMBR, the E-RABs To Be Setup List, with the E-RAB ID, the transport layer address and the GTP-TEID of the S-GW for the uplink, and the E-RAB Level QoS Parameters, such as the QCI and the ARP, the Source to Target Transparent Container, the UE Security Capabilities, the Handover Restriction List, if available, and the Security Context, with the {NH, NCC} pair from the source MME (TS 36.413 clause 9.1.5.4, and TS 33.401 clause 7.2.8.4.3).
6. The **target eNodeB** performs admission control for the requested E-RABs and returns an S1AP `Handover Request Acknowledge` message to the **target MME**. The message carries the MME UE S1AP ID, the eNB UE S1AP ID, the E-RABs Admitted List, with the E-RAB ID, the transport layer address and the GTP-TEID of the target eNodeB for the downlink, and, if forwarding applies, the DL and UL transport layer addresses and GTP-TEIDs for the forwarded data, the E-RABs Failed to Setup List, and the Target to Source Transparent Container (TS 36.413 clause 9.1.5.5). The container holds the RRC handover command for the UE, with the NCC from the received {NH, NCC} pair (TS 33.401 clause 7.2.8.4.3).
7. The **target MME** returns a GTPv2 `Forward Relocation Response` message to the **source MME** over S10. The message carries the Cause set to "Request accepted" (16), the Sender's F-TEID for Control Plane of the target MME, the Indication Flags, with the SGW Change Indication set to 1 if the target MME has selected a new S-GW, the List of Set-up Bearers, with the EBI and the eNodeB F-TEID for DL data forwarding or, with indirect forwarding and S-GW relocation, the SGW F-TEID for DL data forwarding, and the E-UTRAN Transparent Container, which holds the Target to Source Transparent Container (TS 29.274 clause 7.3.2).
8. The **source MME** sends an S1AP `Handover Command` message to the **source eNodeB**. The message carries the MME UE S1AP ID, the eNB UE S1AP ID, the Handover Type, the E-RABs Subject to Forwarding List, with the E-RAB ID and the DL and UL transport layer addresses and GTP-TEIDs for data forwarding, the E-RABs to Release List, and the Target to Source Transparent Container (TS 36.413 clause 9.1.5.2, and TS 23.401 clause 5.5.1.2.2, step 9).

9. The **source eNodeB** builds the handover command from the Target to Source Transparent Container and sends it to the **UE** in an RRC `RRCConnectionReconfiguration` message (TS 23.401 clause 5.5.1.2.2, step 9a). The message carries the `mobilityControlInfo` field, with the target physical cell identity, the carrier frequency, timer T304, the new C-RNTI, and, optionally, a dedicated random access preamble, the `radioResourceConfigDedicated` field, and the `securityConfigHO` field, with the security algorithm configuration and the NCC (TS 36.331 clause 6.2.2). The UE removes any EPS bearer for which it hasn't received a radio bearer in the target cell, derives the new KeNB, and accesses the target cell (TS 23.401 clause 5.5.1.2.2, step 9a, and TS 33.401 clause 7.2.8.4.4).
10. The **source eNodeB** sends an S1AP `eNB Status Transfer` message to the **source MME**, carrying the MME UE S1AP ID, the eNB UE S1AP ID, and the eNB Status Transfer Transparent Container (TS 36.413 clause 9.1.5.13). The container holds the E-RABs Subject to Status Transfer List, with the E-RAB ID, the UL COUNT value, and the DL COUNT value of each E-RAB for which PDCP-SN and HFN status preservation applies (TS 36.413 clause 8.4.6). The source eNodeB can omit the message when none of the E-RABs needs PDCP status preservation (TS 23.401 clause 5.5.1.2.2, step 10).
11. Because the MME is relocated, the **source MME** sends the status information to the **target MME** in a GTPv2 `Forward Access Context Notification` message over S10 (TS 23.401 clause 5.5.1.2.2, step 10). The message carries the E-UTRAN Transparent Container, which holds the eNB Status Transfer Transparent Container (TS 29.274 clause 7.3.10).
12. The **target MME** acknowledges the status information by returning a GTPv2 `Forward Access Context Acknowledge` message to the **source MME**, with the Cause set to "Request accepted" (16) (TS 29.274 clause 7.3.11).
13. The **target MME** sends the status information to the **target eNodeB** in an S1AP `MME Status Transfer` message, carrying the MME UE S1AP ID, the eNB UE S1AP ID, and the eNB Status Transfer Transparent Container (TS 36.413 clause 9.1.5.14).
14. After the **UE** has synchronized to the target cell, it sends an RRC `RRCConnectionReconfigurationComplete` message to the **target eNodeB**, carrying the RRC Transaction Identifier (TS 36.331 clause 6.2.2). The target eNodeB can then deliver the forwarded downlink data to the UE, and the uplink data of the UE flows to the target S-GW and on to the P-GW (TS 23.401 clause 5.5.1.2.2, step 12).
15. The **target eNodeB** informs the **target MME** that the UE has arrived in the target cell by sending an S1AP `Handover Notify` message, which carries the MME UE S1AP ID, the eNB UE S1AP ID, the E-UTRAN CGI, and the TAI of the target cell (TS 36.413 clause 9.1.5.7).
16. The **target MME** sends a GTPv2 `Forward Relocation Complete Notification` message to the **source MME** over S10 (TS 23.401 clause 5.5.1.2.2, step 14). The message has no mandatory IE, and it carries the Indication Flags IE only when one of its flags is set to 1 (TS 29.274 clause 7.3.3).
17. The **source MME** returns a GTPv2 `Forward Relocation Complete Acknowledge` message to the **target MME**, with the Cause set to "Request accepted" (16) (TS 29.274 clause 7.3.4). The source MME starts a timer that supervises the release of the resources in the source eNodeB and, if the S-GW is relocated, in the source S-GW (TS 23.401 clause 5.5.1.2.2, step 14).
18. The **target MME** sends a GTPv2 `Modify Bearer Request` message to the **target S-GW** over S11, one message for each PDN connection (TS 23.401 clause 5.5.1.2.2, step 15). When the S-GW isn't relocated, the target S-GW is the source S-GW. The message carries the Bearer Contexts to be modified, with the

EBI and the S1 eNodeB F-TEID of the target eNodeB for the downlink, and, when they apply, the User Location Information, the Serving Network, and the User CSG Information. When the S-GW isn't relocated, the message also carries the Sender F-TEID for Control Plane of the target MME (TS 29.274 clause 7.2.7).

19. If the S-GW is relocated, the **target S-GW** allocates the downlink TEIDs for the traffic from the P-GW and sends a GTPv2 `Modify Bearer Request` message to the **P-GW** over S5/S8, one message for each PDN connection. The message carries the Sender F-TEID for Control Plane of the target S-GW, the Bearer Contexts to be modified, with the EBI and the S5/8-U SGW F-TEID, and, when the MME has provided it, the User Location Information (TS 23.401 clause 5.5.1.2.2, step 16, and TS 29.274 clause 7.2.7).
20. If the S-GW is relocated, the **P-GW** updates its context, switches the downlink path to the target S-GW, and returns a GTPv2 `Modify Bearer Response` message to the **target S-GW**. The message carries the Cause set to "Request accepted" (16), the MSISDN, if the P-GW has stored it, and the Bearer Contexts modified, with the Charging ID of each bearer (TS 29.274 clause 7.2.8). Immediately after switching the path, the P-GW sends one or more end marker packets on the old path, and the source S-GW forwards these packets to the source eNodeB (TS 23.401 clause 5.5.1.2.2, step 16).
21. The **target S-GW** returns a GTPv2 `Modify Bearer Response` message to the **target MME** over S11. The message carries the Cause set to "Request accepted" (16), the Bearer Contexts modified, with the EBI, the Cause, and the S1-U SGW F-TEID of each bearer, and, when applicable, the Change Reporting Action (TS 29.274 clause 7.2.8). If the S-GW isn't relocated, the S-GW sends one or more end marker packets on the old path immediately after switching the path (TS 23.401 clause 5.5.1.2.2, step 17).
22. When the timer of step 17 expires, the **source MME** sends an S1AP `UE Context Release Command` message to the **source eNodeB**, carrying the UE S1AP IDs and a Cause, for example "Successful Handover" (TS 23.401 clause 5.5.1.2.2, step 19, and TS 36.413 clauses 9.1.4.6 and 9.2.1.3).
23. The **source eNodeB** releases its resources for the UE and returns an S1AP `UE Context Release Complete` message to the **source MME** (TS 23.401 clause 5.5.1.2.2, step 19, and TS 36.413 clause 9.1.4.7).
24. If the source MME has received the SGW Change Indication in the `Forward Relocation Response` message, the **source MME** deletes the bearer resources in the **source S-GW** when the timer of step 17 expires, by sending a GTPv2 `Delete Session Request` message over S11. The message carries the Indication Flags, with the Operation Indication flag not set, so that the source S-GW doesn't start a deletion towards the P-GW, and with the Scope Indication flag set to 1, together with the User Location Information. The message carries a Cause only when it also deactivates ISR, with the value "ISR deactivation" (TS 23.401 clause 5.5.1.2.2, step 19, and TS 29.274 clause 7.2.9.1).
25. The **source S-GW** releases the bearer resources of the UE and returns a GTPv2 `Delete Session Response` message to the **source MME**, with the Cause set to "Request accepted" (16) (TS 29.274 clause 7.2.10).

The figure doesn't show indirect data forwarding. When indirect forwarding applies, the target MME and the source MME set up the forwarding tunnels in the S-GW with GTPv2 `Create Indirect Data Forwarding Tunnel Request` messages during the preparation phase, and release them with GTPv2 `Delete Indirect Data Forwarding Tunnel Request` messages when their timers expire (TS 23.401 clause 5.5.1.2.2, steps 6, 8, 20, and 21). After the handover, the UE starts a Tracking Area Update procedure when one of the TAU triggers applies, and the target MME performs only a subset of the procedure (TS 23.401 clause 5.5.1.2.2, step 18).

6.7.2.4. Summary of Key Information Elements

The following table summarizes the key IEs of the main messages of the procedure, grouped by protocol.

PROTOCOL	MESSAGE	KEY IES
S1AP (TS 36.413)	`Handover Required`	MME UE S1AP ID, eNB UE S1AP ID, Handover Type, Cause, Target ID (Global eNB ID, selected TAI), Direct Forwarding Path Availability, Source to Target Transparent Container
GTPv2-C (TS 29.274)	`Forward Relocation Request`	IMSI, Sender's F-TEID for Control Plane, MME/SGSN/AMF UE MM Context (KASME, eKSI, {NH, NCC}), MME/SGSN/AMF UE EPS PDN Connections, SGW S11/S4 IP Address and TEID for Control Plane, Target Identification, S1-AP Cause, E-UTRAN Transparent Container
GTPv2-C (TS 29.274)	`Create Session Request` (S-GW relocation)	IMSI, Sender F-TEID for Control Plane, PGW S5/S8 Address for Control Plane, RAT Type, Serving Network, Bearer Contexts to be created (EBI, Bearer Level QoS)
GTPv2-C (TS 29.274)	`Create Session Response` (S-GW relocation)	Cause ("Request accepted", 16), Sender F-TEID for Control Plane, Bearer Contexts created (EBI, Cause, S1-U SGW F-TEID)
S1AP (TS 36.413)	`Handover Request`	MME UE S1AP ID, Handover Type, Cause, UE-AMBR, E-RABs To Be Setup List (S-GW transport layer address and GTP-TEID, E-RAB Level QoS Parameters), Source to Target Transparent Container, Security Context ({NH, NCC})
S1AP (TS 36.413)	`Handover Request Acknowledge`	MME UE S1AP ID, eNB UE S1AP ID, E-RABs Admitted List (target eNodeB transport layer address and GTP-TEID, forwarding addresses), E-RABs Failed to Setup List, Target to Source Transparent Container
GTPv2-C (TS 29.274)	`Forward Relocation Response`	Cause ("Request accepted", 16), Sender's F-TEID for Control Plane, Indication Flags (SGW Change Indication), List of Set-up Bearers (forwarding F-TEIDs), E-UTRAN Transparent Container
S1AP (TS 36.413)	`Handover Command`	MME UE S1AP ID, eNB UE S1AP ID, Handover Type, E-RABs Subject to Forwarding List, E-RABs to Release List, Target to Source Transparent Container
GTPv2-C (TS 29.274)	`Forward Access Context Notification`	E-UTRAN Transparent Container (eNB Status Transfer Transparent Container)
S1AP (TS 36.413)	`Handover Notify`	MME UE S1AP ID, eNB UE S1AP ID, E-UTRAN CGI, TAI
GTPv2-C (TS 29.274)	`Modify Bearer Request`	Bearer Contexts to be modified (EBI, S1 eNodeB F-TEID on S11, S5/8-U SGW F-TEID on S5/S8), ULI, Sender F-TEID for Control Plane (S11 with MME change and no S-GW change, S5/S8 with S-GW change)
GTPv2-C (TS 29.274)	`Modify Bearer Response`	Cause ("Request accepted", 16), Bearer Contexts modified (EBI, Cause, S1-U SGW F-TEID on S11, Charging ID on S5/S8)

6.7.2.5. Possible Failures and Required Actions

Resource allocation failure in the target eNodeB

If the target eNodeB can't allocate resources for any of the requested EPS bearers, it sends an S1AP

`Handover Failure` message to the target MME, with a Cause such as "No Radio Resources Available in Target Cell" or "Cell not available" (TS 36.413 clauses 9.1.5.6 and 9.2.1.3). The target MME also rejects the handover if the target eNodeB accepts it but none of the default EPS bearers is in the EPS Bearer Setup list. In both cases, the target MME clears the resources that it has reserved for the UE. If the S-GW was relocated, the target MME deletes the bearer resources in the target S-GW with GTPv2 `Delete Session Request` messages. The target MME then sends a GTPv2 `Forward Relocation Response` message with a rejection Cause to the source MME, and the source MME sends an S1AP `Handover Preparation Failure` message to the source eNodeB (TS 23.401 clause 5.5.1.2.3), for example with the Cause "Handover Failure In Target EPC/eNB Or Target System" (TS 36.413 clause 9.2.1.3). TS 29.274 clause 7.3.2 lists "Relocation failure" (81) as a message-specific Cause of the `Forward Relocation Response` message, which also carries the S1-AP Cause that the target eNodeB has returned. The UE stays in the source eNodeB and the source MME (TS 23.401 clause 5.5.1.2.3).

Access restriction in the target cell

When the source eNodeB provides a CSG ID, the source MME checks the CSG subscription of the UE. If the subscription has no entry for this CSG ID, or the entry has expired, and the target cell is a CSG cell, the source MME rejects the handover with an appropriate cause, unless the UE has emergency bearer services (TS 23.401 clause 5.5.1.2.2, step 3). The source MME then returns an S1AP `Handover Preparation Failure` message to the source eNodeB, for example with the Cause "Handover Target not allowed" (TS 36.413 clause 9.2.1.3), and the source eNodeB can evaluate other target cells.

Handover failure at the target cell

If the UE fails to synchronize to the target cell before timer T304 expires, the UE detects a handover failure (TS 36.331 clause 5.3.5.6). The UE reverts to the configuration of the source cell and starts the RRC connection re-establishment procedure, with the `reestablishmentCause` set to `handoverFailure` (TS 36.331 clause 5.3.7.4). If the cell that receives the re-establishment request has the UE context, for example the source eNodeB, the radio connection is restored, because the source eNodeB keeps part of the UE context to allow the UE to return after a handover failure (TS 36.300 clauses 10.1.2.1.0 and 10.1.6). If the re-establishment fails, the UE leaves the RRC_CONNECTED state with the release cause "RRC connection failure" (TS 36.331 clauses 5.3.7.6 and 5.3.7.8). The NAS layer then recovers the NAS signaling connection with a Tracking Area Update when no uplink signaling or user data is pending (TS 24.301 clause 5.5.3.2.2, case i), or with a Service Request when user data is pending (TS 24.301 clause 5.6.1.1). The source eNodeB can cancel an ongoing or already prepared handover with an S1AP `Handover Cancel` message (TS 36.413 clause 8.4.5), although TS 23.401 clause 5.5.1.2.4 allows the cancellation only up to the time when the source eNodeB sends the handover command to the UE.

6.7.2.6. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 5.5.1.2.1 — S1-based handover, general • Clause 5.5.1.2.2 — S1-based handover, normal • Clause 5.5.1.2.3 — S1-based handover, Reject • Clause 5.5.1.2.4 — S1-based handover, Cancel

SPECIFICATION	CLAUSES AND COVERAGE
TS 36.413	• Clause 8.4.1 — Handover Preparation procedure • Clause 8.4.2 — Handover Resource Allocation procedure • Clause 8.4.3 — Handover Notification procedure • Clause 8.4.5 — Handover Cancellation procedure • Clauses 8.4.6 and 8.4.7 — eNB Status Transfer and MME Status Transfer procedures • Clauses 9.1.5.1 to 9.1.5.7, 9.1.5.13, and 9.1.5.14 — handover message contents • Clauses 9.1.4.6 and 9.1.4.7 — UE CONTEXT RELEASE COMMAND and UE CONTEXT RELEASE COMPLETE message contents • Clause 9.2.1.3 — Cause
TS 29.274	• Clauses 7.3.1 and 7.3.2 — Forward Relocation Request/Response • Clauses 7.3.3 and 7.3.4 — Forward Relocation Complete Notification/Acknowledge • Clauses 7.3.10 and 7.3.11 — Forward Access Context Notification/Acknowledge • Clauses 7.2.1 and 7.2.2 — Create Session Request/Response • Clauses 7.2.7 and 7.2.8 — Modify Bearer Request/Response • Clauses 7.2.9 and 7.2.10 — Delete Session Request/Response • Table 8.4-1 — Cause values • Annex C — Cause mapping
TS 33.401	• Clause 7.2.8.4.3 — Key derivation in S1-handover • Clause 7.2.8.4.4 — UE handling of the NCC in a handover
TS 36.300	• Clause 10.1.2.1.0 — Context kept in the source eNB for a return after a handover failure • Clause 10.1.6 — Radio link failure • Clause 19.2.2.5.4 — Handover cancellation
TS 36.331	• Clause 5.3.5.6 — T304 expiry (handover failure) • Clause 5.3.7 — RRC connection re-establishment • Clause 6.2.2 — RRCConnectionReconfiguration and RRCConnectionReconfigurationComplete message contents
TS 24.301	• Clause 5.5.3.2.2 — Tracking area updating procedure initiation • Clause 5.6.1.1 — Service request procedure

6.7.3. S1-Based Handover Procedure without MME Relocation

6.7.3.1. Technical Overview

The S1-based handover procedure without MME relocation moves a UE in ECM-CONNECTED mode from a source eNodeB to a target eNodeB through the MME, over S1-MME, when the X2-based handover can't be used and the MME that serves the UE doesn't change (TS 23.401 clause 5.5.1.2.1). Because the MME isn't relocated, the procedure needs no S10 signaling: the single MME performs the roles of both the source MME and the target MME and exchanges the S1AP messages with both eNodeBs (TS 23.401 clause 5.5.1.2.2,

and TS 33.401 clause 7.2.8.4.3, NOTE). The MME decides whether the S-GW is relocated (TS 23.401 clause 5.5.1.2.2, step 4). When no direct forwarding path is available between the eNodeBs, the MME can set up indirect data forwarding through the S-GW (TS 23.401 clause 5.5.1.2.1).

The procedure has these high-level effects on the network elements:

On the UE

The UE stays in the ECM-CONNECTED state and in the EMM-REGISTERED state while it switches its radio connection from the source cell to the target cell. It applies the radio configuration of the target cell and derives a new KeNB from the NCC that it receives in the handover command (TS 33.401 clause 7.2.8.4.4).

On the source eNodeB

The source eNodeB starts the handover with the S1AP `Handover Required` message, receives the forwarding tunnel endpoints in the S1AP `Handover Command` message, and forwards downlink and, optionally, uplink data directly to the target eNodeB or indirectly through the S-GW. It sends the PDCP-SN and HFN status of the E-RABs to the MME and releases its resources when the MME sends the S1AP `UE Context Release Command` message (TS 23.401 clauses 5.5.1.2.1 and 5.5.1.2.2).

On the target eNodeB

The target eNodeB performs admission control for the requested E-RABs, allocates the radio resources, builds the handover command for the UE, receives the PDCP-SN and HFN status in the S1AP `MME Status Transfer` message, and starts serving the user traffic when the UE has arrived in the target cell (TS 23.401 clause 5.5.1.2.2).

On the MME

The MME coordinates the procedure. It increases its locally kept NCC by one, computes a fresh NH from the KASME, and sends the {NH, NCC} pair to the target eNodeB (TS 33.401 clause 7.2.8.4.3). It relays the PDCP status from the source eNodeB to the target eNodeB, switches the downlink path in the S-GW over S11, and supervises the release of the source resources with a timer (TS 23.401 clause 5.5.1.2.2).

On the S-GW

Without S-GW relocation, the S-GW that serves the UE switches the downlink path of the S1-U bearers to the target eNodeB and sends one or more end marker packets on the old path. With S-GW relocation, the target S-GW establishes the S5/S8 bearers towards the P-GW, and the source S-GW forwards the end marker packets of the P-GW to the source eNodeB (TS 23.401 clause 5.5.1.2.2, steps 16 and 17).

On the P-GW

The P-GW remains the anchor of the PDN connection on SGi. With S-GW relocation, the P-GW switches the downlink path to the target S-GW and sends one or more end marker packets on the old path (TS 23.401 clause 5.5.1.2.2, step 16).

6.7.3.2. Call Flow

The call flow has four phases: Handover Preparation, Handover Execution, Handover Completion, and Resource Release. When the S-GW isn't relocated, the S-GW that serves the UE acts as the target S-GW in the

figure.

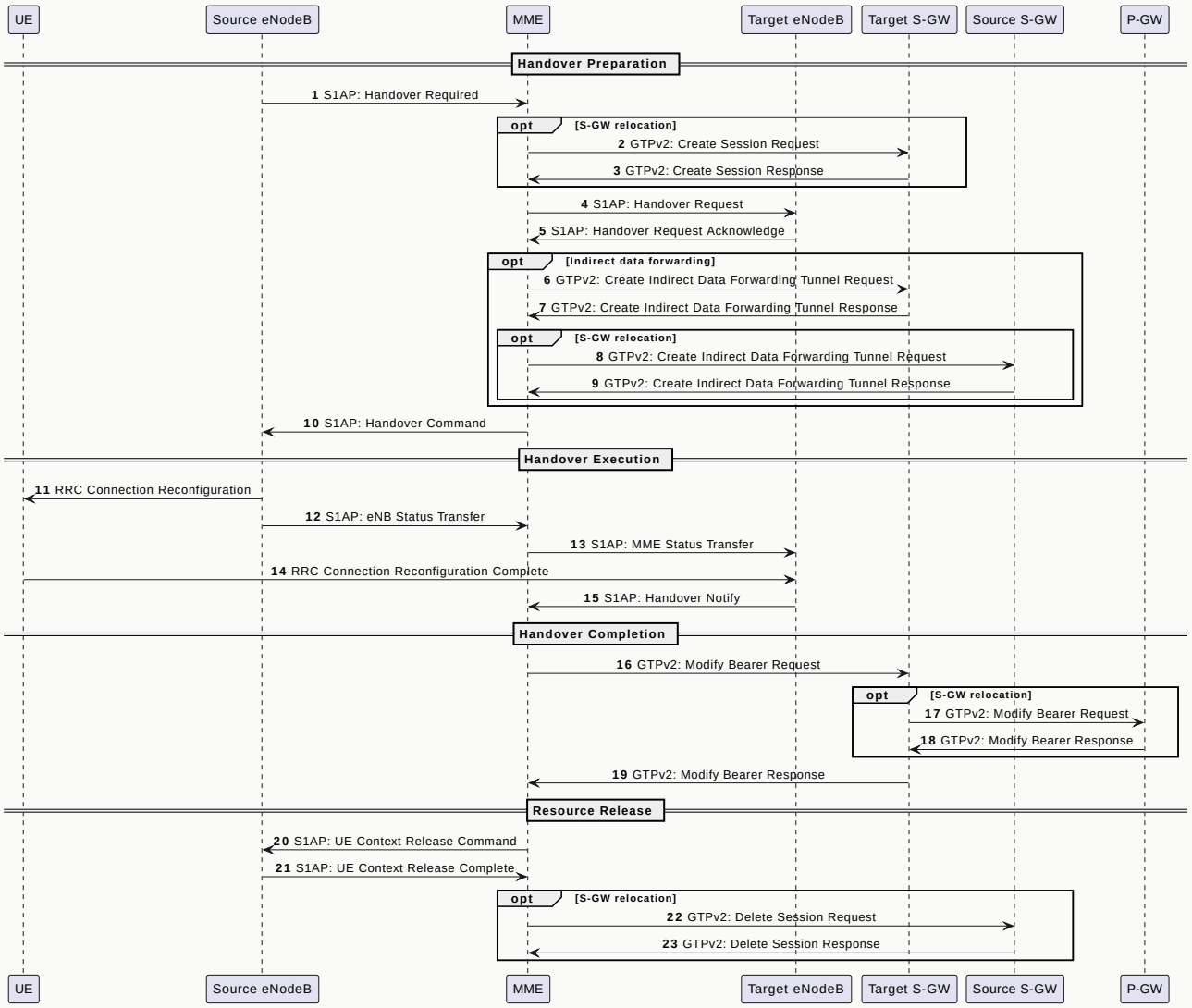


Figure 24. S1-based handover procedure without MME relocation call flow

6.7.3.3. Step-by-Step Description

1. The **source eNodeB** decides on an S1-based handover, for example because it has no X2 connectivity to the target eNodeB, and sends an S1AP `Handover Required` message to the **MME** over S1-MME (TS 23.401 clause 5.5.1.2.2, steps 1 and 2). The message carries the MME UE S1AP ID, the eNB UE S1AP ID, the Handover Type set to "IntraLTE", the Cause, for example "Handover desirable for radio reasons", the Target ID, with the Global eNB ID of the target eNodeB and the selected TAI, the Direct Forwarding Path Availability, and the Source to Target Transparent Container (TS 36.413 clauses 9.1.5.1 and 9.2.1.6). The container holds the RRC Container, the E-RABs Information List, the Target Cell ID (ECGI), the Subscriber Profile ID for RAT/Frequency priority, and the UE History Information (TS 36.413 clause 9.2.1.7), and the AS ciphering and integrity algorithms of the source cell (TS 33.401 clause 7.2.8.4.3).
2. If the MME relocates the S-GW, for example because the target cell is outside the service area of the current S-GW, the **MME** selects a target S-GW and sends a GTPv2 `Create Session Request` message to the **target S-GW** over S11, one message for each PDN connection (TS 23.401 clause 5.5.1.2.2, step 4).

The message carries the IMSI, the Sender F-TEID for Control Plane of the MME, the PGW S5/S8 Address for Control Plane, the RAT Type, the Serving Network, the Indication Flags, and the Bearer Contexts to be created, with the EBI, the Bearer Level QoS, and the S5/S8-U PGW F-TEID (TS 29.274 clause 7.2.1). The message doesn't carry the User Location Information, which the MME sends later in the `Modify Bearer Request` message (TS 29.274 clause 7.2.1, and TS 23.401 clause 5.5.1.2.2, steps 4 and 15). The S-GW selection function selects an S-GW that serves the location of the UE (TS 23.401 clause 4.3.8.2).

3. If the S-GW is relocated, the **target S-GW** allocates one S1-U uplink TEID for each bearer and returns a GTPv2 `Create Session Response` message to the **MME** over S11. The message carries the Cause set to "Request accepted" (16), the Sender F-TEID for Control Plane of the target S-GW, and the Bearer Contexts created, with the EBI, the Cause, and the S1-U SGW F-TEID of each bearer (TS 29.274 clause 7.2.2).

4. On receiving the `Handover Required` message, the MME has increased its locally kept NCC by one and computed a fresh NH (TS 33.401 clause 7.2.8.4.3). The **MME** sends an S1AP `Handover Request` message to the **target eNodeB** to create the UE context there. The message carries the MME UE S1AP ID, the Handover Type set to "IntraLTE", the Cause, the UE-AMBR, the E-RABs To Be Setup List, with the E-RAB ID, the transport layer address and the GTP-TEID of the S-GW for the uplink, and the E-RAB Level QoS Parameters, such as the QCI and the ARP, the Source to Target Transparent Container, the UE Security Capabilities, the Handover Restriction List, if available, and the Security Context, with the fresh {NH, NCC} pair (TS 36.413 clause 9.1.5.4).

5. The **target eNodeB** performs admission control for the requested E-RABs and returns an S1AP `Handover Request Acknowledge` message to the **MME**. The message carries the MME UE S1AP ID, the eNB UE S1AP ID, the E-RABs Admitted List, with the E-RAB ID, the transport layer address and the GTP-TEID of the target eNodeB for the downlink, and, if forwarding applies, the DL and UL transport layer addresses and GTP-TEIDs for the forwarded data, the E-RABs Failed to Setup List, and the Target to Source Transparent Container (TS 36.413 clause 9.1.5.5). The container holds the RRC handover command for the UE, with the NCC from the {NH, NCC} pair (TS 33.401 clause 7.2.8.4.3).

6. If indirect forwarding applies, the **MME** sends a GTPv2 `Create Indirect Data Forwarding Tunnel Request` message to the **target S-GW**, which is the S-GW that serves the UE when the S-GW isn't relocated (TS 23.401 clause 5.5.1.2.2, steps 6 and 8). The message carries the Bearer Contexts, with the EBI and the eNodeB F-TEID for DL data forwarding of the target eNodeB. It carries the Sender F-TEID for Control Plane only when the S-GW that the MME selects for indirect forwarding isn't the S-GW that anchors the bearers of the UE (TS 29.274 clause 7.2.18).

7. If indirect forwarding applies, the **S-GW** allocates the forwarding tunnels and returns a GTPv2 `Create Indirect Data Forwarding Tunnel Response` message to the **MME**. The message carries the Cause, the Bearer Contexts, with the EBI, the Cause, and the S-GW F-TEID for the forwarded data, and the Sender F-TEID for Control Plane if the request carried one (TS 29.274 clause 7.2.19).

8. If indirect forwarding applies and the S-GW is relocated, the **MME** also sends a GTPv2 `Create Indirect Data Forwarding Tunnel Request` message to the **source S-GW**. The Bearer Contexts of this message carry the SGW F-TEID for DL data forwarding that the target S-GW has allocated in step 7 (TS 23.401 clause 5.5.1.2.2, step 8, and TS 29.274 clause 7.2.18).

9. The **source S-GW** allocates the forwarding tunnels and returns a GTPv2 `Create Indirect Data`

`Forwarding Tunnel Response` message to the **MME**, with the Cause and the forwarding F-TEIDs of the source S-GW (TS 29.274 clause 7.2.19).

10. The **MME** sends an S1AP `Handover Command` message to the **source eNodeB**. The message carries the MME UE S1AP ID, the eNB UE S1AP ID, the Handover Type, the E-RABs Subject to Forwarding List, with the E-RAB ID and the DL and UL transport layer addresses and GTP-TEIDs for data forwarding, which belong to the target eNodeB or to the S-GW, the E-RABs to Release List, and the Target to Source Transparent Container (TS 36.413 clause 9.1.5.2, and TS 23.401 clause 5.5.1.2.2, step 9).
11. The **source eNodeB** builds the handover command from the Target to Source Transparent Container and sends it to the **UE** in an RRC `RRCConnectionReconfiguration` message. The message carries the `mobilityControlInfo` field, with the target physical cell identity, the carrier frequency, timer T304, the new C-RNTI, and, optionally, a dedicated random access preamble, the `radioResourceConfigDedicated` field, and the `securityConfigHO` field, with the security algorithm configuration and the NCC (TS 36.331 clause 6.2.2). The UE derives the new KeNB and accesses the target cell (TS 33.401 clause 7.2.8.4.4).
12. The **source eNodeB** sends an S1AP `eNB Status Transfer` message to the **MME**, carrying the MME UE S1AP ID, the eNB UE S1AP ID, and the eNB Status Transfer Transparent Container, with the E-RABs Subject to Status Transfer List, that is the E-RAB ID, the UL COUNT value, and the DL COUNT value of each E-RAB for which PDCP-SN and HFN status preservation applies (TS 36.413 clauses 8.4.6 and 9.1.5.13). The source eNodeB can omit the message when none of the E-RABs needs PDCP status preservation (TS 23.401 clause 5.5.1.2.2, step 10).
13. Because the MME isn't relocated, the **MME** sends the status information directly to the **target eNodeB** in an S1AP `MME Status Transfer` message, without any S10 signaling. The message carries the MME UE S1AP ID, the eNB UE S1AP ID, and the eNB Status Transfer Transparent Container (TS 23.401 clause 5.5.1.2.2, step 10, and TS 36.413 clause 9.1.5.14).
14. After the **UE** has synchronized to the target cell, it sends an RRC `RRCConnectionReconfigurationComplete` message to the **target eNodeB**, carrying the RRC Transaction Identifier (TS 36.331 clause 6.2.2).
15. The **target eNodeB** informs the **MME** that the UE has arrived in the target cell by sending an S1AP `Handover Notify` message, which carries the MME UE S1AP ID, the eNB UE S1AP ID, the E-UTRAN CGI, and the TAI of the target cell (TS 36.413 clause 9.1.5.7). The MME starts a timer that supervises the release of the resources in the source eNodeB and, if the S-GW is relocated, in the source S-GW (TS 23.401 clause 5.5.1.2.2, step 14).
16. The **MME** sends a GTPv2 `Modify Bearer Request` message to the **target S-GW** over S11, one message for each PDN connection (TS 23.401 clause 5.5.1.2.2, step 15). The message carries the Bearer Contexts to be modified, with the EBI and the S1 eNodeB F-TEID of the target eNodeB for the downlink, and, when they apply, the User Location Information, the Serving Network, and the User CSG Information (TS 29.274 clause 7.2.7).
17. If the S-GW is relocated, the **target S-GW** allocates the downlink TEIDs for the traffic from the P-GW and sends a GTPv2 `Modify Bearer Request` message to the **P-GW** over S5/S8, one message for each PDN connection. The message carries the Sender F-TEID for Control Plane of the target S-GW, the Bearer Contexts to be modified, with the EBI and the S5/8-U SGW F-TEID, and, when the MME has provided it, the User Location Information (TS 23.401 clause 5.5.1.2.2, step 16, and TS 29.274 clause 7.2.7).

18. If the S-GW is relocated, the **P-GW** updates its context, switches the downlink path to the target S-GW, and returns a GTPv2 `Modify Bearer Response` message to the **target S-GW**. The message carries the Cause set to "Request accepted" (16), the MSISDN, if the P-GW has stored it, and the Bearer Contexts modified, with the Charging ID of each bearer (TS 29.274 clause 7.2.8). Immediately after switching the path, the P-GW sends one or more end marker packets on the old path, and the source S-GW forwards these packets to the source eNodeB (TS 23.401 clause 5.5.1.2.2, step 16).
19. The **target S-GW** returns a GTPv2 `Modify Bearer Response` message to the **MME** over S11. The message carries the Cause set to "Request accepted" (16), the Bearer Contexts modified, with the EBI, the Cause, and the S1-U SGW F-TEID of each bearer, and, when applicable, the Change Reporting Action (TS 29.274 clause 7.2.8). If the S-GW isn't relocated, the S-GW sends one or more end marker packets on the old path immediately after switching the path (TS 23.401 clause 5.5.1.2.2, step 17).
20. When the timer of step 15 expires, the **MME** sends an S1AP `UE Context Release Command` message to the **source eNodeB**, carrying the UE S1AP IDs and a Cause, for example "Successful Handover" (TS 23.401 clause 5.5.1.2.2, step 19, and TS 36.413 clauses 9.1.4.6 and 9.2.1.3).
21. The **source eNodeB** releases its resources for the UE and returns an S1AP `UE Context Release Complete` message to the **MME** (TS 23.401 clause 5.5.1.2.2, step 19, and TS 36.413 clause 9.1.4.7).
22. If the S-GW is relocated, the **MME** deletes the bearer resources in the **source S-GW** when the timer of step 15 expires, by sending a GTPv2 `Delete Session Request` message over S11. The message carries the Indication Flags, with the Operation Indication flag not set, so that the source S-GW doesn't start a deletion towards the P-GW, and with the Scope Indication flag set to 1, together with the User Location Information. The message carries a Cause only when it also deactivates ISR, with the value "ISR deactivation" (TS 23.401 clause 5.5.1.2.2, step 19, and TS 29.274 clause 7.2.9.1).
23. The **source S-GW** releases the bearer resources of the UE and returns a GTPv2 `Delete Session Response` message to the **MME**, with the Cause set to "Request accepted" (16) (TS 29.274 clause 7.2.10).

If indirect forwarding was used, the expiry of the timer of step 15 also triggers the release of the forwarding tunnels with GTPv2 `Delete Indirect Data Forwarding Tunnel Request` messages (TS 23.401 clause 5.5.1.2.2, steps 20 and 21). After the handover, the UE starts a Tracking Area Update procedure when one of the TAU triggers applies (TS 23.401 clause 5.5.1.2.2, step 18).

6.7.3.4. Summary of Key Information Elements

The following table summarizes the key IEs of the main messages of the procedure, grouped by protocol.

PROTOCOL	MESSAGE	KEY IES
S1AP (TS 36.413)	`Handover Required`	MME UE S1AP ID, eNB UE S1AP ID, Handover Type, Cause, Target ID (Global eNB ID, selected TAI), Direct Forwarding Path Availability, Source to Target Transparent Container
S1AP (TS 36.413)	`Handover Request`	MME UE S1AP ID, Handover Type, Cause, UE-AMBR, E-RABs To Be Setup List (S-GW transport layer address and GTP-TEID, E-RAB Level QoS Parameters), Source to Target Transparent Container, Security Context ({NH, NCC})

PROTOCOL	MESSAGE	KEY IES
S1AP (TS 36.413)	`Handover Request Acknowledge`	MME UE S1AP ID, eNB UE S1AP ID, E-RABs Admitted List (target eNodeB transport layer address and GTP-TEID, forwarding addresses), E-RABs Failed to Setup List, Target to Source Transparent Container
GTPv2-C (TS 29.274)	`Create Session Request` (S-GW relocation)	IMSI, Sender F-TEID for Control Plane, PGW S5/S8 Address for Control Plane, RAT Type, Serving Network, Bearer Contexts to be created (EBI, Bearer Level QoS)
GTPv2-C (TS 29.274)	`Create Session Response` (S-GW relocation)	Cause ("Request accepted", 16), Sender F-TEID for Control Plane, Bearer Contexts created (EBI, Cause, S1-U SGW F-TEID)
GTPv2-C (TS 29.274)	`Create Indirect Data Forwarding Tunnel Request`	Bearer Contexts (EBI, eNodeB F-TEID or SGW F-TEID for DL data forwarding), Sender F-TEID for Control Plane (S-GW other than the anchor)
S1AP (TS 36.413)	`Handover Command`	MME UE S1AP ID, eNB UE S1AP ID, Handover Type, E-RABs Subject to Forwarding List, E-RABs to Release List, Target to Source Transparent Container
S1AP (TS 36.413)	`eNB Status Transfer` and `MME Status Transfer`	MME UE S1AP ID, eNB UE S1AP ID, eNB Status Transfer Transparent Container (E-RAB ID, UL COUNT value, DL COUNT value)
S1AP (TS 36.413)	`Handover Notify`	MME UE S1AP ID, eNB UE S1AP ID, E-UTRAN CGI, TAI
GTPv2-C (TS 29.274)	`Modify Bearer Request`	Bearer Contexts to be modified (EBI, S1 eNodeB F-TEID on S11, S5/8-U SGW F-TEID on S5/S8), ULI, Sender F-TEID for Control Plane (S5/S8 with S-GW relocation)
GTPv2-C (TS 29.274)	`Modify Bearer Response`	Cause ("Request accepted", 16), Bearer Contexts modified (EBI, Cause, S1-U SGW F-TEID on S11, Charging ID on S5/S8)

6.7.3.5. Possible Failures and Required Actions

Resource allocation failure in the target eNodeB

If the target eNodeB can't allocate resources for any of the requested EPS bearers, it sends an S1AP `Handover Failure` message to the MME, with a Cause such as "No Radio Resources Available in Target Cell" or "Cell not available" (TS 36.413 clauses 9.1.5.6 and 9.2.1.3). The MME also rejects the handover if the target eNodeB accepts it but none of the default EPS bearers is in the EPS Bearer Setup list. Because the MME isn't relocated, the MME acts as the target MME of TS 23.401 clause 5.5.1.2.3 (NOTE 2). It clears the resources that it has reserved for the UE and, if the S-GW was relocated, deletes the bearer resources in the target S-GW with GTPv2 `Delete Session Request` messages. The MME then sends an S1AP `Handover Preparation Failure` message to the source eNodeB (TS 23.401 clause 5.5.1.2.3), for example with the Cause "Handover Failure In Target EPC/eNB Or Target System" (TS 36.413 clause 9.2.1.3). The UE stays in the source eNodeB, which continues to serve it.

S-GW allocation failure

If the S-GW is relocated and the target S-GW can't accept the GTPv2 `Create Session Request` message of step 2, for example because it lacks user-plane capacity, the target S-GW returns a `Create Session Response` message with a rejection Cause, such as #73, "No resources available", or #94, "Request

rejected (reason not specified)" (TS 29.274 clause 8.4).

Handover failure at the target cell

If the UE fails to synchronize to the target cell before timer T304 expires, the UE detects a handover failure (TS 36.331 clause 5.3.5.6). The UE reverts to the configuration of the source cell and starts the RRC connection re-establishment procedure, with the `reestablishmentCause` set to `handoverFailure` (TS 36.331 clause 5.3.7.4). If the source eNodeB receives the re-establishment request and still has the UE context, the radio connection is restored, because the source eNodeB keeps part of the UE context to allow the UE to return after a handover failure (TS 36.300 clauses 10.1.2.1.0 and 10.1.6). If the re-establishment fails, the UE leaves the RRC_CONNECTED state with the release cause "RRC connection failure" (TS 36.331 clauses 5.3.7.6 and 5.3.7.8). The NAS layer then recovers the NAS signaling connection with a Tracking Area Update when no uplink signaling or user data is pending (TS 24.301 clause 5.5.3.2.2, case i), or with a Service Request when user data is pending (TS 24.301 clause 5.6.1.1). The source eNodeB can cancel an ongoing or already prepared handover with an S1AP `Handover Cancel` message (TS 36.413 clause 8.4.5), although TS 23.401 clause 5.5.1.2.4 allows the cancellation only up to the time when the source eNodeB sends the handover command to the UE.

6.7.3.6. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 5.5.1.2.1 — S1-based handover, general • Clause 5.5.1.2.2 — S1-based handover, normal • Clause 5.5.1.2.3 — S1-based handover, Reject, with NOTE 2 on the handover without MME relocation • Clause 5.5.1.2.4 — S1-based handover, Cancel • Clause 4.3.8.2 — Serving GW selection function
TS 36.413	• Clause 8.4.1 — Handover Preparation procedure • Clause 8.4.2 — Handover Resource Allocation procedure • Clause 8.4.3 — Handover Notification procedure • Clause 8.4.5 — Handover Cancellation procedure • Clauses 8.4.6 and 8.4.7 — eNB Status Transfer and MME Status Transfer procedures • Clauses 9.1.5.1 to 9.1.5.7, 9.1.5.13, and 9.1.5.14 — handover message contents • Clauses 9.1.4.6 and 9.1.4.7 — UE CONTEXT RELEASE COMMAND and UE CONTEXT RELEASE COMPLETE message contents • Clause 9.2.1.3 — Cause

SPECIFICATION	CLAUSES AND COVERAGE
TS 29.274	• Clauses 7.2.1 and 7.2.2 — Create Session Request/Response • Clauses 7.2.7 and 7.2.8 — Modify Bearer Request/Response • Clauses 7.2.9 and 7.2.10 — Delete Session Request/Response • Clauses 7.2.18 and 7.2.19 — Create Indirect Data Forwarding Tunnel Request/Response • Table 8.4-1 — Cause values • Annex C — Cause mapping
TS 33.401	• Clause 7.2.8.4.3 — Key derivation in S1-handover, with the NOTE on the handover without MME relocation • Clause 7.2.8.4.4 — UE handling of the NCC in a handover
TS 36.300	• Clause 10.1.2.1.0 — Context kept in the source eNB for a return after a handover failure • Clause 10.1.6 — Radio link failure • Clause 19.2.2.5.4 — Handover cancellation
TS 36.331	• Clause 5.3.5.6 — T304 expiry (handover failure) • Clause 5.3.7 — RRC connection re-establishment • Clause 6.2.2 — RRCConnectionReconfiguration and RRCConnectionReconfigurationComplete message contents
TS 24.301	• Clause 5.5.3.2.2 — Tracking area updating procedure initiation • Clause 5.6.1.1 — Service request procedure

6.8. RADIUS Usage on the Gi/SGi Interface

6.8.1. Technical Overview

The Remote Authentication Dial-In User Service (RADIUS) protocol can run on the Gi/SGi reference points to provide AAA for a UE that establishes a PDN connection through non-transparent access (TS 29.061 clauses 11.2.1.2.2 and 11.2.1.3). In the EPC, the P-GW acts as the RADIUS client, and an AAA server in the external packet data network, which this section calls the RADIUS AAA Server, acts as the RADIUS server. The operator configures the use of RADIUS separately for each APN, and can configure a separate RADIUS AAA Server for authentication and for accounting (TS 29.061 clause 16.3a.1). When the network separates the control plane and the user plane of the P-GW, the PGW-C exchanges the RADIUS messages with the RADIUS AAA Server. The PGW-C communicates with the RADIUS AAA Server directly, or through the PGW-U when the RADIUS AAA Server is reachable only through the PGW-U, in which case the PGW-U forwards the RADIUS messages (TS 29.061 clause 11.2.1.6). To report the packet counts that the accounting messages carry, the PGW-U supports the Measurement of Number of Packets (MNOP) feature (TS 29.061 clause 16.4.4, Table 4, NOTE 10).

SGi RADIUS serves two purposes, which the P-GW can enable independently of each other.

Authentication and authorization

The P-GW sends the credentials that the UE supplies with the Password Authentication Protocol (PAP) or

the Challenge Handshake Authentication Protocol (CHAP) to the RADIUS AAA Server, which accepts or rejects the UE for the requested APN. The UE carries these credentials in the PCO IE. When the RADIUS AAA Server also manages the address pool of the external network, the RADIUS AAA Server returns the allocated IPv4 address or IPv6 prefix in its response (TS 29.061 clause 16.1).

Accounting

The P-GW reports the start, the updates, and the end of each session to the RADIUS AAA Server, together with usage counters such as octets, packets, and session duration. The RADIUS AAA Server can store this information, and application servers in the packet data network can use the information to correlate the identity of the UE with its IP address (TS 29.061 clause 16.2).

The P-GW completes the PDN connection establishment only after it receives a RADIUS `Access-Accept` message. If the P-GW receives an `Access-Reject` message, or no response, it rejects the initial access request with a suitable cause (TS 29.061 clause 16.1). The information that the P-GW exchanges with the RADIUS AAA Server lets the external network correlate the UE’s identity, that is the MSISDN or the IMSI, with the IPv4 address or IPv6 prefix that the network allocates to the UE.

6.8.2. Call Flow

The call flow has four phases: IP-CAN Session Establishment, Session Active, SGi Session Update, and Session Termination. The flow follows the GTP-based S5/S8 examples in TS 29.061 Figures 25a.1 and 25a.2.

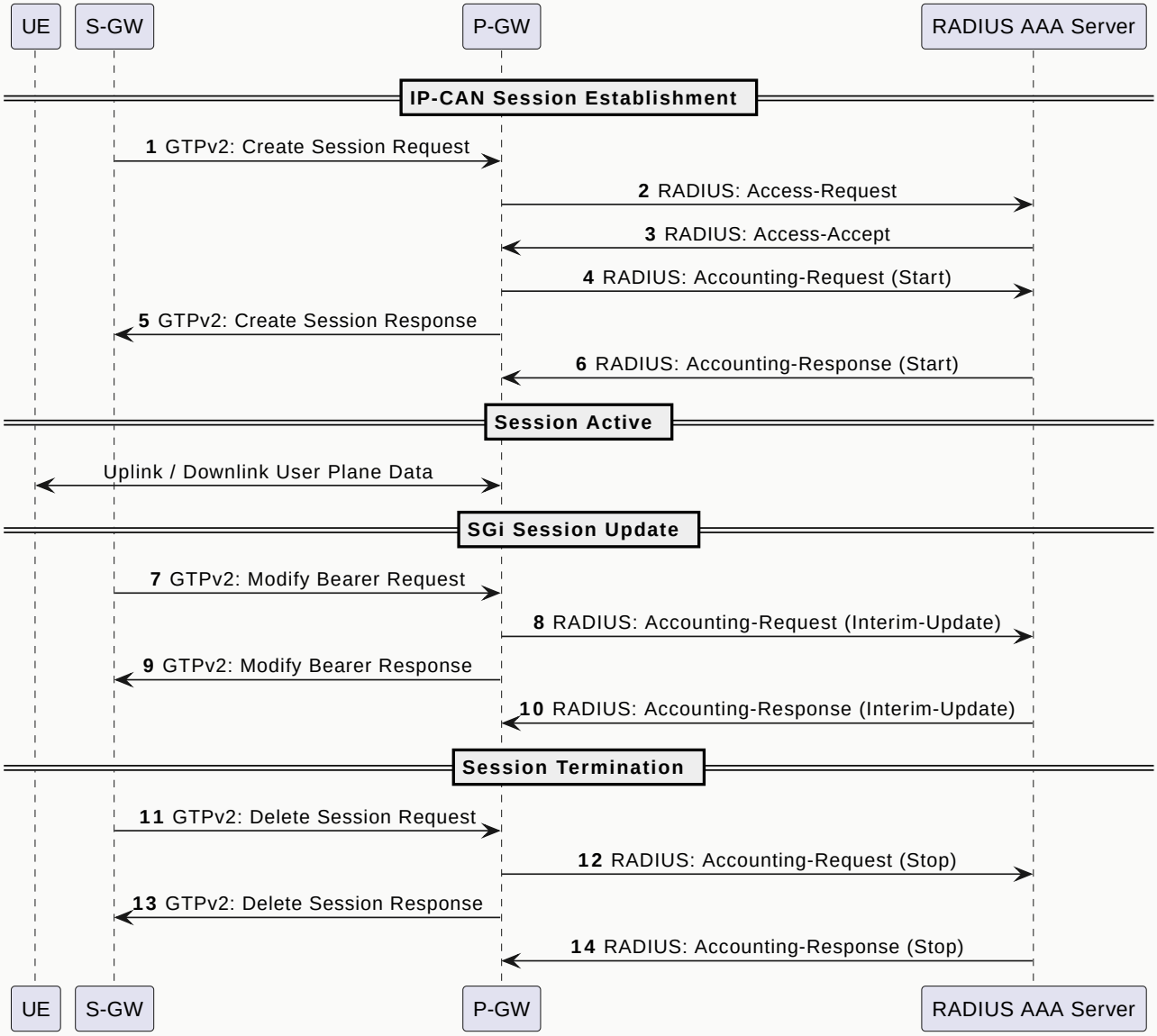


Figure 25. RADIUS usage on the Gi/SGi interface call flow

6.8.3. Step-by-Step Description

1. During an E-UTRAN Initial Attach or a UE-requested PDN connectivity procedure, the **S-GW** sends a GTPv2 `Create Session Request` message to the **P-GW**, to request the default bearer of the PDN connection. The message carries the IMSI, the MSISDN, the Sender F-TEID for Control Plane, the RAT Type, the APN, the Selection Mode, the PDN Type, and the APN-AMBR. The message also carries the PDN Address Allocation (PAA), with the IPv4 address set to 0.0.0.0 or the IPv6 prefix set to zero when the network allocates the address dynamically, and the PCO with the PAP or CHAP credentials of the UE. The Bearer Contexts to be created IE carries the EBI, the S5/S8-U SGW F-TEID, and the Bearer Level QoS (TS 29.274 clause 7.2.1).

2. The **P-GW** reads the credentials from the PCO and sends a RADIUS `Access-Request` message to the **RADIUS AAA Server**, to authenticate and authorize the UE for the APN (TS 29.061 clause 16.3a.1). The message carries the `User-Name` (attribute 1), that is the PAP or CHAP username, and the `User-Password` (attribute 2) for PAP or the `CHAP-Password` (attribute 3) and `CHAP-Challenge` (attribute 60) for CHAP. The

message also carries the NAS-IP-Address (attribute 4), that is the P-GW IPv4 address for communication with the RADIUS AAA Server, or the NAS-Identifier (attribute 32), and the Service-Type (attribute 6), set to Framed. The message also carries the Framed-Protocol (attribute 7), set to GPRS PDP Context, the Called-Station-Id (attribute 30), that is the APN, and the Calling-Station-Id (attribute 31), that is the MSISDN in international format. The 3GPP Vendor-Specific Attribute (attribute 26, vendor 10415) can carry sub-attributes such as 3GPP-IMSI (1), 3GPP-Charging-Id (2), 3GPP-PDP-Type (3), 3GPP-Charging-Characteristics (13), 3GPP-RAT-Type (21), and 3GPP-User-Location-Info (22) (TS 29.061 clause 16.4.1, Table 1, and clause 16.4.7, Table 7). The 3GPP-Allocate-IP-Type (27) sub-attribute tells the RADIUS AAA Server which type of address, if any, to allocate. The P-GW includes this sub-attribute when the PDN connection needs more than one Access-Request message, for example for PDN type IPv4v6 with deferred IPv4 address allocation, and can include it when the P-GW needs only one address type although the RADIUS AAA Server can allocate both. When the Access-Request message does not carry this sub-attribute, the RADIUS AAA Server allocates addresses according to its own configured policy (TS 29.061 clause 16.4.7.2).

3. The **RADIUS AAA Server** validates the credentials. If validation succeeds, the RADIUS AAA Server returns a RADIUS Access-Accept message to the **P-GW**, which authorizes the session. When the RADIUS AAA Server allocates the address, the message carries the Framed-IP-Address (attribute 8) for an IPv4 allocation, the Framed-IPv6-Prefix (attribute 97) for an IPv6 allocation, or both. The message can also carry the Framed-Interface-Id (attribute 96), the Session-Timeout (attribute 27), the Idle-Timeout (attribute 28), the primary and secondary Domain Name System (DNS) server addresses, and the Class (attribute 25), which the P-GW then copies into each later accounting message (TS 29.061 clause 16.4.2, Table 2).

4. The **P-GW** sends a RADIUS Accounting-Request message, with the Acct-Status-Type (attribute 40) set to Start, to the **RADIUS AAA Server**, to indicate that the user session has started. The message carries the Acct-Session-Id (attribute 44), which concatenates the P-GW IP address and the Charging ID of the bearer as UTF-8 encoded hexadecimal characters, and which uniquely identifies the session. The message also carries the User-Name, the NAS-IP-Address, the Framed-IP-Address or the Framed-IPv6-Prefix, the Called-Station-Id, and the Class, if the Access-Accept carried it. The message can also carry the sub-attributes 3GPP-IMSI, 3GPP-Charging-Id, 3GPP-PDP-Type, 3GPP-NSAPI (10), which identifies the EPS Bearer ID on GTP-based S5/S8, 3GPP-RAT-Type, and 3GPP-User-Location-Info (TS 29.061 clause 16.4.3, Table 3).

5. The **P-GW** returns a GTPv2 Create Session Response message to the **S-GW**, to confirm the PDN connection. The message carries the Cause, set to "Request accepted", the PGW S5/S8 F-TEID for Control Plane, the PAA with the allocated IPv4 address or IPv6 prefix, the APN Restriction, and the PCO with the configuration parameters for the UE, for example the DNS server addresses. The Bearer Contexts created IE carries the EBI, the Cause, the S5/S8-U PGW F-TEID, and the Charging ID (TS 29.274 clause 7.2.2). The P-GW usually sends the Create Session Response without waiting for the Accounting-Response message, but the operator can configure the APN so that the P-GW waits for the Accounting-Response before it sends the Create Session Response (TS 29.061 clause 16.3a.1, Figure 25a.1, NOTE 1).

6. The **RADIUS AAA Server** records the session start and returns a RADIUS Accounting-Response message to the **P-GW**. If external applications need the start information before they can process user packets, the operator can configure the APN so that the P-GW drops user data until it receives this Accounting-

Response, and the P-GW can reject the bearer if the response does not arrive (TS 29.061 clause 16.3a.1). Without this configuration, the P-GW does not wait for this Accounting-Response before it forwards uplink and downlink user data between the UE and the external PDN.

7. During the session, the **S-GW** sends a GTPv2 Modify Bearer Request message to the **P-GW** when a procedure changes the access characteristics of the session, for example an inter-RAT mobility procedure or a handover or Tracking Area Update with S-GW relocation. The message can carry the ULI, the Serving Network, the RAT Type, the UE Time Zone, and the User CSG Information (UCI). For a Tracking Area Update (TAU), a Routeing Area Update (RAU), or a handover with S-GW relocation, the new S-GW also includes the Sender F-TEID for Control Plane and the Bearer Contexts to be modified IE, which carries the S5/S8-U SGW F-TEID for each bearer. For a procedure without S-GW relocation, the S-GW does not include the Bearer Contexts to be modified IE on S5/S8 (TS 29.274 clause 7.2.7, Table 7.2.7-1).
8. The **P-GW** checks whether the Modify Bearer Request indicates a chargeable event, that is a RAT change, an S-GW address change, or a QoS change. If so, the P-GW can send a RADIUS Accounting-Request message, with the Acct-Status-Type set to Interim-Update, to the **RADIUS AAA Server**, to update the session record (TS 29.061 clause 16.3a.2). The message carries the Acct-Session-Id and can carry the current usage counters, for example the Acct-Input-Octets (attribute 42) and the Acct-Output-Octets (attribute 43). The message can also carry the updated sub-attributes 3GPP-RAT-Type, 3GPP-User-Location-Info, and 3GPP-MS-TimeZone (23) (TS 29.061 clause 16.4.8, Table 8). The P-GW can also send an interim update when an operator-configured time limit expires.
9. The **P-GW** returns a GTPv2 Modify Bearer Response message to the **S-GW** without waiting for the RADIUS Accounting-Response message (TS 29.061 clause 16.3a.2, Figure 25a.2). The message carries the Cause, set to "Request accepted". For a TAU, RAU, or handover with S-GW relocation, the message also carries the MSISDN, if the P-GW stores it in the UE context, and the Bearer Contexts modified IE carries the Charging ID of each bearer (TS 29.274 clause 7.2.8, Tables 7.2.8-1 and 7.2.8-2). During the same procedures, the Indication Flags IE can carry the PDN Pause Enable Indication, which lets the new S-GW use the PDN GW Pause of Charging procedure for the PDN connection (TS 29.274 clause 7.2.8 and TS 23.401 clause 5.3.6A).
10. The **RADIUS AAA Server** updates its session record and returns a RADIUS Accounting-Response message to the **P-GW**. If the P-GW does not receive this response, the P-GW can delete the bearer (TS 29.061 clause 16.3a.2).
11. When the UE detaches, the MME starts a detach, or the UE requests a PDN disconnection, the **S-GW** sends a GTPv2 Delete Session Request message to the **P-GW**, to release the PDN connection. The message carries the LBI, that is the EBI of the default bearer, and it can carry the ULI with the last known location of the UE, the ULI Timestamp, the UE Time Zone, and the Secondary RAT Usage Data Report when the network collects secondary RAT usage data (TS 29.274 clause 7.2.9.1).
12. Because the P-GW previously sent an Accounting-Request (Start) message for the session, the **P-GW** sends a RADIUS Accounting-Request message, with the Acct-Status-Type set to Stop, to the **RADIUS AAA Server** (TS 29.061 clause 16.3a.1). The message carries the Acct-Session-Id and the final usage of the session, for example the Acct-Input-Octets (attribute 42), the Acct-Output-Octets (attribute 43), the Acct-Session-Time (attribute 46), the Acct-Input-Packets (attribute 47), the Acct-Output-Packets (attribute 48), and the Acct-Terminate-Cause (attribute 49) (TS 29.061 clause 16.4.4, Table 4). For the last

bearer of the IP-CAN session, the P-GW includes the `3GPP-Session-Stop-Indicator` (11) sub-attribute, and the RADIUS AAA Server does not consider the IP-CAN session terminated until it receives an `Accounting-Request` (Stop) message with this sub-attribute (TS 29.061 clause 16.2). The message can also carry the `3GPP-User-Location-Info-Time` (30) sub-attribute, which indicates when the UE was last known to be at the reported location.

13. The **P-GW** returns a GTPv2 `Delete Session Response` message to the **S-GW** immediately, without waiting for the RADIUS `Accounting-Response` message (TS 29.061 clause 16.3a.1, Figure 25a.1). The message carries the Cause, set to "Request accepted", and can carry the PCO for the UE (TS 29.274 clause 7.2.10.1).
14. The **RADIUS AAA Server** records the end of the session and returns a RADIUS `Accounting-Response` message to the **P-GW**. If the RADIUS AAA Server allocated the IPv4 address or IPv6 prefix of the UE and no other session exists for the subscriber, the RADIUS AAA Server deallocates the address so that it can assign the address again (TS 29.061 clauses 16.2 and 16.3a.1).

6.8.4. Possible Failures and Required Actions

RADIUS authentication or authorization failure

The RADIUS AAA Server rejects the credentials of the UE and returns a RADIUS `Access-Reject` message to the P-GW. The P-GW treats an `Access-Challenge` message, or the absence of a response, in the same way (TS 29.061 clauses 16.1 and 16.3a.1). The P-GW rejects the `Create Session Request` with GTPv2 Cause #92, "User authentication failed" (TS 29.274 clause 8.4, Table 8.4-1), and the S-GW forwards the rejection to the MME. The MME maps GTPv2 Cause #92 to ESM cause #29, "User authentication or authorization failed" (TS 29.274 Annex C, Table C.1). For a standalone PDN connectivity request, the MME sends a `PDN Connectivity Reject` message with ESM cause #29 to the UE, and the UE stops timer T3482 (TS 24.301 clause 6.5.1.4.1). During an attach, the MME sends an `Attach Reject` message with EMM cause #19, "ESM failure", that contains the `PDN Connectivity Reject` message. Depending on operator policy, the MME can instead send the `Attach Reject` message with EMM cause #15, "No suitable cells in tracking area", which lets a roaming UE obtain service in another PLMN (TS 24.301 clause 5.5.1.2.5 and TS 29.274 Annex C, Table C.1, NOTE 4).

APN congestion or resource limitation at the P-GW

The P-GW detects congestion for an APN, for example because the APN reaches its maximum number of active bearers or its maximum rate of bearer activations, or the P-GW has no addresses or other resources left. The P-GW rejects the `Create Session Request` with GTPv2 Cause #113, "APN Congestion", or Cause #73, "No resources available" (TS 29.274 clause 8.4, Table 8.4-1). The MME can map either cause to ESM cause #26, "Insufficient resources" (TS 29.274 Annex C, Table C.1). For APN congestion only, the P-GW can include the PGW Back-Off Time IE in the `Create Session Response` message (TS 29.274 clause 7.2.2). While the back-off time runs, the MME rejects further PDN connection requests for that APN at that P-GW, or selects another P-GW for the APN instead. The MME cannot select another P-GW when the UE already has a PDN connection to the same APN, and in that case the MME rejects the request (TS 23.401 clause 4.3.7.5). The MME can include a Back-off timer value IE in the `PDN Connectivity Reject` message, except when the UE sent the request with high-priority access or as an emergency request (TS 24.301 clause 6.5.1.4.1). When the UE receives ESM cause #26 with a Back-off timer value IE, the UE

starts timer T3396 for the APN, and does not send another PDN connectivity, bearer resource allocation, or bearer resource modification request for that APN until T3396 expires or stops (TS 24.301 clause 6.5.1.4.2).

6.8.5. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 4.3.7.5 — PDN GW control of overload and the PDN GW back-off time • Clause 5.3.2.1 — E-UTRAN Initial Attach • Clause 5.3.6A — PDN GW Pause of Charging procedure • Clause 5.10.3 — UE or MME requested PDN disconnection
TS 24.301	• Clause 5.5.1.2.5 — Attach not accepted by the network • Clause 6.5.1.4 — UE requested PDN connectivity procedure not accepted by the network • Clause 9.9.4.4 — ESM cause
TS 29.274	• Clauses 7.2.1 and 7.2.2 — Create Session Request and Create Session Response • Clauses 7.2.7 and 7.2.8 — Modify Bearer Request and Modify Bearer Response • Clauses 7.2.9.1 and 7.2.10.1 — Delete Session Request and Delete Session Response • Clause 8.4 — Cause values, Table 8.4-1 • Annex C — Mapping from S11/S4 to NAS cause values, Table C.1
TS 29.061	• Clause 11.2.1.2.2 — EPC based IPv4 non-transparent access • Clause 11.2.1.3 — IPv6 non-transparent access • Clause 11.2.1.6 — Support for CUPS across SGi • Clauses 16.1 and 16.2 — RADIUS authentication, authorization, and accounting • Clauses 16.3a.1 and 16.3a.2 — RADIUS message flows on the SGi interface, Figures 25a.1 and 25a.2 • Clauses 16.4.1 to 16.4.8 — RADIUS attributes and 3GPP Vendor-Specific sub-attributes

6.9. Tracking Area Update Procedure

6.9.1. Technical Overview

The TAU procedure is an EMM procedure that a UE in the EMM-REGISTERED state starts by sending a NAS `Tracking Area Update Request` message to the MME (TS 24.301 clause 5.5.3.2.2). The UE starts the procedure in either the ECM-IDLE state or the ECM-CONNECTED state (TS 23.401 clause 5.3.3.0), for example in these cases:

- The UE enters a tracking area whose TAI isn't in the list of TAIs that it has registered with the network, so that the network learns the current location of the UE.
- The periodic tracking area update timer T3412 expires, so that the UE periodically notifies the network that it is still available, and the UE then indicates "periodic updating" in the EPS update type IE.

- The UE performs an inter-system change, for example from N1 mode to S1 mode, which is a change from 5GS to EPS.
- The UE changes its UE network capability, MS network capability, or UE specific DRX parameter, or the CIoT EPS optimizations that it needs to use change.

TS 24.301 clause 5.5.3.2.2 lists all the triggers, and TS 23.401 clause 5.3.3.0 lists the stage 2 triggers. The MME decides whether to relocate the S-GW independently of the trigger (TS 23.401 clause 5.3.3.0). This section describes the procedure with an MME change, both with S-GW relocation (TS 23.401 clause 5.3.3.1) and without S-GW relocation (TS 23.401 clause 5.3.3.2).

The procedure has these high-level effects on the network elements:

On the UE

The UE stores the TAI list that it receives, sets its EPS update status to EU1 UPDATED when the network accepts the update, and stores the new GUTI if the MME has reallocated one (TS 24.301 clause 5.5.3.2.4). If the UE has set the "active" flag, the network can set up the user-plane radio and S1 bearers together with the `Tracking Area Update Accept` message (TS 23.401 clause 5.3.3.1, steps 2 and 20).

On the eNodeB

The eNodeB relays the NAS signaling between the UE and the MME over S1AP and adds the TAI and the E-UTRAN CGI of the cell from which it has received the `Tracking Area Update Request` message (TS 23.401 clause 5.3.3.1, step 3).

On the new MME

The new MME uses the NAS integrity protection of the request to validate the UE, retrieves the MM context and the EPS bearer contexts of the UE from the old MME over S10, or from the old AMF over N26 (TS 29.274 clause 7.3.5), and selects a new S-GW when the S-GW is relocated. It then registers itself with the HSS over S6a and updates the bearers in the S-GW (TS 23.401 clause 5.3.3.1, steps 4 to 17).

On the old MME

The old MME validates the `Context Request` message, transfers the security context and the PDN connections of the UE to the new MME, removes the MM context when the HSS cancels the location, and, when the S-GW is relocated, deletes the bearer resources in the old S-GW (TS 23.401 clause 5.3.3.1, steps 5, 14, and 18).

On the S-GW

With S-GW relocation, the new S-GW allocates the tunnel endpoints for the bearers and establishes the S5/S8 bearers towards the P-GW. Without S-GW relocation, the S-GW updates its bearer context with the information from the new MME (TS 23.401 clause 5.3.3.1, step 11, and clause 5.3.3.2, step 13). When an S1-U GTP-U tunnel is set up during the TAU, the S-GW receives the downlink S1 eNodeB F-TEID in a `Modify Bearer Request` message (TS 29.274 clause 7.2.7).

On the P-GW

The P-GW remains the IP anchor of the PDN connection. With S-GW relocation, the P-GW switches the

downlink path to the new S-GW and sends one or more end marker packets on the old path. If dynamic PCC is deployed and the RAT type information needs to reach the PCRF, the P-GW sends it to the PCRF in an IP-CAN Session Modification procedure (TS 23.401 clause 5.3.3.1, steps 9, 9a, and 10).

On the HSS

The HSS stores the identity of the new MME, cancels the location in the old MME, and returns the subscription data of the UE to the new MME (TS 23.401 clause 5.3.3.1, steps 12, 13, and 17).

6.9.2. Call Flow

The call flow has four phases: Tracking Area Update Request and Context Transfer, Session Update, Location Update, and Completion. When the S-GW isn't relocated, the New S-GW in the figure is the S-GW that already serves the UE. Without an MME change, the context transfer and the location update are skipped, and when the S-GW isn't relocated either, the Modify Bearer exchanges of the Session Update phase are also skipped (TS 23.401 clause 5.3.3.1, NOTE 2, and clause 5.3.3.2, NOTE 2).

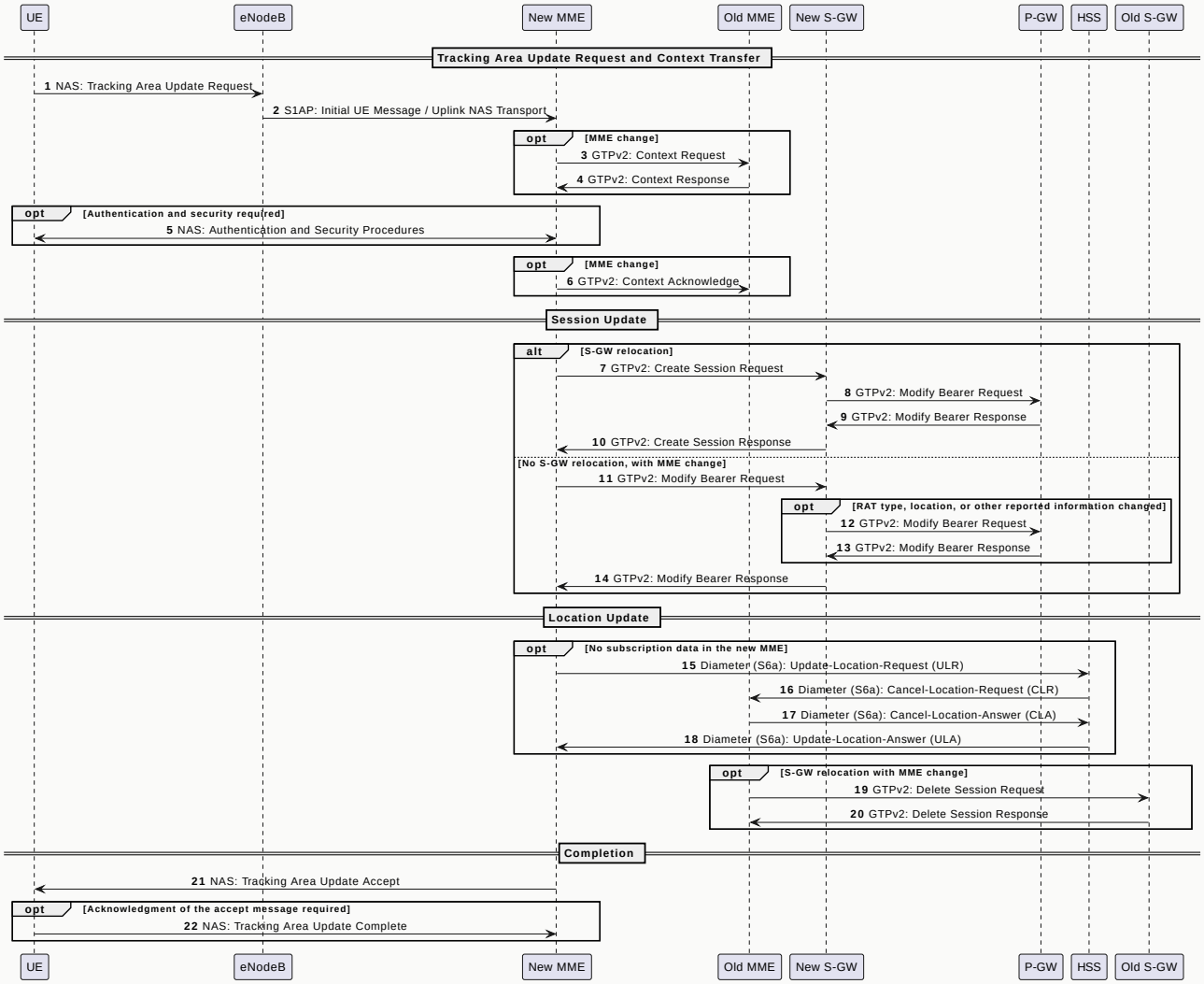


Figure 26. Tracking area update procedure call flow

6.9.3. Step-by-Step Description

1. The **UE** sends a NAS `Tracking Area Update Request` message over the Uu interface to the **eNodeB**, together with RRC parameters that indicate the selected network and the old GUMMEI (TS 23.401 clause 5.3.3.1, step 2). The message carries the EPS update type, which can be "TA updating", "combined TA/LA updating", "combined TA/LA updating with IMSI attach", "periodic updating", or "disaster roaming update", the "active" flag, which is part of the EPS update type IE and requests the establishment of the radio and S1 bearers, the NAS key set identifier with the eKSI, the old GUTI, the old GUTI type, which indicates whether the old GUTI is native or mapped from a P-TMSI and Routeing Area Identity (RAI), the last visited registered TAI, the EPS bearer context status, the UE network capability, the MS network capability, and the voice domain preference and UE's usage setting (TS 24.301 clause 8.2.29.1, and clause 9.9.3.14). A UE that uses the control plane CIoT EPS optimization sets the "signalling active" flag in the Additional update type IE (TS 24.301 clause 5.5.3.2.2). The UE integrity protects the message with the NAS-MAC (TS 23.401 clause 5.3.3.1, step 2, and TS 33.401 clause 7.2.7), and starts timer T3430 after it has sent the message (TS 24.301 clause 5.5.3.2.2).
2. The **eNodeB** derives the MME address from the old GUMMEI and the selected network. If that MME isn't associated with the eNodeB, if the GUMMEI isn't available, or if the UE indicates load re-balancing, the eNodeB selects an MME with the MME selection function (TS 23.401 clause 5.3.3.1, step 3, and clause 4.3.8.3). The eNodeB forwards the NAS message to the **new MME** over S1-MME in an S1AP `Initial UE Message` message, which carries the eNB UE S1AP ID, the NAS-PDU, the TAI, the E-UTRAN CGI, the RRC Establishment Cause, and, optionally, the S-TMSI and the GUMMEI (TS 36.413 clause 9.1.7.1). When the UE is already in the ECM-CONNECTED state, the eNodeB uses an S1AP `Uplink NAS Transport` message, which carries the MME UE S1AP ID, the eNB UE S1AP ID, the NAS-PDU, the E-UTRAN CGI, and the TAI (TS 36.413 clause 9.1.7.3, and TS 23.401 clause 5.3.3.0A).
3. If the MME has changed, the **new MME** derives the address of the old MME from the old GUTI and sends a GTPv2 `Context Request` message to the **old MME** over S10 to retrieve the MM context and the EPS bearer contexts of the UE (TS 23.401 clause 5.3.3.1, step 4). The message carries the GUTI, the Complete TAU Request Message, which the old MME uses to check the integrity of the request, the S3/S16/S10/N26 Address and TEID for Control Plane of the new MME, the RAT Type, and the Indication IE with the MS Validated flag, which the new MME sets when it has authenticated the UE or validated the integrity protection of the request (TS 29.274 clause 7.3.5).
4. The **old MME** validates the request with the Complete TAU Request Message and, if the validation succeeds, starts a timer and returns a GTPv2 `Context Response` message to the **new MME** over S10 (TS 23.401 clause 5.3.3.1, steps 4 and 5). The message carries the Cause set to "Request accepted" (16), the IMSI, and the MME/SGSN/AMF UE MM Context, which holds the KASME, the eKSI, the NAS security algorithms, the NAS uplink and downlink counts, and the subscribed UE-AMBR (TS 29.274 clauses 7.3.6 and 8.38). The MME/SGSN/AMF UE EPS PDN Connections IE carries, for each PDN connection, the APN, the APN-AMBR, the PGW S5/S8 IP Address for Control Plane or PMIP, and the bearer contexts, each with the EBI, the Bearer Level QoS, the SGW S1/S4/S12/S11 IP Address and TEID for user plane, and the PGW S5/S8 IP Address and TEID for user plane (TS 29.274 clause 7.3.6). The message also carries the SGW S11/S4 IP Address and TEID for Control Plane and, when session trace is active, the Trace Information (TS 29.274 clause 7.3.6). If the UE isn't known in the old MME, or if the integrity check of the request fails, the old MME responds with an error cause instead (TS 23.401 clause 5.3.3.1, step 5).

5. If the integrity check of the `Tracking Area Update Request` message has failed, authentication is mandatory, and the **new MME** and the **UE** perform the authentication and NAS security procedures of TS 23.401 clause 5.3.10 (TS 23.401 clause 5.3.3.1, steps 4 and 6). The NAS `Authentication Request` message carries the NAS key set identifier for the KASME, the RAND, and the AUTN, and the UE returns the RES in the NAS `Authentication Response` message (TS 24.301 clauses 8.2.7 and 8.2.8). If the NAS algorithms change with the change of MME, the new MME starts a NAS security mode command procedure, whose `Security Mode Command` message carries the selected NAS security algorithms for ciphering and integrity protection, the NAS key set identifier, and the replayed UE security capabilities, protected with the NAS-MAC (TS 33.401 clause 7.2.4.3.2, and TS 24.301 clause 8.2.20).
6. If the MME has changed, the **new MME** sends a GTPv2 `Context Acknowledge` message to the **old MME** over S10, with the Cause set to "Request accepted" (16) (TS 23.401 clause 5.3.3.1, step 7, and TS 29.274 clause 7.3.7). If the new MME has selected a new S-GW, the message carries the Indication Flags with the SGW Change Indication set to 1 (TS 29.274 clause 7.3.7). The old MME then marks in its UE context that the information in the gateways and in the HSS is invalid, so that it updates the gateways and the HSS if the UE returns to it before the procedure completes (TS 23.401 clause 5.3.3.1, step 7, and clause 5.3.3.2, step 7).
7. If the MME relocates the S-GW, the **new MME** selects a new S-GW with the Serving GW selection function, which can use DNS to resolve the candidate S-GW addresses, and sends a GTPv2 `Create Session Request` message to the **new S-GW** over S11, one message for each PDN connection (TS 23.401 clause 5.3.3.1, steps 7 and 8, and clause 4.3.8.2). The message carries the IMSI, the Sender F-TEID for Control Plane of the new MME, the PGW S5/S8 Address for Control Plane or PMIP, the Bearer Contexts to be created, with the EBI, the Bearer Level QoS, and the S5/S8-U PGW F-TEID, the RAT Type, the Serving Network, and the Indication Flags (TS 29.274 clause 7.2.1). The new MME includes the User Location Information if the P-GW has requested location information change reporting and the information has changed (TS 23.401 clause 5.3.3.1, step 8).
8. If the S-GW is relocated, the **new S-GW** sends a GTPv2 `Modify Bearer Request` message to the **P-GW** over S5/S8, one message for each PDN connection, to report the change of S-GW and, for example, the RAT type for charging (TS 23.401 clause 5.3.3.1, step 9). The message carries the Sender F-TEID for Control Plane of the new S-GW, the Bearer Contexts to be modified, with the EBI and the S5/8-U SGW F-TEID of each bearer, the RAT Type, and the Serving Network, together with the User Location Information and the User CSG Information if the new MME has sent them in step 7 (TS 23.401 clause 5.3.3.1, step 9, and TS 29.274 clause 7.2.7). The APN-AMBR is sent in this message only for a TAU from a Gn/Gp SGSN (TS 29.274 clause 7.2.7).
9. If the S-GW is relocated, the **P-GW** updates its bearer contexts, switches the downlink path to the new S-GW, and sends one or more GTP-U end marker packets on the old path. It then returns a GTPv2 `Modify Bearer Response` message to the **new S-GW** (TS 23.401 clause 5.3.3.1, step 10). The message carries the Cause set to "Request accepted" (16), the MSISDN, if the P-GW has it stored, the Bearer Contexts modified, with the Charging ID of each bearer, and, when location change reporting is started or stopped, the Change Reporting Action (TS 29.274 clause 7.2.8).
10. The **new S-GW** stores the tunnel endpoints of the P-GW, updates its bearer context, and returns a GTPv2 `Create Session Response` message to the **new MME** over S11 (TS 23.401 clause 5.3.3.1, step 11). The message carries the Cause set to "Request accepted" (16), the Sender F-TEID for Control Plane of

the new S-GW, and the Bearer Contexts created, with the EBI, the Cause, and the S1-U SGW F-TEID for the uplink of each bearer (TS 29.274 clause 7.2.2), together with the P-GW TEIDs for the uplink traffic and for the control plane (TS 23.401 clause 5.3.3.1, step 11).

11. If the S-GW isn't relocated and the MME has changed, the **new MME** sends a GTPv2 `Modify Bearer Request` message to the **S-GW** over S11, one message for each PDN connection. If the S-GW doesn't need to signal to the P-GW, the new MME can instead send one `Modify Access Bearers Request` message for the UE (TS 23.401 clause 5.3.3.2, step 9). The `Modify Bearer Request` message carries the Sender F-TEID for Control Plane of the new MME and the Bearer Contexts to be modified, with the EBI, and, when they apply, the User Location Information, the RAT Type, the UE Time Zone, the Serving Network, and the User CSG Information (TS 29.274 clause 7.2.7, and TS 23.401 clause 5.3.3.2, step 9). The User CSG Information is sent only if the "active" flag is set (TS 23.401 clause 5.3.3.2, NOTE 7). When an S1-U GTP-U tunnel is set up during the TAU, the Bearer Contexts to be modified also carry the S1 eNodeB F-TEID for the downlink (TS 29.274 clause 7.2.7). Without an MME change, this step is skipped, and the MME reports a change of the UE Time Zone, the User CSG Information, or the Serving Network in the next Service Request (TS 23.401 clause 5.3.3.2, NOTE 2).
12. If the RAT type has changed, or if the S-GW has received the User Location Information, the UE Time Zone, the User CSG Information, or the Serving Network from the new MME, the **S-GW** sends a GTPv2 `Modify Bearer Request` message with this information to the **P-GW** over S5/S8, one message for each PDN connection (TS 23.401 clause 5.3.3.2, step 10). For a TAU without S-GW change, the message doesn't carry the Bearer Contexts to be modified (TS 29.274 clause 7.2.7).
13. The **P-GW** updates its context so that it routes downlink packets to the correct S-GW and returns a GTPv2 `Modify Bearer Response` message to the **S-GW** (TS 23.401 clause 5.3.3.2, step 12). If there has been a RAT change towards E-UTRAN and location information change reporting is required and supported in the new MME, the message carries the MS Info Change Reporting Action (TS 23.401 clause 5.3.3.2, step 12). TS 23.401 clause 5.3.3.2, step 12, also lists the MSISDN when the P-GW has it stored, but TS 29.274 clause 7.2.8 requires the MSISDN on S5/S8 only for a TAU, RAU, or handover with S-GW relocation.
14. The **S-GW** updates its bearer context and returns a GTPv2 `Modify Bearer Response` message to the **new MME** over S11 (TS 23.401 clause 5.3.3.2, step 13). The message carries the Cause set to "Request accepted" (16) and the Bearer Contexts modified, with the EBI, the Cause, and the S1-U SGW F-TEID of each bearer (TS 29.274 clause 7.2.8).
15. If the new MME holds no subscription data for the UE, or, in some network sharing scenarios, if the PLMN-ID of the TAI differs from that of the GUTI, the **new MME** sends a Diameter `Update-Location-Request` (ULR) message to the **HSS** over S6a (TS 23.401 clause 5.3.3.1, step 12). The message registers the new MME as the serving MME and carries the User-Name with the IMSI, the ULR-Flags, the Visited-PLMN-Id, the RAT-Type, and, optionally, the Terminal-Information with the International Mobile Equipment Identity (IMEI) and the Software-Version (TS 29.272 clause 5.2.1.1.1). The HSS takes the MME identity from the Origin-Host AVP of the request (TS 29.272 clause 5.2.1.1.3). The new MME sets the S6a/S6d-Indicator in the ULR-Flags, sets the Single-Registration-Indication only if the previous node is a Gn/Gp SGSN, and, as a combined MME/SGSN, sets the Skip Subscriber Data flag if it already holds the subscriber data (TS 29.272 clause 5.2.1.1.2, and clause 7.3.7).
16. The **HSS** sends a Diameter `Cancel-Location-Request` (CLR) message to the **old MME** over S6a, carrying

the User-Name with the IMSI and the Cancellation-Type set to MME_UPDATE_PROCEDURE (0) (TS 23.401 clause 5.3.3.1, step 13, and TS 29.272 clauses 5.2.1.1.3 and 7.3.24).

17. If the timer that the old MME started in step 4 isn't running, the **old MME** removes the MM context of the UE; otherwise, the old MME removes the contexts when the timer expires, so that the MM context is kept for the case in which the UE starts another TAU towards the old MME. The old MME acknowledges the cancellation with a Diameter `Cancel-Location-Answer` (CLA) message to the **HSS**, carrying the Result-Code `DIAMETER_SUCCESS` (2001) (TS 23.401 clause 5.3.3.1, step 14, TS 29.272 clause 5.2.1.2.2, and IETF RFC 6733 section 7.1.2).

18. The **HSS** acknowledges the location update with a Diameter `Update-Location-Answer` (ULA) message to the **new MME** (TS 23.401 clause 5.3.3.1, step 17). The message carries the Result-Code `DIAMETER_SUCCESS` (2001), the ULA-Flags, and the Subscription-Data, with the Subscriber-Status, the AMBR, the APN-Configuration-Profile, whose Context-Identifier identifies the default APN configuration and whose APN-Configuration AVPs carry the EPS-Subscribed-QoS-Profile and the APN-AMBR of each APN, and the CSG-Subscription-Data (TS 29.272 clauses 5.2.1.1.1, 7.3.2, 7.3.34, and 7.3.35). If the TAU is started at a CSG cell, the new MME checks the CSG subscription and rejects the TAU if the CSG ID isn't present or has expired (TS 23.401 clause 5.3.3.1, step 17).

19. If the MME has changed and the old MME has received the SGW Change Indication in step 6, the **old MME** deletes the EPS bearer resources in the **old S-GW** when the timer started in step 4 expires, by sending GTPv2 `Delete Session Request` messages over S11 (TS 23.401 clause 5.3.3.1, step 18). The message carries the Indication Flags with the Operation Indication flag not set, so that the old S-GW doesn't start a deletion towards the P-GW, and with the Scope Indication flag set to 1 (TS 29.274 clause 7.2.9.1). The message carries a Cause when ISR is deactivated, with the value "ISR deactivation", or when the MME sends the message because of a network failure. The User Location Information is sent only for the Detach procedure (TS 29.274 clause 7.2.9.1). Without an MME change, the `Create Session Response` message of step 10 triggers the release of the resources in the old S-GW (TS 23.401 clause 5.3.3.1, step 18).

20. The **old S-GW** discards any packets that it has buffered for the UE and returns a GTPv2 `Delete Session Response` message to the **old MME** over S11, with the Cause set to "Request accepted" (16) (TS 23.401 clause 5.3.3.1, step 19, and TS 29.274 clause 7.2.10).

21. The **new MME** sends a NAS `Tracking Area Update Accept` message to the **UE** (TS 23.401 clause 5.3.3.1, step 20). The message carries the EPS update result, the TAI list, the EPS bearer context status, and, if the MME has allocated one, a new GUTI (TS 24.301 clause 8.2.26.1, and TS 23.401 clause 5.3.3.1, step 20). It can also carry the T3412 extended value, which provides a longer periodic TAU timer, the T3324 value, which the network includes when the UE has requested Power Saving Mode (PSM) and the network accepts it, the EPS network feature support IE, with the IMS voice over PS session indicator and the emergency bearer services indicator, and, if a combined TAU was successful for EPS services only, the EMM cause (TS 24.301 clauses 8.2.26.8, 8.2.26.13, 8.2.26.15, and 8.2.26.16). If the MME includes a GUTI, it starts timer T3450 (TS 24.301 clause 5.5.3.2.4). On receiving the message, the UE stops timer T3430, enters the EMM-REGISTERED state, and sets its EPS update status to EU1 UPDATED (TS 24.301 clause 5.5.3.2.4).

22. The **UE** returns a NAS `Tracking Area Update Complete` message to the **new MME** to acknowledge a GUTI, a TMSI in a combined TAU, a UE radio capability ID IE, or a UE radio capability ID deletion indication IE in

the `Tracking Area Update Accept` message. The UE also returns the message when it has a negotiated IMSI offset stored and the accept message doesn't contain the Negotiated IMSI offset IE (TS 24.301 clause 5.5.3.2.4). The message carries only the protocol discriminator, the security header type, and the message type (TS 24.301 clause 8.2.27). On receiving the message, the MME stops timer T3450 and considers the new GUTI valid (TS 24.301 clause 5.5.3.2.4). If the "active" flag isn't set and the TAU wasn't started in the ECM-CONNECTED state, the new MME then releases the signaling connection with the UE (TS 23.401 clause 5.3.3.1, step 21).

6.9.4. Summary of Key Information Elements

The following table summarizes the key IEs of the main messages of the procedure, grouped by protocol.

PROTOCOL	MESSAGE	KEY IES
NAS EMM (TS 24.301)	`Tracking Area Update Request`	EPS update type ("active" flag), NAS key set identifier (eKSI), Old GUTI, Old GUTI type, Last visited registered TAI, EPS bearer context status, UE network capability, MS network capability, Additional update type ("signalling active" flag)
NAS EMM (TS 24.301)	`Tracking Area Update Accept`	EPS update result, GUTI (if reallocated), TAI list, EPS bearer context status, T3412 extended value, T3324 value, EPS network feature support
NAS EMM (TS 24.301)	`Tracking Area Update Complete`	Protocol discriminator, Security header type, Message type only
S1AP (TS 36.413)	`Initial UE Message` / `Uplink NAS Transport`	eNB UE S1AP ID (and MME UE S1AP ID in `Uplink NAS Transport`), NAS-PDU, TAI, E-UTRAN CGI, RRC Establishment Cause, S-TMSI, GUMMEI (`Initial UE Message` only)
GTPv2-C (TS 29.274)	`Context Request` (S10)	GUTI, Complete TAU Request Message, S3/S16/S10/N26 Address and TEID for Control Plane, RAT Type, Indication (MS Validated flag)
GTPv2-C (TS 29.274)	`Context Response` (S10)	Cause ("Request accepted", 16), IMSI, MME/SGSN/AMF UE MM Context (KASME, eKSI, NAS counts), MME/SGSN/AMF UE EPS PDN Connections (APN, PGW S5/S8 IP Address for Control Plane or PMIP, bearer contexts with EBI and Bearer Level QoS), SGW S11/S4 IP Address and TEID for Control Plane
GTPv2-C (TS 29.274)	`Context Acknowledge` (S10)	Cause ("Request accepted", 16), Indication Flags (SGW Change Indication)
GTPv2-C (TS 29.274)	`Create Session Request` (S11)	IMSI, Sender F-TEID for Control Plane, PGW S5/S8 Address for Control Plane or PMIP, Bearer Contexts to be created (EBI, Bearer Level QoS, S5/S8-U PGW F-TEID), RAT Type, ULI
GTPv2-C (TS 29.274)	`Create Session Response` (S11)	Cause ("Request accepted", 16), Sender F-TEID for Control Plane, Bearer Contexts created (EBI, Cause, S1-U SGW F-TEID)
GTPv2-C (TS 29.274)	`Modify Bearer Request`	Sender F-TEID for Control Plane, Bearer Contexts to be modified (EBI, S1 eNodeB F-TEID on S11 when S1-U is set up, S5/8-U SGW F-TEID on S5/S8 with S-GW change), ULI, RAT Type

PROTOCOL	MESSAGE	KEY IES
GTPv2-C (TS 29.274)	`Modify Bearer Response`	Cause ("Request accepted", 16), Bearer Contexts modified (EBI, Cause, S1-U SGW F-TEID on S11, Charging ID on S5/S8), MSISDN (on S5/S8 with S-GW relocation), Change Reporting Action
GTPv2-C (TS 29.274)	`Delete Session Request` (S11)	Indication Flags (Operation Indication not set, Scope Indication set to 1), Cause ("ISR deactivation" when ISR is deactivated, or a network failure cause)
Diameter S6a (TS 29.272)	`Update-Location-Request` (ULR)	User-Name (IMSI), ULR-Flags, Visited-PLMN-Id, RAT-Type, Terminal-Information, Origin-Host (MME identity)
Diameter S6a (TS 29.272)	`Cancel-Location-Request` (CLR)	User-Name (IMSI), Cancellation-Type (MME_UPDATE_PROCEDURE)
Diameter S6a (TS 29.272)	`Update-Location-Answer` (ULA)	Result-Code (`DIAMETER_SUCCESS`), ULA-Flags, Subscription-Data (Subscriber-Status, AMBR, APN-Configuration-Profile with the default APN, EPS-Subscribed-QoS-Profile, and APN-AMBR, CSG-Subscription-Data)

6.9.5. Possible Failures and Required Actions

Failed UE validation or context retrieval

If the old MME can’t find the UE, or if the integrity check of the `Tracking Area Update Request` message fails, the old MME returns the `Context Response` message with an error cause, and the new MME starts the security functions (TS 23.401 clause 5.3.3.1, steps 4 and 5). If the security functions don’t authenticate the UE correctly, the new MME rejects the TAU and sends a reject indication to the old MME, which continues as if it had never received the `Context Request` message (TS 23.401 clause 5.3.3.1, step 7). The MME sends a NAS `Tracking Area Update Reject` message with EMM cause #9 "UE identity cannot be derived by the network" when the UE changes from N1 mode to S1 mode and the MME doesn’t support the N26 interface (TS 24.301 clause 5.5.3.2.5). When the AMF informs the MME that the integrity check of the request has failed and the MME can’t retrieve the current EPS security context of the UE, the MME can first identify the UE with an `Identity Request` message, and it uses cause #9 if it needs to reject the TAU (TS 24.301 clause 5.5.3.2.5). On receiving the reject message, the UE stops timer T3430. With cause #9, the UE sets its EPS update status to EU2 NOT UPDATED, deletes any GUTI, last visited registered TAI, TAI list, and eKSI, and enters the EMM-DEREGISTERED.NORMAL-SERVICE state. Unless the rejected request was for a PDN connection for emergency bearer services, the UE then automatically starts the attach procedure (TS 24.301 clause 5.5.3.2.5).

Rejection by the HSS or subscription restrictions

If the HSS rejects the `Update-Location-Request`, for example because the UE isn’t allowed to roam into the visited PLMN, the new MME rejects the TAU with an appropriate cause and releases its local EPS bearer contexts for the UE. With S-GW relocation, the new MME also deletes the bearer resources in the new S-GW with `Delete Session Request` messages, in which the Operation Indication flag isn’t set (TS 23.401 clause 5.3.3.1, step 17). The MME also rejects the TAU if regional subscription restrictions or access restrictions, such as CSG restrictions, don’t allow the UE to access the tracking area (TS 23.401 clause 5.3.3.1, step 20). TS 29.272 Annex A maps the S6a errors to EMM causes.

`DIAMETER_ERROR_ROAMING_NOT_ALLOWED` (5004) maps to #11 "PLMN not allowed" without an Error Diagnostic, to #14 "EPS services not allowed in this PLMN" with the Error Diagnostic ODB_HPLMN_APN or ODB_VPLMN_APN, and to #15 "No suitable cells in tracking area" with the Error Diagnostic ODB_ALL_APN. The `DIAMETER_ERROR_UNKNOWN_EPS_SUBSCRIPTION` (5420) error maps to #15, or to #7 "EPS services not allowed" with the Error Diagnostic NO_GPRS_DATA_SUBSCRIBED, and the `DIAMETER_ERROR_RAT_NOT_ALLOWED` (5421) error maps to #15, #13 "Roaming not allowed in this tracking area", or #12 "Tracking area not allowed", at the choice of the operator (TS 29.272 Table A.1). A regional subscription restriction maps to #12 (TS 29.272 Table A.2). The UE handles the causes differently (TS 24.301 clause 5.5.3.2.5):

- With cause #12, the UE sets its EPS update status to EU3 ROAMING NOT ALLOWED, deletes any GUTI, last visited registered TAI, TAI list, and eKSI, resets the TAU attempt counter, stores the current TAI in the list of "forbidden tracking areas for regional provision of service", and enters the EMM-DEREGISTERED.LIMITED-SERVICE state.
- With cause #13, the UE sets its EPS update status to EU3 ROAMING NOT ALLOWED, resets the TAU attempt counter, stores the current TAI in the list of "forbidden tracking areas for roaming", enters the EMM-REGISTERED.PLMN-SEARCH state, and performs a PLMN selection.
- With cause #15, the UE sets its EPS update status to EU3 ROAMING NOT ALLOWED, resets the TAU attempt counter, usually stores the current TAI in the list of "forbidden tracking areas for roaming", enters the EMM-REGISTERED.LIMITED-SERVICE state, and searches for a suitable cell in another tracking area.

The `Tracking Area Update Reject` message carries the Forbidden TAI(s) IEs only when the network sends the message via satellite E-UTRAN access (TS 24.301 clauses 8.2.28.4 and 8.2.28.5).

Network congestion

When general NAS level mobility management congestion control is active, the MME rejects the TAU with EMM cause #22 "Congestion" and assigns a value for the mobility management back-off timer T3346 in the `Tracking Area Update Reject` message (TS 24.301 clauses 5.3.9 and 5.5.3.2.5). If the MME can’t send a request to the HSS because the HSS is overloaded, TS 29.272 recommends cause #22 and allows the MME to ask the UE not to retry before a back-off timer expires (TS 29.272 Table A.2). On receiving cause #22 with a T3346 value that is neither zero nor deactivated, the UE aborts the procedure, resets the TAU attempt counter, sets its EPS update status to EU2 NOT UPDATED, and enters the EMM-REGISTERED.ATTEMPTING-TO-UPDATE state, unless the request was for a PDN connection for emergency bearer services. The UE starts timer T3346 with the received value if the message is integrity protected, and with a random value from the default range otherwise (TS 24.301 clause 5.5.3.2.5). In the EMM-REGISTERED.ATTEMPTING-TO-UPDATE state, the UE sends no user data and starts the TAU again when timer T3346 expires, although it can still start a TAU for a PDN connection for emergency bearer services and still responds to paging (TS 24.301 clause 5.2.3.2.2).

6.9.6. References

SPECIFICATION	CLAUSES AND COVERAGE
TS 23.401	• Clause 5.3.3.0 — Triggers for tracking area update • Clause 5.3.3.0A — Provision of UE's TAI to MME in ECM-CONNECTED state • Clause 5.3.3.1 — Tracking Area Update procedure with Serving GW change • Clause 5.3.3.2 — E-UTRAN Tracking Area Update without S-GW Change • Clauses 4.3.8.2 and 4.3.8.3 — Serving GW selection function and MME selection function
TS 24.301	• Clause 5.2.3.2.2 — ATTEMPTING-TO-UPDATE substate • Clause 5.3.9 — Handling of NAS level mobility management congestion control • Clause 5.5.3 — Tracking area updating procedure (S1 mode only) • Clauses 5.5.3.2.2, 5.5.3.2.4, and 5.5.3.2.5 — Normal and periodic tracking area updating procedure initiation, acceptance, and rejection • Clauses 8.2.26 to 8.2.29 — TRACKING AREA UPDATE ACCEPT, COMPLETE, REJECT, and REQUEST message contents • Clauses 8.2.7, 8.2.8, and 8.2.20 — AUTHENTICATION REQUEST, AUTHENTICATION RESPONSE, and SECURITY MODE COMMAND message contents • Clause 9.9.3.14 — EPS update type • Tables 10.2.1 and 10.2.2 — EPS mobility management timers (T3430, T3346, and T3450)
TS 36.413	• Clause 9.1.7.1 — INITIAL UE MESSAGE message content • Clause 9.1.7.3 — UPLINK NAS TRANSPORT message content
TS 29.274	• Clauses 7.3.5, 7.3.6, and 7.3.7 — Context Request, Context Response, and Context Acknowledge • Clauses 7.2.1 and 7.2.2 — Create Session Request/Response • Clauses 7.2.7 and 7.2.8 — Modify Bearer Request/Response • Clauses 7.2.9.1 and 7.2.10 — Delete Session Request/Response • Clause 8.38 — MM Context
TS 29.272	• Clause 5.2.1.1 — Update Location • Clause 5.2.1.2 — Cancel Location • Clauses 7.3.2, 7.3.7, and 7.3.24 — Subscription-Data, ULR-Flags, and Cancellation-Type • Annex A — MME mapping table for S6a and NAS cause code values
TS 33.401	• Clause 7.2.4.3.2 — NAS algorithm selection at MME change • Clause 7.2.7 — Key handling for the TAU procedure when registered in E-UTRAN
IETF RFC 6733	Section 7.1.2 (`DIAMETER_SUCCESS` result code).

Part III: 5G Core Network (5GC)

This part describes the 5G Core Network (5GC): its network functions and the reference points between them, the protocols that carry signaling between the network functions, and the signaling procedures that run over those protocols.

Chapter 7. Architecture and Specifications

The 5GC is the core network of the 5G System (5GS). TS 23.501 clause 4.2.3 describes the non-roaming 5GS architecture in two equivalent representations: a service-based representation, in which each control-plane network function (NF) exposes its services over a service-based interface (SBI), and a reference point representation, in which a named reference point connects each pair of NFs that interact. This chapter shows the 5GC in both representations, with 3GPP access through the NG-RAN. Roaming (TS 23.501 clause 4.2.4) and non-3GPP access (TS 23.501 clause 4.2.8) are outside the scope of both figures.

7.1. Service-Based Representation

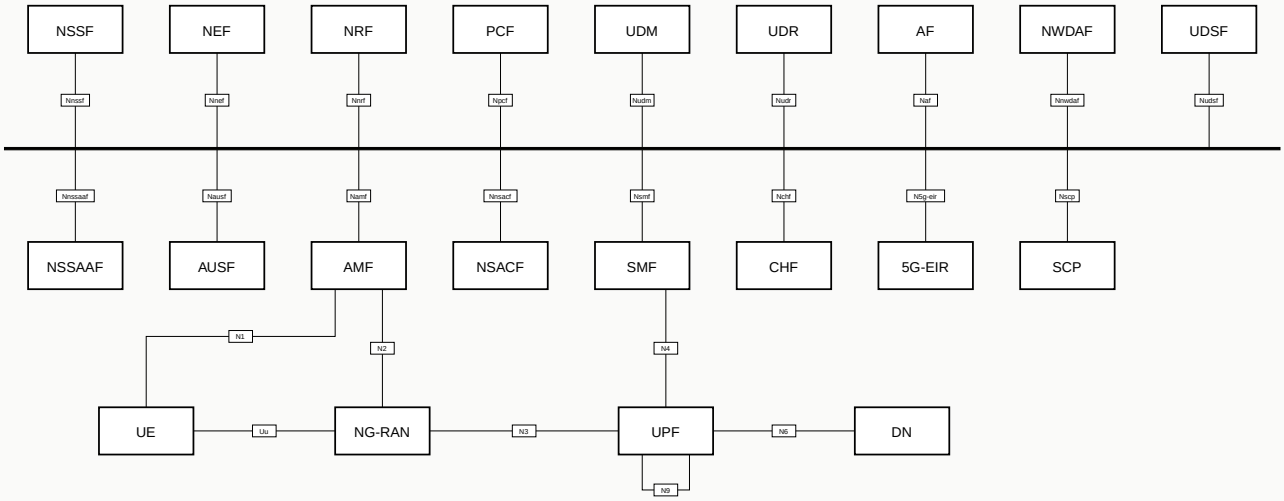


Figure 27. 5GC architecture, service-based representation

The figure above follows TS 23.501 figure 4.2.3-1 and attaches every control-plane NF to the common service-based interconnect through the SBI that the NF exposes, for example Namf for the AMF (TS 23.501 clause 4.2.6). Any NF can consume the services of any other NF over this interconnect, so the figure shows which NFs are part of the 5GC rather than which pairs of NFs interact. The NF services use version 2 of the Hypertext Transfer Protocol (HTTP), HTTP/2, over the Transmission Control Protocol (TCP), as TS 29.500 specifies for the technical realization of the service-based architecture. The UE, the NG-RAN, and the DN do not expose an SBI and therefore connect to the 5GC through the reference points N1, N2, N3, and N6. The SMF controls the UPF over the N4 reference point; the Nupf SBI of the UPF only serves specific exposure features (TS 23.501 clause 4.2.16) and is not shown.

Compared with TS 23.501 figure 4.2.3-1, the figure adds the UDR and the NWDAF, which NOTE 4 and NOTE 5 of TS 23.501 clause 4.2.3 leave out of the TS 23.501 figures for clarity, and the UDSF, the CHF, and the 5G-EIR, which TS 23.501 figure 4.2.3-1 does not show either. The figure leaves out the Edge Application Server Discovery Function (EASDF), which TS 23.501 figure 4.2.3-1 shows, together with the NFs of other specific features, for example the UE radio Capability Management Function (UCMF), the Time Sensitive Communication and Time Synchronization Function (TSCTSF), the Data Collection Coordination Function (DCCF), the Messaging Framework Adaptor Function (MFAF), and the Analytics Data Repository Function (ADRF) (TS 23.501 clause 4.2.2).

7.2. Reference Point Representation

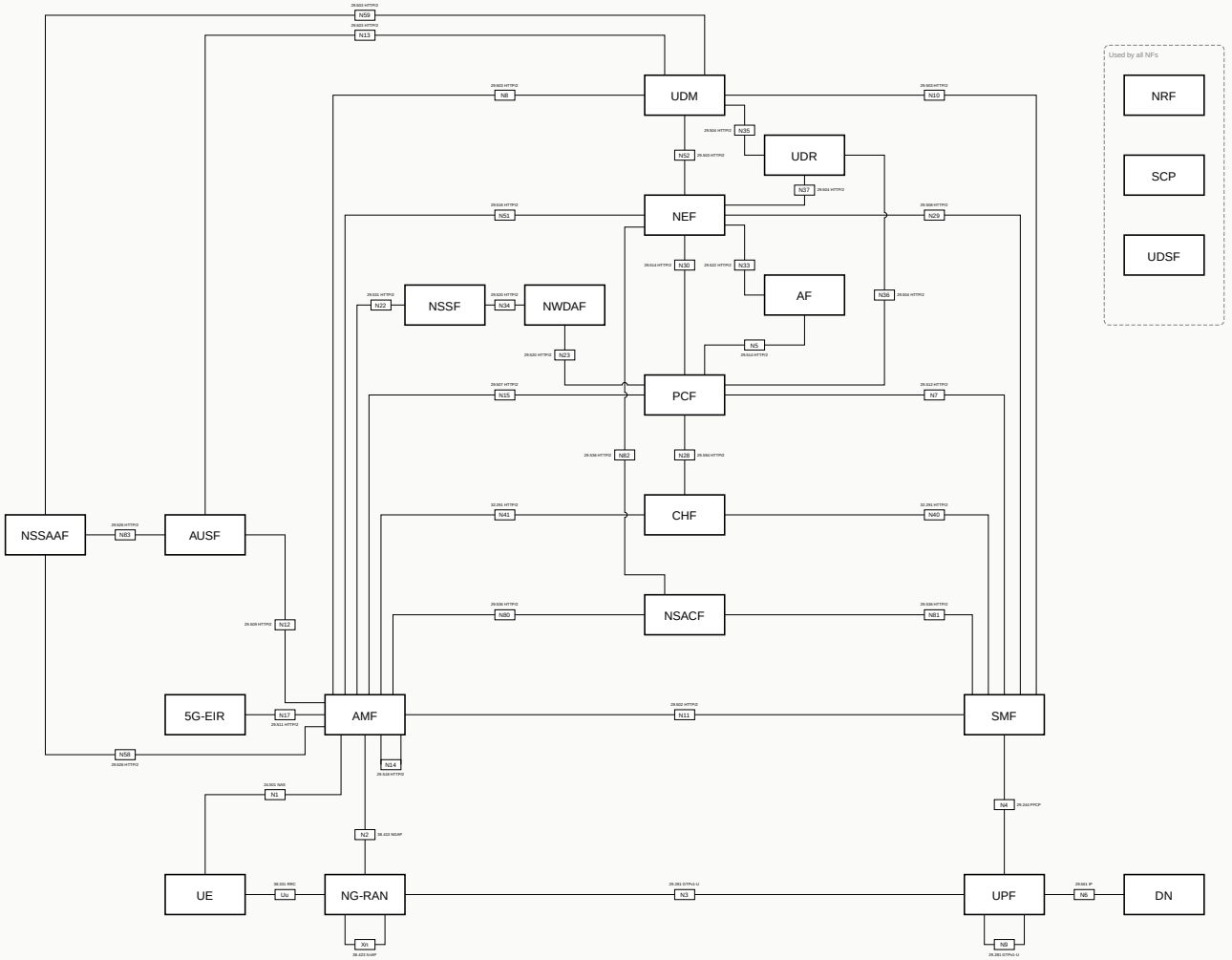


Figure 28. 5GC architecture, reference point representation

The figure above shows the same NFs as the service-based representation and connects them with the reference points that TS 23.501 clause 4.2.7 defines between them. TS 23.501 figure 4.2.3-2 leaves out the NRF, the NEF, the UDR, the UDSF, and the NWDAF for clarity (NOTE 2, NOTE 4, and NOTE 5 of TS 23.501 clause 4.2.3) and does not show the CHF and the 5G-EIR, and TS 23.501 figure 4.2.3-5 shows the NEF separately; this figure combines these NFs into one view.

The figure is arranged around the AMF and the SMF, which interact with more NFs than any other NF. The centre column holds the NFs that both the AMF and the SMF use, namely the UDM, the NEF, the PCF, the CHF, and the NSACF. The AMF reaches each of these NFs over a reference point that rises from the top of the AMF and turns right at the height of the target NF, and the SMF reaches the same NFs over the mirrored reference points on the right, so that each row of the centre column reads as one pair of reference points, for example N8 and N10 for the UDM. The NFs that the AMF uses and the SMF does not use sit to the left: the AUSF, the NSSAAF, and the 5G-EIR to the left of the AMF, and the NSSF, together with the NWDAF that serves the NSSF and the PCF, between the AMF and the centre column. The NFs that only connect to the centre column, namely the UDR and the AF, sit to its right. The bottom row holds the UE and the user-plane path from the NG-RAN through the UPF to the DN.

The NRF, the SCP, and the UDSF are grouped in a frame because every NF can interact with them. The NRF and the SCP have no reference point to a specific NF in a non-roaming Public Land Mobile Network (PLMN), apart from N116 between the SCP and the NWDAF, and N18 connects any NF to the UDSF, so the figure does not draw these reference points.

Next to each reference point, the figure gives the 3GPP technical specification (TS) that defines the protocol on that reference point and the name of the protocol. For a reference point between two control-plane NFs, the TS is the stage 3 specification of the SBI that realizes the reference point, and the protocol is HTTP/2. Where a reference point crosses another reference point without a connection, the figure draws a small arc.

7.3. Network Functions

UE (User Equipment)

The UE is the subscriber's device. The UE communicates with the NG-RAN over the Uu radio interface and with the AMF over N1, which carries the Non-Access Stratum (NAS) protocol of TS 24.501.

NG-RAN (Next Generation Radio Access Network)

The NG-RAN is the 5G radio access network, made up of NR Node Bs (gNBs) and ng-eNBs (TS 38.300). The NG-RAN relays control-plane signaling to the AMF over N2 and user-plane traffic to the UPF over N3, and NG-RAN nodes interconnect over Xn.

AMF (Access and Mobility Management Function)

The AMF terminates N1 and N2 and handles registration, connection, reachability, and mobility management for the UE, together with access authentication and authorization (TS 23.501 clause 6.2.1). The AMF relays session management messages between the UE and the SMF and exposes the Namf SBI (TS 29.518).

SMF (Session Management Function)

The SMF establishes, modifies, and releases Protocol Data Unit (PDU) sessions, allocates the Internet Protocol (IP) address of the UE, and selects and controls the UPF over N4 (TS 23.501 clause 6.2.2). The SMF exposes the Nsmf SBI (TS 29.502).

UPF (User Plane Function)

The UPF is the anchor point of the PDU session in the user plane. The UPF routes and forwards packets between the NG-RAN and the DN and applies the packet detection, Quality of Service (QoS), and usage reporting rules that the SMF provisions over N4 (TS 23.501 clause 6.2.3). Two UPFs interconnect over N9, for example when an intermediate UPF serves a PDU session.

DN (Data Network)

The DN is the data network that the PDU session gives access to, for example the internet, operator services, or third-party services. The UPF connects to the DN over N6.

AUSF (Authentication Server Function)

The AUSF authenticates the UE for 3GPP access and for untrusted non-3GPP access (TS 23.501 clause 6.2.8). The AUSF exposes the Nausf SBI (TS 29.509).

UDM (Unified Data Management)

The UDM generates the authentication credentials, handles the user identification, and manages the subscription data and the registration of the serving NFs for each UE (TS 23.501 clause 6.2.7). The UDM can keep the subscription data in the UDR and exposes the Nudm SBI (TS 29.503).

UDR (Unified Data Repository)

The UDR stores and retrieves the subscription data for the UDM and the policy data for the PCF, together with the structured data for exposure and the application data, for example the Packet Flow Descriptions (PFDs) for application detection (TS 23.501 clause 6.2.11). The UDR exposes the Nudr SBI (TS 29.504).

PCF (Policy Control Function)

The PCF provides the policy rules for access and mobility management to the AMF and the policy and charging control rules for the PDU session to the SMF (TS 23.501 clause 6.2.4). The PCF exposes the Npcf SBI, whose services several stage 3 specifications define, for example TS 29.507, TS 29.512, and TS 29.514.

AF (Application Function)

The AF interacts with the 5GC to influence traffic routing, to request policy control from the PCF, or to use the exposure framework of the NEF (TS 23.501 clause 6.2.10). An AF in a trusted domain can interact with the PCF directly over N5, and any other AF uses the NEF.

NEF (Network Exposure Function)

The NEF exposes the capabilities and events of the 5GC to the AF and translates the information that the AF provides into requests towards the other NFs (TS 23.501 clause 6.2.5). The NEF exposes the Nnef SBI, and TS 29.522 defines the northbound application programming interfaces (APIs) of the NEF towards the AF.

NRF (Network Repository Function)

The NRF holds the profiles of the available NF instances and their services, and it supports NF registration and NF discovery (TS 23.501 clause 6.2.6). The NRF exposes the Nnrf SBI (TS 29.510).

NSSF (Network Slice Selection Function)

The NSSF selects the set of network slice instances that serve the UE and determines the allowed and configured network slices (TS 23.501 clause 6.2.14). The NSSF exposes the Nnssf SBI (TS 29.531).

NSSAAF (Network Slice-specific and SNPN Authentication and Authorization Function)

The NSSAAF performs network slice-specific authentication and authorization with an external authentication, authorization, and accounting (AAA) server, and it supports access to a standalone non-public network (SNPN) with credentials from a credentials holder (TS 23.501 clause 6.2.23). The NSSAAF exposes the Nnssaaf SBI (TS 29.526).

NSACF (Network Slice Admission Control Function)

The NSACF monitors and controls the number of registered UEs and the number of PDU sessions per network slice (TS 23.501 clause 6.2.28). The NSACF exposes the Nnsacf SBI (TS 29.536).

5G-EIR (5G Equipment Identity Register)

The 5G-EIR is an optional NF that checks the status of the Permanent Equipment Identifier (PEI) of the UE, for example to check that the PEI is not prohibited (TS 23.501 clause 6.2.15). The 5G-EIR exposes the N5g-eir SBI (TS 29.511).

CHF (Charging Function)

The CHF performs converged online and offline charging for the charging data that the SMF and the AMF report (TS 32.240, TS 32.255 for the SMF, and TS 32.256 for the AMF), and it provides the policy counters for spending limit control to the PCF (TS 29.594). The CHF exposes the Nchf SBI (TS 32.291).

NWDAF (Network Data Analytics Function)

The NWDAF collects data from the NFs, from the AF, and from operations, administration, and maintenance (OAM) and provides analytics information to the NFs and to the AF (TS 23.501 clause 6.2.18 and TS 23.288). The NWDAF exposes the Nnwdaf SBI (TS 29.520).

UDSF (Unstructured Data Storage Function)

The UDSF is an optional NF in which any NF can store and retrieve its unstructured data, for example UE contexts (TS 23.501 clause 6.2.12 and clause 4.2.5). The UDSF exposes the Nudsf SBI.

SCP (Service Communication Proxy)

The SCP is an optional NF that routes the service requests between NFs for indirect communication and can perform the NF discovery and selection on behalf of the consumer NF (TS 23.501 clause 6.2.19 and Annex E). When an operator deploys no SCP, the NFs communicate with each other directly.

7.4. Reference Points

The following table lists the reference points in the reference point representation figure. TS 23.501 clause 4.2.7 defines all of these reference points except Uu and Xn, which TS 38.300 defines for the NG-RAN.

Table 5. Reference points in the reference point representation

REFERENCE POINT	BETWEEN	SPECIFICATION	PROTOCOL
Uu	UE and NG-RAN	TS 38.331	Radio Resource Control (RRC)
Xn	Two NG-RAN nodes	TS 38.423	Xn Application Protocol (XnAP)
N1	UE and AMF	TS 24.501	NAS
N2	NG-RAN and AMF	TS 38.413	NG Application Protocol (NGAP)
N3	NG-RAN and UPF	TS 29.281	GTP version 1 for the user plane (GTPv1-U)
N4	SMF and UPF	TS 29.244	Packet Forwarding Control Protocol (PFCP)
N5	PCF and AF	TS 29.514	HTTP/2
N6	UPF and DN	TS 29.561	IP

REFERENCE POINT	BETWEEN	SPECIFICATION	PROTOCOL
N7	SMF and PCF	TS 29.512	HTTP/2
N8	UDM and AMF	TS 29.503	HTTP/2
N9	Two UPFs	TS 29.281	GTPv1-U
N10	UDM and SMF	TS 29.503	HTTP/2
N11	AMF and SMF	TS 29.502	HTTP/2
N12	AMF and AUSF	TS 29.509	HTTP/2
N13	UDM and AUSF	TS 29.503	HTTP/2
N14	Two AMFs	TS 29.518	HTTP/2
N15	PCF and AMF	TS 29.507	HTTP/2
N17	AMF and 5G-EIR	TS 29.511	HTTP/2
N22	AMF and NSSF	TS 29.531	HTTP/2
N23	PCF and NWDAF	TS 29.520	HTTP/2
N28	PCF and CHF	TS 29.594	HTTP/2
N29	NEF and SMF	TS 29.508	HTTP/2
N30	PCF and NEF	TS 29.514	HTTP/2
N33	NEF and AF	TS 29.522	HTTP/2
N34	NSSF and NWDAF	TS 29.520	HTTP/2
N35	UDM and UDR	TS 29.504	HTTP/2
N36	PCF and UDR	TS 29.504	HTTP/2
N37	NEF and UDR	TS 29.504	HTTP/2
N40	SMF and CHF	TS 32.291	HTTP/2
N41	AMF and CHF	TS 32.291	HTTP/2
N51	AMF and NEF	TS 29.518	HTTP/2
N52	NEF and UDM	TS 29.503	HTTP/2
N58	AMF and NSSAAF	TS 29.526	HTTP/2
N59	UDM and NSSAAF	TS 29.503	HTTP/2
N80	AMF and NSACF	TS 29.536	HTTP/2
N81	SMF and NSACF	TS 29.536	HTTP/2
N82	NSACF and NEF	TS 29.536	HTTP/2
N83	AUSF and NSSAAF	TS 29.526	HTTP/2

Glossary

This glossary lists the abbreviations that this book uses, together with their expanded forms. The text spells out each abbreviation at its first use in each part and uses only the abbreviation after that, so a reader who starts in the middle of a part can look up an abbreviation here. 3GPP TR 21.905 defines the common vocabulary of the 3GPP specifications, and the specification that each chapter cites defines the abbreviations that are specific to one protocol or procedure.

3GPP	Third Generation Partnership Project
5G-EIR	5G Equipment Identity Register
5GC	5G Core Network
5GS	5G System
AAA	Authentication, Authorization, and Accounting
ADC	Application Detection and Control
ADRF	Analytics Data Repository Function
AF	Application Function
AMBR	Aggregate Maximum Bit Rate
AMF	Access and Mobility Management Function
API	Application Programming Interface
APN	Access Point Name
APN-AMBR	APN Aggregate Maximum Bit Rate
ARP	Allocation and Retention Priority
AS	Access Stratum
ASN.1	Abstract Syntax Notation One
AUSF	Authentication Server Function
AUTN	Authentication Token
AVP	Attribute-Value Pair
BAR	Buffering Action Rule
BCM	Bearer Control Mode

BM-SC	Broadcast Multicast Service Centre
BSS	Base Station Subsystem
C-RNTI	Cell Radio Network Temporary Identifier
CAMEL	Customised Applications for Mobile network Enhanced Logic
CBC	Cell Broadcast Centre
CCA	Credit-Control-Answer (Diameter command)
CCR	Credit-Control-Request (Diameter command)
CDR	Charging Data Record
CGI	Cell Global Identification
CHAP	Challenge Handshake Authentication Protocol
CHF	Charging Function
CIoT	Cellular Internet of Things
CLA	Cancel-Location-Answer (Diameter command)
CLR	Cancel-Location-Request (Diameter command)
CN	Core Network
CP	Control Plane
CS	Circuit-Switched
CSG	Closed Subscriber Group
CUPS	Control and User Plane Separation
DAPS	Dual Active Protocol Stack
DCCF	Data Collection Coordination Function
DCN	Dedicated Core Network
DDN	Downlink Data Notification (GTPv2-C message)
DN	Data Network
DNS	Domain Name System

DRB	Data Radio Bearer
DRX	Discontinuous Reception
DTI	Direct Tunnel Indicator
DTM	Dual Transfer Mode
E-CID	Enhanced Cell-ID
E-RAB	E-UTRAN Radio Access Bearer
E-SMLC	Evolved Serving Mobile Location Centre
E-UTRA	Evolved Universal Terrestrial Radio Access
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
EASDF	Edge Application Server Discovery Function
EBI	EPS Bearer Identity
ECA	ME-Identity-Check-Answer (Diameter command)
ECGI	E-UTRAN Cell Global Identifier
ECM	EPS Connection Management
ECR	ME-Identity-Check-Request (Diameter command)
EDGE	Enhanced Data rates for GSM Evolution
eDRX	Extended Discontinuous Reception
EEA0	EPS Encryption Algorithm 0
EHPLMN	Equivalent HPLMN
EIR	Equipment Identity Register
eKSI	Key Set Identifier for E-UTRAN
EMM	EPS Mobility Management
eMPS	Enhanced Multimedia Priority Service
EN-DC	E-UTRA-NR Dual Connectivity
eNodeB, eNB	E-UTRAN Node B

EP	Elementary Procedure
EPC	Evolved Packet Core
ePDG	Evolved Packet Data Gateway
EPS	Evolved Packet System
ESM	EPS Session Management
ETSI	European Telecommunications Standards Institute
F-TEID	Fully Qualified Tunnel Endpoint Identifier
FAR	Forwarding Action Rule
GBR	Guaranteed Bit Rate
GERAN	GSM EDGE Radio Access Network
GGSN	Gateway GPRS Support Node
gNB	NR Node B
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
GSN	GPRS Support Node
GTP	GPRS Tunnelling Protocol
GTP-C	GTP for the control plane
GTP-U	GTP for the user plane
GTPv0	GTP version 0
GTPv1	GTP version 1
GTPv1-C	GTP version 1 for the control plane
GTPv1-U	GTP version 1 for the user plane
GTPv2	GTP version 2
GTPv2-C	GTP version 2 for the control plane
GUMMEI	Globally Unique MME Identifier

GUTI	Globally Unique Temporary UE Identity
HFN	Hyper Frame Number
HLR	Home Location Register
HPLMN	Home PLMN
HRPD	High Rate Packet Data
HSS	Home Subscriber Server
HTTP	Hypertext Transfer Protocol
IDA	Insert-Subscriber-Data-Answer (Diameter command)
IDR	Insert-Subscriber-Data-Request (Diameter command)
IE	Information Element
IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
IMEI	International Mobile Equipment Identity
IMEISV	International Mobile Equipment Identity and Software Version Number
IMS	IP Multimedia Subsystem
IMSI	International Mobile Subscriber Identity
IoT	Internet of Things
IP	Internet Protocol
IP-CAN	IP Connectivity Access Network
ISR	Idle mode Signalling Reduction
ITU-T	International Telecommunication Union, Telecommunication Standardization Sector
KSI	Key Set Identifier
KSI_ASME	Key Set Identifier for the Access Security Management Entity
LAPI	Low Access Priority Indicator
LBI	Linked EPS Bearer Identity

LCI	Load Control Information
LLC	Logical Link Control
LPPa	LTE Positioning Protocol Annex
LTE	Long Term Evolution
MAC	Medium Access Control
MAP	Mobile Application Part
MBMS	Multimedia Broadcast Multicast Service
MBR	Maximum Bit Rate
MDT	Minimization of Drive Tests
ME	Mobile Equipment
MFAF	Messaging Framework Adaptor Function
MLD	Multicast Listener Discovery
MM	Mobility Management
MME	Mobility Management Entity
MNOP	Measurement of Number of Packets
MNRG	Mobile station Not Reachable for GPRS
MS	Mobile Station
MSISDN	Mobile Station International Subscriber Directory Number
NAS	Non-Access Stratum
NAS-MAC	NAS Message Authentication Code
NAS-PDU	NAS Protocol Data Unit
NB-IoT	Narrowband Internet of Things
NCC	Next hop Chaining Counter
NEF	Network Exposure Function
NF	Network Function

NG-RAN	Next Generation Radio Access Network
NGAP	NG Application Protocol
NH	Next Hop
NOA	Notify-Answer (Diameter command)
NOR	Notify-Request (Diameter command)
NR	New Radio
NRF	Network Repository Function
NSACF	Network Slice Admission Control Function
NSAPI	Network layer Service Access Point Identifier
NSSAAF	Network Slice-specific and SNPN Authentication and Authorization Function
NSSF	Network Slice Selection Function
NWDAF	Network Data Analytics Function
OAM	Operations, Administration, and Maintenance
OCI	Overload Control Information
OCS	Online Charging System
OFCS	Offline Charging System
OTDOA	Observed Time Difference Of Arrival
P-CSCF	Proxy Call Session Control Function
P-GW, PGW	PDN Gateway
P-TMSI	Packet Temporary Mobile Subscriber Identity
PAA	PDN Address Allocation
PAP	Password Authentication Protocol
PCC	Policy and Charging Control
PCEF	Policy and Charging Enforcement Function
PCF	Policy Control Function

PCO	Protocol Configuration Options
PCRF	Policy and Charging Rules Function
PDCP	Packet Data Convergence Protocol
PDCP-SN	PDCP Sequence Number
PDI	Packet Detection Information
PDN	Packet Data Network
PDP	Packet Data Protocol
PDR	Packet Detection Rule
PDU	Protocol Data Unit
PEI	Permanent Equipment Identifier
PER	Packed Encoding Rules
PFCP	Packet Forwarding Control Protocol
PFD	Packet Flow Description
PGW-C	PDN Gateway - Control Plane
PGW-U	PDN Gateway - User Plane
PLMN	Public Land Mobile Network
PMIP	Proxy Mobile IP
ProSe	Proximity-based Services
PS	Packet-Switched
PSCell	Primary SCG Cell
PSM	Power Saving Mode
PTI	Procedure Transaction Identity
PWS	Public Warning System
QCI	QoS Class Identifier
QER	QoS Enforcement Rule

QoS	Quality of Service
RAA	Re-Auth-Answer (Diameter command)
RAB	Radio Access Bearer
RADIUS	Remote Authentication Dial-In User Service
RAI	Routeing Area Identity
RAN	Radio Access Network
RANAP	Radio Access Network Application Part
RAND	Random Challenge
RAR	Re-Auth-Request (Diameter command)
RAT	Radio Access Technology
RAU	Routeing Area Update
RB	Radio Bearer
RES	Authentication Response
RFC	Request for Comments
RIM	RAN Information Management
RLC	Radio Link Control
RNC	Radio Network Controller
RNS	Radio Network Subsystem
RRC	Radio Resource Control
S-GW, SGW	Serving Gateway
S-TMSI	S-Temporary Mobile Subscriber Identity
S1AP	S1 Application Protocol
SAE	System Architecture Evolution
SAI	Service Area Identifier
SAPI	Service Access Point Identifier

SBI	Service-Based Interface
SCG	Secondary Cell Group
SCP	Service Communication Proxy
SCTP	Stream Control Transmission Protocol
SDF	Service Data Flow
SDU	Service Data Unit
SEID	Session Endpoint Identifier
SGSN	Serving GPRS Support Node
SGW-C	Serving Gateway - Control Plane
SGW-U	Serving Gateway - User Plane
SIM	Subscriber Identity Module
SIPTO	Selected IP Traffic Offload
SM	Session Management
SMF	Session Management Function
SMS	Short Message Service
SNDCP	Subnetwork Dependent Convergence Protocol
SNPN	Standalone Non-Public Network
SON	Self-Organizing Network
SRNS	Serving Radio Network Subsystem
SRVCC	Single Radio Voice Call Continuity
SS7	Signalling System No. 7
TAI	Tracking Area Identity
TAU	Tracking Area Update
TCP	Transmission Control Protocol
TDF	Traffic Detection Function

TDF-C	Traffic Detection Function - Control Plane
TDF-U	Traffic Detection Function - User Plane
TEID	Tunnel Endpoint Identifier
TFT	Traffic Flow Template
TI	Transaction Identifier
TLV	Type-Length-Value
TMGI	Temporary Mobile Group Identity
TMSI	Temporary Mobile Subscriber Identity
TS	Technical Specification
TSCTSF	Time Sensitive Communication and Time Synchronization Function
TV	Type-Value
TWAN	Trusted WLAN Access Network
UCI	User CSG Information
UCMF	UE radio Capability Management Function
UDM	Unified Data Management
UDP	User Datagram Protocol
UDR	Unified Data Repository
UDSF	Unstructured Data Storage Function
UE	User Equipment
UE-AMBR	UE Aggregate Maximum Bit Rate
ULA	Update-Location-Answer (Diameter command)
ULI	User Location Information
ULR	Update-Location-Request (Diameter command)
UMTS	Universal Mobile Telecommunications System
UP	User Plane

UPF	User Plane Function
URR	Usage Reporting Rule
USIM	Universal Subscriber Identity Module
UTDOA	Uplink Time Difference Of Arrival
UTRAN	Universal Terrestrial Radio Access Network
VoLTE	Voice over LTE
WLAN	Wireless Local Area Network
X2AP	X2 Application Protocol
XnAP	Xn Application Protocol