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Foreword

This Technical Specification (TS) has been produced by ETSI 3rd Generation Partnership Project (3GPP).

The present document may refer to technical specifications or reports using their 3GPP identities, UMTS identities or GSM identities. These should be interpreted as being references to the corresponding ETSI deliverables.

The cross reference between GSM, UMTS, 3GPP and ETSI identities can be found under http://webapp.etsi.org/key/queryform.asp.

Contents

Foreword

This Technical Specification (TS) has been produced by the 3rd Generation Partnership Project (3GPP).

The present document defines the restoration procedures within the 3GPP system.

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

- x the first digit:
  - 1 presented to TSG for information;
  - 2 presented to TSG for approval;
  - 3 or greater indicates TSG approved document under change control.
- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

1 Scope

The data stored in location registers are automatically updated in normal operation; the main information stored in a location register defines the location of each mobile station and the subscriber data required to handle traffic for each mobile subscriber. The loss or corruption of these data will seriously degrade the service offered to mobile subscribers; it is therefore necessary to define procedures to limit the effects of failure of a location register, and to restore the location register data automatically. The present document defines the necessary procedures.

The basic principle is that restoration should be based on radio contact to avoid faulty data being spread in the system.

Subscriber data for supplementary services must also be correctly restored, although the impact on service of corruption of supplementary service data is less severe.

Procedures for supporting these functions are defined in 3GPP TS 29.002 [6] and 3GPP TS 29.060 [8].

The MAP operation "IMSI Attach" is used only in MAP version 1; in MAP version 2 the same function is performed by the MAP operation "Update Location Area". References in this specification to IMSI attach apply only to MAP version 1 network entities.

If the restoration of subscriber data in the VLR is triggered by Location Updating or IMSI Attach, the VLR retrieves subscriber data from the HLR by sending an "Update Location" request, which triggers one or more "Insert Subscriber Data" operations from the HLR. The "Update Location" request may also be used to send the LMSI to the HLR.

If the restoration of subscriber data in the VLR is triggered by a "Provide Roaming Number" request, the behaviour of the VLR depends on whether it is implemented according to MAP version 1 or MAP version 2. For MAP version 2, the VLR retrieves subscriber data from the HLR by sending a "Restore Data" request, which triggers one or more "Insert Subscriber Data" operations from the HLR. The "Restore Data" request is also used to send the LMSI to the HLR. For MAP version 1, the VLR retrieves subscriber data from the HLR by sending a "Send Parameters" request with parameter type "Subscriber Data", which cannot be used to send the LMSI to the HLR.

The VLR number and MSC number in the subscriber data in the HLR are updated by the "Update Location" procedure.

The GGSN (Gateway GPRS Support Node) is the point of PDN interconnection with the GSM PLMN supporting GPRS. The GGSN contains routing information for GPRS users with a PDP context active. The necessary procedures needed to restore GGSN data information after a restart are described in this document.

The SGSN (Serving GPRS Support Node) is the node that is serving the MS. The SGSN stores information regarding e.g. mobility management, routing and security. The necessary procedures needed to restore this SGSN information after a restart are described in this document.

The MME (Mobility Management Entity) is the node that is serving the UE when attached to E-UTRAN. The MME stores information regarding e.g. mobility management, routing and security. The necessary procedures needed to restore this MME information after a restart are described in this document.

A Type A LMU (Location Measurement Unit) is a network node, accessed over the GSM air interface, that is functionally similar to an MS. All requirements associated with a non-GPRS MS in this specification apply also to a Type A LMU except where specified otherwise.

1.1 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary of 3GPP Specifications ".

[2] Void

[3] Void

[4] 3GPP TS 23.040: "Technical realization of the Short Message Service (SMS)".

[5] 3GPP TS 23.060: "General Packet Radio Service (GPRS); Service description; Stage 2".

[6] 3GPP TS 29.002: "Mobile Application Part (MAP) specification".

[7] 3GPP TS 29.018: "General Packet Radio Service (GPRS); Serving GPRS Support Node (SGSN) - Visitors Location Register (VLR); Gs interface layer 3 specification".

[8] 3GPP TS 29.060: "General Packet Radio Service (GPRS); GPRS Tunneling Protocol (GTP) across the Gn and Gp interface".

[9] 3GPP TS 43.005: "Technical performance objectives".

[10] 3GPP TS 23.071: " Location Services (LCS); Functional description; Stage 2".

[11] Void

[12] 3GPP TS 23.246: "Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description".

[13] 3GPP TS 29.274: "3GPP Evolved Packet System (EPS); Evolved General Packet Radio Service (GPRS) Tunnelling Protocol for Control plane (GTPv2-C); Stage 3".

[14] 3GPP TS 29.118:"Mobility Management Entity (MME) – Visitor Location Register (VLR) SGs interface specification".

[15] 3GPP TS 23.401: "General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access".

[16] 3GPP TS 29.275: "Proxy Mobile IPv6 (PMIPv6) based Mobility and Tunneling protocols; Stage 3".

[17] 3GPP TS 29.281: "General Packet Radio System (GPRS) Tunneling Protocol User Plane (GTPv1-U)".

[18] 3GPP TS 23.402: "Architecture enhancements for non-3GPP accesses".

[19] 3GPP TS 24.301: "Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3".

[20] 3GPP TS 24.008: "Mobile radio interface Layer 3 specification; Core network protocols; Stage 3".

[21] 3GPP TS 29.213: "Policy and charging control signalling flows and Quality of Service (QoS) parameter mapping ".

[22] IETF RFC 5847: "Heartbeat Mechanism for Proxy Mobile IPv6".

[23] 3GPP TS 23.018: "Basic call handling; Technical realization".

[24] 3GPP TS 23.236: "Intra-domain connection of Radio Access Network (RAN) nodes to multiple Core Network (CN) nodes".

[25] 3GPP TS 29.212: "Policy and Charging Control (PCC); Reference points".

[26] IETF draft-krishnan-netext-update-notifications-00: "Update Notifications for Proxy Mobile IPv6".

Editor's Note: The above document cannot be formally referenced until it is published as an RFC.

1.2 Abbreviations

For the purposes of the present document, the abbreviations listed in 3GPP TR 21. 905 [1] apply.

2 Design objectives

To avoid loss of all the data stored in a location register when part of the equipment of the location register fails, a regime must be implemented to secure the data. This regime can include replication of volatile storage units and periodic back-up of data to non-volatile storage. If the data security regime ensures the integrity of the data in spite of failure of part of the location register equipment then there will be no impact on service. This Technical Specification describes the procedures to be used when the integrity of data in the location register cannot be ensured; that situation is referred to below as "failure".

The VLR and SGSN shall erase all IMSI records affected by the failure when it restarts after a failure. The GGSN shall erase all non-static PDP records affected by the failure and restore static PDP records when it restarts after a failure.

For the HLR/HSS or CSS, periodic back-up of data to non-volatile storage is mandatory.

The reliability objectives of location registration are listed in 3GPP TS 43.005 [9].

The MME, S-GW and P-GW must similarly have a regime to secure the PDN connection and bearer data at failures. When an MME, SGW or PGW has a full node restart or fails all PDN connections and bearer records associated with the failing node shall be erased and any internal resources released.

Clause 18 "GTP-C based restart procedures" specifies how a GTP-C entity restart is detected and handled by the peer.

3 Restoration indicators in location registers and in GPRS support nodes

3.1 Restoration Indicators in the VLR

Three restoration indicators are provided in the VLR for each IMSI record: "Confirmed by Radio Contact", "Subscriber Data Confirmed by HLR" and "Location Information Confirmed in HLR".

The indicator "Confirmed by Radio Contact" indicates whether the VLR"s record of location area identity and MSC number for the mobile station is confirmed by radio contact.

The indicator "Confirmed by Radio Contact" in an IMSI record is set to the initial value "Not Confirmed" when the VLR receives a "Provide Roaming Number" request, an "Update Location Area" request or an "IMSI Attach" request for an MS for which the VLR does not have an IMSI record. The indicator "Confirmed by Radio Contact" in an IMSI record may also be set to the initial value "Not Confirmed" when the VLR receives a Reset indication message from the SGSN serving the MS if the MS is attached to both GPRS and non-GPRS services (see 3GPP TS 29.018 [7]) , or a Reset indication message from the MME serving the UE if the UE is attached to both EPS and non-EPS services or for SMS only (see 3GPP TS 29.118 [14]).

The indicator "Confirmed by Radio Contact" is set to "Confirmed" when the radio contact that has been established with the MS is authenticated.

The indicator "Subscriber Data Confirmed by HLR" indicates whether the subscriber data set for the mobile station held by the VLR is consistent with that held by the HLR.

The indicator "Subscriber Data Confirmed by HLR" is set to the initial value "Not Confirmed" when the VLR receives a "Provide Roaming Number" request, an "Update Location Area" request or an "IMSI Attach" request for an MS for which the VLR does not have an IMSI record.

The indicator "Subscriber Data Confirmed by HLR" is set to "Confirmed" at either of the following events:

- The VLR successfully performs an "Update Location" to the HLR;
- The VLR successfully performs a "Restore Data" operation to the HLR.

The indicator "Location Information Confirmed in HLR" indicates whether the HLR's record of VLR number and MSC number for the mobile station is confirmed by radio contact.

The indicator "Location Information Confirmed in HLR" is set to "Not Confirmed" at any of the following events:

- The VLR receives an "Update Location Area" request or an IMSI Attach" request for an MS for which the VLR has no IMSI record;
- A VLR which serves two or more MSCs receives a "Provide Roaming Number" request for an MS for which the VLR has no IMSI record;
- The VLR receives a "Reset" message from the HLR with which the MS is registered;
- The VLR in a Super-Charged network receives a Send Identification message from the serving VLR;
- The VLR in a Super-Charged network receives a Cancel Location message that indicates an "updateProcedure".

The indicator "Location Information Confirmed in HLR" is set to "Confirmed" at either of the following events:

- A VLR which serves only one MSC receives a "Provide Roaming Number" request for an MS for which the VLR has no IMSI record;
- Successful completion of the "Update Location" procedure triggered by authenticated radio contact.

The indicator "Location Information Confirmed in SMLC" indicates whether an SMLC's record of MSC number for a particular LMU is confirmed by radio contact.

The indicator "Location Information Confirmed in SMLC" is set to "Not Confirmed" at any of the following events:

- The VLR receives an "Update Location Area" request or an "IMSI Attach" request for an MS for which the VLR has no IMSI record. The indicator, in this case, becomes valid only if HLR subscriber data later indicates an LMU;
- The VLR receives an "LCS Reset" message from an SMLC where the message is targetted to either a specific LMU or all LMUs registered with the SMLC;
- The VLR receives an "IMSI Detach" from an LMU that is registered with an SMLC.

The indicator "Location Information Confirmed in SMLC" is set to "Confirmed" at the following event:

- Successful completion of the "LCS Registration" procedure triggered by a successful location update;
- Successful transfer of an LCS Information message from an SMLC to the LMU.

Also the following two restoration indicators may be provided in the VLR for each IMSI record: "Subscriber Data Confirmed by CSS" and "Location Information Confirmed by CSS".

The indicator "Subscriber Data Confirmed by CSS" indicates whether the CSG subscriber data set for the roaming mobile station held by the VLR is consistent with that held by the CSS.

The indicator "Subscriber Data Confirmed by CSS" is set to the initial value "Not Confirmed" at the following event:

- The VLR receives a "Provide Roaming Number" request, an "Update Location Area" request or an "IMSI Attach" request for a roaming MS for which the VLR does not have an IMSI record.

- The VLR receives a "Cancel VCSG Location Request" message from the CSS after the VLR restart if the roaming MS attached to the macro cell after the VLR restart.The indicator "Subscriber Data Confirmed by CSS" is set to "Confirmed" at the following event:

- The VLR successfully performs an "Update VCSG Location" to the CSS.
- The VLR receives an "Insert/Delete VCSG Subscription Data Request" message from the CSS after the VLR restart if the roaming MS attached to the macro cell after the VLR restart.

The indicator "Location Information Confirmed by CSS" indicates whether the VLR number for the roaming mobile station registered is confirmed by the CSS.

The indicator "Location Information Confirmed by CSS" is set to "Not Confirmed" at any of the following events:

- The VLR receives an "Update Location Area" request or an "IMSI Attach" request for a roaming MS for which the VLR has no IMSI record;
- The VLR receives a "Reset" message from the CSS with which the roaming MS is registered.
- The VLR receives a "Cancel VCSG Location Request" message from the CSS after the VLR restart if the roaming MS attached to the macro cell after the VLR restart.

The indicator "Location Information Confirmed by CSS" is set to "Confirmed" at the following event:

- Successful completion of the "Update VCSG Location" procedure to the CSS.
- The VLR receives an "Insert/Delete VCSG Subscription Data Request" message from the CSS after the VLR restart if the roaming MS attached to the macro cell after the VLR restart.

3.2 Restoration Indicators in the HLR

As an implementation option, one restoration indicator may be provided in the HLR for each IMSI record: "Check SS".

The "Check SS" indicator is set to "Check Required" when the HLR restarts after a failure.

The "Check SS" indicator is checked whenever the HLR receives an "Update Location" request from a VLR. If it is set to "Check Required", after successful completion of subscriber data retrieval that ran embedded in the "Update Location" procedure the HLR sends a "Forward Check SS Indication" request message to the VLR and sets the "Check SS" indicator to "Check Not Required".

3.3 Restoration Indicators in the SGSN

Two restoration indicators are provided in the SGSN for reach IMSI record: "Subscriber Data Confirmed by HLR" and "Location Information Confirmed in HLR".

The indicator "Subscriber Data Confirmed by HLR" indicates whether the subscriber data set for the mobile station held by the SGSN is consistent with that held by the HLR.

The indicator "Subscriber Data Confirmed by HLR" is set to the initial value "Not Confirmed" when the SGSN receives a Routing Area Update request or an IMSI- and/or GPRS Attach request for an MS for which the SGSN does not have an IMSI record.

The indicator "Subscriber Data Confirmed by HLR" is set to "Confirmed" at the following event:

- The SGSN successfully performs an Update GPRS Location to the HLR;

The indicator "Location Information Confirmed in HLR" indicates whether the HLRs record of the SGSN address for the mobile station is confirmed by radio contact.

The indicator "Location Information Confirmed in HLR" is set to "Not Confirmed" at any of the following events:

- The SGSN receives a Routing Area Update request or an IMSI- and/or GPRS Attach request for an MS for which the SGSN has no IMSI record;
- The SGSN receives a "Reset" message from the HLR with which the MS is registered;
- The SGSN in a Super-Charged network receives a Send Identification message from the serving SGSN;
- The SGSN in a Super-Charged network receives a Cancel Location message that indicates an "updateProcedure".

The indicator "Location Information Confirmed in HLR" is set to "Confirmed" at the following event:

- Successful completion of the Update GPRS Location procedure to the HLR.

The indicator "VLR-Reliable" indicates whether the VLR serving the MS has performed a restart.

The indicator "VLR-Reliable" is set to the value "false" when the SGSN receives a Reset indication message from the VLR serving the MS if the MS is attached to both GPRS and non-GPRS services. The indicator "VLR-Reliable" is set to the value "true" when the SGSN receives a confirmation from a VLR that a location update procedure to the affected VLR has been successfully performed.

The indicator "SGSN-Reset" indicates whether the SGSN has recently experienced a restart.

The indicator "SGSN-Reset" is set to the value "true" when the SGSN suffers a restart. This indicator is unique per SGSN. The indicator "SGSN-Reset" is set to the value "false" after a certain time specified by the operator. The value of the timer controlling the reset of the "SGSN-Reset" indicator shall be longer than the periodic routeing area update timer value used by the MSs.

Also the following two restoration indicators may be provided in the SGSN for each IMSI record: "Subscriber Data Confirmed by CSS" and "Location Information Confirmed by CSS".

The indicator "Subscriber Data Confirmed by CSS" indicates whether the CSG subscriber data set for the roaming mobile station held by the SGSN is consistent with that held by the CSS.

The indicator "Subscriber Data Confirmed by CSS" is set to the initial value "Not Confirmed" at any of the following events:

- The SGSN receives a Routing Area Update request or an IMSI- and/or GPRS Attach request for a roaming MS for which the SGSN does not have an IMSI record.

- The SGSN receives a "Cancel VCSG Location Request" message from the CSS after the SGSN restart if the roaming MS attached to the macro cell after the SGSN restart.

The indicator "Subscriber Data Confirmed by CSS" is set to "Confirmed" at the following event:

- The SGSN successfully performs an "Update VCSG Location" to the CSS.

- The SGSN receives an "Insert/Delete VCSG Subscription Data Request" message from the CSS after the SGSN restart if the roaming MS attached to the macro cell after the SGSN restart.

The indicator "Location Information Confirmed by CSS" indicates whether the SGSN address for the roaming mobile station registered is confirmed by the CSS.

The indicator "Location Information Confirmed by CSS" is set to "Not Confirmed" at any of the following events:

- The SGSN receives a Routing Area Update request or an IMSI- and/or GPRS Attach request for a roaming MS for which the SGSN has no IMSI record;

- The SGSN receives a "Reset" message from the CSS with which the roaming MS is registered.

- The SGSN receives a "Cancel VCSG Location Request" message from the CSS after the SGSN restart if the roaming MS attached to the macro cell after the SGSN restart.The indicator "Location Information Confirmed by CSS" is set to "Confirmed" at the following event:

- Successful completion of the "Update VCSG Location" procedure to the CSS.

- The SGSN receives an "Insert/Delete VCSG Subscription Data Request" message from the CSS after the SGSN restart if the roaming MS attached to the macro cell after the SGSN restart.

3.4 Restoration Indicators in the MME

Two restoration indicators are provided in the MME for each IMSI record: "Subscriber Data Confirmed by HSS" and "Location Information Confirmed in HSS".

The indicator "Subscriber Data Confirmed by HSS" indicates whether the subscriber data set for the mobile station held by the MME is consistent with that held by the HSS.

The indicator "Subscriber Data Confirmed by HSS" shall be set to the initial value "Not Confirmed" when the MME receives a Tracking Area Update request or an Attach request for an UE for which the MME does not have an IMSI record.

The indicator "Subscriber Data Confirmed by HSS" shall be set to "Confirmed" at the following event:

- The MME successfully performs an Update Location to the HSS;

The indicator "Location Information Confirmed in HSS" indicates whether the HSS"s record of the MME address for the UE is confirmed by radio contact.

The indicator "Location Information Confirmed in HSS" shall be set to "Not Confirmed" at any of the following events:

- The MME receives a Tracking Area Update request or an Attach request for an UE for which the MME has no IMSI record;

- The MME receives a "Reset" message from the HSS with which the UE is registered;

The indicator "Location Information Confirmed in HSS" shall be set to "Confirmed" at the following event:

- Successful completion of the Update Location procedure to the HSS.

Also the following two restoration indicators may be provided in the MME for each IMSI record: "Subscriber Data Confirmed by CSS" and "Location Information Confirmed by CSS".

The indicator "Subscriber Data Confirmed by CSS" indicates whether the CSG subscriber data set for the roaming UE held by the MME is consistent with that held by the CSS.

The indicator "Subscriber Data Confirmed by CSS" is set to the initial value "Not Confirmed" at any of the following events:

- The MME receives a Tracking Area Update request or an Attach request for a roaming UE for which the MME has no IMSI record;

- The MME receives a "Cancel VCSG Location Request" message from the CSS after the MME restart if the roaming UE attached to the macro cell after the MME restart.

The indicator "Subscriber Data Confirmed by CSS" is set to "Confirmed" at the following event:

- The MME successfully performs an "Update VCSG Location" to the CSS.

- The MME receives an "Insert/Delete VCSG Subscription Data Request" message from the CSS after the MME restart if the roaming UE attached to the macro cell after the MME restart.

The indicator "Location Information Confirmed by CSS" indicates whether the MME address for the roaming UE registered is confirmed by the CSS.

The indicator "Location Information Confirmed by CSS" is set to "Not Confirmed" at any of the following events:

- The MME receives a Tracking Area Update request or an Attach request for a roaming UE for which the MME has no IMSI record;

- The MME receives a "Reset" message from the CSS with which the roaming UE is registered.

- The MME receives a "Cancel VCSG Location Request" message from the CSS after the MME restart if the roaming UE attached to the macro cell after the MME restart.

The indicator "Location Information Confirmed by CSS" is set to "Confirmed" at the following event:

- Successful completion of the "Update VCSG Location" procedure to the CSS.

- The MME receives an "Insert/Delete VCSG Subscription Data Request" message from the CSS after the MME restart if the roaming UE attached to the macro cell after the MME restart.

4 Restoration of data in the VLR

The effect on service of failure of a VLR is different from the effect of failure of an HLR. The procedures for restoration of a VLR and an HLR are therefore different.

4.0 VLR Failure with Restart

When a VLR fails, all its associations with SGSNs affected by the failure become invalid and may be deleted. Based on configuration data, the MSC/VLR sends a BSSAP+ Reset message to each of its associated SGSNs. The SGSNs mark all associations containing the restarted VLR as invalid. After receipt of the first valid LLC frame (for A/Gb mode) or after receipt of the first valid GTP-U packet or uplink signalling message (for Iu mode) from an MS that is both GPRS-attached and IMSI-attached, the SGSN shall return a Detach Request (Detach Type) message in order to request the MS to perform a combined RA / LA update. Detach Type shall be set to IMSI Detach. The detach procedure may be delayed by the SGSN for a maximum operator-configuration depending on resource utilisation during given time period to avoid high signalling load.

Editor"s note: stage 2 and stage 3 specifications are not aligned on the trigger points for the SGSN to send a Detach Request (Detach Type) message to the MS. This needs to be fixed.

When a VLR fails, all its associations with MMEs affected by the failure become invalid and may be deleted. The VLR and MME shall behave as per subclause 4.2.10. Upon receipt of a combined Tracking Area update request or periodic Tracking Area Update request from a UE that is attached to both EPS and non-EPS services, the MME may request the UE to re-attach to non-EPS services or may alternatively immediately perform the Location Update for non-EPS services procedure towards the VLR.

4.0a VLR Failure without Restart

Upon reception of a Combined RA / LA update or periodic Routing Area Update from an MS that is attached for non-GPRS service, if the VLR serving the MS is no longer in service, the SGSN may either:

- request the MS to re-attach to non-GPRS services and then select an alternative available VLR to serve the UE for CS services during the subsequent combined RA / LA update procedure;
- or immediately perform the Location Update for non-GPRS services procedure towards an alternative available VLR.

See 3GPP TS 29.018 [7].

Upon reception of a Combined TA / LA update or periodic Tracking Area Update from a UE that is attached for non-EPS service, if the VLR serving the UE is no longer in service, the MME may either:

- request the UE to re-attach to non-EPS services and then select an alternative available VLR to serve the UE for CS services during the subsequent combined TA / LA update procedure;
- or immediately perform the Location Update for non-EPS services procedure towards an alternative available VLR.

See 3GPP TS 29.118 [14].

NOTE: How an SGSN or MME detects that a VLR is no longer in service is implemention specifc, e.g. if there are no more SCTP associations in service with that VLR for a given period.

4.1 Restart of the VLR

When a VLR restarts after a failure, all IMSI records affected by the failure are erased.

There will be no subscriber data or location information stored for an affected mobile station until after the VLR has received either a "Provide Roaming Number" request or an "Update location Area" request for that mobile station.

The VLR causes all affected TMSIs and all affected LMSIs to become invalid. "Invalid" in this context means that the TMSI and LMSI can no longer be regarded as accurate. The term is used to avoid unnecessary constraints on the implementation.

On receipt of either a "Provide Roaming Number" request or an "Update Location Area" request, restoration of subscriber data in the VLR is triggered individually for each IMSI record as described below.

4.2 Restoration Procedures

4.2.0 General

The objective of the restoration procedure is to handle all traffic for each mobile subscriber correctly. In order to meet this objective, the procedure must make the subscriber data in the VLR consistent with that in the HLR or in the CSS, and make the location information in the HLR and VLR or the location information in the CSS and VLR reflect accurately the current location of the MS.

4.2.1 Incoming Call

a) Send Routing Information (GMSC->HLR):

The HLR sends "Provide Roaming Number" to the VLR as for normal operation. The LMSI is updated by the VLR when the VLR requests the transfer of subscriber data from the HLR using the "Restore Data" operation.

b) Provide Roaming Number (HLR->VLR):

- Regardless of whether the VLR has an IMSI record corresponding to the IMSI in the "Provide Roaming Number", it returns an MSRN. If no IMSI record exists, the VLR creates a skeleton IMSI record, sets the indicators "Subscriber Data Confirmed by Radio Contact" and "Subscriber Data Confirmed by HLR" to "Not Confirmed" and (if IMSI Attach is used) marks the IMSI as attached. If the VLR serves two or more MSCs, the VLR sets the indicator "Location Information Confirmed in HLR" to "Not Confirmed". Otherwise, if the VLR serves only one MSC, the indicator "Location Information Confirmed in HLR" is set to the initial value "Confirmed". Also the VLR may set the indicators "Subscriber Data Confirmed by CSS" and "Location Information Confirmed by CSS" to "Not Confirmed".

- If the indicator "Subscriber Data Confirmed by HLR" is "Not Confirmed" the VLR requests authentication data, if required and still not available and subscriber data from the HLR. When the dialogue that covers the subscriber data retrieval procedure is completed successfully, the VLR sets the indicator "Subscriber Data Confirmed by HLR" to "Confirmed". The indicators "Confirmed by Radio Contact" and "Location Information Confirmed in HLR" remain unchanged.

- If the IMSI record for the MS is marked "Subscriber Data Confirmed by HLR" but "Not Confirmed by Radio Contact" the operator may choose an appropriate method to limit the number of "Search for MS" procedures for that MS.

c) Send Information for I/C Call Setup (MSC->VLR)

- If the VLR has no IMSI record, or if the record is marked "Subscriber Data Not Confirmed by HLR" the VLR returns a "System Failure" error.

- If the VLR has an IMSI record marked "Subscriber Data Confirmed by HLR" and "Not Confirmed by Radio Contact", the VLR handles the request in the normal way, except that the "Search for MS" procedure is used instead of the "Page MS" procedure.

- If the VLR has an IMSI record marked "Subscriber Data Confirmed by HLR" and "Confirmed by Radio Contact", the VLR handles the request in the normal way; for this MS, VLR restoration is complete.

- The state of the indicator "Location Information Confirmed in HLR" does not affect the "Send Information for I/C Call Setup" procedure.

d) Process Access Request in Response to Search (MSC->VLR):

- If the MS responds to paging, the MSC sends a positive response to the search request and a "Process Access Request" to the VLR. After successful authentication, if required, the VLR sets the indicator "Confirmed by Radio Contact" to "Confirmed", sets the location area information for the MS, and handles the request in the normal way.

- The VLR checks the indicator "Location Information Confirmed in HLR". If it indicates "Not Confirmed" the VLR starts an "Update Location" procedure to the HLR. When this procedure is successfully completed the VLR sets the indicator "Location Information Confirmed in HLR" to "Confirmed".

- If the MS is roaming, the VLR checks the indicators "Subscriber Data Confirmed by CSS" if the CSS has the corresponding valid CSG subscription data and "Location Information Confirmed by CSS". If either of them indicates "Not Confirmed" the VLR shall start an "Update VCSG Location" procedure to the CSS if the roaming MS is still in the CSG cell. When this procedure is successfully completed the VLR sets the indicator "Subscriber Data Confirmed by CSS" if the CSS has the corresponding valid CSG subscription data and "Location Information Confirmed by CSS" to "Confirmed".

For this MS, VLR restoration is complete.

4.2.2 Mobile Terminated Short Message

a) Send Routing Information for MT SMS (SMS-GMSC->HLR):

   The HLR returns the MSC number as for normal operation.

b) Send Information for MT SMS (MSC->VLR) - MAP version 2:

   - If the VLR has no IMSI record, or if the record is marked "Subscriber Data Not Confirmed by HLR", the VLR proceeds as follows:

     - the VLR returns an "Unidentified Subscriber" error. This causes the MSC to report a short message delivery failure, with cause "Unidentified Subscriber", to the SMS gateway MSC. The Gateway MSC sends a "Report SM Delivery Status" request, with a cause of "Absent Subscriber", to the HLR. This causes the HLR to set the "Mobile Station Not Reachable Flag" for the MS, as described in Technical Specifications 3GPP TS 23.040 [4] and 3GPP TS 29.002 [6]; or

     - the VLR performs the data restoration procedure as specified in subclause 4.2.1 for an incoming call and delay the mobile terminating SMS until the data restoration procedure is complete. During the data restoration procedure, the HLR shall send to the VLR the MME name or/and the SGSN Number if the subscriber is registered on this VLR and is registered to EPS or/and GPRS services respectively.

   - If the VLR has an IMSI record marked "Subscriber Data Confirmed by HLR" and "Not Confirmed by Radio Contact", the VLR handles the request in the normal way, except that the "Search for MS" procedure is used instead of the "Page MS" procedure.

   - If the VLR has an IMSI record marked "Subscriber Data Confirmed by HLR" and "Confirmed by Radio Contact", the VLR handles the request in the normal way; for this MS, VLR restoration is complete.

   - The state of the indicator "Location Information Confirmed in HLR" does not affect the "Send Information for MT SMS" procedure.

c) Send Information for I/C Call Setup (MSC->VLR) - MAP version 1:

   - If the VLR has no IMSI record, or if the record is marked "Subscriber Data Not Confirmed by HLR", the VLR proceeds as follows:

     - the VLR returns a "System Failure" error. This causes the MSC to report a short message delivery failure, with cause "System Failure", to the SMS gateway MSC; or

     - the VLR performs the data restoration procedure as specified in subclause 4.2.1 for an incoming call and delay the mobile terminating SMS until the data restoration procedure is complete. During the data restoration procedure, the HLR shall send to the VLR the MME name or/and the SGSN Number if the subscriber is registered on this VLR and is registered to EPS or/and GPRS services respectively.

- If the VLR has an IMSI record marked "Subscriber Data Confirmed by HLR" and "Not Confirmed by Radio Contact", the VLR handles the request in the normal way, except that the "Search for MS" procedure is used instead of the "Page MS" procedure.

- If the VLR has an IMSI record marked "Subscriber Data Confirmed by HLR" and "Confirmed by Radio Contact", the VLR handles the request in the normal way; for this MS, VLR restoration is complete.

- The state of the indicator "Location Information Confirmed in HLR" does not affect the "Send Information for MT SMS" procedure.

d) Process Access Request in Response to Search (MSC->VLR):

- If the MS responds to paging, the MSC sends a positive response to the search request and a "Process Access Request" to the VLR. After successful authentication, if required, the VLR sets the indicator "Confirmed by Radio Contact" to "Confirmed", sets the location area information for the MS, and handles the request in the normal way.

- The VLR checks the indicator "Location Information Confirmed in HLR". If it indicates "Not Confirmed" the VLR starts an "Update Location" procedure to the HLR. When this procedure is successfully completed, the VLR sets the indicator "Location Information Confirmed in HLR" to "Confirmed".

- If the MS is roaming, the VLR checks the indicators "Subscriber Data Confirmed by CSS" if the CSS has the corresponding valid CSG subscription data and "Location Information Confirmed by CSS". If either of them indicates "Not Confirmed" the VLR shall start an "Update VCSG Location" procedure to the CSS if the roaming UE is still in the CSG cell. When this procedure is successfully completed the VLR sets the indicator "Subscriber Data Confirmed by CSS" if the CSS has the corresponding valid CSG subscription data and "Location Information Confirmed by CSS" to "Confirmed".

For this MS, VLR restoration is complete.

4.2.3 Mobile Terminating Location Request (MT-LR)

Receipt of an MT-LR for a target MS identified by its IMSI in a serving MSC during VLR restoration is supported by the procedures below.

a) Provide Subscriber Location (GMLC->MSC/VLR):

- If the VLR has no IMSI record, or if the record is marked "Subscriber Data Not Confirmed by HLR" the VLR returns an "Unidentified Subscriber" error. This causes the MSC to report a location failure, with cause "Unidentified Subscriber", to the GMLC.

- If the VLR has an IMSI record marked "Subscriber Data Confirmed by HLR" and "Not Confirmed by Radio Contact", the VLR handles the request in the normal way, except that the "Search for MS" procedure is used instead of the "Page MS" procedure when paging for the MS.

- If the VLR has an IMSI record marked "Subscriber Data Confirmed by HLR" and "Confirmed by Radio Contact", the VLR handles the request in the normal way; for this MS, VLR restoration is complete.

- The state of the indicator "Location Information Confirmed in HLR" does not affect the "Provide Subscriber Location" procedure.

b) Process Access Request in Response to Search (MSC->VLR):

- If the MS responds to paging, the MSC sends a positive response to the search request and a "Process Access Request" to the VLR. After successful authentication, if required, the VLR sets the indicator "Confirmed by Radio Contact" to "Confirmed", sets the location area information for the MS, and handles the request in the normal way.

- The VLR checks the indicator "Location Information Confirmed in HLR". If it indicates "Not Confirmed" the VLR starts an "Update Location" procedure to the HLR. When this procedure is successfully completed, the VLR sets the indicator "Location Information Confirmed in HLR" to "Confirmed".

- If the MS is roaming, the VLR checks the indicators "Subscriber Data Confirmed by CSS" if the CSS has the corresponding valid CSG subscription data and "Location Information Confirmed by CSS". If either of them indicates "Not Confirmed" and the roaming MS is still in the CSG cell, the VLR shall start an "Update VCSG Location" procedure to the CSS. When this procedure is successfully completed the VLR sets the indicator "Subscriber Data Confirmed by CSS" if the CSS has the corresponding valid CSG subscription data and "Location Information Confirmed by CSS" to "Confirmed".

For this MS, VLR restoration is complete.

4.2.4 Incoming LCS Information Request (GSM only)

Receipt of an incoming BSSMAP-LE LMU Connection Request from an SMLC directed to a specific Type A LMU is supported by the procedures below.

a) Request associated with an LMU (SMLC->MSC/VLR):

- If the VLR has no IMSI record, or if the record is marked "Subscriber Data Not Confirmed by HLR", the VLR returns an "Unidentified Subscriber" error.

- If the VLR has an IMSI record for an LMU marked "Subscriber Data Confirmed by HLR" and "Not Confirmed by Radio Contact", the VLR handles the request in the normal way, except that the "Search for MS" procedure is used instead of the "Page MS" procedure when paging for the LMU.

- If the VLR has an IMSI record marked "Subscriber Data Confirmed by HLR" and "Confirmed by Radio Contact", the VLR handles the request in the normal way. For this LMU, data restoration is complete.

- The state of the indicator "Location Information Confirmed in HLR" does not affect the incoming LMU Connection Request.

b) Process Access Request in Response to Search (MSC->VLR):

- If the LMU responds to paging, the MSC sends a positive response to the search request and a "Process Access Request" to the VLR. After successful authentication, if required, the VLR sets the indicator "Confirmed by Radio Contact" to "Confirmed", sets the location area information for the LMU, and handles the request in the normal way.

- The VLR checks the indicator "Location Information Confirmed in HLR". If it indicates "Not Confirmed" the VLR starts an "Update Location" procedure to the HLR. When this procedure is successfully completed, the VLR sets the indicator "Location Information Confirmed in HLR" to "Confirmed".

- If the MS is roaming, the VLR checks the indicators "Subscriber Data Confirmed by CSS" if the CSS has the corresponding valid CSG subscription data and "Location Information Confirmed by CSS". If either of them indicates "Not Confirmed" and the roaming MS is still in the CSG cell, the VLR shallstart an "Update VCSG Location" procedure to the CSS. When this procedure is successfully completed the VLR sets the indicator "Subscriber Data Confirmed by CSS" if the CSS has the corresponding valid CSG subscription data and "Location Information Confirmed by CSS" to "Confirmed".

For this LMU, VLR restoration is complete.

4.2.5 Outgoing MS request

An outgoing request (MS originated call, mobile originated Short Message or call-independent supplementary service activity) from the MS causes the VLR to check its IMSI record for that MS.

- If the MS is unknown in this VLR (i.e. the VLR has no IMSI record for the MS) or there is an IMSI record marked "Subscriber Data Not Confirmed by HLR" the outgoing request is rejected with error cause "Unidentified Subscriber". This causes the MS to initiate the location registration procedure described below.

- If the VLR has an IMSI record for the MS marked "Subscriber Data Confirmed by HLR" the request is handled in the normal way, and after any necessary authentication and/or IMEI checking the record is marked "Confirmed by Radio Contact".

- The VLR checks the indicator "Location Information Confirmed in HLR". If it indicates "Not Confirmed" the VLR starts an "Update Location" procedure to the HLR. When this procedure is successfully completed the VLR sets the indicator "Location Information Confirmed in HLR" to "Confirmed".

- If the MS is roaming, the VLR checks the indicators "Subscriber Data Confirmed by CSS" if the CSS has the corresponding valid CSG subscription data and "Location Information Confirmed by CSS". If either of them indicates "Not Confirmed" and the roaming MS is still in the CSG cell, the VLR shall start an "Update VCSG Location" procedure to the CSS. When this procedure is successfully completed the VLR sets the indicator "Subscriber Data Confirmed by CSS" if the CSS has the corresponding valid CSG subscription data and "Location Information Confirmed by CSS" to "Confirmed".

For this MS, VLR restoration is complete.

4.2.6 Outgoing LMU Request (GSM only)

An outgoing request (CM ServiceRequest) for LCS from a Type A LMU causes the VLR to check its IMSI record for that LMU.

- If the LMU is unknown in this VLR (i.e. the VLR has no IMSI record for the LMU) or there is an IMSI record marked "Subscriber Data Not Confirmed by HLR" the outgoing request is rejected with error cause "Unidentified Subscriber". This causes the LMU to initiate the location registration procedure described below.

- If the VLR has an IMSI record for the MS marked "Subscriber Data Confirmed by HLR", the request is handled in the normal way, and after any necessary authentication and/or IMEI checking the record is marked "Confirmed by Radio Contact".

- The VLR checks the indicator "Location Information Confirmed in HLR". If it indicates "Not Confirmed" the VLR starts an "Update Location" procedure to the HLR. When this procedure is successfully completed the VLR sets the indicator "Location Information Confirmed in HLR" to "Confirmed".

- If the MS is roaming, the VLR checks the indicators "Subscriber Data Confirmed by CSS" if the CSS has the corresponding valid CSG subscription data and "Location Information Confirmed by CSS". If either of them indicates "Not Confirmed" the VLR and the roaming MS is still in the CSG cell, may start an "Update VCSG Location" procedure to the CSS. When this procedure is successfully completed the VLR sets the indicator "Subscriber Data Confirmed by CSS" if the CSS has the corresponding valid CSG subscription data and "Location Information Confirmed by CSS" to "Confirmed".

For this LMU, VLR restoration is complete.

4.2.7 Location Updating or IMSI Attach

A location registration request (location updating or IMSI attach) from an MS causes the VLR to check its IMSI record for that MS.

- If the MS is unknown in this VLR (i.e. the VLR has no IMSI record for the MS) the VLR creates a skeleton IMSI record for the MS and sets the indicators "Confirmed by Radio Contact", "Location Information Confirmed in HLR", "Subscriber Data Confirmed by HLR", "Location Information Confirmed by CSS" and "Subscriber Data Confirmed by CSS" to "Not Confirmed". If authentication is required, the VLR retrieves authentication data. When the radio contact with the Mobile Station is authenticated, the VLR sets the indicator "Confirmed by Radio Contact" to "Confirmed. The VLR then performs an "Update Location" to the HLR. If this is successful, the VLR sets the indicators "Location Information Confirmed in HLR" and "Subscriber Data Confirmed by HLR" to "Confirmed". For this MS, VLR restoration is complete. If the VPLMN supports Autonomous CSG Roaming and the HPLMN has enabled Autonomous CSG Roaming in the VPLMN, the VLR may perform an "Update VCSG Location" to the CSS if the requested cell is a CSG/hybrid cell. If this is successful, the VLR sets the indicators "Location Information Confirmed by CSS" and "Subscriber Data Confirmed by CSS" to "Confirmed" if the CSS has the corresponding valid CSG subscription data.

- If the VLR has an IMSI record for the MS, after successful authentication, if required, the VLR sets the indicator "Confirmed by Radio Contact" to "Confirmed". If the record is marked "Location Information Not Confirmed in HLR" or "Subscriber Data Not Confirmed by HLR" the VLR performs an "Update Location" to the HLR. If this is successful, the VLR sets the indicators "Location Information Confirmed in HLR" and "Subscriber Data Confirmed by HLR" to "Confirmed". For this MS, VLR restoration is complete. If the record is marked "Location Information Not Confirmed by CSS" or "Subscriber Data Not Confirmed by CSS" if the CSS has the

valid CSG subscription data, and the VPLMN supports Autonomous CSG Roaming and the HPLMN has enabled Autonomous CSG Roaming in the VPLMN, the VLR may perform an "Update VCSG Location" to the CSS if the requested cell is a CSG/hybrid cell. If this is successful, the VLR sets the indicators "Location Information Confirmed by CSS" if the CSS has the valid CSG subscription data and "Subscriber Data Confirmed by CSS" to "Confirmed".

4.2.8 Use of TMSI

After the VLR has restarted but before the next authenticated radio contact the TMSI known by the MS is invalid, as it was allocated before the VLR restarted. The VLR therefore uses the IMSI to identify the MS on the first radio contact during restoration.

- A VLR which initiates a "Search for Subscriber" procedure uses the IMSI to identify the MS.
- If an MS identifies itself by a TMSI in a "Location Registration" request, the VLR proceeds as follows:

  a) The VLR checks the location area identity (LAI) of the previous location area sent by the MS. If this LAI is in a VLR different from the current one, the request is handled in the normal way.

  b) If the LAI is in the current VLR, the status of the TMSI is checked:

  - If the TMSI was allocated after the VLR restarted, and corresponds to a valid IMSI record, the request is handled as described in subclause 4.2.7.
  - If the TMSI was allocated before the VLR restarted, or does not correspond to a valid IMSI record, the VLR requests the IMSI from the MS. If the MS returns an IMSI the VLR proceeds as described in subclause 4.2.7. If the MS does not return an IMSI the network aborts the location registration procedure.
  - If an MS identifies itself by a TMSI in an outgoing MS request, the VLR proceeds as follows:
  - If the TMSI was allocated after the VLR restarted, and corresponds to a valid IMSI record, the request is handled as described in subclause 4.2.5.
  - If the TMSI was allocated before the VLR restarted, or does not correspond to a valid IMSI record, the VLR requests the IMSI from the MS. If the MS returns an IMSI the VLR proceeds as described in subclause 4.2.5. If the MS does not return an IMSI the network aborts the outgoing request.

4.2.9 SGSN associations

Based on configuration data, "Reset" messages are sent on the Gs-interface to the SGSNs in the Location Areas served by the VLR as described in the 3GPP TS 29.018 [7]. The SGSNs mark all associations with the VLR as unreliable by setting the restoration indicator "VLR-Reliable" to "False" for the UEs served by that VLR. The associations will be re-initiated one by one by the SGSN at the next Routing Area update or combined RA/LA update from each UE.

4.2.10 MME associations

Based on configuration data, "Reset" messages are sent on the SGs-interface to the MMEs by the VLR as described in the 3GPP TS 29.118 [14]. The MMEs mark all associations with the VLR as unreliable by setting the restoration indicator "VLR-Reliable" to "False" for the UEs served by that VLR. The associations will be re-initiated one by one by the MME at the next Tracking Area update or combined TA/LA update from each UE.

5 Restoration of data in the HLR

The loss or corruption of subscriber data in the HLR has an impact not only in the HLR"s own PLMN but also on the service for its mobiles in other PLMNs. Restoration of the data in the HLR requires co-operation from all the VLRs to which its mobiles have roamed.

5.1 Restart of the HLR/HSS

When an HLR restarts, it sends to each SGSN where one or more of its MSs are registered a Reset message. This causes the SGSN to mark the relevant MM contexts as invalid, and to set NGAF if an SGSN – MSC/VLR association exists. After receipt of the first valid LLC frame (for A/Gb mode) or after receipt of the first valid GTP-U packet or uplink signalling message (for Iu mode) from a marked MS, the SGSN performs an update location to the HLR as in the attach or inter-SGSN RA update procedures, and, if NGAF is set, the procedure in clause "Non-GPRS Alert" is followed. The update location procedure and the procedure towards the MSC/VLR may be delayed by the SGSN for a maximum operator configuration-depending on the utilisation of resources during given time period to avoid high signalling load. The periodic backup of HLR data to non-volatile storage is mandatory.

When an HLR restarts after failure it shall perform the following actions for the subscriber data records that have been affected by the HLR fault:

- reload all data from the non-volatile back-up;
- reset all "MS Purged" flags;
- mark each subscriber record "SS Check Required" by setting the "Check SS" indicator if the "Forward Check SS Indication" service is implemented;
- send a "Reset" message to each VLR where one or more of its MSs are registered. This causes each VLR concerned to mark each relevant subscriber record "Location Information Not Confirmed in HLR", and
- send a "Reset" message to each SGSN where one or more of its MSs are registered. This causes each SGSN to mark each relevant MM context "Location Information Not Confirmed in HLR".
- send a "Reset" message to each MME where one or more of its UEs are registered. This causes each MME to mark each relevant MM context "Location Information Not Confirmed in HSS".

5.2 Procedures During Restoration

5.2.1 Mobile terminated call

If the VLR receives a "Process Access Request" request in response to a "Page" or "Search for MS" operation, after successful authentication, if required, it checks the indicator "Location Information Confirmed in HLR". If this indicates "Not Confirmed" the VLR triggers an "Update Location" to the HLR as described in subclause 4.2.1.d).

When the HLR receives the "Update Location" request it stores the VLR number, MSC number and LMSI in the subscriber record as for normal operation.

If the "Forward Check SS Indication" service is implemented, the HLR checks the indicator "Check SS". If this indicates "Check Required", after successful completion of the subscriber data retrieval procedure that ran embedded in the "Update Location" procedure the HLR sends a "Forward Check SS Indication" to the VLR and marks the subscriber record "Check Not Required. When the VLR receives the "Forward Check SS Indication" request it forwards an indication to the MS to alert the user that supplementary service parameters should be checked.

5.2.2 Mobile Originated Activity

When the VLR receives a request from an MS (MS originated call, mobile originated Short Message, call-independent supplementary service activity or location registration request) whose IMSI record is marked "Location Information Not Confirmed in HLR", it will perform an "Update Location" to the HLR as described in subclauses 4.2.5 and 4.2.7 above.

When the HLR receives an "Update Location" request from the VLR, it proceeds as described in subclause 5.2.1.

6 Periodic location updating

The time taken to confirm the location of an MS after location register failure is governed by the frequency with which the MS establishes radio contact with the network. The location information for an MS which remains silent for a long time will remain doubtful for a long time.

A method of reducing this time is to require the MS to establish radio contact with the network at intervals, purely to confirm its location, if the MS does not move to a new location area (which would lead to a normal location registration) or respond to paging for a mobile terminated call or request a mobile originated call or call-independent supplementary service activity.

The interval between successive periodic location updatings is controlled by a timer in the MS; this timer is reset to its initial value at the end of each successfully established radio contact between the MS and the network.

The use of the periodic location update timer is described in 3GPP TS 43.022.

7 Periodic routeing area updating

All GPRS-attached MSs, except MSs in class-B mode of operation engaged in CS communication, shall perform periodic RA updates. For MSs that are both IMSI-attached and GPRS-attached, the periodic updates depend on whether the Gs interface is installed or not:

- If the Gs interface is installed, periodic RA updates shall be performed, and periodic LA updates shall not be performed. If the SGSN has the indicator "VLR-reliable" set to ´false´ the SGSN shall perform a location area update procedure towards the VLR
- If the Gs interface is not installed, both periodic RA updates and periodic LA updates shall be performed independently. RA updates are performed via the Gb interface, and LA updates are performed via the A interface.

The periodic routeing area update is described in 3GPP TS 23.060.

8 Stand-alone operation of the VLR

In a 2G authentication regime, triplets, regardless of its nature (generated in a 2G AuC or derived from quintuplets in a 3G VLR or a 3G HLR), may be reused when no unused authentication triplets are available in the VLR for an IMSI record. It is an operator option to define how many times an authentication triplet may be reused in the VLR.

In a 3G authentication regime, quintuplets, regardless of its nature (generated in a 3G AuC or derived from triplets in a 3G VLR), shall not be reused when no unused authentication quintuplets are available in the VLR for an IMSI record.

If the Update Location response contains an error different from "Unknown Subscriber" or "Roaming Not Allowed" or if there is a parameter problem (e.g. no HLR number included), no error shall be indicated to the MSC and the IMSI record in the VLR shall not be affected, provided that the associated "Subscriber Data Confirmed by HLR" indicator is in the "Confirmed" status.

9 Stand-alone operation of the SGSN

In a 2G authentication regime, triplets, regardless of their nature (generated in a 2G AuC or derived from quintuplets in a 3G SGSN or a 3G HLR), may be reused when no unused authentication triplets are available in the SGSN for an IMSI record. It is an operator option to define how many times an authentication triplet may be reused in the SGSN.

In a 3G authentication regime, quintuplets, regardless of their nature (generated in a 3G AuC or derived from triplets in a 3G SGSN), shall not be reused when no unused authentication quintuplets are available in the SGSN for an IMSI record.

9A Stand-alone operation of the MME

In a E-UTRAN authentication regime, EPS authentication vectors shall not be reused when no unused EPS authentication vectors are available in the MME for an IMSI record.

10 Restoration of data in the GGSN

10.0 GGSN failure

When a GGSN fails, all its PDP contexts affected by the failure become invalid and may be deleted. GGSN storage of subscriber data is volatile.

When the GGSN receives a GTP-U PDU for which no PDP context exists, it shall discard the GTP-U PDU and return a a GTP error indication to the originating node (the SGSN or, if Direct Tunnel is established, the RNC).

The GGSN should ensure as far as possible that previously used TEID values are not immediately reused after a GGSN restart, in order to avoid inconsistent TEID allocation throughout the network.

10.1 Restart of the GGSN

After a GGSN restart, all the PDP contexts, the MBMS UE contexts, and the MBMS Bearer contexts stored in the GGSN and affected by the restart become invalid and may be deleted.

When the SGSN detects a restart in a GGSN (see clause 18 "GTP-C based restart procedures") with which it has one or more PDP contexts activated, it shall deactivate all these PDP contexts and request the MS to reactivate them. When the SGSN detects a restart in a GGSN with which it has MBMS Bearer context(s) and/or MBMS UE context(s), it shall delete all these MBMS Bearer context(s) and/or MBMS UE context(s).

10.2 Restoration Procedures

10.2.0 General

The GGSN will receive the SGSN restart counters in GTPv1 echo response from the SGSN. When a GGSN detects that a peer SGSN has restarted it shall delete all PDP context(s), MBMS UE context(s), MBMS Bearer context(s) associated with the peer node that failed as well as freeing any internal GGSN resources associated with those PDP context(s), MBMS UE context(s) and MBMS Bearer context(s). The GGSN may optionally perform other implementation specific actions such as messages to clear other external resources (e.g. PCC messages).

If the GGSN needs to send a request for IP-CAN Session Modification procedure towards a PCRF which is known to have restarted since the IP-CAN session establishment, the GGSN may discard the request and may tear down all the PDP context(s) associated with the PDP address of the IP-CAN session, based on operator policy, by initiating a PDP Context Deactivation procedure towards the SGSN with the cause set to "Reactivation requested". This leads the UE to initiate PDP Context Activation procedure for the same APN. Emergency sessions should not be torn down.

NOTE: The procedure above just enables to clean up all the PDP Context(s) associated with the PDP address of the IP-CAN session, affected by the PCRF failure when a specific interaction with the PCRF is required. Prior to that interaction, PCC controlled services can not be provided to the UE.

10.2.1 Mobile terminated transmission

When the GGSN receives a mobile terminated PDU for which no valid PDP context exists the GGSN discards the received PDU and may also return an appropriate Error message depending on the protocol used. No further actions are performed by the GGSN. Alternatively, if the GGSN has static PDP information about the PDP address, the GGSN may try to deliver the PDU by initiating the Network-Requested PDP Context Activation procedure (see 3GPP TS 23.060).

10.2.2 Mobile originated transmission

When the GGSN receives a tunnel PDU for which no PDP context exists it discards the tunnel PDU and sends an Error indication message to the originating SGSN. The SGSN deactivates the PDP context and sends an Error indication to the MS. The MS may then re-activate the PDP context.

11 Restoration of data in the SGSN

11.0 SGSN Failure

11.0.1 Gn/Gp SGSN failure

When an SGSN fails, it deletes all MM and PDP contexts affected by the failure. SGSN storage of subscriber data is volatile. Based on configuration data, the SGSN may send a Reset message to each of its associated VLRs. If a Reset message is sent, the VLR may mark all associations containing the restarted SGSN as unreliable. See 3GPP TS 29.018 [7]. In the case of optional CAMEL interaction the failing SGSN shall invoke the CAMEL-GPRS-Exception procedure towards the GSM-SCFs.

If data or signalling, except GPRS attach and RA update, is received in an SGSN from an MS for which no MM context exists in the SGSN, the SGSN shall discard the data or signalling.

If an RA update request is received in an SGSN from an MS for which no MM context exists in the SGSN, or in the old SGSN for the inter-SGSN RA update case, the SGSN shall reject the RA update with an appropriate cause. In order to remain GPRS-attached, the MS shall then perform a new GPRS attach and should (re-)activate PDP contexts.

If a service request is received in a 3G-SGSN from an MS for which no MM context exists in the 3G-SGSN, the 3G-SGSN shall reject the service request with an appropriate cause. In order to remain GPRS-attached, the MS shall then perform a new GPRS attach and should (re-) activate PDP contexts.

NOTE: In some cases, user interaction may be required, and then the MS cannot (re-)activate the PDP contexts automatically.

When the SGSN receives a PDU Notification Request message for which no MM context exists, the SGSN returns a PDU Notification Response message to the GGSN with an appropriate cause (see clause "Unsuccessful Network-Requested PDP Context Activation Procedure" in 3GPP TS 23.060 [5]), and the SGSN may search the MS by paging with the IMSI in the SGSN area. An MS that is paged for PS services with IMSI as the identifier shall perform a new GPRS attach and should (re-)activate PDP contexts.

When the SGSN receives a GTP-U PDU from the GGSN for which no PDP context exists, it shall discard the GTP-U PDU and send a GTP error indication to the originating GGSN.

When the SGSN receives a GTP-U PDU from the RNC for which no PDP context exists, the SGSN shall discard the GTP-U PDU and send a GTP error indication to the originating RNC.

When the SGSN receives a mobile-terminated SM from the SMS-GMSC for an IMSI unknown in the SGSN, it rejects the request.

When the SGSN receives a paging request over the Gs interface for an IMSI unknown in the SGSN and the SGSN has not completed recovery, the SGSN may page the MS for packet services with IMSI as identifier in the area specified by the location information provided by the MSC/VLR. If no such location information is provided, the SGSN may page the MS in the routeing areas corresponding to that MSC/VLR. After the MS performs a combined GPRS attach, the SGSN may continue serving the Gs interface paging request.

11.0.2 SGSN Failure using S4

When the SGSN receives a GTP-U PDU from the Serving GW for which no Bearer context exists, it shall discard the GTP-U PDU and send a GTP error indication to the originating Serving GW.

When the SGSN receives a GTP-U PDU from the MBMS GW for which no MBMS Point to Point Bearer context exists, it shall discard the GTP-U PDU and send a GTP Error Indication to the originating MBMS GW.

An S4-SGSN and an SGW supporting the optional network triggered service restoration procedure shall behave as specified in clause 25.

When the S4-SGSN which does not support the optional network triggered service restoration procedure as specified in clause 25 receives a Downlink Data Notification message for which no MM context exists, the S4-SGSN returns a Downlink Data Notification Acknowledge message to the Serving GW with an appropriate cause. The Serving GW shall delete the related Bearer context related to S4-SGSN; and if there is no ISR associated MME recorded on the related Bearer context the Serving GW shall also notify the PDN GW to delete the Bearer context.

11.1 Restart of the SGSN

After an SGSN restart, the SGSN deletes all MM, PDP, MBMS UE, and MBMS Bearer contexts affected by the restart.

When the GGSN detects a restart in an SGSN (see clause 18 "GTP-C based restart procedures") with which it has PDP context(s) activated and/or MBMS UE context(s), it shall delete all these PDP context(s) and/or MBMS UE context(s). When the GGSN detects a restart in an SGSN with which it has any MBMS Bearer context, it shall not delete the MBMS bearer context unless all SGSNs connected to the GGSN restart.

When the MBMS GW detects a restart in an SGSN (see clause 18 "GTP-C based restart procedures") with which it has any MBMS Bearer context, it shall not delete the MBMS Bearer context unless all SGSNs/MMEs connected to the MBMS GW restart.

11.2 Restoration Procedures

11.2.1 Mobile terminated user data transmission

When a Gn-SGSN receives a tunnel PDU for which no PDP context or MBMS Bearer Context exists it discards the tunnel PDU and sends an Error indication message to the originating GGSN.

An S4-SGSN and an SGW supporting the optional network triggered service restoration procedure shall behave as specified in clause 25.

11.2.2 Mobile terminated services requested by the MSC/VLR

When the SGSN receives a request for CS paging from an MSC/VLR for an IMSI unknown by the SGSN, if the "SGSN-Reset" indicator is set to "true", the SGSN sends the paging request with the location information provided by the VLR. If no such location information is provided, the SGSN should page for the MS in all the routeing areas corresponding to that SGSN.

If the "SGSN-Reset" indicator is set to "false" and the IMSI is unknown or the MS is marked as GPRS or non-GPRS detached by the SGSN, the paging request is rejected.

If the "SGSN-Reset" indicator is set to "false" and the IMSI is known and the MS is marked as GPRS and is non-GPRS attached by the SGSN, the paging request shall be sent to the MS.

11.2.3 Mobile terminated SMS over GPRS

a) Send Routing Information for MT SMS (SMS-GMSC -> HLR):

The HLR returns the SGSN number as for normal operation.

b) Send Information for MT SMS:

- When the SGSN receives a mobile terminated SMS for an unknown MM context for the MS, or if the SGSN indicator "Subscriber Data Confirmed by HLR" is marked "Not Confirmed" it rejects the SMS request and returns a failure report with cause value "Unidentified Subscriber" to the SMS gateway MSC indicating unsuccessful delivery of the SMS. The Gateway MSC sends a "Report SM Delivery Status" request, with a cause of "Absent Subscriber", to the HLR. This causes the HLR to set the "Mobile Station Not Reachable for GPRS Flag" for the MS, as described in the Technical Specifications3GPP TS 23.040 and 3GPP TS 29.002.

- If the SGSN has the indicator "Subscriber Data Confirmed by HLR" set to "Confirmed", the SGSN handles the SMS request in the normal way.

The state of the indicator "Location Information Confirmed in HLR" does not affect the Mobile Terminated SMS procedure.

11.2.4 Mobile originated Routeing Area Updating or Attach

For attach, where the MS is unknown in the SGSN (i.e. the SGSN has no MM context for the MS) the SGSN creates an MM context for the MS and sets the indicators "Location Information Confirmed in HLR", "Subscriber Data Confirmed by HLR", "Location Information Confirmed by CSS" and "Subscriber Data Confirmed by CSS" to "Not Confirmed". If authentication is required, the SGSN retrieves authentication data. The SGSN then performs an "Update GPRS Location" to the HLR. If this is successful, the SGSN sets the indicators "Location Information Confirmed in HLR" and "Subscriber Data Confirmed by HLR" to "Confirmed". If the VPLMN supports Autonomous CSG Roaming and the HPLMN has enabled Autonomous CSG Roaming in the VPLMN, the SGSN may perform an "Update VCSG Location" to the CSS if the requested cell is a CSG/hybrid cell. If this is successful, the SGSN sets the indicators "Location Information Confirmed by CSS" and "Subscriber Data Confirmed by CSS" if the CSS has the valid CSG subscription data to "Confirmed".

For routing area update, where the MS is unknown in the SGSN (i.e. the SGSN has no MM context for the MS) or for inter-SGSN routing area update, where the MS is unkown in the old SGSN, the SGSN shall reject the RA update with an appropriate cause. In order to remain GPRS-attached, the MS shall then perform a new GPRS attach and should (re-)activate its PDP contexts.

If the SGSN has an MM context for the MS, and the indicators "Location Information Confirmed in HLR" or "Subscriber Data Confirmed by HLR" is set to "Not Confirmed" the SGSN performs an "Update GPRS Location" to the HLR. If this is successful, the SGSN sets the indicators "Location Information Confirmed in HLR" and "Subscriber Data Confirmed by HLR" to "Confirmed". If the indicators "Location Information Confirmed by CSS" or "Subscriber Data Confirmed by CSS" if the CSS has the valid CSG subscription data is set to "Not Confirmed", and the VPLMN supports Autonomous CSG Roaming and the HPLMN has enabled Autonomous CSG Roaming in the VPLMN, the SGSN may perform an "Update VCSG Location" to the CSS if the requested cell is a CSG/hybrid cell. If this is successful, the SGSN sets the indicators "Location Information Confirmed by CSS" and "Subscriber Data Confirmed by CSS" if the CSS has the valid CSG subscription data to "Confirmed".

If the SGSN has an MM context for the MS with the indicator "Subscriber Data Confirmed by HLR" marked "Confirmed" the originated transmission is handled in the normal way.

The SGSN retrieves subscriber data from the HLR by sending an "Update GPRS Location" request, which triggers one or more "Insert Subscriber Data" operations from the HLR.

The SGSN retrieves CSG subscriber data from the CSS by sending an "Update VCSG Location" request, which triggers one or more "Insert Subscriber Data" operations from the CSS if the CSS has the valid CSG subscription data.

11.2.5 Mobile originated LLC frame

If an SGSN receives an LLC frame for which no MM context exists in the SGSN, and if the LLC frame does not contain an Attach Request or a Routeing Area Update Request signalling message, then the LLC frame shall be discarded. The MS may determine that the network is not responding and attempt to re-attach or eventually a periodic Routing Area Update message is sent by the MS which initiates the attach procedures.

11.2.6 Mobile originated Service Request

For service request, where the MS is unknown in the SGSN (i.e. the SGSN has no MM context for the MS), the SGSN shall reject the service request with an appropriate cause. In order to remain GPRS-attached, the MS shall then perform a new GPRS attach and should (re-)activate its PDP contexts.

If the SGSN has an MM context for the MS, and the indicators "Location Information Confirmed by CSS" or "Subscriber Data Confirmed by CSS" if the CSS has the valid CSG subscription data is set to "Not Confirmed", and the VPLMN supports Autonomous CSG Roaming and the HPLMN has enabled Autonomous CSG Roaming in the VPLMN, the SGSN may perform an "Update VCSG Location" to the CSS if the requested cell is a CSG/hybrid cell. If this is successful, the SGSN sets the indicators "Location Information Confirmed by CSS" and "Subscriber Data Confirmed by CSS" if the CSS has the valid CSG subscription data to "Confirmed".

The SGSN retrieves CSG subscriber data from the CSS by sending an "Update VCSG Location" request, which triggers one or more "Insert Subscriber Data" operations from the CSS if the CSS has the valid CSG subscription data.

11.3 Use of TLLI

After the SGSN has restarted but before the next authenticated radio contact the P-TMSI and TLLI known by the MS are invalid, as the P-TMSI was allocated before the SGSN restarted. The SGSN may request the MS to identify itself with the IMSI in order to make a relationship between the IMSI and the received old TLLI. The SGSN shall allocate a new P-TMSI for that MS.

If an MS identifies itself by a TLLI in an MS originating transmission, the SGSN proceeds as follows:

a) The SGSN checks the routing area identity (RAI) of the previous routing area sent by the MS. If this previous RAI belongs to a different SGSN, the request is handled in the normal way.

b) If the previous RAI belongs to the current SGSN, the status of the TLLI is checked.

- If the P-TMSI derived from the TLLI was allocated after the SGSN restarted, and corresponds to a valid IMSI record, then the request is handled in the normal way.

- If the P-TMSI derived from the TLLI was allocated before the SGSN restarted, or does not correspond to a valid IMSI record, then the SGSN requests the IMSI from the MS. If the MS returns an IMSI the SGSN proceeds in the normal way. If the MS does not return an IMSI the network aborts the originating transmission request or location registration procedure.

11.4 VLR associations

All associations with VLRs affected by the restart of an SGSN are marked as unreliable and may be deleted. Based on configuration data, Reset messages may be sent on the Gs-interface to the VLRs served by the SGSN. If Reset messages are sent, the VLRs may mark all associations with the SGSN as unreliable by setting the restoration indicator "Confirmed by radio contact" to "Not Confirmed" for the MSs served by that SGSN. See 3GPP TS 29.018 [7]. The associations will be re-initiated one by one by the SGSN at the next Routing Area update, or combined RA/LA update from each MS.

12 Restoration of Data in an SMLC (GSM only)

12.1 Restart of an SMLC

When an SMLC restarts after a failure, it performs the following actions for those of its associated LMUs whose records have been affected by the fault:

- Reload all administered LMU data from non-volatile back-up;

- Reinitialize other temporary data for each LMU to indicate no ongoing measurement or diagnostic activities;

- Perform data restoration for each affected Type A and Type B LMU as described below.

12.2 Data Restoration for a Specific LMU

An SMLC may restore data for a specific LMU when the data in the SMLC or LMU is considered unreliable (e.g. if there is no communication between the SMLC and LMU for a long time or if messages received by the SMLC are inconsistent with the LMU state kept by the SMLC). To restore data for a specific LMU, the SMLC shall open a signalling connection to the LMU if this is Type A, as described in 3GPP TS 23.071. For both a Type A LMU and a Type B LMU, the SMLC shall then send an LLP Reset message to the LMU. On receiving an LLP Reset, an LMU shall cancel any LCS measurement and O&M tasks previously ordered by the SMLC and shall return an LLP Reset acknowledgement to the SMLC.

13 Restoration of Data in an LMU (GSM only)

When an LMU restarts following a failure, it shall reinitialize all data concerning LCS measurement and O&M tasks to indicate that no tasks ordered by an SMLC are active. A Type A LMU shall then perform an "IMSI Attach". A Type A LMU shall then open a signaling connection to its controlling SMLC as described in 3GPP TS 23.071. Both a Type A LMU and a Type B LMU shall send an LLP Status Update message to their controlling SMLC containing an indication that the LMU has restarted following a failure. The SMLC shall update its data regarding the state of the LMU and shall return an LLP Update Status acknowledgment to the LMU.

14 Restoration of data in the MME

14.1 Restart of the MME

14.1.1 Restoration Procedures

After an MME restart, the MME shall delete all MM Bearer contexts affected by the restart that it may have stored.

When the MBMS GW detects a restart in an MME (see clause 18 "GTP-C based restart procedures") with which it has any MBMS Bearer context, it shall not delete the MBMS Bearer context unless all SGSNs/MMEs connected to the MBMS GW restart.

An MME and an SGW supporting the optional network triggered service restoration procedure shall behave as specified in clause 25.

When the MME which does not support the optional network triggered service restoration procedure as specified in clause 25 receives a Downlink Data Notification message for which no MM context exists, the MME returns a Downlink Data Notification Acknowledge message to the Serving GW with an appropriate cause. The Serving GW shall delete the related Bearer context related to MME; and if there is no ISR associated S4-SGSN recorded on the related Bearer context the Serving GW shall also notify the PDN GW to delete the Bearer context.

14.1.2 Mobile originated Tracking Area Updating or E-UTRAN Attach

For attach, where the UE is unknown in the MME (i.e. the MME has no MM context for the UE) the MME shall create an MM context for the UE and shall set the indicators "Location Information Confirmed in HSS", "Subscriber Data Confirmed by HSS", "Location Information Confirmed by CSS" and "Subscriber Data Confirmed by CSS" to "Not Confirmed". If authentication is required, the MME shall retrieve the authentication data. The MME then performs an "Update Location" to the HSS. If this is successful, the MME shall set the indicators "Location Information Confirmed in HSS" and "Subscriber Data Confirmed by HSS" to "Confirmed". If the VPLMN supports Autonomous CSG Roaming and the HPLMN has enabled Autonomous CSG Roaming in the VPLMN, the MME may perform an "Update VCSG Location" to the CSS if the requested cell is a CSG/hybrid cell. If this is successful, the MME shall set the indicators "Location Information Confirmed by CSS" and "Subscriber Data Confirmed by CSS" if the CSS has the valid CSG subscription data to "Confirmed".

For tracking area update, where the UE is unknown in the MME (i.e. the MME has no MM context for the UE) or for inter-MME tracking area update, where the UE is unkown in the old MME, the MME shall reject the TA update with an

appropriate cause. In order to remain attached, the UE shall then perform a new attach and should (re-)activate its EPS Bearer contexts.

If the MME has an MM context for the UE, and the indicator "Location Information Confirmed in HSS" or "Subscriber Data Confirmed by HSS" is set to "Not Confirmed" the MME shall perform an "Update Location" to the HSS. If this is successful, the MME shall set the indicators "Location Information Confirmed in HSS" and "Subscriber Data Confirmed by HSS" to "Confirmed". If the indicators "Location Information Confirmed by CSS" or "Subscriber Data Confirmed by CSS" is set to "Not Confirmed", and the VPLMN supports Autonomous CSG Roaming and the HPLMN has enabled Autonomous CSG Roaming in the VPLMN, the MME may perform an "Update VCSG Location" to the CSS if the requested cell is a CSG/hybrid cell. If this is successful, the MME shall set the indicators "Location Information Confirmed by CSS" and "Subscriber Data Confirmed by CSS" if the CSS has the valid CSG subscription data to "Confirmed".

If the MME has an MM context for the UE with the indicator "Subscriber Data Confirmed by HSS" marked "Confirmed" the originated transmission shall be handled in the normal way.

The MME retrieves subscriber data from the HSS by sending an "Update Location" request, which triggers an "Update Location" answer which contains the subscriber data.

The MME retrieves CSG subscriber data from the CSS by sending an "Update VCSG Location" request, which triggers an "Update VCSG Location" answer which may contain the valid CSG subscription data.

14.1.3 Mobile terminated services requested by the MSC/VLR

An MME and a VLR supporting mobile terminated CS service delivery via an alternative MME in MME pool shall behave as specified in clause 26.

When the MME receives a request for CS paging from an MSC/VLR for an IMSI unknown by the MME, if the "MME-Reset" indicator is set to "true", the MME sends the paging request with the location information provided by the VLR. If no such location information is provided, the MME should page for the UE in all the tracking areas corresponding to that MME.

If the "MME-Reset" indicator is set to "false" and the IMSI is unknown or the UE is marked as EMM-DEREGISTERED by the MME, the paging request is rejected.

If the "MME-Reset" indicator is set to "false" and the IMSI is known and the UE is marked as EMM-REGISTERED by the MME, the paging request shall be sent to the UE.

14.1.4 Mobile terminated user data transmission

An MME and an SGW supporting the optional network triggered service restoration procedure shall behave as specified in clause 25.

14.1.5 Mobile originated Service Request

For service request, where the UE is unknown in the MME (i.e. the MME has no MM context for the UE), the MME shall reject the service request with an appropriate cause. In order to remain attached, the UE shall then perform a new attach and should (re-)activate its EPS Bearer contexts.

If the MME has an MM context for the UE, and the indicators "Location Information Confirmed by CSS" or "Subscriber Data Confirmed by CSS" is set to "Not Confirmed", and the VPLMN supports Autonomous CSG Roaming and the HPLMN has enabled Autonomous CSG Roaming in the VPLMN, the MME may perform an "Update VCSG Location" to the CSS if the requested cell is a CSG/hybrid cell. If this is successful, the MME shall set the indicators "Location Information Confirmed by CSS" and "Subscriber Data Confirmed by CSS" if the CSS has the valid CSG subscription data to "Confirmed".

The MME retrieves CSG subscriber data from the CSS by sending an "Update VCSG Location" request, which triggers an "Update VCSG Location" answer which may contain the valid CSG subscription data.

14.1A Restart of a peer node

14.1A.1 SGW Failure

When an MME detects that a peer SGW has failed with or without restart (relying on restart counter as specified in clause 18 "GTP-C based restart procedures" or implementation e.g. preconfigured path failure timer) it shall either:

- as a default delete all PDN connection table data/MM bearer contexts associated with the peer node that fails as well as freeing any internal MME resources associated with those PDN connections. The MME may optionally perform other implementation specific actions such as to clear external resources (e.g. S1-MME messages to clear eNodeB resources) or more advanced forms of restoration;

or

- follow the procedures specified in clause 27 to restore the PDN connections affected by the SGW failure, if the MME/S4-SGSN and the PGW support these procedures.

NOTE: The MME will have the identity of the PGW and SGW currently in use for a PDN connection available in the MME"s PDN connection table as part of existing EPC procedures as well as other peer state data.

14.2 VLR associations

All associations with VLRs affected by the restart of an MME are marked as unreliable and may be deleted. Based on configuration data, Reset messages may be sent on the SGs interface to the VLRs served by the MME. If Reset messages are sent, the VLRs may mark all associations with the MME as unreliable by setting the restoration indicator "Confirmed by radio contact" to "Not Confirmed" for the UEs served by that MME. See 3GPP TS 29.118 [14]. The associations will be re-initiated one by one by the MME at the next Combined TA/LA update from each UE.

14.3 Partial Failure Handling at MME

14.3.1 General

See Section 23.

14.3.2 Procedures during PDN Connection Establishment

If the MME supports the feature, the following procedures apply.

During a PDN connection establishment, the MME shall provide one MME FQ-CSID containing exactly one CSID for that particular PDN connection to the SGW in the S11 Create Session Request. The MME shall store the Node-ID and CSID values from the FQ-CSID provided by the SGW and the PGW in the S11 Create Session Response in its PDN Connection table maintained as part of MME MM and EPS Bearer Contexts as specified in Table 5.6.2-15.7.2-1 in 3GPP TS 23.401 [15].

The MME should ensure as far as possible that previously used FQ-CSIDs are not immediately reused after a partial/full failure of an MME.

The MME determines that the SGW supports partial failure handling by the presence of the SGW FQ-CSID in the S11 Create Session Response.

14.3.3 Procedures during MME Partial Failure

If the MME supports the feature the following procedures apply.

When an MME detects that it has undergone a partial failure, it shall verify that one or more corresponding CSID(s) are present for the component(s) undergoing a partial fault. If there is no such CSID, then the following does not apply. When one or more CSIDs are currently assigned, the MME shall perform the following.

The MME may perform implementation-specific operations to clean up any residual state associated with the CSID(s).

The MME shall send a GTPv2 Delete PDN Connection Set Request containing all the MME CSID(s) of the component(s) failing in MME FQ-CSID(s) to the SGW peers that support the feature.

Upon receiving a GTPv2 Delete PDN Connection Set Response message with Cause value "Success", the MME shall conclude that the SGW peer has initiated the internal deletion of the PDN connections corresponding to the FQ-CSID(s) present in the GTPv2 Delete PDN Connection Set Request message.

Regardless of the "Cause" value in the response, the MME is not required to perform any further recovery actions towards SGW and PGW peers for PDN connections in the connection set identified by the MME FQ-CSID(s).

14.3.4 Procedures during a Peer"s Partial Failure

If the MME supports the feature, the following procedures apply.

When an MME receives a GTPv2 Delete PDN Connection Set Request message from an SGW, the MME shall retrieve all the PDN connections corresponding to each of the FQ-CSID(s) present in the message. The MME shall delete all the retrieved PDN connections and the associated resources. Other implementation-specific actions may be performed.

As a response, the MME shall send a GTPv2 Delete PDN Connection Set Response message with appropriate Cause value immediately to the SGW.

14.3.5 Procedures during PDN Connection Removal or Modification

If an MME and an SGW support the feature, the following procedures apply.

During an S11 procedure, impacting an existing PDN connection removal or modification the following apply:

1) If the SGW is being relocated then the MME shall clear the currently stored SGW FQ-CSID .

2) If an MME relocation occurs (for example, TAU with MME change), or if an SGW relocation occurs, (for example, TAU with SGW change), the MME shall include its MME FQ-CSID in the S11 Create Session Request for SGW change and the S11 Modify Bearer Request for MME change without SGW change.

3) Additionally, if MME decides to change own FQ-CSID, the MME shall include MME FQ-CSID in other S11 messages.

4) If the MME receives a FQ-CSID value of an SGW over S11, the MME shall overwrite the current stored SGW FQ-CSID value with the received value.

5) If the MME receives a FQ-CSID value of a PGW over S11, the MME shall overwrite the current stored PGW FQ-CSID value with the received value.

6) During a S11 procedure removing an existing PDN connection the MME removes the PDN data as well as any stored FQ-CSID values(s) of the PGW FQ-CSID and SGW FQ-CSID. The same actions are done on the old MME if there is an MME relocation.

The MME determines that the SGW supports partial failure handling by the presence of the SGW FQ-CSID in the S11 Create Session Response with SGW change; and S11 Modify Bearer Response without SGW change.

15 Restoration of data in GERAN/UTRAN

15.1 BSS Failure (A/Gb mode)

When a BSS fails, all its BSS contexts affected by the failure become invalid and shall be deleted. BSS storage of data is volatile.

15.2 RNC/BSC Failure (Iu mode)

When an RNC/BSC fails, all its RNC/BSC contexts affected by the failure become invalid and shall be deleted. RNC/BSC storage of data is volatile. An SGSN that recognises unavailability of an RNC/BSC or receives a Reset from an RNC/BSC, shall locally release the RABs for all affected PDP contexts.

Any affected PDP contexts that use Direct Tunnel and have an invalid tunnel in GGSN will be recovered when the SGSN receives an Iu connection establishment request from the MS or when the GGSN informed the SGSN that the GGSN has received a GTP error indication from RNC.

When the RNC/BSC receives a GTP-U PDU for which no RAB context exists, the RNC/BSC shall discard the GTP-U PDU and return a GTP error indication to the originating node that may be SGSN or GGSN if Direct Tunnel is established.

The RNC should ensure as far as possible that previously used TEID values are not immediately reused after an RNC restart, in order to avoid inconsistent TEID allocation throughout the network.

15.3 RNC/BSC Failure (Iu mode) using S4

When an RNC/BSC fails, all its RNC/BSC contexts affected by the failure become invalid and shall be deleted. RNC/BSC storage of data is volatile. An SGSN that recognises unavailability of an RNC/BSC or receives a Reset from an RNC/BSC, shall locally release the RABs for all affected PDP contexts. If ISR is activated or direct tunnel is established, the S4-SGSN shall initiate release of the access bearer for all bearers towards the Serving GW as defined in Iu Release Procedure Using S4 in 3GPP TS 23.060 [5]. For the other cases, the S4-SGSN may send the Release Access Bearers Request message to the Serving GW to remove the downlink user plane address and TEID as specified in 3GPP TS 23.060 [5]. In addition, based on operator policy, the SGSN may initiate the Dedicated Bearer Deactivation procedure for bearers using streaming or conversational traffic class. Any affected EPS bearers contexts in Serving GW are recovered when the SGSN receives an Iu connection establishment request from the MS or when the Serving GW initiates the Network Triggered Service Request procedure as specified in 3GPP TS 23.060 [5].

When the RNC/BSC receives a GTP-U PDU for which no RAB Context exists, the RNC/BSC shall discard the GTP-U PDU and return a GTP Error Indication to the originating node that may be SGSN or Serving GW if Direct Tunnel is established.

15A Restoration of data in E-UTRAN

15A.1 eNodeB Failure

When an eNodeB fails, all its eNodeB contexts affected by the failure become invalid and shall be deleted. An MME that recognises unavailability of an eNodeB (e.g. no more SCTP association in service) or receives a Reset from an eNodeB, shall locally delete the eNodeB related information ("eNodeB Address in Use for S1-MME" and "eNodeB UE S1AP ID"). The MME initiates release of all S1 bearers towards the Serving GW by sending a Release Access Bearer Request message as defined in the S1 Release procedure in 3GPP TS 23.401 [15]. The MME shall initiate the Dedicated Bearer Deactivation procedure to deactivate the GBR bearers in the packet core.

If the Serving GW receives Release Access Bearers Request message, the Serving GW shall release all eNodeB related information (address and TEIDs) for the UE, but other elements of the UE's Serving GW context shall not be affected. Any Bearer contexts affected by eNodeB failure that have no valid S1-U tunnel in Serving GW are recovered during the UE Triggered Service Request or during the Network Triggered Service Request procedure as specified in 3GPP TS 23.401 [15].

The eNodeB should ensure as far as possible that previously used TEID values are not immediately reused after an eNodeB restart, in order to avoid inconsistent TEID allocation throughout the network.

15A.2 S1-AP path failure

Upon detection of an S1-AP path failure (i.e. no more SCTP association in service),

- the eNodeB shall release the RRC connection of the affected UEs;
- the MME shall proceed as specified for the eNodeB failure in subclause 15A.1.

16 Restoration of data in the SGW

16.1 Restart of the SGW

16.1.0 SGW Failure

When a SGW fails, all its Bearer contexts affected by the failure become invalid and may be deleted. SGW storage of subscriber data is volatile.

When the SGW receives a GTP-U PDU for which no Bearer context exists, it shall discard the GTP-U PDU and return a GTP error indication to the originating node (the PGW, the eNodeB, the S4-SGSN, or if Direct Tunnel is established, the RNC).

The SGW should ensure as far as possible that previously used TEID values are not immediately reused after a SGW restart, in order to avoid inconsistent TEID allocation throughout the network.

16.1.1 Restoration Procedures

After an SGW restart, the SGW shall delete all MM Bearer contexts affected by the restart that it may have stored.

During or immediately after an SGW Restart the SGW shall place local SGW restart counter value in all GTPv2 Echo requests/responses messages and PMIPv6 heartbeat responses the SGW sends.

16.1A Restart of a peer node

16.1A.1 MME/S4-SGSN Failure

16.1A.1.1 General

The SGW will receive the MME/S4-SGSN restart counter in GTPv2 Echo requests and Echo response messages that the SGW receives from the MME/S4-SGSN.

When an SGW detects that a peer MME /S4-SGSN has restarted (see clause 18 "GTP-C based restart procedures") it shall either:

- delete all PDN connection table data/MM bearer contexts associated with the peer node that fails as well as freeing any internal SGW resources associated with those PDN connections. The SGW may optionally perform other implementation specific actions such as messages to clear other external resources (e.g. PCC messages to clear the resources in the PCRF or GTP/PMIP messages to release the corresponding PDN connection in the PGW);

or

- follow the network triggered service restoration procedure as specified in clause 25 if the MME, the S4-SGSN and the SGW support this procedure.

16.1A.2 PGW Failure

The SGW will receive the PGW restart counter in GTPv2 Echo requests/ responses and PMIPv6 heartbeat responses that the SGW receives from the PGW.

When an SGW detects that a peer PGW has restarted (see clause 18 "GTP-C based restart procedures") it shall delete all PDN connection table data/MM bearer contexts associated with the peer node that fails as well as freeing any internal

SGW resources associated with those PDN connections. In addition, if the optional feature PGW Restart Notification is supported by the SGW and MME/S4-SGSN as specified in clause 8.83 in 3GPP TS 29.274[13], the SGW shall initiate the cleanup of the hanging PDN connections associated with the SGW and the restarted PGW at the corresponding MMEs/S4-SGSNs by sending GTPv2 message(s) PGW Restart Notification, with the control plane IP address of the restarted PGW and the control plane IP address of the SGW on the S11/S4 interface included. The SGW may optionally perform other implementation specific actions such as messages to clear other external resources (e.g. PCC messages).

If the optional feature PGW Restart Notification is supported by the SGW and MME/S4-SGSN as specified in clause 8.83 in 3GPP TS 29.274[13], the SGW may also send a PGW Restart Notification message to the MME or S4-SGSN if the SGW detects that a peer PGW has failed and not restarted. The PGW Restart Notification message shall include the control plane IP address of the PGW, the control plane IP address of the SGW on the S11/S4 interface and the cause value "PGW not responding". It is an implementation matter how an SGW becomes aware that a PGW has failed and has not restarted, e.g. the SGW detects a signalling path failure with the PGW for a duration exceeding the maximum path failure duration timer (see clause 20.2.1).

When the MME/S4-SGSN receives this message, according to the control plane IP address of the restarted PGW and the control plane IP address of the SGW on the S11/S4 interface included in the message, the MME/S4 SGSN should delete all PDN connection table data/MM bearer contexts associated with the SGW and the restarted PGW as well as freeing any internal MME/S4-SGSN resources associated with those PDN connections. Additionally the MME/S4-SGSN may decide to restore certain PDN connections based on operator's policy e.g. based on the QCI and/or ARP and/or APN. If so,

- the S4-SGSN shall deactivate the corresponding PDN connections using the "reactivation requested" cause value as specified in clause 9.2.4.2 of 3GPP TS 23.060 [5];
- the MME shall deactivate the corresponding PDN connections using the "reactivation requested" cause value as specified in clause 5.10.3 of 3GPP TS 23.401 [15] if only a subset of the PDN connections of the UE need to be restored; if all the PDN connections of the UE need to be restored, the MME shall initiate the "explicit detach with reattach required" procedure as specified in clause 5.3.8.3 of 3GPP TS 23.401 [15].

The MME/S4-SGSN may optionally perform other implementation specific actions such as to clear external resources (e.g. S1-MME messages to clear eNodeB resources or Iu messages to clear RNC resources) or more advanced forms of restoration.

NOTE 1: The SGW will have the identity of the MME/S4-SGSN and PGW currently in use for a PDN connection available in the SGW"s PDN connection table as part of existing EPC procedure.

If PMIPv6 based S5/S8 interface is used and if the SGW needs to send a request for Gateway Control and QoS Policy Rules Provision procedure towards a PCRF which is known to have restarted since the Gateway Control Session Establishment, the SGW may discard the request and may tear down the associated PDN connection, based on operator policy, by initiating a PDN connection deactivation procedure towards the MME/S4-SGSN with the cause set to "Reactivation requested". Additionally, SGW initiates PDN connection deactivation procedure towards PGW. This leads the UE to initiate a UE requested PDN connectivity procedure for the same APN. Emergency and eMPS sessions should not be torn down.

NOTE 2: The procedure above just enables to clean up the PDN connection affected by the PCRF failure when a specific interaction with the PCRF is required. Prior to that interaction, PCC controlled services can not be provided to the UE.

16.2 Partial Failure Handling at SGW

16.2.1 General

See Section 23.

In addition, the following applies. If an SGW, which supports the feature receives Delete PDN Connection Set Request/Reply messages from MME or the PGW it shall forward the messages to the appropriate peer.

If the SGW does not support the feature then partial failure handling does not apply to that specific PDN connection.

16.2.2 Procedures during PDN Connection Establishment

If the SGW supports the feature, the following procedures apply.

During a PDN connection establishment, the SGW shall provide one SGW FQ-CSID for that particular PDN connection to the PGW. Similarly, the SGW shall provide one SGW FQ-CSID for that particular PDN connection to the MME. The SGW shall store the Node-ID and CSID from the FQ-CSID provided by the PGW and the MME respectively for that particular PDN connection in its PDN Connection table maintained as part of "EPS Bearer Contexts" table as specified in Table 5.7.3-1 in 3GPP TS 23.401 [15].

The SGW shall forward the MME FQ-CSID provided by the MME on S11 to the PGW in the S5/S8 Create Session Request (Proxy Binding Update for PMIPv6) for that PDN connection. Similarly, the SGW shall forward the PGW FQ-CSID provided by the PGW on S5/S8 to the MME in theS11 Create Session Response for that PDN connection.

The SGW determines that the MME supports partial failure handling by the presence of the MME FQ-CSID in the S11 Create Session Request.

The SGW determines that the PGW supports partial failure handling by the presence of the PGW FQ-CSID in the S5/S8 Create Session Response for GTPv2 based S5/S8 and the Proxy Binding Acknowledgement for PMIPv6 based S5/S8.

16.2.3 Procedures during SGW Partial Failure

If the SGW supports the feature, the following procedures apply.

When an SGW detects that it has undergone a partial failure, it shall verify that one or more corresponding CSID(s) are present for the component undergoing a partial fault. If there is no such CSID, then the following does not apply. When one or more CSIDs are currently assigned, the SGW shall perform the following.

The SGW may perform implementation-specific operations to clean up any residual state associated with the CSID(s).

The SGW shall send the GTPv2 Delete PDN Connection Set Request containing all the SGW CSIDs of the component(s) failing in SGW FQ-CSID to MME peers supporting the feature. The SGW shall send the GTPv2 Delete PDN Connection Set Request (or PMIP6 Binding Revocation Indication with G bit set) message containing the equivalent SGW FQ-CSID(s) to PGW peers supporting the feature.

Upon receiving a GTPv2 Delete PDN Connection Set Response message with Cause value "Success", the SGW shall conclude that the PGW (for GTPv2 S5/S8) or the MME (for S11) has initiated the internal deletion of the PDN connections corresponding to the FQ-CSID(s) present in the GTPv2 Delete PDN Connection Set Request message. Similarly, upon receiving a successful PMIP6 Binding Revocation Acknowledgment message with G bit set, the SGW shall conclude that the PGW has initiated the internal deletion of the PDN connections corresponding to the CSID(s) present in the PMIP6 Binding Revocation Indication message.

The SGW is not required to perform any further recovery actions towards MME and PGW peers for PDN connections in the connection set identified by the SGW FQ-CSID(s).

16.2.4 Procedures during a Peer"s Partial Failure

If the SGW supports the feature, the following procedures apply.

When an SGW receives a S11 GTPv2 Delete PDN Connection Set Request message from an MME, the SGW shall retrieve all the PDN connections corresponding to each of the FQ-CSID(s) present in the message. The SGW shall send a S5/S8 GTPv2 Delete PDN Connection Set Request (or PMIP6 Binding Revocation Indication with G bit set) message containing the FQ-CSID(s) provided by the MME to PGW peers supporting the feature. The SGW shall delete all the retrieved PDN connections and the associated resources. Other implementation-specific actions may be performed.

As a response, the SGW shall send a S11 GTPv2 Delete PDN Connection Set Response message with an appropriate Cause value immediately to the MME.

When an SGW receives a S5/S8 GTPv2 Delete PDN Connection Set Request (or PMIP6 Binding Revocation Indication with G bit set) message from a PGW, the SGW shall retrieve all the PDN connections corresponding to each of the FQ-CSID(s) present in the message. The SGW shall send a S11 GTPv2 Delete PDN Connection Set Request message containing the FQ-CSID(s) provided by the PGW to MME peers supporting the feature. The SGW shall delete all the retrieved PDN connections and the associated resources. Other implementation-specific actions may be performed.

As a response, the SGW shall send a S5/S8 GTPv2 Delete PDN Connection Set Response message with an appropriate Cause value to the PGW. On PMIP6-based S5/S8 interface, the SGW shall send a PMIP6 Binding Revocation Acknowledgment message with G bit set.

If the SGW detects the full/complete failure of an MME or PGW, e.g., through the Echo Request/Echo Response procedure, it may send a Delete PDN Connection Set Request (or PMIP6 Binding Revocation Indication with G bit set) message, containing all of the FQ-CSIDs of the associated hanging PDN connections of the failed node, to the corresponding remote node (MME or PGW).

16.2.5 Procedures during PDN Connection Removal or Modification

Only if the SGW supports the feature, the following procedures apply.

During a S11 or an S5/S8 procedure, impacting an existing PDN connection removal or modification the following apply:

1) If the MME is being relocated then the SGW shall clear the currently stored MME FQ-CSID value (if any).

2) For inter MME and intra SGW HO/TAU, and if the new MME supports the feature, then the SGW shall:

   - include SGW FQ-CSID in the S11 Modify Bearer Response. If PGW supports the feature, the SGW shall also include PGW FQ-CSID into the message.

   - inform the feature supporting PGW about the change of FQ-CSID values with the following messages:

     - Modify Bearer Request, when Modify Bearer Request message needs to be sent to the PGW as specified in the 3GPP TS 23.401 [15], e.g. if the sending of this message is triggered by user location reporting procedure. The message shall contain both SGW FQ-CSID and MME FQ-CSID.

     - Update PDN Connection Set Request message, only if Modify Bearer Request is not sent. The message shall contain both SGW FQ-CSID and MME FQ-CSID.

     - Proxy Binding Update (if PMIPv6 is used). The message shall contain both SGW FQ-CSID and MME FQ-CSID.

3) For inter MME and intra SGW HO/TAU, and if the new MME does not support the feature, then the SGW shall:

   - not include any FQ-CSID in the S11 Modify Bearer Response.

   - inform the feature supporting PGW with the following messages:

     - Modify Bearer Request when Modify Bearer Request message needs to be sent to the PGW as specified in the 3GPP TS 23.401 [15], e.g. if the sending of this message is triggered by user location reporting procedure. The message shall contain only SGW FQ-CSID.

     - Update PDN Connection Set Request message, only if Modify Bearer Request is not sent. The message shall contain only SGW FQ-CSID.

     - Proxy Binding Update (if PMIPv6 is used). The message shall contain only the SGW FQ-CSID.

4) For inter SGW HO/TAU, if the new MME supports the feature, then the new SGW shall:

   - include SGW FQ-CSID in the S11 Create Session Response. If PGW supports the feature, the SGW shall also include PGW FQ-CSID into the message.

   - inform the feature supporting PGW about the change of FQ-CSID values with the following messages:

     - Modify Bearer Request. The message shall contain both SGW FQ-CSID and MME FQ-CSID.

     - Proxy Binding Update (if PMIPv6 is used). The message shall contain both SGW FQ-CSID and MME FQ-CSID.

5) For inter SGW HO/TAU, if the MME does not support the feature, then the SGW shall:

   - not include any FQ-CSID in the S11 Create Session Response.

- inform the feature supporting PGW about the change of SGW FQ-CSID value with the following messages:
  - Modify Bearer Request. The message shall contain only SGW FQ-CSID
  - Proxy Binding Update (if PMIPv6 is used). The message shall contain only the SGW FQ-CSID.

6) If the SGW receives a FQ-CSID value of a PGW over S5/S8, or a FQ-CSID value of a MME over S11, the SGW shall overwrite the current stored FQ-CSID value with the received value.

7) During the PDN connection removing procedures, a PGW removes the PDN data as well as any stored FQ-CSID values(s) of the MME and SGW FQ-CSIDs.

8) For the following procedures, if the procedures as specified in 3GPP TS 23.401 [15] e.g. Location Change reporting is enabled, the SGW shall send its own FQ-CSID and the MME FQ-CSID in Modify Bearer Request and Proxy Binding Update across S5/S8 interface to the respective PGW even if the MME did not update its FQ-CSID, e.g.:
   - X2-based Handover without SGW relocation
   - TAU without MME and without SGW relocation
   - UE Triggered Service Request

During a S11 or S5/S8 procedure removing an existing PDN connection the SGW simply removes the PDN data as well as any stored FQ-CSID values(s) of the PGW FQ-CSID and MME FQ-CSID or pointers to such data. The same actions are done on the old SGW if there is an SGW relocation.

An SGW determines that the MME supports partial failure handling if MME FQ-CSID is present in the received S11 Modify Bearer Request or S11 Create Session Request (with both MME and SGW change) messages.

A new SGW determines that the PGW supports partial failure handling if PGW FQ-CSID is present in the S5/S8 Modify Bearer Response for GTPv2 based S5/S8 or in the Proxy Binding Acknowledgement for PMIPv6 based S5/S8.

17 Restoration of data in the PGW

17.1 Restart of the PGW

17.1.0 PGW Failure

When a PGW fails, all its Bearer contexts affected by the failure become invalid and may be deleted. PGW storage of subscriber data is volatile.

When the PGW receives a GTP-U PDU for which no Bearer context exists, it shall discard the GTP-U PDU and return a GTP error indication to the originating node i.e. the SGW/ePDG/TWAN.

The PGW should ensure as far as possible that previously used TEID values are not immediately reused after a PGW restart, in order to avoid inconsistent TEID allocation throughout the network.

17.1.1 Restoration Procedures

After a PGW restart, the PGW shall delete all MM Bearer contexts affected by the restart that it may have stored.

During or immediately after a PGW Restart, the PGW shall place this PGW restart counter value in all GTPv2 echo requests/responses and PMIPv6 heartbeat responses the PGW sends.

17.1A Restart of a peer node

17.1A.1 SGW/ePDG/TWAN Failure

The PGW will receive the SGW/ePDG/TWAN restart counters in GTPv2 echo requests/responses and PMIPv6 heartbeat responses that the PGW receives from the SGW/ePDG/TWAN.

When a PGW detects that a peer ePDG/peer TWAN has restarted it shall delete all PDN connection table data/MM bearer contexts associated with the peer node that fails as well as freeing any internal PGW resources associated with those PDN connections. The PGW may optionally perform other implementation specific actions such as messages to clear other external resources (e.g. PCC messages).

When a PGW detects that a peer SGW has failed with or without restart it shall either:

- proceed as specified above when the PGW detects that a peer ePDG/TWAN fails; or
- follow the procedures specified in clause 27 to restore the PDN connections affected by the SGW failure, if the MME/S4-SGSN and the PGW support these procedures.

NOTE: The PGW will have the identity of SGW/ePDG/TWAN currently in use for a PDN connection available in the PGW"s PDN connection table as part of existing EPC procedure.

17.1A.2 PCRF Failure

If the PGW needs to send a request for IP-CAN Session Modification procedure towards a PCRF which is known to have restarted since the IP-CAN session establishment, the PGW may discard the request and may tear down the associated PDN connection, based on operator policy, by initiating a PDN connection deactivation procedure towards the MME/S4-SGSN with the cause set to "Reactivation requested". This leads the UE to initiate a UE requested PDN connectivity procedure for the same APN. Emergency and eMPS sessions should not be torn down.

NOTE: The procedure above just enables to clean up the PDN connection affected by the PCRF failure when a specific interaction with the PCRF is required. Prior to that interaction, PCC controlled services can not be provided to the UE.

17.2 Partial Failure Handling at PGW

17.2.1 General

See Section 23.

17.2.2 Procedures during PDN Connection Establishment

If the PGW supports the feature, the following procedures apply.

During a PDN connection establishment, the PGW shall provide one FQ-CSID containing exactly one CSID for that particular PDN connection to the SGW, the ePDG or the TWAN. The PGW shall store the FQ-CSID provided by the SGW and the MME in the PDN Connection table maintained as part of P-GW Context as specified in Table 5.7.3-1 in 3GPP TS 23.401 [15]. Similarly, the PGW shall store the FQ-CSID received from the ePDG or the TWAN.

The PGW should ensure as far as possible that previously used FQ-CSIDs are not immediately reused after a partial/full failure of a PGW.

PGW determines that the partial failure handling does not apply to this PDN connection if it does not receive an SGW FQ-CSID in the S5/S8 Create Session Request (for GTP based interface) or in Proxy Binding Update (for PMIPv6 based interface), or if it does not receive a TWAN FQ-CSID in the S2a Create Session Request (for GTP based S2a) or in Proxy Binding Update (for PMIPv6 based S2a), or if it does not receive an ePDG FQ-CSID in the S2b Create Session Request (for GTP based S2b) or in Proxy Binding Update (for PMIPv6 based S2b).

17.2.3 Procedures during PGW Partial Failure

If the PGW supports the feature, the following procedures apply.

When a PGW detects that it has undergone a partial failure, it shall verify that one or more corresponding CSID(s) are present for the component(s) undergoing a partial fault. If there is no such CSID, then the following does not apply. When one or more CSIDs are currently assigned, the PGW shall perform the following:

- The PGW may perform implementation-specific operations to clean up any residual state associated with the CSID(s).
- The PGW shall send the GTPv2 Delete PDN Connection Set Request (or PMIPv6 Binding Revocation Indication with G bit set) message containing all the PGW FQ-CSID(s) of the component(s) failing to the SGW, the TWAN or the ePDG that support the feature.

Upon receiving a GTPv2 Delete PDN Connection Set Response message with Cause value "Success", the PGW shall conclude that the SGW, the ePDG peer or the TWAN peer has initiated the internal deletion of the PDN connections corresponding to the FQ-CSID(s) present in the GTPv2 Delete PDN Connection Set Request message. Similarly, upon receiving a PMIP6 Binding Revocation Acknowledgment message with G bit set, the PGW shall conclude that the SGW, the ePDG or the TWAN has initiated the internal deletion of the PDN connections corresponding to the CSID(s) present in the PMIPv6 Binding Revocation Indication message with G bit set.

The PGW is not required to perform any further recovery actions towards SGW, MME peers, an ePDG peer or a TWAN peer for PDN connections in the connection set identified by the PGW FQ-CSID regardless of the "Cause" value in the response.

17.2.4 Procedures during a Peer"s Partial Failure

If the PGW supports the feature, the following procedures apply.

When a PGW receives a GTPv2 Delete PDN Connection Set Request (or PMIPv6 Binding Revocation Indication with G bit set) message from an SGW, an ePDG or a TWAN, the PGW shall retrieve all the PDN connections corresponding to each of the FQ-CSIDs present in the message. The PGW shall delete all the retrieved PDN connections and the associated resources. Other implementation-specific actions may be performed.

As a response, the PGW shall send a GTPv2 Delete PDN Connection Set Response message. On PMIPv6-based S5/S8 interface, the PGW shall send a PMIPv6 Binding Revocation Acknowledgment message with G bit set.

17.2.5 Procedures during PDN Connection Removal or Modification

If the PGW supports the feature, the following procedures apply.

During a S5/S8 procedure, impacting an existing PDN connection Removal or Modification the following apply:

1) If an SGW is being relocated then the PGW shall clear the currently stored MME and SGW FQ-CSID values.
2) If the SGW includes a SGW FQ-CSID in the S5/S8 Modify Bearer Request (Proxy Binding Update for PMIPv6), or Update PDN Connection Request message, then the PGW shall include PGW FQ-CSID in the S5/S8 Modify Bearer Response (Proxy Binding Acknowledgement for PMIPv6), or Update PDN Connection Response message.
3) If the new SGW does not include a SGW FQ-CSID in the S5/S8 Modify Bearer Request (Proxy Binding Update for PMIPv6), then the new SGW does not support the feature and the feature does not apply for this PDN connection. In such case, PGW shall not include PGW FQ-CSID in the S5/S8 Modify Bearer Response (Proxy Binding Acknowledgement for PMIPv6).
4) If the PGW receives an SGW FQ-CSID and/or an MME FQ-CSID value of a SGW over S5/S8 then the PGW shall overwrite the respective stored FQ-CSID value with the received value.
5) If the PGW receives an Update PDN Connection Request, a Modify Bearer Request or Proxy Binding Update with an SGW FQ-CSID but without an MME FQ-CSID then the PGW shall erase the MME FQ-CSID value (i.e. the current MME does not support the feature).

6) During a S5/S8 procedure removing an existing PDN connection the PGW simply removes the PDN data as well as any stored FQ-CSID values(s) of the MME and SGW or pointers to such data.

During an S2a/S2b procedure, impacting an existing PDN connection Removal or Modification the following apply:

1) If the PGW receives a TWAN or an ePDG FQ-CSID value then the PGW shall overwrite the respective stored FQ-CSID value with the received value;

2) During an S2a/S2b procedure removing an existing PDN connection, the PGW removes the corresponding PDN data as well as any stored FQ-CSID value of the TWAN or the ePDG FQ-CSID.

17A Restoration of data in the MBMS GW

17A.1 Restart of the MBMS GW

When a MBMS GW fails, all its MBMS Bearer contexts affected by the failure become invalid and will be deleted. MBMS GW storage of subscriber data is volatile.

After a MBMS GW restart, all the MBMS Bearer contexts stored in the MBMS GW and affected by the restart become invalid and will be deleted.

When the SGSN/MME detects a restart in a MBMS GW (see clause 18 "GTP-C based restart procedures") with which it has MBMS Bearer contexts activated, it shall deactivate all these MBMS Bearer contexts.

17B Restoration of data in the ePDG

17B.1 Restart of the ePDG

17B.1.1 ePDG Failure

When an ePDG fails, all its Bearer contexts/PDN connections affected by the failure become invalid and may be deleted. ePDG storage of subscriber data is volatile.

When the ePDG receives a GTP-U PDU over GTPv2 based S2b for which no Bearer context exists, it shall discard the GTP-U PDU and return a GTP error indication to the originating node (i.e. the PGW).

The ePDG should ensure as far as possible that previously used TEID values are not immediately reused after an ePDG restart, in order to avoid inconsistent TEID allocation throughout the network.

When the ePDG receives a user packet with an unknown GRE Key over PMIPv6 based S2b, the ePDG shall discard the packet and optionally response back with an ICMP message, as specified in Sections 8.2 and 8.3 of IETF RFC2473 [31] for the node unreachable error case.

17B.1.2 Restoration Procedures

After an ePDG restart, the ePDG shall delete all MM Bearer contexts affected by the restart that it may have stored.

During or immediately after an ePDG Restart the ePDG shall place local ePDG restart counter value in all GTPv2 Echo requests/responses messages and PMIPv6 heartbeat responses the ePDG sends to the PGW.

17B.1A Restart of a peer node

17B.1A.1 PGW Failure

The ePDG will receive the PGW restart counter in GTPv2 Echo requests/ responses and PMIPv6 heartbeat responses that the ePDG receives from the PGW.

When an ePDG detects that a peer PGW has restarted (see clause 18 "GTP-C based restart procedures' and clause 19 "PMIPv6 based restart procedures") it shall delete all PDN connection table data/MM bearer contexts associated with the peer node that fails, free any internal ePDG resources associated with those PDN connections and initiate the release of the corresponding SWu instances (i.e. IKEv2 tunnels).

17B.2 Partial Failure Handling at ePDG

17B.2.1 General

See section 23.

The partial failure feature is optional for ePDG.

If the ePDG does not support the feature then partial failure handling does not apply to that specific PDN connection.

17B.2.2 Procedures during PDN Connection Establishment

If the ePDG supports the feature, the following procedures apply.

During a PDN connection establishment, the ePDG shall provide one ePDG FQ-CSID containing exactly one CSID for that particular PDN connection to the PGW. The ePDG shall store the Node-ID and CSID from the FQ-CSID provided by the PGW for that particular PDN connection in its PDN Connection table.

The ePDG determines that the PGW supports partial failure handling by the presence of the PGW FQ-CSID in the Create Session Response for GTPv2 based S2b and/or Proxy Binding Acknowledgement message for PMIPv6 based S2b.

17B.2.3 Procedures during ePDG Partial Failure

If the ePDG supports the feature, the following procedures apply.

When an ePDG detects that it has undergone a partial failure, it shall verify that one or more corresponding CSID(s) are present for the component undergoing a partial fault. If there is no such CSID, then the following does not apply. When one or more CSIDs are currently assigned, the ePDG shall perform the following.

The ePDG may perform implementation-specific operations to clean up any residual state associated with the CSID(s).

The ePDG shall send Delete PDN Connection Set Request containing all the ePDG CSIDs of the component(s) failing in ePDG FQ-CSID over the GTPv2 based S2b interface or PMIPv6 Binding Revocation Indication with G bit set message containing the equivalent ePDG FQ-CSID(s) over the PMIPv6 based S2b interface to PGW peers supporting the feature.

On the GTPv2 based S2b interface, upon receiving a GTPv2 Delete PDN Connection Set Response message with Cause value "Success", the ePDG shall conclude that the PGW has initiated the internal deletion of the PDN connections corresponding to the FQ-CSID(s) present in the GTPv2 Delete PDN Connection Set Request message. Similarly, on the PMIPv6 based S2b interface, upon receiving a successful PMIP6 Binding Revocation Acknowledgment message with G bit set, the ePDG shall conclude that the PGW has initiated the internal deletion of the PDN connections corresponding to the CSID(s) present in the PMIP6 Binding Revocation Indication message.

The ePDG is not required to perform any further recovery actions towards PGW peers for PDN connections in the connection set identified by the PGW FQ-CSID(s).

17B.2.4 Procedures during PGW Partial Failure

If the ePDG supports the feature, the following procedures apply.

When an ePDG receives a GTPv2 Delete PDN Connection Set Request or PMIP6 Binding Revocation Indication with G bit set message from a PGW, the ePDG shall retrieve all the PDN connections corresponding to each of the FQ-CSID(s) present in the message. The ePDG shall delete all the retrieved PDN connections, free the associated internal resources and initiate the release of the corresponding SWu instances (i.e. IKEv2 tunnels). Other implementation-specific actions may be performed.

As a response, the ePDG shall send a GTPv2 Delete PDN Connection Set Response message with an appropriate Cause value or a PMIPv6 Binding Revocation Acknowledgment message with G bit set to the PGW.

17B.2.5 Procedures during PDN Connection Removal or Modification

For the modification of an existing PDN connection established over 2b, if the corresponding ePDG and PGW support the partial failure feature, when the ePDG receives an FQ-CSID value of a PGW over S2b, the ePDG shall overwrite the currently stored FQ CSID value with the received value.

For the removal of an existing PDN connection established over S2b, if the corresponding ePDG and PGW support the partial failure feature, an ePDG removes the corresponding PDN data as well as any relevant stored FQ-CSID value of the PGW FQ-CSID.

17C Restoration of data in the TWAN

17C.1 Restart of the TWAN

17C.1.1 TWAN Failure

When a TWAN fails, all its Bearer contexts/PDN connections affected by the failure become invalid and may be deleted. TWAN storage of subscriber data is volatile.

When the TWAN receives a GTP-U PDU over GTPv2 based S2a for which no Bearer context exists, it shall discard the GTP-U PDU and return a GTP error indication to the originating node (i.e. the PGW).

The TWAN should ensure as far as possible that previously used TEID values are not immediately reused after a TWAN restart, in order to avoid inconsistent TEID allocation throughout the network.

When the TWAN receives a user packet with an unknown GRE Key over PMIPv6 based S2a, the TWAN shall discard the packet and optionally respond back with an ICMP message, as specified in Sections 8.2 and 8.3 of IETF RFC2473 [31] for the node unreachable error case.

17C.1.2 Restoration Procedures

After a TWAN restart, the TWAN shall delete all Bearer contexts affected by the restart that it may have stored and place local TWAN restart counter value in all GTPv2 Echo requests/responses messages and PMIPv6 heartbeat responses the TWAN sends to the PGW.

17C.1A Restart of a peer node

17C.1A.1 PGW Failure

The TWAN will receive the PGW restart counter in GTPv2 Echo requests/ responses and PMIPv6 heartbeat responses that the TWAN receives from the PGW.

When a TWAN detects that a peer PGW has restarted (see clause 18 "GTP-C based restart procedures" and clause 19 "PMIPv6 based restart procedures") it shall delete all PDN connection table data/bearer contexts associated with the peer node that fails, and may free the associated internal TWAN resources.

17C.2 Partial Failure Handling at TWAN

17C.2.1 General

See section 23.

The partial failure feature is optional for TWAN.

If the TWAN does not support the feature then partial failure handling does not apply to that specific PDN connection.

17C.2.2 Procedures during PDN Connection Establishment

If the TWAN supports the feature, the following procedures apply.

During a PDN connection establishment, the TWAN shall provide one TWAN FQ-CSID containing exactly one CSID for that particular PDN connection to the PGW. The TWAN shall store the Node-ID and CSID from the FQ-CSID provided by the PGW for that particular PDN connection in its PDN Connection table.

The TWAN determines that the PGW supports partial failure handling by the presence of the PGW FQ-CSID in the Create Session Response for GTPv2 based S2a and/or Proxy Binding Acknowledgement message for PMIPv6 based S2a.

17C.2.3 Procedures during TWAN Partial Failure

If the TWAN supports the feature, the following procedures apply.

When a TWAN detects that it has undergone a partial failure, it shall verify that one or more corresponding CSID(s) are present for the component undergoing a partial fault. If there is no such CSID, then the following does not apply. When one or more CSIDs are currently assigned, the TWAN shall perform the following.

The TWAN may perform implementation-specific operations to clean up any residual state associated with the CSID(s).

The TWAN shall send Delete PDN Connection Set Request containing all the TWAN CSIDs of the component(s) failing in TWAN FQ-CSID over the GTPv2 based S2a interface or PMIPv6 Binding Revocation Indication with G bit set message containing the equivalent TWAN FQ-CSID(s) over the PMIPv6 based S2a interface to PGW peers supporting the feature.

On the GTPv2 based S2a interface, upon receiving a GTPv2 Delete PDN Connection Set Response message with Cause value "Success", the TWAN shall conclude that the PGW has initiated the internal deletion of the PDN connections corresponding to the FQ-CSID(s) present in the GTPv2 Delete PDN Connection Set Request message. Similarly, on the PMIPv6 based S2a interface, upon receiving a successful PMIPv6 Binding Revocation Acknowledgment message with G bit set, the TWAN shall conclude that the PGW has initiated the internal deletion of the PDN connections corresponding to the CSID(s) present in the PMIPv6 Binding Revocation Indication message.

The TWAN is not required to perform any further recovery actions towards PGW peers for PDN connections in the connection set identified by the PGW FQ-CSID(s).

17C.2.4 Procedures during PGW Partial Failure

If the TWAN supports the feature, the following procedures apply.

When an TWAN receives a GTPv2 Delete PDN Connection Set Request or PMIP6 Binding Revocation Indication with G bit set message from a PGW, the TWAN shall retrieve all the PDN connections corresponding to each of the FQ-CSID(s) present in the message. The TWAN shall delete all the retrieved PDN connections, and may free the associated internal TWAN resources.

As a response, the TWAN shall send a GTPv2 Delete PDN Connection Set Response message with an appropriate Cause value or a PMIPv6 Binding Revocation Acknowledgment message with G bit set to the PGW.

17C.2.5 Procedures during PDN Connection Removal or Modification

For the modification of an existing PDN connection established over S2a, if the corresponding TWAN and PGW support the partial failure feature, when the TWAN receives an FQ-CSID value of a PGW over S2a, the TWAN shall overwrite the currently stored FQ CSID value with the received value.

For the removal of an existing PDN connection established over S2a, if the corresponding TWAN and PGW support the partial failure feature, a TWAN removes the corresponding PDN data as well as any relevant stored FQ-CSID value of the PGW FQ-CSID.

18 GTP-C based restart procedures

Across GTP-C based interfaces an SGSN, GGSN, MME, SGW, PGW, TWAN and ePDG utilize either GTPv1-C or GTPv2-C Echo Request and Echo Response messages or GTP-C messages containing the Recovery Information Element to detect and handle a restart.

A GTP-C entity shall maintain two Restart counters:

- in volatile memory a remote Restart counter of a peer with which the entity is in contact;
- in non-volatile memory own, or local Restart counter that was sent to a peer.

After a GTP-C entity has restarted, it shall immediately increment all local Restart counters and shall clear all remote Restart counters.

A GTP-C entity may have a common local Restart counter for all peers, or it may have a separate local Restart counter for each peer.

A GTP-C entity may probe the liveliness of each peer with which it is in contact by sending an Echo Request message (see clause 20 "Path management procedures") . The presence of the Restart counter in Echo Request or in a GTP-C message depends on the GTP-C version and therefore is specified in 3GPP TS 29.060 [8] and 3GPP TS 29.274 [13], respectively. The restart counter signalled in the GTP-C message is associated with the GTP-C entity identified by the sender"s F-TEID or SGSN/GGSN IP address for control plane if present in the message, otherwise (e.g. in echo request message) it is associated with the GTP-C entity identified by the source IP address of the message.

The GTP-C entity that receives a Recovery Information Element in an Echo Response or in another GTP-C message from a peer, shall compare the received remote Restart counter value with the previous Restart counter value stored for that peer entity.

- If no previous value was stored the Restart counter value received in the Echo Response or in the GTP-C message shall be stored for the peer.
- If the value of a Restart counter previously stored for a peer is smaller than the Restart counter value received in the Echo Response message or the GTP-C message, taking the integer roll-over into account, this indicates that the entity that sent the Echo Response or the GTP-C message has restarted. The received, new Restart counter value shall be stored by the receiving entity, replacing the value previously stored for the peer.
- If the value of a Restart counter previously stored for a peer is larger than the Restart counter value received in the Echo Response message or the GTP-C message, taking the integer roll-over into account, this indicates a possible race condition (newer message arriving before the older one). The received new Restart counter value shall be discarded and an error may be logged.

19 PMIPv6 based restart procedures

Across PMIPv6 based interfaces, SGW, PGW, TWAN and ePDG utilize PMIPv6 Heartbeat mechanism for node restart detection as specified in 3GPP TS 29.275 [16].

A PMIPv6 entity shall maintain two restart counters:

- in volatile memory a remote restart counter of a peer with which the entity is in contact;
- in non-volatile memory an own, or local restart counter that was sent to a peer.

After a PMIPv6 entity has restarted, it shall immediately increment all local restart counters and shall clear all remote restart counters.

A PMIPv6 entity may have a common local restart counter for all peers, or it may have a separate local restart counter for each peer.

20 Path management procedures

20.1 General

This clause specifies path management procedures for GTP-C based and PMIP based interfaces. For GTP based interfaces, Echo Request / Response procedure is used. The usage depends on the GTP-C version in the following way:

- GTPv1-C entity may periodically send an Echo Request message as specified in 3GPP TS 29.060 [8].
- GTPv2 entity shall probe the liveliness of each peer with which it is in contact by sending an Echo Request messages (see TS 29.274 [13]). When and how often a GTPv2 Echo Request message may be sent is implementation specific but an Echo Request shall not be sent more often than every 60 s on each path. This does not prevent resending an Echo Request with the same sequence number according to the T3-RESPONSE timer.

It is recommended that GTPv2 Echo Request should be sent only when a GTP-C entity has not received any GTP response message for a previously sent request message on the GTP-C path for, an implementation dependent period of time.

A GTP-C entity (both GTPv1-C and GTPv2) shall be prepared to receive an Echo Request message at any time and it shall reply with an Echo Response message.

For the PMIP based S5/S8 interface, the SGW and PGW shall detect respectively a peer PGW and SGW as currently unavailable by sending a series of PMIPv6 Heartbeat Request messages, and not receiving within a period of time respectively a PMIPv6 Heartbeat Response message (see 3GPP TS 29.275 [16]).

20.2 Signalling path failure detection and handling

20.2.1 General

GTP-C entities shall support detection of path failure by using Echo Request / Echo Response messages in the following way. A peer's IP address specific counter shall be reset each time an Echo Response message is received from that peer's IP address and incremented when the T3-RESPONSE timer expires for an Echo Request message sent to that peer's IP address. The path shall be considered to be down if the counter exceeds N3-REQUESTS.

PMIP entities shall support detection of path failure as specified for Failure Detection in IETF RFC 5847 [22].

Upon detecting a path failure, the network node should notify the failure via the Operation and Maintenance system and may either:

- delete the PDN connections (EPS bearer contexts) or PDP contexts associated with this peer's IP address; or
- maintain the PDN connections (EPS bearer contexts) or PDP contexts associated with the peer's IP address during an operator configurable maximum path failure duration. The network node shall delete the maintained resources if the path is still down when this duration expires. The network node may delete the maintained resources if control/user plane signalling is received across other interface(s) during the path failure and before the maximum path failure duration timer expires.

NOTE 1: During transient path failures (e.g. path failures not exceeding few minutes at most), maintaining the EPS bearer contexts or PDP contexts associated with the peer's IP address enables the delivery of end user services (when the path is reestablished again) and also avoids unnecessary signalling in the network for restoring those connections.

NOTE 2: It is not intended to maintain PDN connections during long path failures (e.g. exceeding few minutes at most) as this would imply undesirable effects like undue charging.

The following subclauses specify further specific network element requirements.

20.2.2 SGW functionality

It is optional for the SGW to maintain the S5/S8 bearer contexts when the SGW detects a path failure to the MME/S4-SGSN (see subclause 20.2.1). However upon detecting a path failure to the MME/S4-SGSN, an SGW that supports the network triggered service restoration procedure (see clause 25) should maintain the S5/S8 bearer contexts eligible for network initiated service restoration and proceed with the network triggered service restoration procedure with the following modification:

- if the path to the MME/S4-SGSN is down for a duration exceeding the maximum path failure duration and if there is no alternative reachable path, e.g. another MME/S4-SGSN in the same pool or another control plane IP address belonging to the same MME/S4-SGSN, the SGW should locally delete the maintained PDN connections associated with the failed path.

In addition, for UEs in connected state associated with the failed path, the SGW should continue sending downlink packets to the eNodeB/RNC as long as the impacted PDN connections are maintained, regardless of whether the SGW supports the network triggered service restoration procedure or not.

20.3 User plane path failure detection and handling

20.3.1 General

GTP-U entities shall support detection of path failure by using Echo Request / Echo Response messages in the following way. A path counter shall be reset each time an Echo Response is received on the path and incremented when the T3-RESPONSE timer expires for any Echo Request message sent on the path. The path shall be considered to be down if the counter exceeds N3-REQUESTS.

Upon detecting a path failure, the network node should notify the failure via the Operation and Maintenance system and may either

- delete the bearer contexts associated with the path in failure; or

- maintain the bearer contexts associated with the path in failure during an operator configurable maximum path failure duration. The network node shall delete the maintained resources if the path is still down when this duration expires.

NOTE 1: During transient path failures (e.g. path failures not exceeding few minutes at most), maintaining the bearer contexts associated with the peer's IP address enables the delivery of end user services (when the path is reestablished again) and also avoids unnecessary signalling in the network for restoring those bearers.

NOTE 2: It is not intended to maintain bearer contexts during long path failures (e.g. exceeding few minutes at most) as this would imply undesirable effects like undue charging.

21 Error Indication handling

21.1 General

The following subclauses specify a network element behaviour, if it receives a GTPv1-U Error Indication message. The reception of the message triggers a node internal procedure and/or a Control Plane procedure (GTPv1-C, GTPv2, RANAP, S1-AP).

For the PMIP based S5/S8 interface, an error in the form of an ICMP message is used instead of a GTPv1-U Error Indication message for the Error Indication handling.

21.2 GGSN

GTP error indication message shall be handled as follows:

- If the GGSN receives a GTP error indication for a PDP context that has the DTI flag set (i.e. from an RNC), the GGSN should not delete the associated PDP context but mark it as invalid. Any subsequent packets arriving for an invalid PDP context should be discarded. The GGSN shall inform the SGSN that the GGSN received a GTP error indication from RNC. The SGSN shall re-establish the tunnel between the SGSN and GGSN as specified in 3GPP TS 29.060 [8], which sets the related PDP context as valid again in the GGSN. The GGSN then forwards any subsequent downlink packets to the SGSN.

- If the GGSN receives a GTP error indication for a PDP context that has the no DTI flag set (i.e. from an SGSN), the GGSN shall delete its PDP context and may notify the Operation and Maintenance network element.

21.3 Gn/Gp SGSN

GTP error indication message shall be handled as follows:

- If the SGSN receives a GTP error indication from a GGSN, the SGSN shall delete its PDP context and may notify the Operation and Maintenance network element. Additionally it shall send a Deactivate PDP Context Request message to the MS with cause "re-activation required"

- If the SGSN receives a GTP error indication from the RNC it shall locally release the RAB. The SGSN should preserve the associated PDP context. The SGSN may initiate the RAB Assignment procedure in order to re-establish the RAB.

- For MBMS, when an Error Indication is received from an SGSN, the receiving GGSN shall delete all information associated with the relevant SGSN in its MBMS Bearer Context and the GGSN may notify the Operation and Maintenance network element. In addition, for broadcast mode the GGSN may request the re-establishment of the MBMS Bearer Context by sending an MBMS Session Start Request message (see subclause 7.5A.2.5 of 3GPP TS 29.060 [8]). Furthermore, if the GGSN serves only one downstream SGSN for MBMS data transfer and the GGSN does not support the re-establishment procedure, the GGSN shall delete its MBMS Bearer Context together with the affected MBMS UE Context(s).

21.4 S4 SGSN

GTP error indication message shall be handled as follows:

- If the S4-SGSN receives a GTP error indication from a SGW, the S4-SGSN shall delete its Bearer context and may notify the Operation and Maintenance network element. Additionally it shall send a Deactivate PDP Context Request message to the MS with cause "re-activation required"

- If the S4-SGSN receives a GTP error indication from the RNC it shall locally release the RAB. The S4-SGSN should preserve the associated Bearer context. The S4-SGSN may initiate the RAB Assignment procedure in order to re-establish the RAB.

21.5 RNC or NodeB

GTP error indication message shall be handled as follows:

- When the RNC receives GTP error indication from the SGSN, it shall initiate the RAB Release procedure with the error cause "GTP Resources Unavailable" and shall immediately locally release the RAB (i.e. without waiting for a response from the SGSN).

- If the RNC receives a GTP error indication from the GGSN (i.e. if Direct Tunnel is established), it shall initiate the RAB Release procedure with the error cause "GTP Resources Unavailable" and immediately locally release the RAB (i.e. without waiting for a response from the SGSN).

- If the RNC receives a GTP error indication from the SGW (i.e. if Direct Tunnel is established), it shall initiate the RAB Release procedure with the error cause "GTP Resources Unavailable" and immediately locally release the RAB (i.e. without waiting for a response from the SGSN).

21.6 eNodeB

GTP error indication message shall be handled as follows:

- If the eNodeB receives a GTP error indication from the SGW over an S1-U tunnel not doing indirect forwarding, it shall initiate the E-RAB Release procedure and immediately locally release the E-RAB (i.e. without waiting for a response from the MME).

- If the eNodeB receives a GTP error indication from a peer eNodeB over an X2, direct forwarding tunnel or from an SGW over an S1-U indirect forwarding tunnel, the source eNodeB may ignore the error indication received over the forwarding tunnels or delete the forwarding tunnel context locally without deleting the EPS bearers.

21.7 SGW

GTP error indication message shall be handled as follows:

- For an 'Active' mode UE having a user plane connection with an RNC, i.e. SGW has F-TEIDs assigned by RNC for user plane for the UE,when the SGW receives a GTP Error Indication for a Bearer Context that has the DTI flag set (i.e. from an RNC), the SGW should not delete the associated Bearer Context but delete all the RNC GTP-U tunnel TEIDs for this MS and sends a Downlink Data Notification message to the SGSN (the complete behaviour is specified in clause 22). Then the SGW starts buffering downlink packets received for this MS.

- For an 'Active' mode UE having a user plane connection with an eNB, i.e. SGW has F-TEIDs assigned by eNB for user plane for the UE, when the SGW receives a GTP Error Indication for a Bearer Context from an eNodeB, the SGW should not delete the associated Bearer Context but delete all the eNodeB GTP-U tunnel TEIDs for this UE and sends a Downlink Data Notification message to the MME (the complete behaviour is specified in clause 22). Then the SGW starts buffering downlink packets received for this UE.

- If the SGW receives a GTP error indication from S4-SGSN for a Bearer Context other than the default bearer when S4-U is used, the SGW may delete its Bearer context and may notify the Operation and Maintenance network element, or as an alternative, the SGW may send Downlink Data Notification message to the S4-SGSN to re-establish the user plane path without deleting the bearer context.

- If the SGW receives a GTP error indication from S4-SGSN for the default bearer when S4-U is used, the SGW may delete all the Bearer contexts associated with the PDN connection (identified by the default bearer) and may notify the Operation and Maintenance network element, or as an alternative, the SGW may send Downlink Data Notification message to the S4-SGSN to re-establish the user plane path without deleting the PDN connection.

- If the SGW receives a GTP error indication from a PGW for the bearer other than the default bearer, the SGW shall delete its Bearer context and may notify the Operation and Maintenance network element.

- If the SGW receives a GTP error indication from a PGW for the default bearer, the SGW shall delete all the Bearer contexts associated with the PDN connection (identified by the default bearer) and may notify the

Operation and Maintenance network element. The SGW may send the Delete Bearer Request to the MME/S4 SGSN to inform that it has received an Error Indication from the PGW for the default bearer.

PMIP error indication message shall be handled as follows:

- If the SGW receives an ICMP message from a PGW that indicates the UE specific error indication as specified in the 3GPP TS 29.275 [16], the SGW may delete the associated PDN connection (identified by the GRE key included in the ICMP message) and may notify the Operation and Maintenance network element.

21.8 PGW

GTP error indication message shall be handled as follows:

- If the PGW receives a GTP error indication from a SGW/a TWAN /an ePDG for the bearer other than the default bearer, the PGW shall delete its Bearer context and may notify the Operation and Maintenance network element.

- If the PGW receives a GTP error indication from a SGW/a TWAN /an ePDG for the default bearer, the PGW shall delete all the Bearer contexts associated with the PDN connection (identified by the default bearer) and may notify the Operation and Maintenance network element.

PMIP error indication message shall be handled as follows:

- If the PGW receives an ICMP message from an SGW/an ePDG/a Trusted Non-3GPP IP access node that indicates the UE specific error indication as specified in the 3GPP TS 29.275 [16], the PGW may delete the associated PDN connection (identified by the GRE key included in the ICMP message) and may notify the Operation and Maintenance network element.

21.9 MBMS GW

GTP Error Indication message shall be handled as follows:

- If the MBMS GW receives a GTP Error Indication from a SGSN, the MBMS GW shall delete its Bearer context and may notify the Operation and Maintenance network element.

21.10 ePDG

GTP error indication message shall be handled as follows:

- If the ePDG receives a GTP error indication from a PGW for the bearer other than the default bearer, the ePDG shall delete its Bearer context and may notify the Operation and Maintenance network element.

- If the ePDG receives a GTP error indication from a PGW for the default bearer, the ePDG shall delete all the Bearer contexts associated with the PDN connection (identified by the default bearer) and initiate the release of the corresponding SWu instance (i.e. IKEv2 tunnel). The ePDG may notify the Operation and Maintenance network element.

PMIP error indication message shall be handled as follows:

- If the ePDG receives an ICMP message from a PGW that indicates the UE specific error indication as specified in the 3GPP TS 29.275 [16], the ePDG may delete the associated PDN connection (identified by the GRE key included in the ICMP message) and initiate the release of the corresponding SWu instance (i.e. IKEv2 tunnel) . The ePDG may notify the Operation and Maintenance network element.

21.11 TWAN

GTP error indication message shall be handled as follows:

- If the TWAN receives a GTP error indication from a PGW for the bearer other than the default bearer, the TWAN shall delete its Bearer context and may notify the Operation and Maintenance network element.

- If the TWAN receives a GTP error indication from a PGW for the default bearer, the TWAN shall delete all the Bearer contexts associated with the PDN connection (identified by the default bearer) and may initiate the release of the corresponding WLAN specific resource. The TWAN may notify the Operation and Maintenance network element.

PMIP error indication message shall be handled as follows:

- If the TWAN receives an ICMP message from a PGW that indicates the UE specific error indication as specified in the 3GPP TS 29.275 [16], the TWAN may delete the associated PDN connection (identified by the GRE key included in the ICMP message) and may initiate the release of the corresponding WLAN specific resource. The TWAN may notify the Operation and Maintenance network element.

22 Downlink Data Notification Handling at MME/S4 SGSN

If the MME/S4 SGSN receives a Downlink Data Notification message from the SGW as a result of the SGW having received an Error Indication message from the eNodeB/RNC or S4-SGSN over S4 User Plane, the MME/S4 SGSN should perform the following:

- If the UE is in IDLE state, upon receipt of the Downlink Data Notification message, the MME/S4 SGSN shall perform the Network Triggered Service Request procedure as specified in 3GPP TS 23.060 [5] and 3GPP TS 23.401[15].

- If the UE is in CONNECTED state, upon receipt of the Downlink Data Notification message, the MME shall perform S1 Release procedure and perform Network Triggered Service Request procedure as specified in 3GPP TS 23.401[15].

- If the UE is in CONNECTED state, upon receipt of the Downlink Data Notification message and Direct Tunnel is used, the S4-SGSN shall perform Iu Release procedure and perform Network Triggered Service Request procedure as specified in 3GPP TS 23.060 [5] if the cause value included in Downlink Data Notification is "Error Indication received from RNC/eNodeB/S4-SGSN",

- If the UE is in CONNECTED state, upon receipt of the Downlink Data Notification message and Direct Tunnel is not used, the S4-SGSN should re-establish all of the S4-U bearers of this UE if the cause value included in Downlink Data Notification is "Error Indication received from RNC/eNodeB/S4-SGSN".

23 General partial failure handling procedures

The partial failure handling is an optional feature for MME, SGW, ePDG, TWAN and PGW.

A partial failure handling feature may be used when a hardware or software failure affects a significant number of PDN connections while a significant number of PDN connections are unaffected. This feature may also be used for the degenerate case of a full/complete failure of a remote node (MME or PGW) in order to cleanup hanging PDN connections associated with the failed node. When it is impossible to recover the affected PDN connections (for example, using implementation-specific session redundancy procedures), it is useful to inform the peer nodes about the affected PDN connections for recovery on the peer nodes. Such a notification could be performed using an identifier that represents a large set of PDN connections rather than on individual PDN connection basis.

NOTE 1: If a hardware or software failure happens to impact only an insignificant number of PDN connections the node experiencing the fault need not treat the failure as a partial fault but may tear down connections one by one.

For the purposes of partial fault handling the term "node" refers to an entity that takes the role of an MME, PGW, ePDG, TWAN or SGW as defined in an SAE network.

A PDN Connection Set Identifier (CSID) shall identify a set of PDN connections within a node that may belong to an arbitrary number of UEs. A CSID is an opaque parameter local to a node. Each node that supports the feature maintains a local mapping of CSID to its internal resources. When one or more of those resources fail, the corresponding one or more fully qualified CSIDs are signalled to the peer nodes.

The fully qualified CSID (FQ-CSID) is the combination of the node identity and the CSID assigned by the node which together globally identifies a set of PDN connections.

NOTE 2: The node identifier in the FQ-CSID is required since two different nodes may use the same CSID value. A partial fault in one node should not cause completely unrelated PDN connections to be removed accidentally.

The node identifier shall be globally unique across all 3GPP EPS networks. Its format is defined in 3GPP TS 29.274 [13]

For the purposes of partial fault handling the term peer is used as follows: For a particular PDN connection two nodes are peers if both nodes are used for that PDN connection. For a PDN Connection Set the nodes are peers if they have at least one PDN connection in the PDN Connection Set where both nodes are used for that PDN connection. In particular PGW and MME are generally peers for the purposes of partial fault handling.

An FQ-CSID is established in a node and stored in peer nodes in the PDN connection at the time of PDN connection establishment, or during a node relocation, and used later during partial failure handling in messages defined in 3GPP TS 29.274 [13] and 3GPP TS 29.275 [16]. Each node that support the feature, including the MME, SGW, ePDG, TWAN and the PGW, shall maintain the FQ-CSID provided by every other peer node for a PDN connection. The FQ-CSIDs stored by PDN connection are later used to find the matching PDN connections when a FQ-CSID is received from a node reporting a partial fault for that FQ-CSID.

With the exception of the GTPv2 Delete PDN Connection Set Request and PMIPv6 Binding Revocation Indication BRI messages, each feature supporting MME, SGW, ePDG, TWAN or PGW shall assign only one FQ-CSID for itself in messages and each FQ-CSID shall have exactly one CSID within the FQ-CSID.

Following rules shall apply for all the nodes:

1) If a node (MME, SGW, ePDG, TWAN or PGW) supports the partial failure handling feature, it shall generate and include its own FQ-CSID during the PDN connection establishment, node relocation procedures. Explicit list of the relevant GTPv2 messages is given in the respective subclauses (14.3 "Partial Failure Handling at MME", 16.2 "Partial Failure Handling at SGW", 17B.2 "Partial Failure Handling at ePDG", 17C.2 "Partial Failure Handling at TWAN" and 17.2 "Partial Failure Handling at PGW"). A node that supports partial failure handling feature shall also store peers' FQ-CSIDs.

2) Additionally, if an SGW supports partial failure handling feature, it shall forward the peer node"s (of an MME or of a PGW, depending on the direction) FQ-CSID and also Delete Connection Set Request/Response messages. Also, if the SGW detects the full/complete failure of an MME or PGW, e.g., through the Echo Request/Echo Response procedure, it may send a Delete PDN Connection Set Request (or PMIPv6 Binding Revocation Indication with G bit set) message containing all of the FQ-CSIDs of the associated hanging PDN connections of the failed node to the corresponding remote node (MME or PGW) .

3) If a node that supports partial failure handling feature receives peer node"s FQ-CSID during the procedures, which are specified in Rule 1, it shall conclude that the peer node supports the feature. Subsequently, the node shall store the peer node"s FQ-CSID and shall send appropriate partial failure handling messages to the peer.

4) If a node that supports partial failure handling feature does not receive the peer"s FQ-CSID during the procedures, which are specified in Rule 1, it shall conclude that the peer node does not support the feature.

5) A node that supports partial failure handling feature shall not send any FQ-CSID IE or any partial failure handling specific messages to the peer node if the sender is aware (see Rule 4) that the receiver does not support the feature.

6) If a node does not support the partial failure handling feature, it shall ignore any received FQ-CSID IE or any partial failure handling specific message.

7) During session management procedures as specified in 3GPP TS 23.401 [15] and 3GPP TS 23.402 [18] (such as a dedicated bearer activation/deactivation/update), a node supporting the partial failure handling feature may update its FQ-CSID to the supporting peer node(s) in the Create Bearer Request/Response, Delete Bearer Request/Response or Update Bearer Request/Response.

NOTE: FQ-CSID handling for the Initial Attach and various handover cases are addressed in clauses 14, 16 and 17.

Figure 23-1 illustrates FQ-CSID establishment during the Attach or PDN connection establishment procedures for 3GPP E-UTRAN access as specified in the above rules.

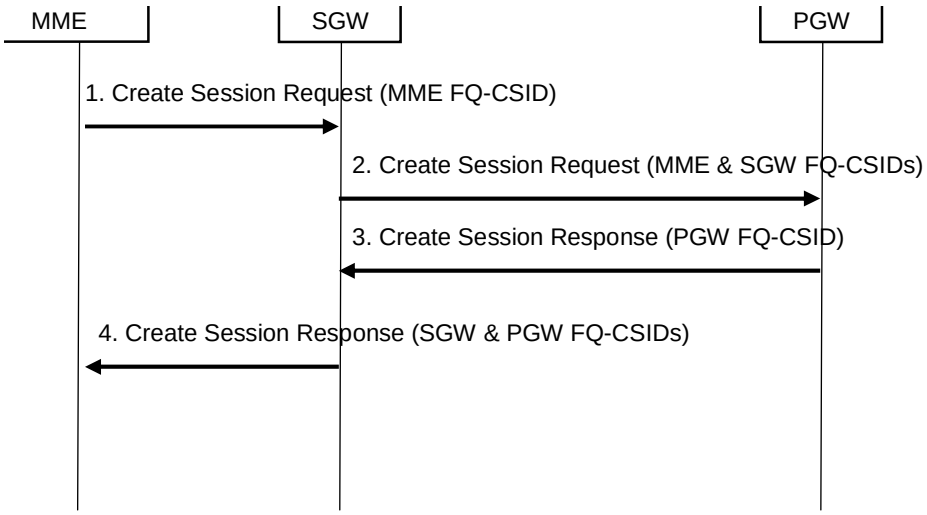

Figure 23-1: FQ-CSID establishment during the Attach or PDN establishment procedure for 3GPP E-UTRAN access

1. If an MME supports partial failure handling, the MME shall send own FQ-CSID to SGW with a Create Session Request message across S11 interface.

   The MME's FQ-CSID indicates to the SGW that MME supports partial failure handling. If the SGW does not receive MME's FQ-CSID, then the SGW shall never send partial failure handling related messages or IEs to the MME.

   If the SGW does not support partial failure handling, then the SGW shall silently discard MME's FQ-CSID.

   If the SGW does support partial fault handling it shall store the MME's FQ-CSID in it's PDN connection table.

2. If the SGW supports partial failure handling, the SGW shall forward MME's FQ-CSID to PGW with a Create Session Request message or a Proxy Binding Update message across S5/S8 interface. The SGW shall also include own FQ-CSID into the message.
   The SGW's FQ-CSID indicates to the PGW that the SGW supports partial failure handling.

   If the PGW does not support partial failure handling, then the PGW shall silently discard both FQ-CSIDs.

3. If the SGW has indicated the support for partial failure handling to PGW, then the PGW, which supports the feature shall send own FQ-CSID back to the SGW with a Create Session Response message or a Proxy Binding Acknowledgement message across S5/S8 interface. PGW's FQ-CSIDs in the S5/S8 Create Session Response or a Proxy Binding Acknowledgement message indicates to the SGW that PGW supports partial failure handling.

   If the SGW has not indicated support for partial failure handling, then PGW shall never send partial failure handling related messages or IEs to the SGW.

4. If the MME has indicated the support for partial failure handling to SGW, then the SGW, which supports the feature, shall forward PGW's FQ-CSID to MME with a Create Session Response message across S11 interface. The SGW shall also include own FQ-CSID into the message.

Figure 23-2 illustrates FQ-CSID establishment during the Attach or PDN connection establishment procedures for untrusted non-3GPP access as specified in the above rules.

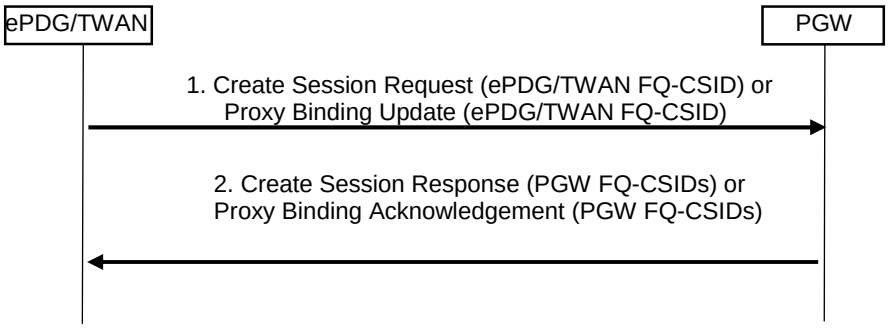

Figure 23-2: FQ-CSID establishment during the Attach or PDN establishment procedure for non-3GPP access

1. If an ePDG/TWAN supports partial failure handling, the ePDG/TWAN shall send own FQ-CSID to PGW with a Create Session Request message across GTPv2 based S2b/S2a interface or a Proxy Binding Update message across PMIPv6 based S2b/S2a interface.

   The ePDG's/TWAN's FQ-CSID indicates to the PGW that ePDG/TWAN supports partial failure handling. If the PGW does not receive ePDG's/TWAN's FQ-CSID, then the PGW shall never send partial failure handling related messages or IEs to the ePDG/TWAN.

2. If the PGW supports partial failure handling, it shall store the ePDG's/TWAN's FQ-CSID in its PDN connection table and it shall send own FQ-CSID back to the ePDG/TWAN with a Create Session Response message across GTPv2 based S2b/S2a interface or a Proxy Binding Acknowledgement message across PMIPv6 based S2b/S2a interface. PGW's FQ-CSIDs in the Create Session Response or Proxy Binding Acknowledgement indicates to the ePDG/TWAN that PGW supports partial failure handling. The ePDG/TWAN shall then store the PGW's FQ-CSID in its PDN connection table.

   If the PGW does not support partial failure handling, then the PGW shall silently discard ePDG's/TWAN's FQ-CSID.

24 Restoration of data in the PCRF

24.1 Restart of the PCRF

24.1.0 PCRF Restart

PCRF storage of PCC contexts is volatile. When a PCRF fails, the PCC contexts and Diameter sessions affected by the failure are lost in the PCRF.

When a PCRF receives a non-initial message for which no Diameter session exists, it shall discard the message and return a Diameter error indication to the originating PCRF client.

25 Network triggered service restoration procedure

25.1 General

The network triggered service restoration procedure is an optional feature for the MME, S4-SGSN and SGW. A node that supports this feature shall support the network triggered service restoration procedure without ISR as specified in subclause 25.2 and the network triggered service restoration procedure with ISR as specified in subclause 25.3 if it supports Idle mode Signalling Reduction (ISR) (see 3GPP TS 23.401 [15] and 3GPP TS 23.060 [5]).

The network triggered restoration procedure without ISR shall apply to UEs for which ISR is not active at the time the ISR associated node fails. The network triggered restoration procedure with ISR shall apply to UEs for which ISR is

active at the time the ISR associated node fails. Both procedures may run in parallel if there is a mix of UEs with ISR and without ISR at the time the ISR associated node fails.

For the PMIP based S5/S8 case, the terminology "S5/S8 bearer" used through clause 25 shall be read as "S5/S8 IP traffic flow" within the GRE tunnel. The detailed concepts of the "IP traffic flow" are specified in 3GPP TS 23.402 [18].

25.2 Network triggered service restoration procedure without ISR

25.2.1 General

The following requirements shall apply if the MME or S4-SGSN and the SGW support this feature.

If an SGW detects that an MME or S4-SGSN has restarted (see clause 18 "GTP-C based restart procedures"), instead of removing all the resources associated with the peer node, the SGW shall maintain the PDN connection table data and MM bearer contexts for some specific S5/S8 bearer contexts eligible for network initiated service restoration, and initiate the deletion of the resources associated with all the other S5/S8 bearers.

NOTE 1: This enables the SGW to still receive downlink user plane or control plane data from the PGW or from a PCRF (PMIP based S5/S8) for the maintained S5/S8 bearers.

The S5/S8 bearers eligible for network initiated service restoration are determined by the SGW based on operator's policy e.g. based on the QCI and/or ARP and/or APN.

Emergency PDN connections for users without authenticated IMSI do not need to be maintained by the SGW and cannot be restored at the initiative of the network.

NOTE 2: Users with an emergency call in progress can re-attach and re-establish the emergency PDN connection after detecting the loss of the signalling connection with the RAN. IMS Emergency PSAP callback is not supported for unauthenticated users with an emergency registration but without an emergency call in progress.

If at least one S5/S8 bearer needs to be maintained, the SGW shall also start a timer controlling the maximum duration during which those bearers shall be maintained. There is one operator configurable timer per SGW. The timer value may be equal to the periodic tracking area update timer (timer T3412) as specified in 3GPP TS 24.301 [19] or the periodic routing area update timer (timer T3312) as specified in 3GPP TS 24.008 [20]. This timer ensures that the S5/S8 bearers eligible for network initiated service restoration are maintained until the corresponding UE reattaches to the network. If the timer expires, the maintained resources shall be locally deleted assuming that the corresponding UE might have reattached to the network via a different SGW.

The SGW shall not release the default bearer of a PDN connection for which one or more dedicated bearers are maintained. Any downlink user plane or control plane packet received on a default bearer which is not eligible for network initiated service restoration but which is maintained for dedicated bearer(s) eligible for such procedure shall be silently discarded by the SGW.

When releasing the maintained S5/S8 bearers, the SGW may optionally perform other implementation specific actions such as messages to clear other external resources (e.g. PCC messages to clear the resources in the PCRF or GTP/PMIP messages to release the corresponding PDN connection in the PGW).

If the SGW receives a Create Session Request message for a UE for which some S5/S8 bearers are maintained, the SGW shall delete all the bearers for this UE and proceed with the Create Session Request message handling as specified in 3GPP TS 29.274 [13].

25.2.2 SGW procedure

Upon receipt of the first downlink user plane or control plane packet on a maintained S5/S8 bearer or PCC signalling from PCRF, the SGW shall immediately send a Downlink Data Notification message including the IMSI to the respective MME or S4-SGSN. In addition, depending on the received downlink packet type the SGW shall proceed as follows:

- if the received downlink packet contains user plane data, the SGW shall silently discard it but the SGW shall continue maintaining the corresponding bearers. If the SGW receives another downlink user plane packet for an

ARP value other than the ARP included in the Downlink Data Notification sent before, it shall proceed as specified in subclause 5.3.4.3 "Network Triggered Service Request" of 3GPP TS 23.401 [15] with the exception that the packet shall be discarded by the SGW.

- For the S5/S8 GTP case:
  - if the received downlink packet contains a control plane message other than a Delete Bearer Request message then the SGW may reject the message and shall continue maintaining the corresponding bearers. If the SGW receives another control plane message for an ARP value other than the ARP included in the Downlink Data Notification sent before, it shall proceed as specified in subclause 5.3.4.3 "Network Triggered Service Request" of 3GPP TS 23.401 [15] with the exception that the message may be rejected by the SGW.
  - if the received downlink packet contains the Delete Bearer Request message, the SGW shall accept the message, and shall release the corresponding S5/S8 bearer(s) immediately.
- For the S5/S8 PMIP case:
  - if the received packet contains a control plane message other than the message of the Gateway Control and QoS Rules Provision procedure as specified in 3GPP TS 29.213 [21] subclause 4.4.3 which results in the SGW to decide to deactivate an existing dedicated bearer, then the SGW may reject the message and shall continue maintaining the corresponding bearers. If the SGW receives another control plane message for an ARP value other than the ARP included in the Downlink Data Notification sent before, it shall proceed as specified in subclause 5.3.4.3 "Network Triggered Service Request" of 3GPP TS 23.401 [15] with the exception that the message may be rejected by the SGW.
  - if the received downlink packet contains the message of the Gateway Control and QoS Rules Provision procedure as specified in 3GPP TS 29.213 [21] subclause 4.4.3 which results in the SGW to decide to deactivate an existing dedicated bearer, the SGW shall accept the message, and shall release the corresponding S5/S8 bearer(s) immediately.

The SGW may send the Downlink Data Notification message to another MME or S4-SGSN (the same type of mobility node as the failed one) located in the same pool as the failed node if the SGW can not send it to the failed MME or S4-SGSN (e.g. because it did not restart). It is an implementation/deployment matter how an SGW becomes aware that an MME/S4-SGSN has failed and has not restarted.

25.2.3 MME/SGSN procedure

Upon receipt of a Downlink Data Notification message including the IMSI, the MME or S4-SGSN shall respond to the SGW with a Downlink Data Notification Acknowledge message and should page and force the UE to re-attach to the network. The paging area and subscriber's identity i.e. IMSI or S-TMSI/P-TMSI used during the paging procedure is implementation dependent.

NOTE 2: Upon receiving a page message with
- the IMSI, the UE starts the reattach procedure as specified in subclause 5.6.2.2.2 of 3GPP TS 24.301 [19] and subclause 4.7.9.1.2 of 3GPP TS 24.008 [20];
- the S-TMSI, the UE starts the service request procedure which is rejected by the MME with Cause #10 – Implicitly detached; the UE then re-attaches to the network as specified in subclause 5.6.2.2.1 of 3GPP TS 24.301 [19];
- the P-TMSI, in case of Iu mode, the UE starts the service request procedure which is rejected by the S4-SGSN with Cause #10 – Implicitly detached; the UE then re-attaches as specified in subclauses 4.7.9.1.1 and 4.7.13 of 3GPP TS 24.008 [20];
- the P-TMSI, in case of A/Gb mode, the UE sends any LLC frame and subsequently re-attaches to the network as specified in subclause 8.1.4 of 3GPP TS 23.060 [5].

NOTE 3: Paging in the MME or S4-SGSN serving area will cause excessive use of radio resources. How to reduce the paging area is implementation dependent.

NOTE 4: It is the responsibility of the MME/S4 SGSN to avoid unnecessary IMSI Paging.

The MME or S4-SGSN may request the SGW to immediately release the maintained S5/S8 bearers by sending the "Downlink Data Notification Acknowledge" message or a "Downlink Data Notification Failure Indication" message with the specific cause "UE already re-attached", e.g. if the UE has already re-attached to the network. The Downlink Data Notification Acknowledge and Downlink Data Notification Failure Indication shall include the IMSI to identify the UE context in the SGW.

25.3 Network triggered service restoration procedure with ISR

25.3.1 General

The following requirements shall apply if the involved MME, S4-SGSN and SGW support the ISR feature and the network triggered service restoration feature.

NOTE: The procedure in this clause does not consider the case where one of ISR associated nodes, i.e. the MME or the S4-SGSN, does not support the network triggered service restoration procedure.

In the rest of this clause, the term "non-failed" node refers to the CN node (MME or S4-SGSN) that remains in normal operation during this procedure, as opposed to the "restarted" node which refers to the CN node (MME or S4-SGSN) that has failed and restarted.

The procedure in the SGW towards the restarted node differs from the procedure towards the non-failed ISR associated node (see subclause 25.3.2).

25.3.2 SGW procedure

If an SGW detects that an ISR associated CN node (i.e. MME or S4-SGSN) has restarted (see clause 18), the SGW shall maintain all the PDN connection table data and MM bearer contexts associated with the non-failed and the restarted ISR associated nodes, and start a timer controlling the maximum duration during which the SGW shall consider that ISR is still active. There is one operator configurable timer per SGW. The timer value may be set to a value that is the greater value of the periodic tracking area update timer (timer T3412) as specified in 3GPP TS 24.301 [19] and the periodic routing area update timer (timer T3312) as specified in 3GPP TS 24.008 [20]. This timer ensures that the SGW can still send Downlink Data Notification messages to the restarted MME or S4-SGSN until the corresponding UE learns that ISR is deactivated. If the timer expires, the SGW shall deactivate ISR by locally releasing the resources for the maintained restarted CN node (i.e. restarted CN node control plane F-TEID).

Upon receipt of the downlink user plane or control plane packet on a maintained S5/S8 bearer for a UE in idle mode or in connected state with the failed CN node, the SGW shall initiate the network triggered service request procedure towards the non-failed CN node as specified in 3GPP TS 23.401 [15] subclause 5.3.4.3. In addition, if the S5/S8 bearer is eligible for network initiated service restoration, the SGW shall also immediately send a Downlink Data Notification message including the IMSI towards the restarted CN node as specified in subclause 25.2.2. The SGW shall continue to forward downlink user plane or control plane packet for a UE in connected state in the non-failed ISR associated node.

The S5/S8 bearers eligible for network initiated service restoration are determined by the SGW based on operator's policy e.g. based on the QCI and/or ARP and/or APN.

Emergency PDN connections for users without authenticated IMSI do not need to be maintained by the SGW and cannot be restored at the initiative of the network.

NOTE 0: Users with an emergency call in progress can re-attach and re-establish the emergency PDN connection after detecting the loss of the signalling connection with the RAN. IMS Emergency PSAP callback is not supported for unauthenticated users with an emergency registration but without an emergency call in progress.

The SGW may send the Downlink Data Notification message with the IMSI to another MME or S4-SGSN (the same type of mobility node as the failed one) in the same MME or S4-SGSN pool if the SGW can not send it to the failed MME or S4-SGSN (e.g. because it did not restart). It is an implementation/deployment matter how an SGW becomes aware that an MME/S4-SGSN has failed and has not restarted.

Upon receipt of a Downlink Data Notification message including the IMSI, the restarted CN node shall respond to the SGW with a Downlink Data Notification Acknowledge message and should page the UE and force it to re-attach to the network as specified in subclause 25.2.

NOTE 1: If the UE camps under the service area of the restarted CN node, then the UE re-attaches to the network (see NOTE 2 in subclause 25.2).

If the SGW receives a Create Session Request message as part of Initial Attach procedure for a UE for which the PDN connections, MM bearer context and ISR state have been maintained, the SGW shall stop the timer, deactivate ISR, and delete the maintained resources associated to the restarted CN node (i.e. CN node control plane F-TEID).

NOTE 2: The SGW may have already deleted the restarted CN node resources since Delete Session Request from non-failed ISR associated CN node may arrive earlier than the Create Session Request message.

If the non-failed ISR associated CN node received a Cancel Location message from HSS/HLR with "Initial Attach procedure" Cancellation Type, the non-failed CN node shall delete all the bearer contexts and send Delete Session Request message(s) to SGW. The SGW shall then release all the resources for this UE and sends one of the following messages to PGWs involved to release all the resources maintained in the PGWs as specified in 3GPP TS 23.401 [15] and 3GPP TS 23.402[18].

- For the GTP based S5/S8 case, Delete Session Request message(s)
- For the PMIP based S5/S8 case, PBU message(s) with Lifetime set to "0"

The SGW shall stop the timer and delete the resources for the maintained restarted CN node (i.e. restarted CN node control plane F-TEID) if it receives one of the following messages while the timer is running:

- a Modify Bearer Request message indicating that ISR is not active, e.g. from the non-failed CN node during a TAU/RAU procedure; or
- a Modify Bearer Request message indicating that ISR is active from another mobility management node with the same type as the restarted node.

25.3.3 MME/S4-SGSN procedure

If an MME/S4-SGSN detects a restart of an ISR associated counterpart (see clause 18), the MME/S4-SGSN shall wait for the next RAU/TAU procedure to deactivate ISR.

NOTE: As an implementation option, an MME/S4-SGSN may internally mark the ISR as not active, but this should not be visible in messages sent to the SGW.

The non-failed CN node may initiate the GUTI Relocation or P-TMSI Relocation Procedure with a non-broadcast TAI or RAI to force the UE to perform the TAU/RAU procedure for ISR deactivation, e.g. if a signalling connection is established with the UE following receipt of a Downlink Data Notification message.

If afterwards the non-failed MME/S4-SGSN receives TAU/RAU Request, then the MME/S4-SGSN shall inform the UE in the TAU/RAU Accept message to disable ISR as specified in 3GPP TS 23.401[15] and 3GPP TS 23.060 [5]. The non-failed CN node shall send a Modify Bearer Request message to the SGW, even if the MME/S4-SGSN did not change during the TAU/RAU, to request the SGW to disable ISR and to update the SGW with the latest RAT Type and Serving Network values. Upon receipt of that message, the SGW shall disable ISR and shall stop sending Downlink Data Notification message with IMSI to the restarted CN node.

26 Mobile terminated CS service delivery via an alternative MME in MME pool

This procedure is an optional feature for VLR and MME. It enables the network to continue delivering mobile terminated CS services to UEs via an alternative MME in the MME pool where the UE is located when the MME to which the UE was registered fails without restart or fails for a long duration.

NOTE 1: UEs in idle mode are not aware of an MME failure until they need to send some uplink data or signalling (e.g. a periodic Tracking Area Update) or until they are forced to re-attach e.g. via the network trigerred service restoration procedure. Without support of the procedure defined in this clause, UEs that remain under LTE may not be able to receive mobile terminated CS services for a long duration after an MME failure without restart or a long MME failure.

The following requirements shall apply if the VLR and MME support this feature.

When the VLR has to page the UE for a mobile terminated CS service (e.g. upon receipt of an incoming CS call), if the VLR detects that the MME serving the UE is no longer in service, the VLR should send an SGs paging request with a CS restoration indicator to one alternative MME in the same MME pool. The VLR should load-balance the paging requests among the available MMEs in the pool during the restoration procedure.

The VLR may know the set of MMEs pertaining to the same MME pool by local configuration or by checking the MME Group ID within the MME name that MMEs signal to the VLR in the SGsAP-LOCATION-UDATE-REQUEST, SGsAP-RESET-INDICATION or SGsAP-RESET-ACK messages. The MME should send an SGsAP-RESET-INDICATION message to the VLR after restart.

The VLR may detect that an MME is no longer in service if there are no more SCTP associations in service with that MME.

NOTE 2: Semi-permanent SCTP associations are established between the MME and VLR, i.e. the SCTP associations remain up under normal circumstances.

The VLR should adjust its paging retransmission delay to avoid requesting again the UE to re-attach before the restoration procedure completes.

The MME shall behave as specified in subclause 14.1.3 upon receipt of an SGs paging request not including the CS restoration indicator.

The MME shall accept the SGs paging request and proceed as follows upon receipt of an SGs paging request including the CS restoration indicator:

- if the IMSI is unknown by the MME, or if the IMSI is known and the UE is marked as EMM-DEREGISTERED, the MME shall send the paging request with the location information provided by the VLR, regardless of the value of the "MME-Reset" indicator. If no such location information is provided, the MME may either page the UE in all the tracking areas corresponding to that MME or in the tracking areas served by the MME and by the VLR, or reject the paging request per operator policy. The paging request shall include the IMSI and the CN domain indicator set to "PS" to request the UE to re-attach;

- if the IMSI is known by the MME and the UE is considered to be attached to both EPS and non-EPS services or for SMS only (for an SGs paging request with an 'SMS indicator'), the MME shall page the UE based on the location information stored in the MME.

Upon receipt of a paging request including the IMSI and the CN domain indicator set to "PS", the UE re-attaches to one MME of the pool (that may not be necessarily the MME that initiated the paging procedure towards the UE) and a new SGs association is established with the VLR. This may be a different VLR than the VLR that initiated the SGs paging procedure, e.g. if Intra Domain Connection of RAN Nodes to Multiple CN Nodes is deployed for GERAN or UTRAN (see 3GPP TS 23.236 [24]).

If the new SGs association is established towards the same VLR, the VLR should repeat the SGs paging request after the UE has re-attached to non-EPS services. The MT CS service or SMS is then delivered according to normal procedures.

If the new SGs association is established towards a different VLR, the MT CS service may be delivered via the new VLR using Mobile Terminating Roaming Retry or Mobile Terminating Roaming Forwarding (see 3GPP TS 23.018 [23]); the on-going MT SMS is retransmitted by the SMS-SC using the existing SMS procedures (SMS alert).

Subsequent MT CS services are delivered as per normal procedures.

NOTE 3: A UE with ISR active before the MME failure and using GERAN or UTRAN radio access will not receive the paging request sent by the alternative MME. The VLR can deliver the MT CS service by paging the UE on the A/Iu interface as per existing principles of 3GPP TS 29.118 [14] when the UE does not respond to a first paging on the SGs interface. Paging the UE on the A interface fails if the network operates in NMO I and the UE is in PS connected mode in GERAN.

See 3GPP TS 29.118 [14] for a comprehensive description.

27 Restoration of PDN connections after an SGW failure

27.1 General

The procedures specified in this clause enable to restore in the EPC the PDN connections affected by an SGW failure with or without restart, and thus to resume delivery of downlink data towards the UE with minimum service interruption and with minimal signalling in the network.

All the procedures specified in this clause are optional to support.

The procedures specified in subclause 27.2 apply to UEs for which ISR is not active when the SGW fails. The procedures specified in subclause 27.3 apply to UEs for which ISR is active when SGW fails. The procedures specified in these clauses only apply to PDN connections established between MME/S4-SGSN and PGW pertaining to the same operator, i.e. for non-roaming and roaming scenarios with local breakout. The MME/S4-SGSN and the PGW shall behave as per the restoration requirements specified in subclauses 14.1A.1 and 17.1A.1 for PDN connections established between nodes pertaining to different operators, i.e. as if the remote peer node does not support these SGW restoration procedures.

NOTE 1: The applicability of these procedures is restricted to PDN connections established between MME/S4-SGSN and PGW pertaining to the same operator to ensure, simply by local configuration, that MME/S4-SGSN and PGWs apply the same logic i.e. same operator's policies when determining whether and which PDN connections should be restored. This enables to restore in particular IMS PDN connections (even in roaming scenarios, for which local break out is used).

NOTE 2: The use of these SGW restoration procedures may be extended by Service Level Agreements to PDN connections established between MME/S4-SGSN and PGW pertaining to different operators, i.e. for roaming scenarios with home routed traffic, but this is not further considered in 3GPP specifications.

27.2 Restoration of PDN connections after an SGW failure for UEs without ISR

27.2.1 General

The PGW triggered SGW restoration procedure is an optional add-on feature for the MME/S4-SGSN, SGW and PGW on top of the MME/S4-SGSN triggered SGW restoration procedure as specified in subclause 27.2.2. A node that supports the PGW triggered SGW restoration procedure shall support the requirements specified in subclause 27.2.2 and in subclause 27.2.3.

27.2.2 MME/S4-SGSN triggered SGW restoration

27.2.2.1 General

The following requirements shall apply if the MME/S4-SGSN, the PGW, and the PCRF for PMIP based S5, support this feature.

Editor"s Note: It is FFS whether there is PCRF requirement/dependency to support this feature for the GTP based S5 interface. If a new rejection cause is introduced over the Gx interface when the PGW rejects an IP-CAN Session Modification received from the PCRF, then the PCRF will be impacted.

The MME/S4-SGSN, PGW, and PCRF for PMIP based S5, shall know by local configuration whether this MME/S4-SGSN triggered SGW restoration procedure is supported in the PLMN, i.e. by peer PGWs, PCRFs for PMIP based S5, and MME/S4-SGSNs. The PGW shall assume that either all or none of the MMEs/S4-SGSNs in the PLMN support this procedure.Upon detecting an SGW failure with or without restart (relying on restart counter as specified in clause 18 "GTP-C based restart procedures" and clause 19 "PMIP based restart procedures", or implementation e.g. preconfigured path failure timer), the MME/S4-SGSN and PGW shall maintain the bearers and MM contexts of the PDN connections affected by the SGW failure and eligible for restoration, instead of removing associated resources as per procedures specified in subclauses 14.1A.1 and 17.1A.1.

For PMIP based S5, when the PCRF detects an SGW failure or restart, the PCRF shall maintain the IP-CAN sessions and delete locally the Gxc sessions affected by the SGW failure.

NOTE 1: The PGW notifies the PCRF about the termination of IP-CAN sessions associated to PDN connections that are not restored by the MME/S4-SGSN within an operator configurable period.

The PDN connections eligible for restoration are determined by the MME/S4-SGSN and PGW based on same operator's policies, e.g. based on QCI, ARP and/or APN.

NOTE 2: For PMIP based S5, the PCRF is not aware of which PDN connections are eligible for restoration. When the PGW detects an SGW failure, the PGW requests the PCRF to terminate IP-CAN sessions associated to PDN connections affected by the SGW failure and not eligible for restoration.

Maintaining the PDN connections affected by the SGW failure enables the MME/S4-SGSN to restore the corresponding bearers of the UE by selecting a new SGW or the restarted SGW. These PDN connections are maintained for an operator configurable period (T-Release-PDN timer), which is locally provisioned on MME/S4-SGSN and PGW, that by default should cover the periodic tracking area update timer (timer T3412) as specified in 3GPP TS 24.301 [19] or the periodic routing area update timer (timer T3312) as specified in 3GPP TS 24.008 [20]. After the expiry of the T-Release-PDN timer the MME/S4-SGSN and the PGW should delete any EPS bearer contexts that have not been restored via a new or the restarted SGW.

NOTE 3: The PGW's capability of supporting this SGW restoration procedure is stored per PDN and per UE by the serving MME/S4-SGSN. For a UE with multiple active PDN connections, some PGWs may support the SGW restoration procedure while others do not support the same. E.g. SGW restoration procedure may be supported for a PDN connection with local breakout while not supported for another PDN connection with home routed traffic. The restoration procedures upon SGW failure specified in subclauses 14.1A.1 and 17.1A.1 apply to the PDN connections for which the SGW restoration procedure is not supported or not applicable.

27.2.2.2 MME/S4-SGSN procedure

After detecting an SGW failure, the MME/S4-SGSN should attempt to restore the PDN connections eligible for restoration for all the UEs affected by the SGW failure, i.e. including UEs in ECM_IDLE / PMM-IDLE / GPRS STANDBY not engaged in any Service Request or other mobility procedure. The MME/S4-SGSN shall control the pace of the SGW relocations to avoid core network node overload. The MME/S4-SGSN should prioritize the SGW relocation for UEs engaged in a Service Request or RAU/TAU procedures or having GBR bearers over UEs which are not engaged in any mobility procedure and that do not have a signaling connection to the MME/S4-SGSN nor GBR bearers. The MME/S4-SGSN should also prioritize the SGW relocation for UEs with an emergency PDN connection.

NOTE 1: This is to allow all the affected UEs to be reconnected to the network in a relatively short time (that is function of the speed of the SGW relocations that the MME/S4-SGSN performs, based on implementation and the network load) so that downlink packets may be delivered to the UEs with minimum service interruption.

NOTE 2: Prioritizing the restoration of emergency PDN connections can enable to preserve emergency calls in progress for authenticated and unauthenticated users, and enable PSAP to call back authenticated users with an emergency registration but without an emergency call in progress.

To restore the PDN connection(s) of a UE, the MME/S4-SGSN shall perform an SGW relocation procedure by sending a Create Session Request message (per PDN connection to restore) to the new or restarted SGW as per the steps 8-11 of a Tracking Area Update procedure with Serving GW change in subclause 5.3.3.1 in 3GPP TS 23.401[15]. For PDN connections with GBR bearers existing before the SGW failure, the MME/S4-SGSN may either request to restore or remove the GBR bearers in the Create Session Request (e.g. depending on how quickly the PDN connection is restored). The MME/S4-SGSN shall restore the PDN connections of the affected UEs after the SGW failure as follows:

1) for UEs in ECM_IDLE/PMM-IDLE/GPRS STANDBY state:

   - the MME/S4-SGSN shall select a new SGW or the restarted SGW based on the last visited TAI/RAI;

   - the MME/S4-SGSN shall then perform an SGW relocation procedure as specified above.

2) for UEs in ECM_CONNECTED/PMM-CONNECTED/GPRS READY state not engaged in any mobility procedure (TAU/RAU, Handover):

- the MME/S4-SGSN shall release the S1/Iu/radio resources; if the eNodeB/RNC detects the SGW failure, the eNodeB/RNC may request the MME/S4-SGSN to release the S1/Iu resources;

- the MME/S4-SGSN shall then handle these UEs as specified for UEs in ECM_IDLE/PMM-IDLE/GPRS STANDBY state, or for UEs performing a mobility procedure if the UE performs subsequently such a mobility procedure (e.g. a Service Request to re-establish the S1/Iu/radio bearers);

- as an exception to these rules, for UTRAN without direct tunnel and GERAN, the S4-SGSN may perform SGW relocation while keeping the UEs in PMM-CONNECTED/GPRS READY state (i.e. without tearing down the Iu/radio resources) because S4 user plane is used and the SGW failure remains not visible to the radio network.NOTE 2: An SGW failure with restart may be visible to the radio network and cause bearers to be released for bearers with on-going uplink traffic if an Error Indication is received from the SGW before the S4-SGSN detects the SGW restart.

3) for UEs in ECM-IDLE/PMM-IDLE/GPRS STANDBY state initiating a Service Request procedure:

   - the MME/S4-SGSN shall first perform the SGW relocation procedure as specified above and then continue with the Service Request procedure since the MME/S4-SGSN has no valid SGW F-TEID to send in the S1-AP Initial Context Setup Request towards the eNodeB or in the Iu RAB Assignment Request message towards the RNC if Direct Tunnel is used.

4) for UEs initiating an intra-MME or intra-S4-SGSN TAU/RAU procedure:

   - the MME/S4-SGSN shall perform the SGW relocation procedure as specified above before the TAU/RAU procedure;

5) for UEs initiating an inter-MME/SGSN TAU/RAU procedure:

   - If both the source and target MME/S4-SGSNs support this SGW restoration procedure, the source MME/S4-SGSN should indicate to the target MME/S4-SGSN in the GTPv2 Context Response message that an SGW relocation procedure is needed due to an earlier SGW failure. Upon reception of such indication, the target MME/S4-SGSN shall perform the SGW relocation procedure as specified above and then proceed with the TAU/RAU procedure. The source MME/S4-SGSN may perform the SGW relocation procedure as specified above before responding to the GTPv2 Context Request message if the target MME/S4-SGSN does not support the SGW restoration procedure, e.g. during inter-PLMN RAU/TAU procedures when the target PLMN does not support the SGW restoration procedure.

6) for UEs in ECM-CONNECTED/PMM-CONNECTED/GPRS READY state for which a handover procedure is initiated:

   - The source MME/S4-SGSN should reject the Handover Required / Relocation Required message received from the RAN (for UEs with PDN connection(s) affected by an earlier SGW failure that have not been restored yet); the MME/S4-SGSN should then release the S1/Iu/radio resources of these UEs to force them to enter idle mode. The MME/S4-SGSN shall then proceed with the procedures specified above for UEs in ECM_IDLE/PMM-IDLE/GPRS STANDBY state, or for UEs performing a mobility procedure if the UE performs subsequently such a mobility procedure (e.g. a Service Request to re-establish the S1/Iu/radio bearers).

NOTE 3: S1/Iu/radio resources of UEs in ECM-CONNECTED/PMM-CONNECTED/GPRS READY state affected by an SGW failure are released very shortly after the SGW failure. Therefore only very few UEs affected an SGW failure and with PDN connections not restored yet may be subject to a handover, e.g. handovers taking place just after the SGW failure before the eNodeB/RNC or the MME/S4-SGSN release the S1/Iu/radio resources. This is why it is not necessary to support SGW relocation during Intra/Inter-CN handover procedures.

27.2.2.3 PGW procedure

The PGW shall maintain the PDN connections affected by the SGW failure and eligible for restoration for an operator configurable period (T-Release-PDN timer), as specified in subclause 27.2.2.1.

The PGW should maintain the GBR bearers of the PDN connections eligible for restoration for an operator configurable period (T-Release-GBR), which should be much shorter than the T-Release-PDN timer. Upon expiry of the T-Release-GBR timer, the PGW shall release GBR bearers that have not been restored yet and inform the PCRF about the corresponding PCC rule inactivation, with a cause as specified in 3GPP TS 29.212 [25].

NOTE: This is a safeguard mechanism to avoid e.g. overcharging the user in IMS for sessions not already terminated by IMS (e.g. by the far end user of a VoIP call).

The PGW shall discard downlink packets received for a PDN connection maintained after an SGW failure that has not been restored yet.

The PGW shall stop charging for PDN connections maintained after an SGW failure which have not been restored yet.

The PGW shall reject any IP-CAN Session Modification Request received for a PDN connection maintained after an SGW failure but not restored yet, with a rejection cause as specified in 3GPP TS 29.212 [25]. For these IP-CAN sessions for which an IP-CAN session modification has been rejected, the PGW shall subsequently inform the PCRF when the PDN connection is restored in order to enable the PCRF to update the PCC rules in the PGW if necessary.

Editor's Note: It is up to stage 3 whether to define a new rejection cause or reuse an existing cause if any suitable existing one exists that could satisfy the requirements above.

The PGW shall accept an IP-CAN Session Termination Request received for a PDN connection maintained after an SGW failure but not restored yet, with an acceptance cause as specified in 3GPP TS 29.212 [25] and release the affected PDN connection locally. If subsequently the MME/S4-SGSN attempts to restore the PDN connection, the PGW shall reject the Modify Bearer Request (for GTP based S5) or the Proxy Binding Update (for PMIP based S5) with the cause "Context Not Found" as specified in 3GPP TS 29.274 [13] and 3GPP TS 29.275 [16] after the corresponding PDN connection has been released locally.

27.2.2.4 PCRF procedure

If the PGW rejects an IP-CAN session modification procedure with the rejection cause as specified in subclause 27.2.2.3, the PCRF should maintain the corresponding IP-CAN session and refrain from sending any further IP-CAN session modification request to the PCRF until being notified by the PGW that the PDN connection is restored.

For PMIP based S5, the PCRF can not send any message to the SGW once the Gxc session in the PCRF is removed. The PCRF may however behave as for GTP based S5, e.g. send signaling to the PGW via the Gx interface. The Gxc session is restored when the PCRF receives Gateway Control Session Establishment from the SGW as specified in 3GPP TS 29.212 [25].

27.2.3 PGW triggered SGW restoration

27.2.3.1 General

The following requirements shall apply if the MME/S4-SGSN, the SGW and the PGW support this feature.

NOTE: The PGW triggered SGW restoration procedure does not require any further requirements from the PCRF than those already specified for the MME/S4-SGSN triggered SGW restoration procedure in subclause 27.2.2.1.

The PGW shall know by local configuration whether this PGW triggered SGW restoration procedure is supported in the PLMN. The MME/S4-SGSN/SGW may know the same by local configuration. When supported in the PLMN, the PGW supporting this procedure should be configured with the address of alternative(s) SGW(s) also supporting this procedure. The PGW shall assume that either all or none of the MMEs/S4-SGSNs in the PLMN support the procedure. All MMEs/S4-SGSNs in an MME/S4-SGSN pool should support this procedure when it is deployed.

The PGW triggered SGW restoration procedure does not apply to emergency PDN connections for users without authenticated IMSI.

NOTE: The MME/S4-SGSN can prioritize the restoration of emergency PDN connections (see subclause 27.2.2.2). IMS Emergency PSAP callback is not supported for unauthenticated users with an emergency registration but without an emergency call in progress.

27.2.3.2 MME/S4-SGSN procedure

During normal mode of operation (i.e. before SGW failure with/without restart):

The MME/S4-SGSN supporting the PGW triggered SGW restoration procedure shall include the MME/S4-SGSN identifier IE in existing signalling over the S11/S4 interface, i.e. in

- Create Session Request messages during an E-UTRAN Initial Attach, a UE requested PDN connectivity, and a PDP Context Activation procedure;
- Create Session Request message during TAU/RAU procedures with a SGW change;
- Create Session Request message during X2 based handover/Enhanced SRNS Relocation procedure with a SGW change;
- Modify Bearer Request message during Inter-RAT Handover procedures with/without a SGW change;
- Modify Bearer Request message during Intra-RAT handover procedure with a SGW change;
- Modify Bearer Request message during Inter-RAT TAU/RAU procedures without a SGW change;
- Modify Bearer Request message over S11/S4 if the message is deemed to be sent to the PGW due to other reasons, e.g. reporting ULI, time zone.

During SGW restoration procedure:

Upon receipt of a PGW Downlink Triggering Notification message for which it can not find a UE context corresponding to the received IMSI, the MME/S4-SGSN shall send a PGW Downlink Triggering Acknowledge message with the rejection cause code "Context Not Found" to the SGW to inform the SGW that the PGW Downlink Triggering Notification message has been received by the MME/S4-SGSN. If the PGW Downlink Triggering Notification message contains an MME/S4-SGSN identifier, the MME/S4-SGSN shall also include the IMSI and the MME/S4-SGSN identifier in the PGW Downlink Triggering Acknowledge message.

Upon receipt of a PGW Downlink Triggering Notification message for which it can find a UE context corresponding to the received IMSI, the MME/S4-SGSN shall send a PGW Downlink Triggering Acknowledge message back to the SGW with an acceptance cause code, and perform S-TMSI/P-TMSI paging as part of Network Initiated Service Request procedure as specified in subclause 5.3.4.3 of 3GPP TS 23.401 [15] and in subclause 6.12.1A of 3GPP TS 23.060 [5]. When receiving a Service Request message from the UE, the MME/S4-SGSN shall perform the SGW restoration procedure as specified in the subclause 27.2.2.

27.2.3.3 SGW procedure

During normal mode of operation (i.e. before SGW failure with/without restart):

The SGW shall forward the MME/S4-SGSN identifier IE to the PGW in existing signalling over the S5 interface if it is received over S11/S4 interface.

During SGW restoration procedure:

Upon receipt of a PGW Downlink Triggering Notification message from a PGW, the SGW shall forward the message to the MME/S4-SGSN identified by the MME/S4-SGSN identifier if present in the message. If no MME/S4-SGSN identifier is received from the PGW, the SGW shall forward the PGW Downlink Triggering Notification message to all the MME/S4-SGSN within the MME/S4-SGSN pool as known by local configuration. The SGW shall then send a PGW Downlink Triggering Acknowledge message back to the PGW with an acceptance cause code.

If the SGW receives a PGW Downlink Triggering Acknowledge message from an MME/S4-SGSN with the rejection cause code "Context Not Found" and with an IMSI and an MME/S4-SGSN identifier, the SGW shall then send a PGW Downlink Triggering Notification message, including the IMSI (as received in the PGW Downlink Triggering Acknowledge message), to all the MME/S4-SGSN within the MME/S4-SGSN pool as known by local configuration, except to the MME/S4-SGSN identified by the MME/S4-SGSN identifier received in the Downlink Triggering Acknowledge message.

The MME/S4-SGSN may have more than one IP address on the S11/S4 interface configured, but the PGW Downlink Triggering Notification should be sent only once per MME/S4-SGSN per local configuration in the SGW.

27.2.3.4 PGW procedure

During normal mode of operation (i.e. before SGW failure with/without restart):

The PGW shall store the MME/S4-SGSN identifier received in the last Create Session Request or Modify Bearer Request message (for GTP based S5) or Proxy Binding Update (for PMIP based S5) per PDN connection. If the PGW receives a Modify Bearer Request without MME/SGSN identifier, it shall delete the stored MME/S4-SGSN identifier.

NOTE 1: This allows the PGW to have the serving MME/S4-SGSN address whenever there is S5 signalling message. However this cannot ensure that the PGW is always aware of the current serving MME/S4-SGSN address. E.g. during an inter-MME HO without SGW change, the current serving MME/S4-SGSN address will not be propagated to the PGW if there is no S5 signalling.

During SGW restoration procedure:

When downlink data packets or signalling other than an IP-CAN Session Termination Request arrives at the PGW, for a PDN connection associated with a failed SGW and that has not been restored yet (as specified in subclause 27.2.2), and the PDN connection is eligible for PGW initiated Downlink triggering based on operator's policies, e.g. for IMS PDN connection, the PGW shall proceed as follows:

- the PGW shall select a SGW (i.e. the restarted or an alternative SGW) which supports the PGW triggered SGW restoration procedure, based on local configuration;

- for GTP-based S5, the PGW shall then send a PGW Downlink Triggering Notification message including the IMSI and the MME/S4-SGSN identifier if available;

- for PMIP-based S5, the PGW shall then send an PMIP Update Notification message as specified in IETF Draft-krishnan-netext-update-notifications [26] to indicate it is a PGW initiated downlink triggering notification, including the IMSI and the MME/S4-SGSN Identifier when it is available;

- the PGW should not send a new PGW Downlink Triggering Notification message (for GTP-based S5) or Update Notification message (for PMIP-based S5) in very short time if it continues to receive subsequent downlink data or signaling for the same PDN connection. It is an implementation option how many times/how frequently the PGW should send subsequent PGW Downlink Triggering Notification message (for GTP-based S5) or Update Notification message (for PMIP-based S5) before discarding the downlink packets or rejecting signalling.

- the PGW shall handle an IP-CAN Session Modification Request received from the PCRF as specified in 3GPP TS 29.212 [25] as if the PDN connection had not been affected by the SGW failure i.e. was in a normal state . After accepting an IP-CAN session modification request, if the MME/S4-SGSN does not restore the PDN connection shortly after the PGW initiated triggering, the PGW shall report the modification failure to the PCRF with a cause as specified in 3GPP TS 29.212 [25].

The PGW shall behave as specified in subclause 27.2.2.3 if the PGW receives an IP-CAN Session Termination Request for a PDN connection associated with a failed SGW and that has not been restored yet.

NOTE 2: To ensure the delivery of downlink data, it is implementation specific whether the PGW buffers or not the downlink data until the PDN connection is restored. The application functions e.g. P-CSCF for IMS, may also retransmit the data packets.

NOTE 3: The operator policies for PDN connections eligible for restoration (i.e. to be maintained upon SGW failure as per subclause 27.2.2) and PDN connections eligible for PGW initiated downlink triggering may differ, i.e. the PDN connections eligible for PGW initiated downlink triggering may be a subset of the PDN connections eligible for restoration.

27.3 Restoration of PDN connections after an SGW failure for UEs with ISR

27.3.1 MME/S4-SGSN triggered SGW restoration for UEs with ISR

27.3.1.1 General

The requirement specified in subclause 27.3.1.2 shall apply on top of the MME/S4-SGSN triggered SGW restoration procedure specified in subclause 27.2.2 and the involved MME and S4-SGSN additionally support the ISR feature.

NOTE: The procedure in this subclause does not consider the case where one of ISR associated nodes, i.e. the MME or the S4-SGSN, does not support the MME/S4-SGSN triggered SGW restoration procedure.

27.3.1.2 MME/S4-SGSN procedure

The MME/S4-SGSN shall restore the PDN connections of the affected UEs after the SGW failure as follows:

1) for UEs initiating an intra MME/S4-SGSN TAU/RAU procedure:

   - the MME/S4 SGSN shall perform the SGW relocation procedure as specified in subclause 27.2.2, and inform the UE in the related TAU/RAU Accept message to disable ISR as specified in 3GPP TS 23.401[15] and 3GPP TS 23.060 [5].

2) for UEs in ECM-IDLE/PMM-IDLE/GPRS STANDBY state initiating a Service Request procedure:

   - the MME/S4 SGSN shall perform the SGW relocation procedure as specified in subclause 27.2.2 and initiate the GUTI Relocation or P-TMSI Relocation procedure with a non-broadcast TAI or RAI to force the UE to perform the TAU/RAU procedure for ISR deactivation.

3) for UEs in ECM-CONNECTED/PMM-CONNECTED/GPRS READY state engaged in any handover or inter MME/S4-SGSN TAU/RAU procedure:

   - it shall be handled as specified in subclause 27.2.2.

4) for UEs in ECM-IDLE/PMM-IDLE/GPRS STANDBY state which are not engaged in any Service Request or other mobility procedure:

   - In networks supporting PGW triggered SGW restoration proactive paging of UEs in ECM-IDLE/PMM-IDLE/GPRS STANDBY state shall not be initiated.

     The MME/S4-SGSN shall page the UE to bring the UE to ECM-CONNECTED/PMM-CONNECTED. If the paging is successful and the UE initiates the Service Request procedure, the MME/S4-SGSN shall perform the SGW relocation procedure as specified in subclause 27.2.2 and initiate the GUTI Relocation or P-TMSI Relocation Procedure with a non-broadcast TAI or RAI to force the UE to perform the TAU/RAU procedure for ISR deactivation as specified in subclause 5.3.4.3 of 3GPP TS 23.401[15]. If paging the UE fails, the MME or S4-SGSN should adjust its paging retransmission strategy (e.g. limit the number of short spaced retransmissions) to take into account the fact that the UE might be in GERAN/UTRAN or E-UTRAN coverage. If the associated MME/S4-SGSN receives ISR Status Indication with "deactivation Indication" from S4-SGSN/MME, the MME/S4-SGSN shall release the UE session locally. Otherwise after retrying the paging procedure, the MME/S4-SGSN may release locally the PDN connection context and UE MM context assuming the UE is in GERAN/UTRAN or E-UTRAN coverage area.

     MME/S4-SGSN should handle UEs in ECM-CONNECTED/PMM-CONNECTED and involved in any handover or inter MME/S4-SGSN TAU/RAU procedure first before paging of UEs in ECM-IDLE/PMM-IDLE/GPRS STANDBY to minimise paging of UEs. Furthermore the sequence on how UEs in ECM-IDLE/PMM-IDLE/GPRS STANDBY can be paged to avoid overload are implementation dependent.

The MME/S4-SGSN which initiates the SGW restoration procedure should send ISR Status Indication with "ISR deactivation Indication" to the ISR associated S4-SGSN/MME to release the PDN connection context and UE MM context.

NOTE 1: The PDN connection context and UE MM context can be released after the timer (T-Release-PDN timer), which is used for maintaining the context, expires, as specified in subclause 27.2.2.1.

NOTE 2: The MME will only perform the SGW reselection for the UEs camping on the LTE, ISR activated UEs can camp in the GERAN/UTRAN, so paging is needed.

The S4-SGSN will only perform the SGW reselection for the UEs camping on the GERAN/UTRAN, ISR activated UEs can camp in the LTE, so paging is needed.

NOTE 3: It is the responsibility of the MME/S4-SGSN to avoid Paging Overload.

27.3.2 PGW triggered SGW restoration for UEs with ISR

27.3.2.1 General

The requirement specified in subclause 27.3.2.2 shall apply on top of the PGW triggered SGW restoration procedure specified in subclause 27.2.3 and the involved MME and S4-SGSN additionally support the ISR feature.

NOTE: The procedure in this subclause does not consider the case where one of ISR associated nodes, i.e. the MME or the S4-SGSN, does not support the PGW triggered SGW restoration procedure.

27.3.2.2 MME/S4-SGSN procedure

If the MME/S4-SGSN receives a PGW Downlink Triggering Notification message containing MME/S4-SGSN Identifier from the SGW for those UEs affected by the failed SGW, the MME/S4-SGSN shall behave as specified in subclause 27.2.3.2 and additionally send ISR Status Indication message with "Paging Indication" over the S3 interface to the ISR associated S4-SGSN/MME over the existing GTP-C tunnel between the S4-SGSN and the MME.

The ISR associated S4-SGSN/MME, which receives ISR Status Indication message with "Paging Indication", shall perform P-TMSI/S-TMSI paging as part of the Network Initiated Service Request procedure as specified in subclause 27.3.1.2.

After the MME/S4-SGSN receiving NAS message Service Request, the MME/S4-SGSN shall behave as specified in the subclause 27.3.1.2.

28 Restoration of data in the CSS

28.1 Restart of the CSS

The periodic backup of CSS data to non-volatile storage is mandatory.

When a CSS restarts after failure it shall perform the following actions for the subscriber data records that have been affected by the CSS fault:

- reload all data from the non-volatile back-up;
- send a "Reset" message to each VLR where one or more of its MSs may be registered to the CSS. This causes each VLR concerned to mark each relevant roaming user record "Location Information Not Confirmed by CSS", and
- send a "Reset" message to each SGSN where one or more of its MSs may be registered to the CSS. This causes each SGSN to mark each relevant MM context "Location Information Not Confirmed by CSS".
- send a "Reset" message to each MME where one or more of its UEs may be registered to the CSS.

Annex A (informative): Change history

Change history						
TSG CN#	**Spec**	**Version**	**CR**	**<Phase>**	**New Version**	**Subject/Comment**
Apr 1999	GSM 03.07	6.1.0				Transferred to 3GPP CN1
CN#03	23.007				3.0.0	Approved at CN#03
CN#04	23.007	3.0.0	001	R99	3.1.0	GPRS restoration procedures
CN#06	23.007	3.1.0	002r2	R99	3.2.0	Authentication Enhancements
CN#06	23.007	3.1.0	003	R99	3.2.0	Support of VLR and HLR Data Restoration procedures with LCS
CN#07	23.007	3.2.0	004	R99	3.3.0	Support of VLR and HLR Data Restoration procedures with LCS
CN#08	23.007	3.3.0	005	R99	3.4.0	Clarifications on GSM vs. UMTS specific parts
CN#11	23.007	3.4.0		Rel-4	4.0.0	Release 4 after CN#11
CN#16	23.007	4.0.0	007	Rel-4	4.1.0	Removal of an optional IMSI paging after SGSN restart
CN#16	23.007	4.1.0		Rel-5	5.0.0	Release 5 after CN#16
CN#22	23.007	5.0.0	011r1	Rel-5	5.1.0	Restoration of data in RA update
CN#23	23.007	5.1.0	008r3	Rel-6	6.0.0	Change of Restart Counter definition for enhanced GTP
CN#25	23.007	6.0.0	012	Rel-6	6.1.0	Error Indication during an ongoing MBMS data transfer
CN#25	23.007	6.0.0	013	Rel-6	6.1.0	Restoration of GSNs in MBMS
CT#30	23.007	6.1.0	0014	Rel-6	6.2.0	Incorrect References
CT#32	23.007	6.2.0	0019r1	Rel-7	7.0.0	Correction for Usage of Cancel Location for Supercharger
CT#40	23.007	7.0.0	0020r2	Rel-8	8.0.0	EPS Restoration
CT#41	23.007	8.0.0	0021r3	Rel-8	8.1.0	Moving restoration procedures from TS 23.060 into TS 23.007
CT#41	23.007	8.0.0	0023r2	Rel-8	8.1.0	Node Restart Restoration Procedures for PGW, SGW and MME
CT#42	23.007	8.1.0	0027r2	Rel-8	8.2.0	RNC failure aligns with TS23.060
CT#42	23.007	8.1.0	0028	Rel-8	8.2.0	Restoration procedures for SGs interface
CT#42	23.007	8.1.0	0033r5	Rel-8	8.2.0	Partial Failure Handling
CT#42	23.007	8.1.0	0037r1	Rel-8	8.2.0	PMIP Path management / Restoration Clean-up
CT#43	23.007	8.2.0	0030r5	Rel-8	8.3.0	Moving the description of the restoration procedures (from 29.274) to 23.007
CT#43	23.007	8.2.0	0038r4	Rel-8	8.3.0	Partial fault handling finalization
CT#44	23.007	8.3.0	0043r1	Rel-8	8.4.0	FQ-CSID corrections
CT#44	23.007	8.3.0	0047r1	Rel-8	8.4.0	SGSN and SGW handling in case RNC/BSC Failure (Iu mode) using S4
CT#44	23.007	8.4.0	0045r1	Rel-9	9.0.0	General on PMIP based restart procedure
CT#45	23.007	9.0.0	0065r1	Rel-9	9.1.0	Essential corrections to the partial failure support
			0051			Removal of Editor's note
			0053r1			Restoration of data in MBMS GW
			0058r1			Echo usage for GTPv2
			0063r3			Error Indication cleanup
			0064r4			Restoration of data in E-UTRAN
CT#46	23.007	9.1.0	0066	Rel-9	9.2.0	Paging signalling optimization after SGSN failure
			0067			Paging signalling optimization after MME failure
			0068			Error Indication for MBMS
			0072r1			Removal of Editor's Notes for Partial Failure
			0078r1			Error Indication Handling for MBMS
			0080			Alignment of eNodeB failure sub-clause
			0082r3			Alignment of RNC/BSC failure sub-clause
CT#47	23.007	9.2.0	0091	Rel-9	9.3.0	Bulk Binding Revocation Indication

Change history						
TSG CN#	Spec	Version	CR	<Phase>	New Version	Subject/Comment
			0082r2			Clarifications to eNodeB failure
			0092r1			Reference corrections
			0095r1			Restart counter correction
CT#48	23.007	9.3.0	0100r1	Rel-9	9.4.0	Essential correction to Error Indication message handling for the default bearer
			0076r4			Cleanup of hanging PDN connections/bearers
			0097r1			Failure of remote nodes
		9.4.0	0107r1	Rel-10	10.0.0	Optimization on hanging PDN connection cleanup
CT#49	23.007	10.0.0	0115	Rel-10	10.1.0	Data Restoration for SMS
			0117			GTP-C based restart procedures
			0121			Partial Failure handling
CT#50	23.007	10.1.0	0135r1	Rel-10	10.2.0	Heartbeat Request
			0129r1			ePDG Partial Failure
			0133r1			Restoration of data in the ePDG
			0131r1			Error Indication handling in PGW and ePDG
			0132			ePDG/PGW restart and restoration
			0130r1			PGW Restart Notification
			0124			Essential correction to the MME and PGW restoration procedure
CT#51	23.007	10.2.0	0142r2	Rel-10	10.3.0	Timing for sending Downlink Data Notification as a result of the SGW having received an Error Indication message from the eNodeB/RNC
			0151r1			Unclearness of Downlink Data Notification Handling at MME/S4 SGSN as a result of the SGW having received an Error Indication message from the eNodeB/RNC
			0155			eNodeB failure
			0154r1			RNC failure
			0148r2			Error Indication in SGW
			0145r1			Error Indication for SGW
			0146r5			PCRF Failure and Restoration
			0152r2			Handling of UE specific Error Indication over the PMIP
			0156r5			MME/SGSN restart and restoration procedure
CT#52	23.007	10.3.0	0166r2	Rel-10	10.4.0	SGW behavior when it receives GTP error indication from S4-SGSN
			0160r1			Fix wrong statement for the IMSI page in the Network triggered service restoration procedure
			0164r2			Clarification on Network triggered service restoration procedure
			0167r2			Gateway Control and QoS Policy Rules Provision Procedure handling at SGW
			0161r1			Moving PCRF Restoration text under appropriate heading
			0162			eNB Error Indication Handling
			0163r3			MME/SGSN restart with ISR
CT#53	23.007	10.4.0	0169r2	Rel-10	10.5.0	Signalling path failure handling
			0175r1			Downlink Data Notification Handling at MME/S4 SGSN
			0170r1			User plane path failure handling
			0171r1			PMIP alighnment for the network triggered service restoration procedure
CT#54	23.007	10.5.0	0183	Rel-10	10.6.0	Inter MME and intra SGW HO/TAU procedures
			0176			NTSR with ISR active
			0190			DDN message in the service restoration procedure
			0185r2			Essential correction to Partial failure

Change history						
TSG CN#	**Spec**	**Version**	**CR**	**<Phase>**	**New Version**	**Subject/Comment**
CT#54	23.007	10.6.0	0178	Rel-11	11.0.0	FQ-CSID Reporting
			0168r5			CS service restoration after MME failure
			0177r1			PGW restoration
CT#55	23.007	11.0.0	0193r1	Rel-11	11.1.0	Error Indication Handling on S2a
			0194r2			Restoration of data in the TWAN for S2a
			0195r2			TWAN partial failure
			0196r1			Restoration of data in the PGW for S2a
			0198r1			Correction on the S4-SGSN failure
			0199r1			S1 path failure handling
			0201r2			IP Address of the node sending the recovery IE
CT#56	23.007	11.1.0	0191r1	Rel-11	11.2.0	SGW Restoration procedure
			0204r1			Missing SGSN behavior in the PGW failure
			0206r1			PGW triggered SGW restoration procedure
			0208			Corrections to external resources cleanup upon SGW failure
CT#57	23.007	11.2.0	0210r2	Rel-11	11.3.0	Restoration of Data for VCSG
			0211r1			Downlink Data Notification message handling in S4 SGSN
CT#58	23.007	11.3.0	0209r3	Rel-11	11.4.0	PCC and PMIP impacts for the SGW restoration procedure
			0212			Corrections to reference titles
			0215r1			Handling of emergency PDN connections during EPC node restoration
			0216			Corrections to reference errors
			0217r3			SGW failure when ISR is active
			0214r4			Handling of VLR Failure without Restart

History

Document history		
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