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Foreword

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Version x.y.z

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- 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 present document defines the restoration procedures in the 5G System.

2 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 for 3GPP Specifications".

[2] 3GPP TS 23.007: "Restoration procedures".

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

[4] 3GPP TS 29.244: "Interface between the Control Plane and the User Plane Nodes; Stage 3".

[5] 3GPP TS 23.502:"Procedures for the 5G System; Stage 2"

[6] 3GPP TS 29.518: "5G System; Access and Mobility Management Service; Stage 3".

[7] 3GPP TS 29.510: "5G System; Network Function Repository Services; Stage 3".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

F-SEID	Fully Qualified SEID
PFCP	Packet Forwarding Control Protocol
PSA	PDU Session Anchor

4 Restoration Procedures related to the N4 Interface

4.1 General

This clause specifies the procedures supported in the 5G System to detect and handle failures affecting the N4 interface.

4.2 N4 Failure and Restart Detection

Across PFCP based interfaces an SMF and UPF shall utilize the PFCP Heartbeat Request and Heartbeat Response messages or PFCP messages containing the Recovery Time Stamp to detect a peer PFCP failure or restart as described in clause 19A of 3GPP TS 23.007 [2].

4.3 UPF Restoration Procedures

4.3.1 General

When a UPF fails, all its Session contexts and PFCP associations affected by the failure become invalid and may be deleted.

4.3.2 Restoration Procedure for PSA UPF Restart

If F-TEID allocation is performed in the UPF, the UPF shall ensure that previously used F-TEID values are not immediately reused after a UPF restart, in order to avoid inconsistent TEID allocation throughout the network and to enable the restoration of PFCP sessions affected by the failure. How this is ensured is implementation specific.

The UPF shall not send an Error indication message for a configurable period after an UPF restart when the UPF receives a G-PDU not matching any PDRs.

During or immediately after an UPF Restart, the UPF shall place a local UPF Recovery Time Stamp value in all Heartbeat Request/Response and PFCP Association Setup Request/Response Messages.

Immediately after the re-establishment of a PFCP association between the SMF and the UPF, the SMF may start restoring PFCP sessions in the UPF.

4.3.3 Restoration Procedure for PSA UPF Failure without Restart

Procedures for PSA UPF failure without restart are implementation specific.

4.3.4 Restoration Procedure for Intermediate UPF Restart

The SMF will receive the UPF recovery time stamps in the PFCP association setup Request/Response and the PFCP heartbeat requests/responses.

After an Intermediate UPF restart, the PFCP association between the SMF(s) and the Intermediate UPF has to be re-established.

The restoration of the PFCP sessions may start immediately after the PFCP association setup procedure:

- if the restoration is supported in the SMF on a proactive basis, the SMF may start re-establishing PFCP sessions matching any PDRs.
- if the restoration is supported in the SMF on a reactive basis:
  - the SMF shall establish an PFCP session with a wildcarded PDR to instruct the Intermediate UPF to forward G-PDU packets which are not matching any other PDRs to the SMF (to a F-TEID uniquely assigned in the SMF for this PFCP-u tunnel);
  - upon receipt of G-PDUs from this PFCP-u tunnel, the SMF shall then check if it has an active session for each received G-PDU packet:
    - if so, the SMF shall perform the PFCP Session establishment procedures to re-establish the corresponding PFCP sessions in the Intermediate UPF;
    - otherwise the SMF shall generate a GTP-U Error Indication with a destination address set to the source IP address of the received G-PDU, and send it to the Intermediate UPF. The Intermediate UPF shall forward this GTP-U Error Indication transparently. The SMF shall delete the G-PDU after the check for active sessions.

NOTE 1: The UPF can filter the G-PDU packets with same target F-TEID and send only one such G-PDU to the Intermediate SMF.

The Intermediate UPF shall not send any Error indication messages for a configurable period after an Intermediate UPF restart when the Intermediate UPF receives G-PDU not matching any PDRs.

NOTE 2: If restoration on a reactive basis is used, the period needs to be longer than the time required by the SMF to detect the UPF restart, to establish the PFCP association and provision the wildcarded PDR. Otherwise, the period needs to be longer than the time required by the SMF to restore all the PFCP sessions on a proactive basis.

Editor's Note: Branching point and uplink classifier are FFS.

4.3.5 Restoration Procedure for Intermediate UPF Failure without Restart

Procedures for Intermediate UPF failure without restart are implementation specific.

4.4 SMF Restoration Procedures

4.4.1 General

When a SMF fails, all its PDU session contexts and PFCP associations affected by the failure may become invalid and may be deleted.

If F-TEID allocation is performed in the SMF, the SMF should ensure as far as possible that previously used F-TEID values are not immediately reused after a SMF restart, in order to avoid inconsistent TEID allocation throughout the network.

NOTE: This is to ensure that F-TEIDs are not reused until earlier PDU sessions using them are released.

4.4.2 Restoration Procedure for SMF Restart

During or immediately after a SMF Restart, the SMF shall place local SMF-C Recovery Time Stamp value in all Heartbeat Request/Response and PFCP Association Setup Request/Response Messages.

The UPF will receive the SMF recovery time stamps in PFCP Association Setup Request/Response and PFCP heartbeat requests/responses.

When a UPF detects that the SMF has restarted (as specified in subclause 4.2), the UPF shall delete all session contexts and the PFCP association context affected by the restart that it may have stored. When the UPF receives a GTP-U PDU not matching any PDRs, it shall discard the GTP-U PDU and return a GTP error indication to the originating node (e.g. other UPF, gNB or N3IWF).

4.4.3 Restoration Procedure for SMF Failure without Restart

When a UPF detects that a SMF is not reachable for a preconfigured time, the UPF shall delete all the session contexts and the PFCP association context affected by the SMF failure that it may have stored.

4.5 N4 path failure

If the N4 path to the UPF is down, the SMF should handle this as an UPF Failure without Restart, see subclause 4.3.3.

If the N4 path to the SMF is down, the UPF should handle this as a SMF Failure without Restart, see subclause 4.4.3.

5 Restoration Procedures related to the User Plane Interfaces N3 and N9

5.1 General

This clause specifies the procedures supported in the 5G System to detect and handle failures affecting the user plane interfaces N3 and N9

5.2 User Plane Failure Detection

5.2.1 Loss of GTP-U contexts

A GTP-U entity may lose its GTP-U contexts upon a failure or restart.

When a GTP-U node receives a G-PDU for which no corresponding GTP-U tunnel exists, the GTP-U node shall discard the G-PDU and return a GTP-U Error Indication to the sending node, as specified in subclause 7.3.1 of 3GPP TS 29.281 [3].

The receipt of a GTP-U Error Indication is an indication for the sending GTP-U entity that the peer GTP-U entity cannot receive any more user plane traffic on the corresponding GTP-U tunnel.

5.2.2 User Plane Path Failure

A GTP-U entity may detect a user plane path failure by using GTP-U Echo Request and Echo Response messages, as specified in subclause 20.3.1 of 3GPP TS 23.007 [2].

5.3 Restoration Procedures upon Loss of GTP-U contexts

5.3.1 General

The following subclauses specify the behaviour of the different network entities when receiving a GTP-U Error Indication.

5.3.2 Procedure for GTP-U Error Indication received from 5G-AN

5.3.2.1 Principles

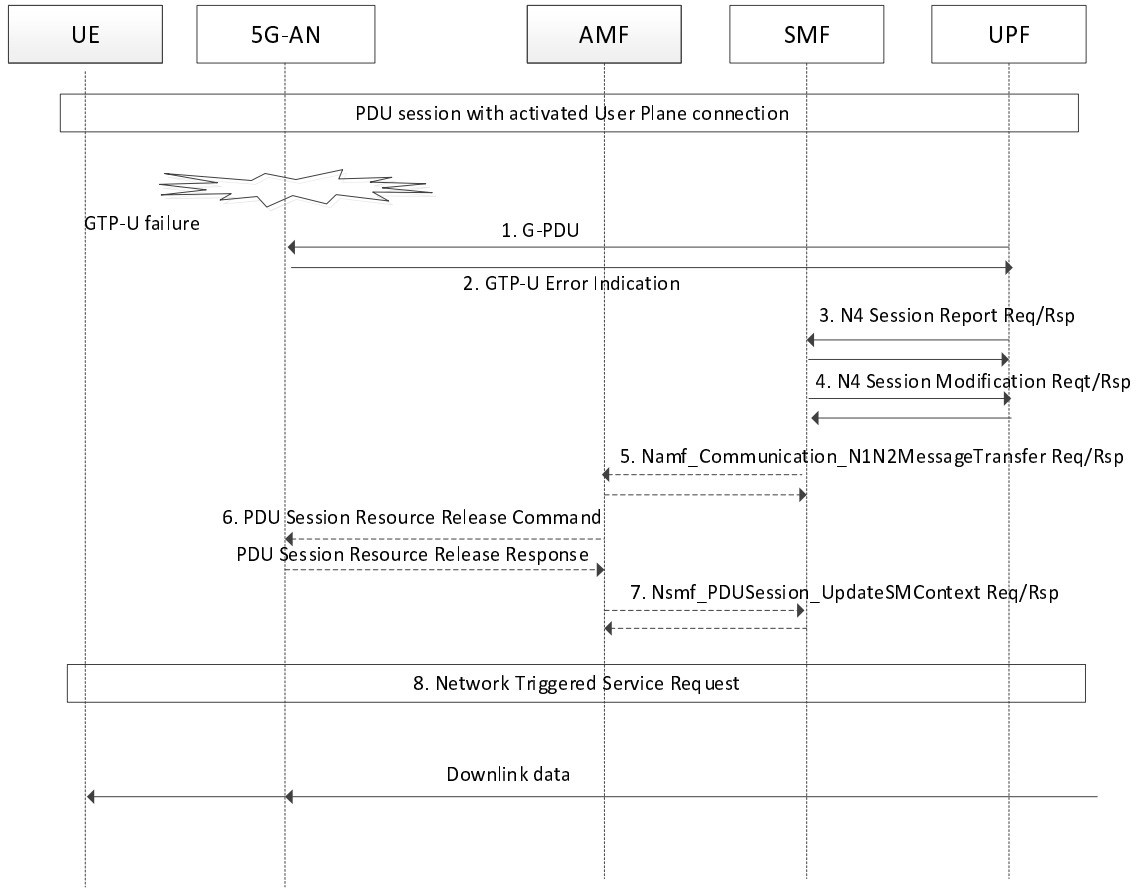

Figure 5.3.2.1-1: GTP-U Error Indication from 5G-AN

1. The user plane connection of an existing PDU session is activated. Downlink G-PDUs are sent towards the 5G-AN.

2. The 5G-AN returns a GTP-U Error Indication if it does not have a corresponding GTP-U context (see subclause 5.2).

3. Upon receipt of a GTP-U Error Indication, the UPF shall identify the related PFCP session and send an Error Indication Report to the SMF, as specified in subclause 5.10 of 3GPP TS 29.244 [4].

4. For a GTP-U Error Indication received from a 5G-AN, the SMF shall modify the PFCP session to instruct the UPF to buffer downlink packets.

5. If the user plane connection of the PDU session is seen as activated by the SMF, the SMF shall initiate an Namf_Communication_N1N2MessageTransfer service operation to request the 5G-AN to release the PDU session's resources, as specified in subclause 4.3.7 of 3GPP TS 23.502 [5] but additionally including a validity condition (for sending the N2 message) that the UE is in CM-CONNECTED state for the Access Network Type (3GPP or non-3GPP access) associated to the PDU session.

6. Upon receipt of an Namf_Communication_N1N2MessageTransfer request including the validity condition that the UE is in CM-CONNECTED state for the Access Network Type (3GPP or non-3GPP access) associated to the PDU session, the AMF shall:

   - proceed with the request, as specified in subclause 5.2.2.3.1 of 3GPP TS 29.518 [6], if the UE is in CM-CONNECTED state for the Access Network Type associated to the PDU session;

   - otherwise, reject the request with an error indicating that the UE is not in CM-CONNECTED state for the Access Network Type associated to the PDU session.

7. If the AMF sent a PDU Session Resource Release Command to the 5G-AN, the PDU session's resource release is acknowledged to the SMF.

8. The SMF initiates the Network Triggered Service Request procedure specified in subclause 4.2.3.3 of 3GPP TS 23.502 [5], to re-activate the user plane connection of the PDU session.

5.3.3 Procedure for GTP-U Error Indication received from UPF

5.3.3.1 GTP-U Error Indication received by 5G-AN

Upon receipt of a GTP-U Error Indication, the 5G-AN shall proceed as follows:

- if the GTP-U Error Indication was received from an UPF for a NG-U tunnel other than an indirect forwarding tunnel, the 5G-AN shall initiate a PDU Session Resource Notify procedure and release immediately the resources of the PDU session for which the Error Indication was received;

- if the GTP-U Error Indication was received from a peer 5G-AN or UPF for a direct or indirect forwarding tunnel, the 5G-AN may ignore the error indication or delete the forwarding tunnel context locally without deleting the corresponding PDU session and bearers.

NOTE: The 5G-AN behaviour for dual connectivity is not described in this specification.

5.3.3.2 GTP-U Error Indication received by another UPF

Upon receipt of a GTP-U Error Indication, the UPF shall identify the related PFCP session and send an Error Indication Report to the SMF, as specified in subclause 5.10 of 3GPP TS 29.244 [4].

Upon receipt of an Error Indication Report from the UPF, the SMF shall identify the PDU session for which the Error Indication is received using the remote F-TEID included in the report.

For a GTP-U Error Indication received from another UPF, the SMF shall delete the PFCP session and PDU session, unless the UPF from which the Error Indication was received is controlled by the same SMF and the SMF is able to restore the user plane connectivity of the PDU session (e.g. Error Indication received from an Intermediate UPF controlled by the same SMF).

5.4 Restoration Procedures upon User Plane Path Failure

Upon detecting a GTP-U user plane path failure as specified in subclause 5.2.2, the UPF shall report the user plane path failure to the SMF, by sending a PFCP Node Report Request (see 3GPP TS 29.244 [4]) including a User Plane Path Failure Report with the IP address of the remote GTP-U peer(s) towards which a failure has been detected. The UPF should also notify the GTP-U user plane path failure via the Operation and Maintenance system.

When the SMF receives the PFCP Node Report Request with a User Plane Path Failure Report, the SMF may:

- delete the PDU session contexts associated with the path in failure; or
- maintain the PDU session contexts associated with the path in failure during an operator configurable maximum path failure duration. The SMF shall delete the PDU session contexts associated with the path in failure 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 PDU session contexts associated with the peer's IP address enables the delivery of end user services (when the path is re-established again) and this also avoids unnecessary signalling in the network for restoring those PDU sessions.

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

When deciding to delete the PDU session contexts associated with the path in failure, the SMF shall modify or delete the affected PFCP sessions in the UPF.

NOTE 3: The SMF need to take care to smoothen the signalling load towards the UPF if a large number of PFCP sessions are affected by the user plane path failure.

6 Restoration Procedures related to Service-Based Interfaces

6.1 General

A NF may detect a failure or a restart of a peer NF or NF service using the NRF as specified in subclause 6.2.

A NF may also detect a restart of a peer NF or NF service by receiving recovery time information in signalling exchanged with that peer NF or NF service.

Editor's Note: the corresponding procedure needs to be described.

The restoration procedures, initiated when detecting a failure or a restart are not specified in this release.

6.2 NF (NF Service) Failure and Restart Detection using the NRF

6.2.1 General

This subclause describes optional procedures that may be supported by NFs to detect the failure or restart of a NF or a NF service using the NRF.

6.2.2 NF (NF Service) Failure

Figure 6.2.2-1 describes a NF failure scenario and how other NFs can be notified of this failure.

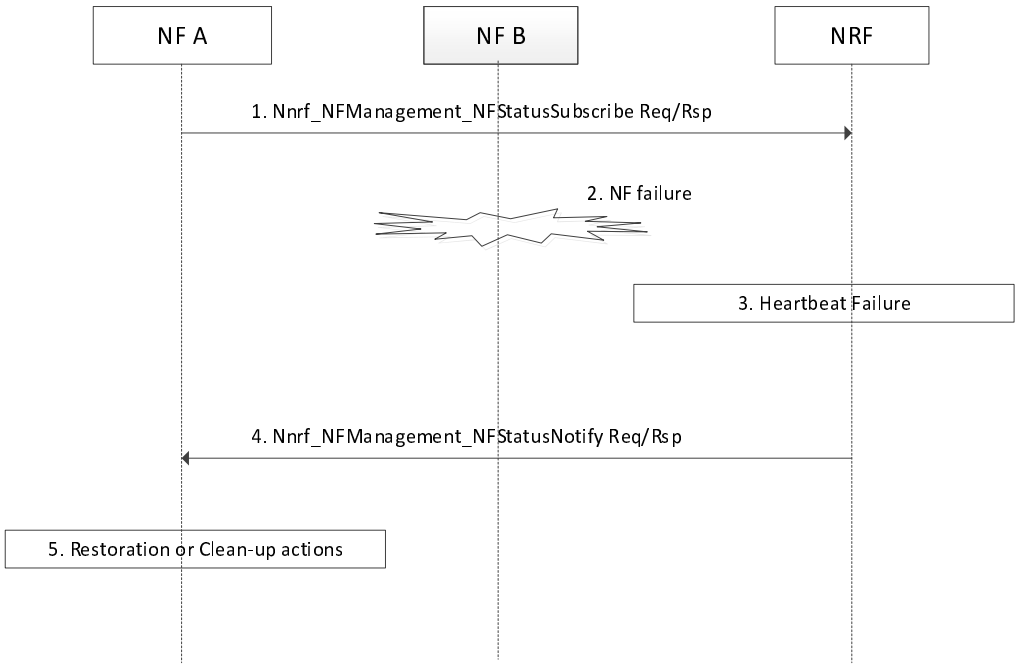

Figure 6.2.2-1: NF Failure Detection and Notification

1. NF A subscribes to the NRF to receive notifications of changes of the NF B Profile, as specified in 3GPP TS 29.510 [7].
2. A NF failure occurs at NF B.
3. The NRF detects that NF B is no longer operative using the NF Heart-Beat procedure as specified in subclause 5.2.2.3.2 of 3GPP TS 29.510 [7]. The NRF changes the NFStatus of NF B to SUSPENDED.
4. The NRF notifies NFs having subscribed to receive notifications of changes of the NF B Profile that the NFStatus of NF B is changed to SUSPENDED.
5. NF A may trigger appropriate restoration or clean-up actions, if it cannot communicate with NF B.

Figure 6.2.2-2 describes a NF service failure scenario and how other NFs can be notified of this failure.

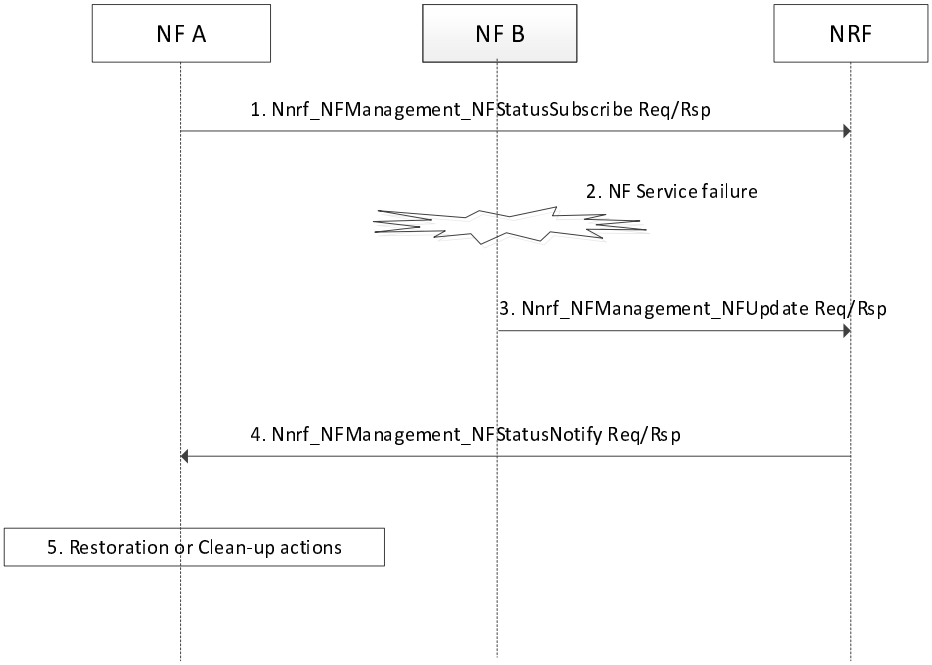

Figure 6.2.2-2: NF Service Failure Detection and Notification

1. NF A subscribes to the NRF to receive notifications of changes of the NF B Profile.
2. A NF Service failure occurs at NF B. NF B (other than the failed NF Service) is still operative.
3. NF B (or OAM) updates its NF Profile in the NRF, by setting the NFServiceStatus of the failed NF Service to SUSPENDED.
4. The NRF notifies NFs having subscribed to receive notifications of changes of NF B Profile that the NF Service status of the failed NF service of NF B is changed to SUSPENDED.
5. NF A triggers appropriate restoration or clean-up actions, if it cannot communicate with the NF B service.

6.2.3 NF (NF Service) Restart

Figure 6.2.3-1 describes a NF restart scenario and how other NFs can be notified of this restart.

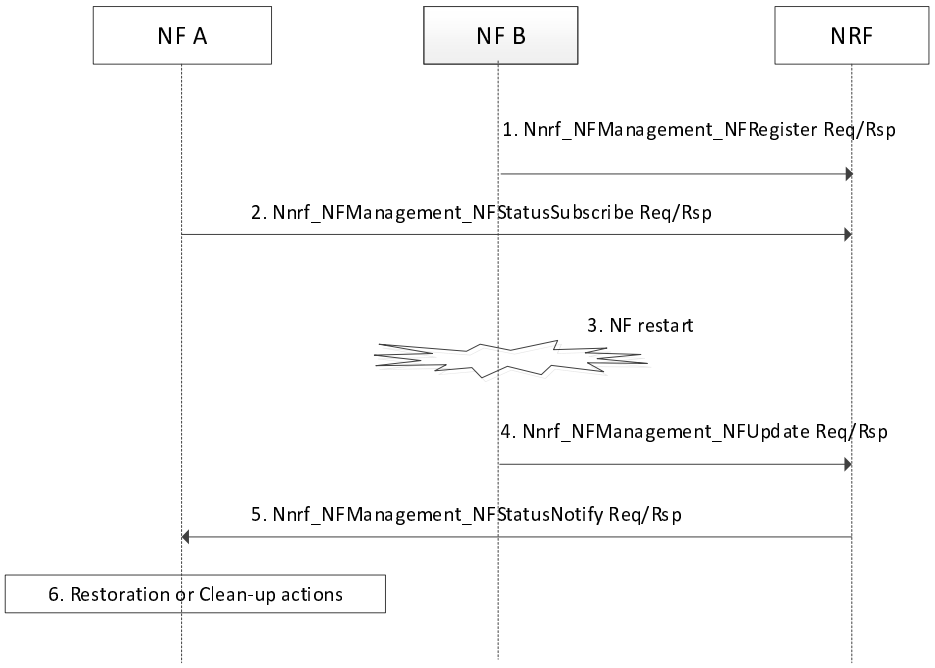

Figure 6.2.3-1: NF Restart Detection and Notification

1. NF B (or OAM) registers NF B Profile to the NRF. The NF B Profile may include the recoveryTime attribute, if a restart of NF B results in losing contexts.
2 NF A subscribes to the NRF to receive notifications of changes of the NF B Profile.
3. NF B restarts.
4. If contexts are lost during the restart, NF B (or OAM) updates the recoveryTime in its NF Profile in the NRF.
5. The NRF notifies NFs having subscribed to receive notifications of changes of NF B Profile about the updated recoveryTime of the NF B Profile.
6. NF A may consider that all the resources created in the NF B before the NF B recovery time as have been lost. NF A triggers then appropriate restoration or clean-up actions.

Figure 6.2.3-2 describes a NF service restart scenario and how other NFs can be notified of this restart.

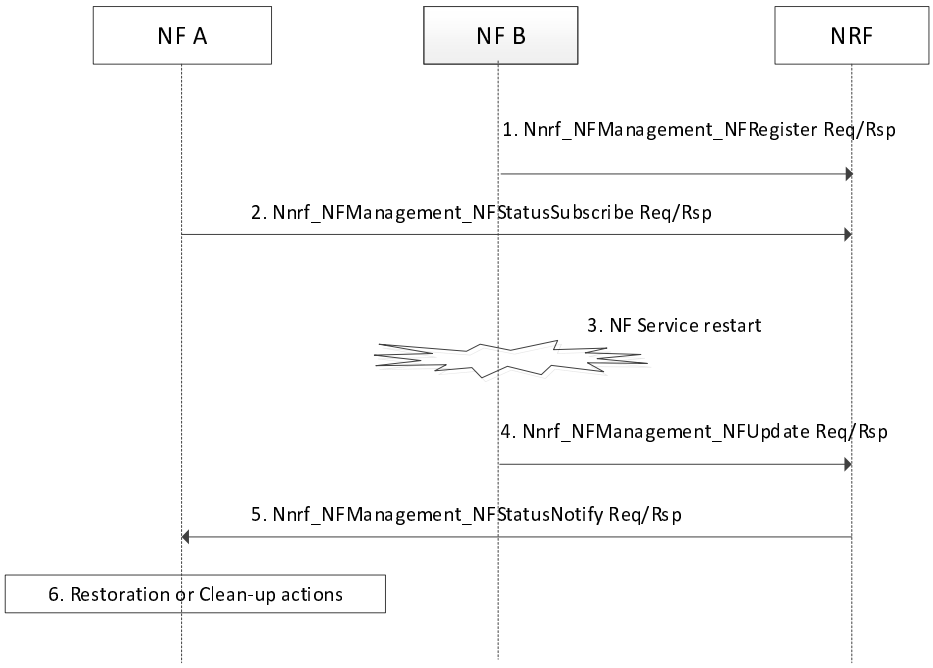

Figure 6.2.3-2: NF Service Restart Detection and Notification

1. NF B (or OAM) registers its NF B Profile (and its services) to the NRF. The NF B Profile may include the recoveryTime attribute for the NF Services it supports, if a restart of a NF B service results in losing contexts.

2 NF A subscribes to the NRF to receive notifications of changes of the NF B Profile.

3. A NF B service restarts.

4. If contexts are lost during the service restart, NF B (or OAM) updates the recoveryTime of the corresponding NF Service in the NRF.

5. The NRF notifies NFs having subscribed to receive notifications of changes of the NF B Profile about the updated recoveryTime of the NF B Service.

6. NF A may consider that all the resources created in the NF B service before the NF B service recovery time as have been lost. NF A triggers then appropriate restoration or clean-up actions.

Annex A (informative): Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2018-07	CT4#85bis	C4-185034				Initial Draft and skeleton.	0.0.2
2018-07	CT4#85bis	C4-185407				N4 Failure and Restart Detection, Restoration procedures for User Plane interfaces N3 and N9 Implementation of C4-185409, C4-185410, C4-185411, C4-185412, C4-185413, C4-185414, C4-185527	0.1.0
2018-08	CT4#86	C4-186509				Implementation of C4-186233, C4-186406, C4-186408, C4-186413, C4-186488	0.2.0
2018-09	CT#81	CP-182082				Presented for Information and approval	1.0.0
2018-09	CT#81					Approved in CT#81	15.0.0

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