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During the presentation of v.2.0.0 of 23.236 in tdoc SP-010508, it was decided that all references of Iu-flex used between CN nodes belonging to different operators shall be deleted, to fit to the scope and to the approved WID, as stressed in SP-010547.

This is done in this version 2.1.0.

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Foreword

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

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:

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Introduction

UMTS will build on the success of GSM and is likely to become even more widespread, increasing the importance of a flexible network structure which the different operational configurations in which these networks will be deployed. The requirements to have a RNC or BSC controlled by a single MSC server or SGSN lead to certain limitations. Allowing the BSCs and RNCs to connect to a number of MSC servers or SGSNs increases the networks performance in terms of scalability, distributing the network load amongst the serving entities, and reducing the required signalling as the user roams.

1 Scope

This document covers the details for the Intra Domain Connection of RAN Nodes to Multiple CN Nodes for GSM and UMTS systems. In particular, it details the impacts to GSM and UMTS systems and the stage 2 procedures for the support of connecting a RNC or BSC to multiple MSC servers or SGSNs. The overall solution is described, and the detailed impacts on the existing specifications are identified.

The reference model to which these procedures apply can be found within 3GPP TS 23.002 [1]. Detailed architectural requirements within the subsystems are contained within the remainder of the 23 series of specifications e.g. the requirements for the Packet Switched (PS) domain are contained within 3GPP TS 23.060 [2] and the requirements for the Bearer Independent CS Core Network are contained in 3GPP TS 23.205[14].

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.

This specification may contain references to pre-Release-4 GSM specifications. These references shall be taken to refer to the Release 5 version where that version exists. Conversion from the pre-Release-4 number to the Release 4 (onwards) number is given in subclause 6.1 of 3GPP TR 41.001.

[1] 3GPP TS 23.002: "Network Architecture".

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

[3] 3GPP TS 23.012: “Location management procedures”.

[5] 3GPP TS 25.331: “Radio Resource Control (RRC) Protocol Specification”.

[6] 3GPP TS 25.301: “Radio interface protocol architecture”.

[7] 3GPP TS 25.303: “UE functions and inter-layer procedures in connected mode”.

[8] 3GPP TR 21.905: "3G Vocabulary".

[9] 3GPP TS 25.413: “UTRAN Iu interface RANAP signalling”.

[10] 3GPP TS 25.410: “UTRAN Iu Interface: General Aspects and Principles”.

[11] 3GPP TS 23.228: “IP Multimedia Subsystem – Stage 2”.

[12] 3GPP TS 43.051: “GSM/EDGE Radio Access Network (GERAN) overall description (Stage 2)”.

[13] 3GPP TS 23.153: "Out of Band Transcoder Control - Stage 2".

[14] 3GPP TS 23.205: “Bearer Independent CS Core Network – Stage 2”.

[15] 3GPP TR 25.931: “ UTRAN Functions, examples on signalling procedures”.

[16] GSM 08.18: “General Packet Radio Service (GPRS);Base Station System (BSS) -Serving GPRS Support Node (SGSN); BSS GPRS Protocol (BSSGP):.

[17] 3GPP TS 48.008: “Mobile-services Switching Centre - Base Station System(MSC - BSS) interface; Layer 3 specification”.

[18] 3GPP TS 23.003: “Numbering, addressing and identification”.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms defined in 3GPP TR 21.905 [8] apply:

NAS node selection Function: The function used to assign specific network resources (i.e. MSC or SGSN) to serve a mobile station and subsequently route the traffic to the assigned network resource.

Network Resource Identifier A specific parameter used to identify the CN node assigned to serve a mobile station.

Pool-area: A pool area is an area within which a MS may roam without need to change the serving CN node. A pool area is served by one or more CN nodes in parallel. All the cells controlled by a RNC or BSC belong to the same one [or more] pool area[s].

RAN node service area: This area contains all the cells controlled by the RAN node (RNC or BSC).

3.2 Symbols

For the purposes of the present document, the following symbols apply:

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AS	Access Stratum
BSC	Base Station Controller
BVCI	BSSGP Virtual Connection Identifier
CN	Core Network
CS	Circuit Switched
CS-MGW	Circuit Switched Media Gateway
DNS	Directory Name Server
IDNNS	Intra Domain NAS Node Selector
LA	Location Area
LAI	Location Area Identity
MS	Mobile Station
MSC	Mobile Switching Centre
NAS	Non Access Stratum
NRI	Network Resource Identifier
O&M	Operation and Maintenance
PS	Packet Switched
RA	Routing Area
RAI	Routing Area Identity
RAN	Radio Access Network
RNC	Radio Network Controller

SRNS	Serving Radio Network Subsystem
TMSI	Temporary Mobile Station Identity
TLLI	Temporary Logical Link Identifier
UE	User Equipment

4 General Description

4.1 Iu Flex Technical Requirements

This provides a (non-exhaustive) set of technical requirements:

1. IuFlex capable RAN nodes such as the RNC/BSC should be able to select any CN node such as the SGSN/MSC-Server within a pool area
2. IuFlex capable RAN nodes and CN nodes should be able to co-exist with pre release-5 RAN nodes and pre release-5 CN nodes.
3. The network should provide the CN node routing information to the UE and the UE should store it.
4. During the initial non-access stratum signalling, the UE should provide to the RAN node the routing information for the current serving CN.
5. The solution shall enable the reduction of signalling within the core network (e.g reduction of the HLR signalling traffic).
6. The solution shall enable an improved scaling between radio access nodes and the core network nodes.

4.2 Overview

Note: Clarification is required in order to remove RAN nodes and CN node terminology and to capture that this is referring to the control signalling aspects.

The Intra Domain Connection of RAN Nodes to Multiple CN Nodes overcomes the strict hierarchy which restricts the connection of a RAN node to just one CN node. This restriction results from routing mechanisms in the RAN nodes which differentiate only between information to be sent to the PS or to the CS domain CN nodes and which do not differentiate between multiple CN node in each domain. The Intra Domain Connection of RAN Nodes to Multiple CN Nodes introduces a routing mechanism (and other related functionality), which enables the RAN nodes to route information to different CN nodes within the CS or PS domain, respectively.

The Intra Domain Connection of RAN Nodes to Multiple CN Nodes introduces further the concept of “pool-areas” which is enabled by the routing mechanism in the RAN nodes. A pool-area is comparable to an MSC or SGSN service area as a collection of one or more RAN node service areas. In difference to an MSC or SGSN service area a pool-area is served by multiple CN nodes (MSCs or SGSNs) in parallel which share the traffic of this area between each other. Furthermore, pool-areas may overlap which is not possible for MSC or SGSN service areas.

The Intra Domain Connection of RAN Nodes to Multiple CN Nodes enables a few different application scenarios with certain characteristics. The service provision by multiple CN nodes within a pool-area enlarges the served area compared to the service area of one CN node. This results in reduced inter CN

node updates, handovers and relocations and it reduces the HLR update traffic. The configuration of overlapping pool-areas allows to separate the overall traffic into different MS moving pattern, e.g. pool-areas where each covers a separate residential area and all the same city centre. Other advantages of multiple CN nodes in a pool-area are the possibility of capacity upgrades by additional CN nodes in the pool-area or the increased service availability as other CN nodes may provide services in case one CN node in the pool-area fails.

An MS is served by one dedicated CN node of a pool-area as long as it is in radio coverage of the pool-area. Figure 1 shows most of the possible pool-area configurations. It contains CS pool-area 1 (RAN area 1, 2, 5, 6 served by MSCs 1, 2, 3), CS pool-areas 2 (RAN area 2, 3, 6, 7 served by MSCs 4, 5, 6), PS pool-area 1 (RAN area 1, 5 served by SGSNs 1, 2) and PS pool-area 2 (RAN area 2, 3, 6, 7 served by SGSNs 3, 4, 5). In addition the RAN areas 4 and 8 are served by MSC 7 and SGSN 6 without any usage of the Intra Domain Connection of RAN Nodes to Multiple CN Nodes. The possibility to configure overlapping pool-areas is shown by the CS pool-areas 1 and 2. The PS pool-areas 1 and 2 are configured non-overlapping. The pool-areas of the CS and the PS domain may be configured identical as CS pool-area 2 and PS pool-area 2 or they may be configured differently as shown by CS pool-area 1 and PS pool-area 1. The number or capacity of CN nodes is configured independently for each pool-area. The usage of the Intra Domain Connection of RAN Nodes to Multiple CN Nodes may be configured in parts of the network only. It co-exists with other areas not using this feature as shown in the figure with RAN areas 4 and 8 which are served by MSC 7 and SGSN 6.

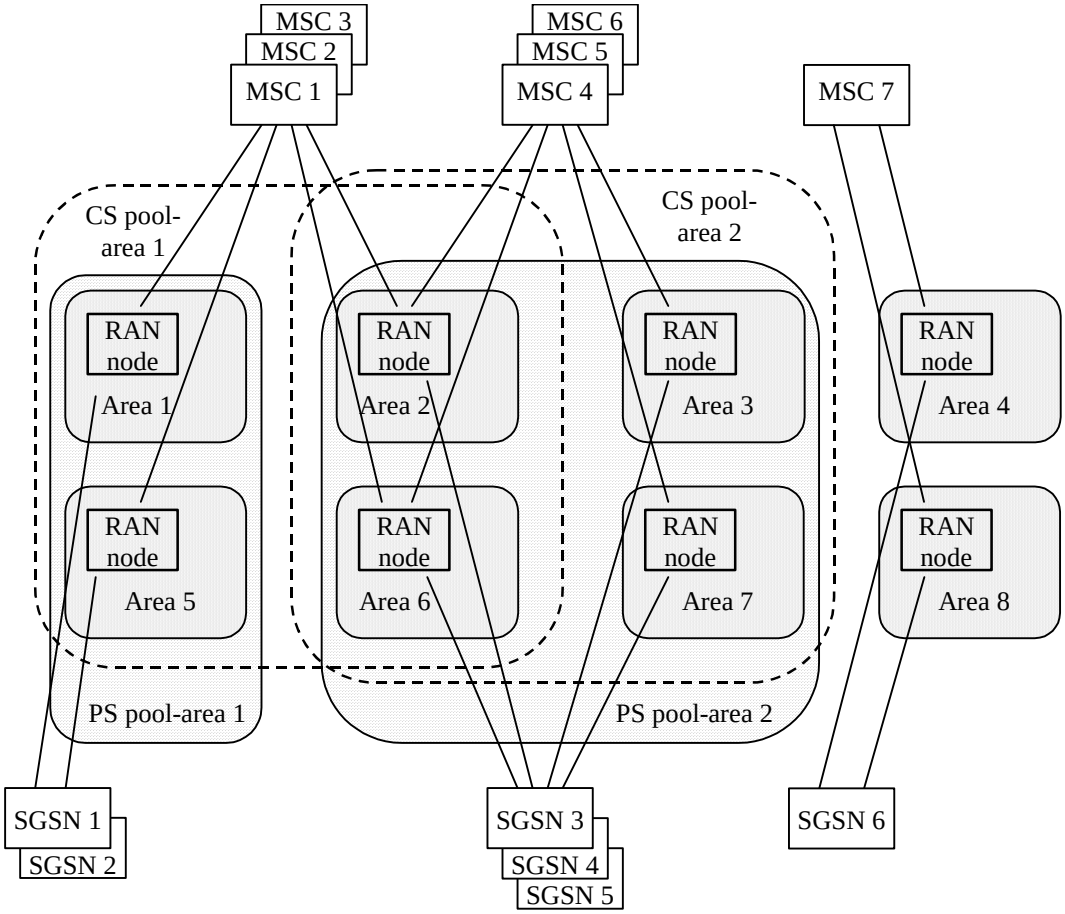


Figure 1: Pool-area configuration example

4.3 Pool-Area and Network Resource Identification

A pool-area is an area within which an MS may roam without a need to change the serving CN node. A pool-area is served by one or more CN nodes in parallel. The complete service area of a RAN node (RNC

or BSC) belongs to the same one or more pool-area(s). A RAN node service area may belong to multiple pool-areas, which is the case when multiple overlapping pool-areas include this RAN node service area. The pool-areas of the CS and of the PS domain are configured independently with the granularity of RAN node service areas. Therefore, all uniqueness statements below apply to each of the domains (CS/PS) separately. If LAs or RAs span over multiple RAN node service areas then all these RAN node service areas have to belong to the same pool-area.

The Network Resource Identifier (NRI) identifies uniquely an individual CN node out of all CN nodes which serve in parallel a pool-area. In areas where pool-areas overlap the NRI identifies uniquely a CN node out of all CN node which serve all these overlapping pool-areas, i.e. an NRI identifies uniquely a CN node within a RAN node. Note again, that the NRIs of the CS and the PS domain are independent of each other as the PS and the CS domain CN nodes are addressed independently. More than one NRI may be assigned to a CN node.

The NRI is part of the temporary identity TMSI (CS domain) or P-TMSI (PS domain) which is assigned by the serving CN node to the MS. Each CN node which support the "Intra Domain Connection of RAN Nodes to Multiple CN Nodes" is configured with its specific one or more NRI(s). The (P-)TMSI allocation mechanism in the CN node generates (P-)TMSIs which contain a configured NRI in the relevant bit positions. The NRI has a flexible length between 10 and 0 bits (0 bits means the NRI is not used and the feature is not applied).

In Iu mode the MS provides an Intra Domain NAS Node Selector (IDNNS) [5] in the AS part of the RRC-Initial-direct-transfer message to the RAN node (RNC or BSC). The IDNNS contains a routing parameter with a fixed length of 10 bits. This routing parameter transports the NRI value. In addition the IDNNS contains an indication from which identity (TMSI, IMSI, IMEI, ...) the routing parameter is derived. The RAN node masks the significant bits out of the routing parameter part of the IDNNS to determine the NRI which is relevant to identify the CN node.

In A/Gb-mode for the A interface the RAN node derives the NRI from any initial NAS signalling message. The RAN node masks the significant bits out of the TMSI to determine the NRI which identifies the CN node. In A/Gb-mode for the Gb interface the RAN node derives the NRI from the TLLI. The RAN node masks the significant bits out of the TLLI to determine the NRI which identifies the CN node. For all three cases, Iu, A interface and Gb mode, it is configured in the RAN node which bits out of the information elements provided by the MS are significant for the NRI.

The whole network may be configured as one pool-area, a network may configure multiple pool-areas and the configuration of pool-areas may be combined with MSC or SGSN service areas which are not belonging to pool-areas. The change of a pool-area is not visible to the MS. In general there is no need to detect a pool-area change. It may be advantageous for load balancing purposes to detect pool-area changes in the network to distribute MSs entering a pool-area to CN nodes with an appropriate load status. MSs changing a pool-area may be detected by configuration of different NRI values for adjacent pool-areas. The pool-area change information potentially provided in the IDNNS by an MS in Iu mode is ignored by the network.

4.4 NAS Node Selection Function

This function is used in RAN nodes and potentially in CN nodes. In the RAN node the function selects the specific CN node (i.e. MSC or SGSN) to which initial NAS signalling messages or LLC frames are routed. The NRI identifies the specific CN node. If the NAS Node Selection Function has a CN node address configured for the NRI derived from the initial NAS signalling message or from the LLC frame then this message or frame is routed to this address. If no CN node address is configured for the derived NRI or if no NRI can be derived (e.g. the MS indicated an identity which contains no NRI) then the NAS Node Selection Function selects an available CN node (e.g. according to load balancing) and routes the message or LLC frame to the selected CN node.

The pool-area has no influence on the decisions of the NAS Node Selection Function as pool-areas may overlap. The NAS Node Selection Function in the RAN node derives the NRI from the IDNNS when the MS is supported in Iu mode. When the MS is supported in Gb mode the NRI is derived from the TLLI and for A interface mode the NRI is derived from the TMSI.

In case a MSC/VLR sends a paging-request/paging with IMSI, the NAS node selection function in the BSC/RNC shall upon reception temporarily store the MSC/VLR-identity of the node that issued the

paging-request/paging message. If the MSC/VLR initiates the paging procedure via Gs-interface the SGSN has to add the MSC/VLR-identity to the paging-request/paging message.

If the NAS node selection function receives a paging-response with an IMSI then it should check the temporarily stored MSC/VLR-identities on entries matching this IMSI and forward the paging-response to the node identified by this MSC/VLR-identity.

An MS will return an Attach Request containing the IMSI parameter as a response to a PS IMSI paging. Also, a PS IMSI paging is not time supervised from the SGSN sending the message. Therefore the RAN node receiving such a paging request does not have to buffer the associated SGSN identity. This again means that the NAS Node Selection Function in the RAN node selects an available SGSN (e.g. according to load balancing) when it receives an Attach Request containing the IMSI parameter.

4.5 Load Balancing

Preferably, the NAS Node Selection Function in the RAN node balances the load between the available CN nodes. This is performed by an appropriate selection of the CN node for an MS which was not yet assigned to a CN node, i.e. when there is no CN node configured for the NRI indicated by the MS, when no NRI can be derived or in exceptional cases, e.g. when the CN node corresponding to an NRI cannot be reached. The load-balancing algorithm is implementation specific.

In case of handover/relocation a load balancing between the CN nodes serving the same pool-area is gained by configuration. For each of the handover/relocation targets in a pool-area another CN node is configured as the target CN node. CN nodes which do not support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes configure only one CN node per handover/relocation target. CN nodes which do support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes may improve the availability by configuring multiple target CN nodes for each handover/relocation target in a pool-area. The mechanism for distribution of the traffic between the handover target CN nodes is implementation specific. This load balancing is complemented by the NAS Node selection Function in the RAN, which distributes MSs between the CN nodes when these MSs enter the pool-area in idle mode.

As more than one SGSN may send downlink data at the same time for a cell or a BVCI the total possible downlink traffic has to shared between the SGSNs as described in chapter 5.3.2 “Gb mode”.

4.6 Mobility Management

An MS performs LA or RA Updates and Attachments, which may result in a change of the serving CN node. In these procedures the new CN node requests from the old CN node MS specific parameters. If multiple CN nodes are configured in the new CN node for the old RA or LA indicated by the MS then the new CN node derives the NRI from the old (P-)TMSI indicated by the MS. The new CN node uses the old RA or LA together with the NRI to derive the signalling address of the old CN node from its configuration data. If the network contains nodes that cannot derive the old CN node from LAI/RAI and NRI a default CN node for each RA or LA (as described below) shall be used to resolve the ambiguity of the multiple CN nodes serving the same area.

4.7 Default CN node and Backwards Compatibility

CN nodes that can only derive one CN node from the LAI or RAI (e.g. because they do not support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes, or no detailed knowledge of the NRIs is configured) are not aware, that multiple CN nodes may serve a LA or RA. These nodes can therefore contact only one CN node per LA or RA, respectively. This node will further on be referred to as default node.

A default node that supports the Intra Domain Connection of RAN Nodes to Multiple CN nodes resolves the ambiguity of the multiple CN nodes per LA or RA by deriving the NRI from the TMSI and P-TMSI. The default node relays the signalling between the new CN node and the old CN node.

Note that the default node is configured per LA or RA. So different CN nodes in a network might have configured different default nodes for a LA or RA. With this approach more than one of the CN nodes that serve a pool-area can be used as default-node, so load concentration on one node and a single point of failure can be avoided.

Note further, that it may be required to keep information on ongoing MAP/GTP dialogues in the default nodes.

The handover/relocation from CN nodes which do support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes to CN nodes not supporting this features does not need a NAS Node Selection Function in the originating CN node as there is only one target CN node. The originating CN node discovers from its configuration data, that there is only one target CN node for the requested handover/relocation target ID.

4.8 Support of combined mobility management procedures

Attach

In case of 'combined GPRS/IMSI attach' or 'GPRS attach when already IMSI attached', the SGSN sends the Location Update Request message to the MSC/VLR. The SGSN selects an MSC/VLR from the available MSC/VLRs which serve the current LA of the MS. The selection bases on a hash value derived from the IMSI. It is configured in the SGSN which range of the hash values relates to which MSC/VLR. This selection mechanism avoids a random change of the MSC/VLR for MSs using combined procedures when an SGSN fails. The new SGSN will select the same MSC/VLR.

Routing area update

The CN node changes in the following considerations result from pool-area changes (when pool-areas are configured) or from CN node service area changes (when no pool-areas are configured). For each domain (PS or CS) it is configured independently whether pool-areas are used or not.

When neither the MSC nor the SGSN are changed, the association for an MS between both CN nodes will also not change.

When the MSC changes but the SGSN does not change, the SGSN selects a new MSC because the new LA is not served by the old MSC/VLR. The selection mechanism is as described for the attach above.

When the SGSN changes but the MSC does not change, the new SGSN selects the old MSC to establish a Gs association because the new SGSN uses the same selection mechanism as described above for the attach with the same parameters as configured in the old SGSN.

When both the MSC and the SGSN change, the new SGSN selects a new MSC to establish a Gs association. The selection mechanism is as described for the attach above.

5 Functional Description

5.1 MS Functions

In Iu mode the MS provides the IDNNS to the RNC in the access stratum part of the *RRC_initial_DT* message as described in [5].

No changes are expected in the MS for Gb or A interface mode.

5.2 RNC Functions

The RNC provides the NAS Node Selection Function. It masks the significant number of bits out of the IDNNS provided by the MS together with the initial NAS signalling message. The significant number of bits is configured in the RNC. The NAS Node Selection Function derives from the NRI the address of the specific CN node for the relevant domain (CS or PS). The association between NRI values and CN node addresses is configured in the RNC (O&M).

The RNC routes the initial NAS signalling messages according to the NRI and the “domain indicator” (CS or PS) to the relevant CN node if a CN node address is configured in the RNC for the specific NRI and the requested domain (CS or PS).

If no CN node address is configured in the RNC for the requested NRI or if the provided identity contains no NRI then the RNC routes the initial NAS signalling message to a CN node selected from the available CN nodes which serve the related domain (CS or PS). The selection mechanism is implementation dependent and should enable load balancing between the available CN nodes.

In case a MSC sends a paging with IMSI, the RNC shall upon reception temporarily store the MSC/VLR-identity of the node that issued the paging message. If the MSC/VLR initiates the paging procedure via Gs-interface the SGSN has to add the MSC/VLR-identity to the paging message.

5.3 BSC Functions

5.3.1 A interface mode

The BSC provides the NAS Node Selection Function. It is aware whenever a new RR connection is established. In particular, the BSC always examines the content of the Initial Layer 3 message sent by the MS in order to determine the position of the MS Classmark and to extract its contents. The examination of the Initial Layer 3 message content allows the BSC to observe the TMSI+LAI or IMSI or IMEI.

The BSC derives from Initial Layer 3 messages the NRI from the TMSI. It is configured in the BSC (O&M) which bits of the TMSI are significant for the NRI. The BSC routes the Initial Layer 3 message according to the NRI to the relevant MSC if an MSC address is configured in the BSC for the specific NRI. The association between NRI values and MSC addresses is configured in the BSC (O&M).

If no MSC address is configured in the BSC for the requested NRI or if no TMSI is sent by the MS (e.g. an IMSI or IMEI) then the BSC routes the initial NAS signalling message to an MSC selected from the available MSCs. In addition, the BSC may route the initial NAS signalling message to an MSC selected from the available MSCs if this message is a Location Update Request messages and the PLMN ID in the LAI is not one of the PLMN IDs served by the BSC (FFS). The selection mechanism is implementation dependent and should enable load balancing between the available MSCs.

In case a MSC sends a paging-request with IMSI, the NAS node selection function in the BSC shall upon reception temporarily store the MSC/VLR-identity of the node that issued the paging-request message.

5.3.2 Gb mode

The BSC provides the NAS Node Selection Function. The MS sends the TLLI to the BSC. The NRI is part of the P-TMSI and therefore also contained in the 'local TLLI' or in the 'foreign TLLI'. The number of bits out of the TLLI which are significant for the NRI is configured in the BSC (O&M).

A 'local TLLI' indicates to the BSC that the TLLI is derived from a P-TMSI which was assigned for the current RA, i.e. the 'local TLLI' contains an NRI which is valid for routing to an SGSN. A 'foreign TLLI'

indicates to the BSC that the TLLI is derived from a P-TMSI which was assigned for another RA than the current RA. The BSC does not know whether the other RA and therefore the related P-TMSI belongs to the same pool-area or not unless this is configured in the BSC (which is not intended). Consequently, the BSC assumes, that the 'foreign TLLI' contains a NRI which is valid for routing to an SGSN.

For 'local TLLIs' and for 'foreign TLLIs' the BSC masks the NRI out of the TLLI which is indicated in each LLC frame. The BSC routes the uplink LLC frame to the relevant SGSN if an SGSN address is configured in the BSC for the specific NRI. The association between NRI values and SGSN addresses is configured in the BSC (O&M).

If no SGSN address is configured in the BSC for the requested NRI, which may happen for NRIs masked out of a 'foreign TLLI', or if the BSC received a 'random TLLI' which contains no NRI at all then the RNC routes the uplink LLC frame to an SGSN selected from the available SGSNs. The selection mechanism is implementation dependent and should enable load balancing between the available SGSNs.

Note: For the selection mechanism in the BSC it is probably sufficient, that the algorithm is ‘slow moving’. If the selection algorithm changes the SGSN to be assigned for 'random TLLIs' or for ’foreign TLLIs’ whose NRI value is not used in the current SGSN pool area during a MS’s Attach procedure or RA update procedure, then the Attach procedure or RA update procedure is likely to fail, but the MS will reattempt the procedure at T3310/T3330 expiry (=15 seconds).

As more than one SGSN may send downlink data at the same time for a cell or a BVCI, the BSC has to share the total possible downlink traffic between the SGSNs that can access a cell. The BSC should use the existing flow control procedure on cell level to control each of the SGSNs in a way not to violate the total possible traffic for the cell. How the BSC decides to share the downlink traffic between each of the SGSNs is an implementation specific issue; e.g. the possible downlink traffic can be equally shared between the SGSNs, or the share of each SGSN can be proportional to the capacity of the SGSN. In case a MSC sends a paging-request with IMSI via Gs-interface the SGSN has to add the MSC/VLR-identity to the paging-request message. The NAS node selection function in the BSC/RNC shall upon reception temporarily store the MSC/VLR-identity.

5.3.3 Iu mode

To support MSs in Iu mode the BSC provides the same functionality as described under "RNC Functions".

5.4 MSC Functions

TMSI Allocation

Every MSC is configured with its one or more specific NRI (O&M). One of these specific NRIs is part of every temporary identity (TMSI) which the MSC assigns to an MS. The TMSI allocation mechanism in the MSC generates TMSIs which contain one of the specific NRIs in the relevant bit positions. An NRI has a flexible length between 10 and 0 bits (0 bits means the NRI is not used and the feature is not applied). The use of the bits not used to encode the NRI is implementation dependent (e.g. to extent the TMSI space).

Mobility Management and Handover/Relocation

For MAP signalling between two MSCs which both support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes the new MSC derives the address of the old MSC from the old LAI and the NRI contained in the old TMSI. The MSC addresses for each LAI and NRI combination are configured in the MSC (O&M). If the network contains MSCs that cannot derive the old MSC from LAI and NRI the default MSC per LAI as described below shall be used (e.g. to reduce the configuration effort). Some redundancy may be required as the default MSC is a single point of failure.

The load balancing between multiple target MSCs at handover/relocation into a pool area is described in "Load Balancing". The handover/relocation from an MSC that supports the Intra Domain Connection of

RAN Nodes to Multiple CN Nodes to an MSC not supporting the feature needs no new functionality, as there is only one MSC that serves the handover/relocation target.

Backward Compatibility and Default MSC

If a default MSC that is serving a pool-area receives MAP signalling (e.g. to fetch the IMSI or to get unused cipher parameters) it has to resolve the ambiguity of the multiple MSCs per LAI by deriving the NRI from the TMSI. The MSC relays the MAP signalling to the old MSC identified by the NRI in the old TMSI unless the default MSC itself is the old MSC. For every NRI value that is used in the pool-area an MSC address is configured in the default MSC (O&M).

Note, that it might be required to keep information on ongoing MAP dialogues in the default MSC.

Support of Combined Procedures

If the SGSN does not support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes then only one default out of the MSCs serving the related LA can be used for the combined procedures. A relaying or diverting from the default MSC to another is FFS. Distributing the associations of the combined procedures according to the LAs would result in MSC changes when the MS is still in the old MSC service area.

5.5 SGSN Functions

P-TMSI Allocation

Every SGSN is configured with its specific one or more NRI (O&M). One of these specific NRIs is part of every temporary identity (P-TMSI) which the SGSN assigns to an MS. The P-TMSI allocation mechanism in the SGSN generates P-TMSIs which contain one of the specific NRIs in the relevant bit positions. An NRI has a flexible length between 10 and 0 bits (0 bits means the NRI is not used and the feature is not applied). The use of the bits not used to encode the NRI is implementation dependent (e.g. to extent the TMSI space).

Mobility Management and Handover/Relocation

For the GTP signalling between two SGSNs supporting the Intra Domain Connection of RAN Nodes to Multiple CN Nodes the new SGSN derives the address of the old SGSN from the old RAI and the NRI contained in the old P-TMSI/TLLI. The SGSN addresses are configured in the SGSN (O&M) or in DNS for each RAI and NRI combination. If the network contains SGSNs that cannot derive the old SGSN from RAI and NRI the default SGSN per RAI as described below shall be used (e.g. to reduce the configuration effort).

The load balancing between multiple target SGSNs at handover/relocation into a pool area is described in "Load Balancing". The handover/relocation from an SGSN that supports the Intra Domain Connection of RAN Nodes to Multiple CN Nodes to an SGSN not supporting the feature needs no new functionality, as there is only one SGSN that serves the handover/relocation target.

Backward Compatibility and Default SGSN

If a default SGSN that is serving a pool-area receives GTP signalling (e.g. to fetch the IMSI or to get unused cipher parameters) it has to resolve the ambiguity of the multiple SGSNs per RAI by deriving the NRI from the P-TMSI. The SGSN relays the GTP signalling to the old SGSN identified by the NRI in the old P-TMSI unless the default SGSN itself is the old SGSN. For every NRI value that is used in the pool-area an SGSN address is configured in the relaying SGSN (O&M) or in DNS.

Note, that it might be required to keep information on ongoing GTP dialogues in the default SGSN.

Support of Combined Procedures

The SGSN has to select an MSC at the Gs interface for the combined procedures if multiple MSCs are configured for the relevant LAI. Preferably, the MSC out of the available MSCs is selected based on the IMSI. This prevents an MSC change for many MSs if an SGSN fails and the re-attaching MSs would get assigned another MSC by the new SGSN. Two HLR updates instead of one would be the result. In addition the SGSN may perform load balancing at the Gs interface if this is required as the load balancing at the RAN - CN interface might be sufficient if not all MSs are attached to PS and CS (FFS).

Note, that the algorithm based on which the SGSN derives the MSC from the IMSI needs to be unique in all SGSNs and therefore should be standardized.

CS Paging

If a CS paging is received via the Gs interface from MSC with mobile identity type IMSI then the SGSN should include the MSC/VLR-id in the paging / paging-request message to RNC/BSC.

6 Application Examples

This clause describes some application examples for networks using the intra domain NAS node selection. In these examples, pool-areas are depicted by boxes or ellipses, while the core network elements which serve the pool-areas are depicted by the NRIs they have been assigned.

6.1 Network configuration example 1

This example configures 9 pool-areas each with 3 CN nodes serving within a pool-area. When a MS moves from one (NRI:1,2,3) to another pool-area (NRI:4,5,6). It indicates the old NRI (3) derived from its old TMSI to the RNC in the new pool-area (NRI:4,5,6). This NRI 3 is not configured in the RNC of the pool-area (NRI:4,5,6). The RNC selects a CN node out of the available NRIs 4,5,6 and establishes the signalling connection for the MS with the selected CN node. This new CN nodes allocates a new TMSI to the MS and thereby the new NRI for the new pool-area.

In this example, the NRIs can be re-used in a pattern where adjacent pool areas do not use the same NRI. Every pool area change will initiate a new selection of a new CN node.

NRI: 19, 20, 21	NRI: 22, 23, 24	NRI: 25, 26, 27
NRI: 16, 17, 18	NRI: 1, 2, 3	NRI: 4, 5, 6
NRI: 13, 14, 15	NRI: 10, 11, 12	NRI: 7, 8, 9

Figure 2: Network configuration example 1

6.2 Network configuration example 2

This example shows a network covering one city centre surrounded by residential areas. The city centre is covered by all 4 pool-areas while each of the residential areas is covered by one pool-area only. Once a MS „found“ its pool-area, it will not change the pool-area while commuting between the city centre and its residential area. Each of the pool-areas is served by 5 MSCs, indicated by the 5 NRI values in the figure below, which share the load within the pool-area. Only distinct NRI values are used for the overlapping pool-areas. Therefore, a MS changing between these pool-areas will always be allocated to a new MSC by the NAS node selection function. In addition it is shown, that the NRIs can be re-used in other pool-areas as indicated in the figure by the smaller areas with only one NRI. Also at a change to these areas the MSs will always be allocated to a new MSC by the NAS node selection function as adjacent areas do not use the same NRI values.

A calculation for the possible number of subscribers in this scenario is in Annex A.1: One city centre surrounded by residential areas

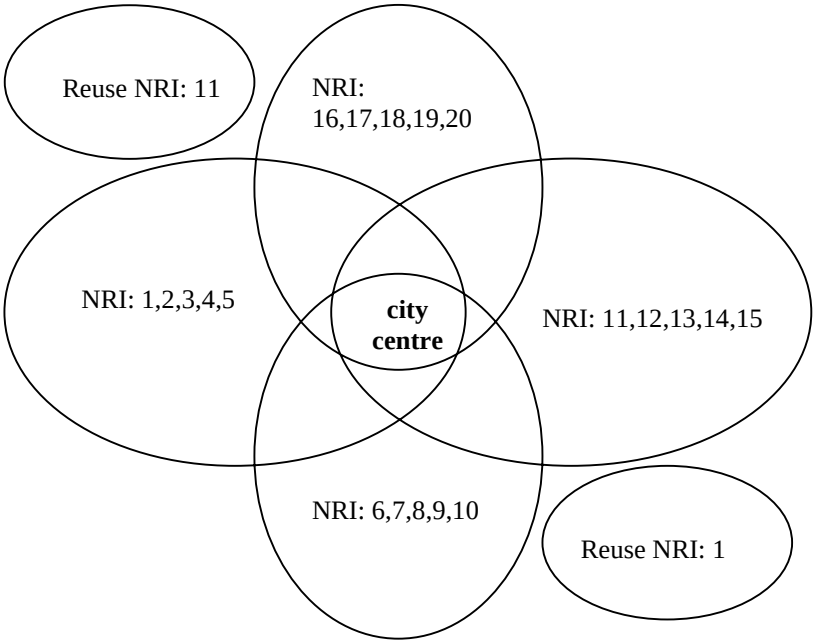


Figure 3: Network configuration example 3

7 Specific Examples

This chapter describes specific examples of IuFlex. First, building blocks of IuFlex are described in 7.1. These building blocks are then used in signalling flows starting from 7.2.

The changes to the signalling flows are indicated in *italic.*

7.1 Building blocks for signalling flows

7.1.1 RAN node selecting CN node in A interface mode

7.1.2 RAN node selecting CN node in Gb interface mode

7.1.3 RAN node selecting CN node in Iu interface mode

7.1.4 New CN node selecting old CN node

This building block describes how a new CN node selects the old CN node which was previously serving the MS. The new CN node has been allocated to serve the MS, and it may have to communicate with the old CN node e.g. in order to get IMSI of the MS or to get MM and PDP contexts of the MS.

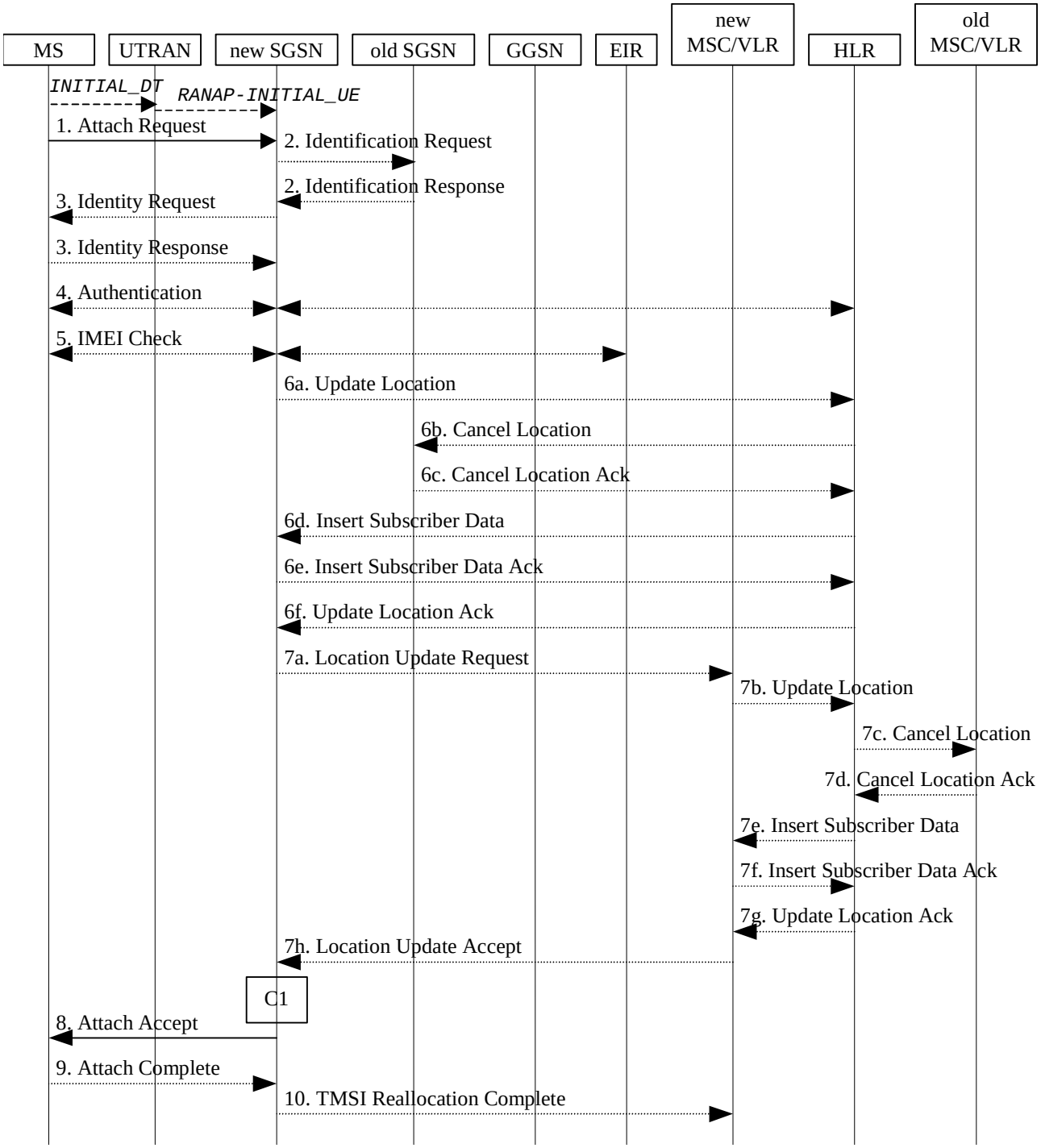
7.1.5 Old CN node selecting new CN node

This building block describes how the old CN node selects a new CN node which starts to serve the MS. The old CN node has to select a new CN node e.g. when performing handover.

7.1.6 SGSN selecting MSC

7.2 Signalling flow for Attach (Iu interface mode)

At attach, the RNC selects an SGSN to serve the MS. The attach procedure is shown in the figure below.



1) The Attach Request (old P-TMSI, old RAI, old P-TMSI Signature) is carried in the Initial Direct Transfer message (RRC) from the MS to the RNC. The RNC selects an SGSN to serve the MS as described in 7.1.3 and relays the Attach Request to the SGSN in the Initial UE message (RANAP).

2) If the MS identifies itself with P-TMSI and the SGSN has changed since detach, the new SGSN sends an Identification Request (P-TMSI, old RAI, old P-TMSI Signature) to the old SGSN to request the IMSI. *The new SGSN selects the old SGSN as described in 7.1.4.* The old SGSN responds with Identification Response (IMSI, Authentication Triplets (for GPRS) or Authentication Vectors (for UMTS)). If the MS is not known in the old SGSN, the old SGSN responds with an appropriate error cause. The old SGSN also validates the old P-TMSI Signature and responds with an appropriate error cause if it does not match the value stored in the old SGSN.

3) If the MS is unknown in both the old and new SGSN, the SGSN sends an Identity Request (Identity Type = IMSI) to the MS. The MS responds with Identity Response (IMSI).

4) The authentication functions are defined in the subclause "Security Function" of 23.060. If no MM context for the MS exists anywhere in the network, then authentication is mandatory. Ciphering procedures are described in subclause "Security Function" of 23.060. If P-TMSI allocation is going to be done and the network supports ciphering, the network shall set the ciphering mode.

5) The equipment checking functions are defined in the subclause "Identity Check Procedures" of 23.060. Equipment checking is optional.

6) If the SGSN number has changed since the GPRS detach, or if it is the very first attach, then the SGSN informs the HLR:

   a) The SGSN sends an Update Location (SGSN Number, SGSN Address, IMSI) to the HLR.

   b) The HLR sends Cancel Location (IMSI, Cancellation Type) to the old SGSN with Cancellation Type set to Update Procedure.

   c) The old SGSN acknowledges with Cancel Location Ack (IMSI). If there are any ongoing procedures for that MS, the old SGSN shall wait until these procedures are finished before removing the MM and PDP contexts.

   d) The HLR sends Insert Subscriber Data (IMSI, GPRS Subscription Data) to the new SGSN.

   e) The new SGSN validates the MS's presence in the (new) RA. If due to regional subscription restrictions the MS is not allowed to attach in the RA, the SGSN rejects the Attach Request with an appropriate cause, and may return an Insert Subscriber Data Ack (IMSI, SGSN Area Restricted) message to the HLR. If subscription checking fails for other reasons, the SGSN rejects the Attach Request with an appropriate cause and returns an Insert Subscriber Data Ack (IMSI, Cause) message to the HLR. If all checks are successful then the SGSN constructs an MM context for the MS and returns an Insert Subscriber Data Ack (IMSI) message to the HLR.

   f) The HLR acknowledges the Update Location message by sending an Update Location Ack to the SGSN after the cancelling of old MM context and insertion of new MM context are finished. If the Update Location is rejected by the HLR, the SGSN rejects the Attach Request from the MS with an appropriate cause.

7) If Attach Type in step 1 indicated GPRS Attach while already IMSI attached, or combined GPRS / IMSI attached, then the VLR shall be updated if the Gs interface is installed. *The VLR number is determined as described in 7.1.6.* The SGSN starts the location update procedure towards the new MSC/VLR upon receipt of the first Insert Subscriber Data message from the HLR in step 6d). This operation marks the MS as GPRS-attached in the VLR.

   a) The SGSN sends a Location Update Request (new LAI, IMSI, SGSN Number, Location Update Type) message to the VLR. Location Update Type shall indicate IMSI attach if Attach Type indicated combined GPRS / IMSI attach. Otherwise, Location Update Type shall indicate normal location update. The VLR creates an association with the SGSN by storing SGSN Number.

   b) If the LA update is inter-MSC, the new VLR sends Update Location (IMSI, new VLR) to the HLR.

   c) If the LA update is inter-MSC, the HLR sends a Cancel Location (IMSI) to the old VLR.

   d) The old VLR acknowledges with Cancel Location Ack (IMSI).

   e) If the LA update is inter-MSC, the HLR sends Insert Subscriber Data (IMSI, GSM subscriber data) to the new VLR.

   f) The VLR acknowledges with Insert Subscriber Data Ack (IMSI).

   g) After finishing the inter-MSC location update procedures, the HLR responds with Update Location Ack (IMSI) to the new VLR.

   h) The VLR responds with Location Update Accept (VLR TMSI) to the SGSN*. An IuFlex aware VLR includes one of its (CS-)NRIs as part of VLR TMSI. The SGSN creates an association with the VLR by storing VLR number.*

8) The SGSN selects Radio Priority SMS, and sends an Attach Accept (P-TMSI, VLR TMSI, P-TMSI Signature, Radio Priority SMS) message to the MS. P-TMSI is included if the SGSN allocates a new P-TMSI. *An IuFlex aware SGSN includes one of its (PS-)NRIs as part of P-TMSI.*

9) If P-TMSI or VLR TMSI was changed, the MS acknowledges the received TMSI(s) by returning an Attach Complete message to the SGSN.

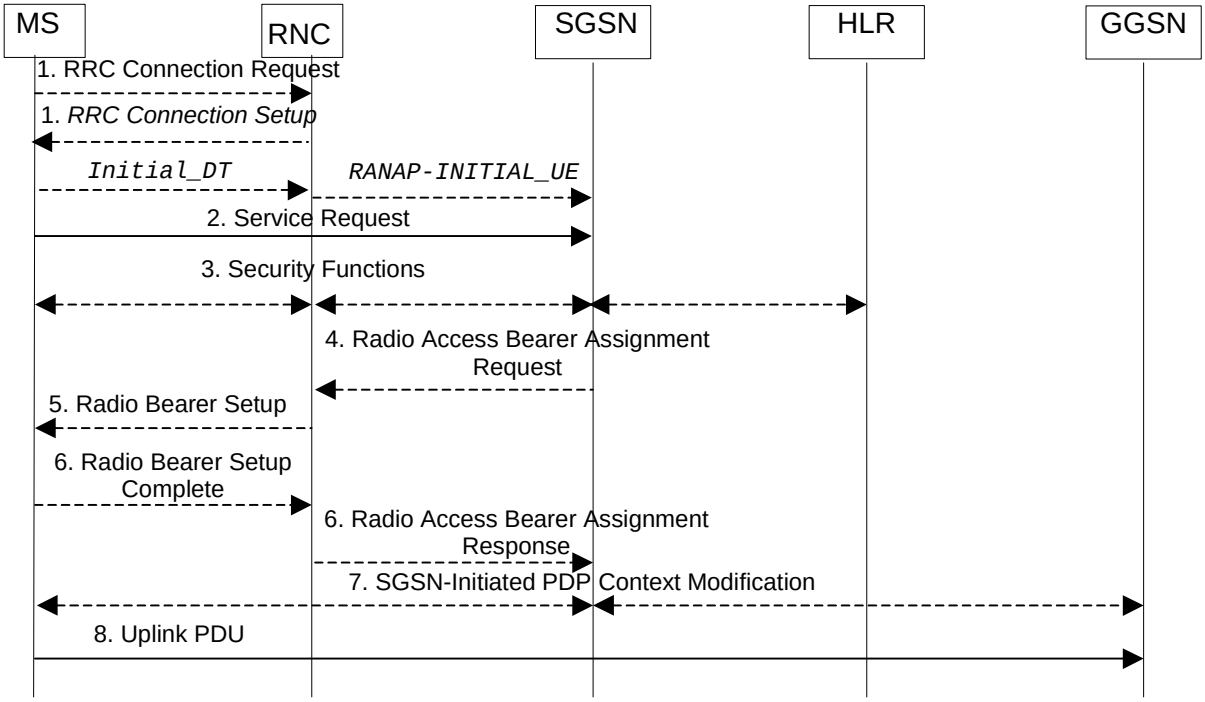
10) If VLR TMSI was changed, the SGSN confirms the VLR TMSI re-allocation by sending a TMSI Reallocation Complete message to the VLR.

7.3 Signalling flows for Service Request (Iu interface mode)

When performing service request, the signalling connection between the MS and the SGSN is re-established.

7.3.1 Service Request initiated by MS

The service request procedure initiated by the MS is shown in the figure below.



1) The MS establishes an RRC connection, if none exists for CS traffic.

2) The MS sends a Service Request (P-TMSI, RAI, CKSN, Service Type) message to the SGSN. Service Type specifies the requested service. Service Type shall indicate one of the following: Data or Signalling. *The Service Request is carried in the Initial Direct Transfer message (RRC) from the MS to the RNC. The RNC selects an SGSN to serve the MS as described in 7.1.3 and relays the Service Request to the SGSN in the Initial UE message (RANAP).* At this point, the SGSN may perform the authentication procedure.

   If Service Type indicates Data, a signalling connection is established between the MS and the SGSN, and resources for active PDP context(s) are allocated, i.e., RAB establishment for the activated PDP context(s).

If Service Type indicates Signalling, the signalling connection is established between the MS and the SGSN for sending upper-layer signalling messages, e.g., Activate PDP Context Request. The resources for active PDP context(s) are not allocated.

3) The SGSN shall perform the security functions if the MS in PMM-IDLE state initiated the service request.

4) If the network is in PMM-CONNECTED state and the Service Type indicates Data, the SGSN shall respond with a Service Accept message towards the MS, in case the service request can be accepted. In case Service Type indicates Data, the SGSN sends a Radio Access Bearer Assignment Request (NSAPIRAB ID(s), TEID(s), QoS Profile(s), SGSN IP Address(es)) message to re-establish radio access bearer for every activated PDP context.

5) The RNC indicates to the MS the new Radio Bearer Identity established and the corresponding RAB ID with the RRC radio bearer setup procedure.

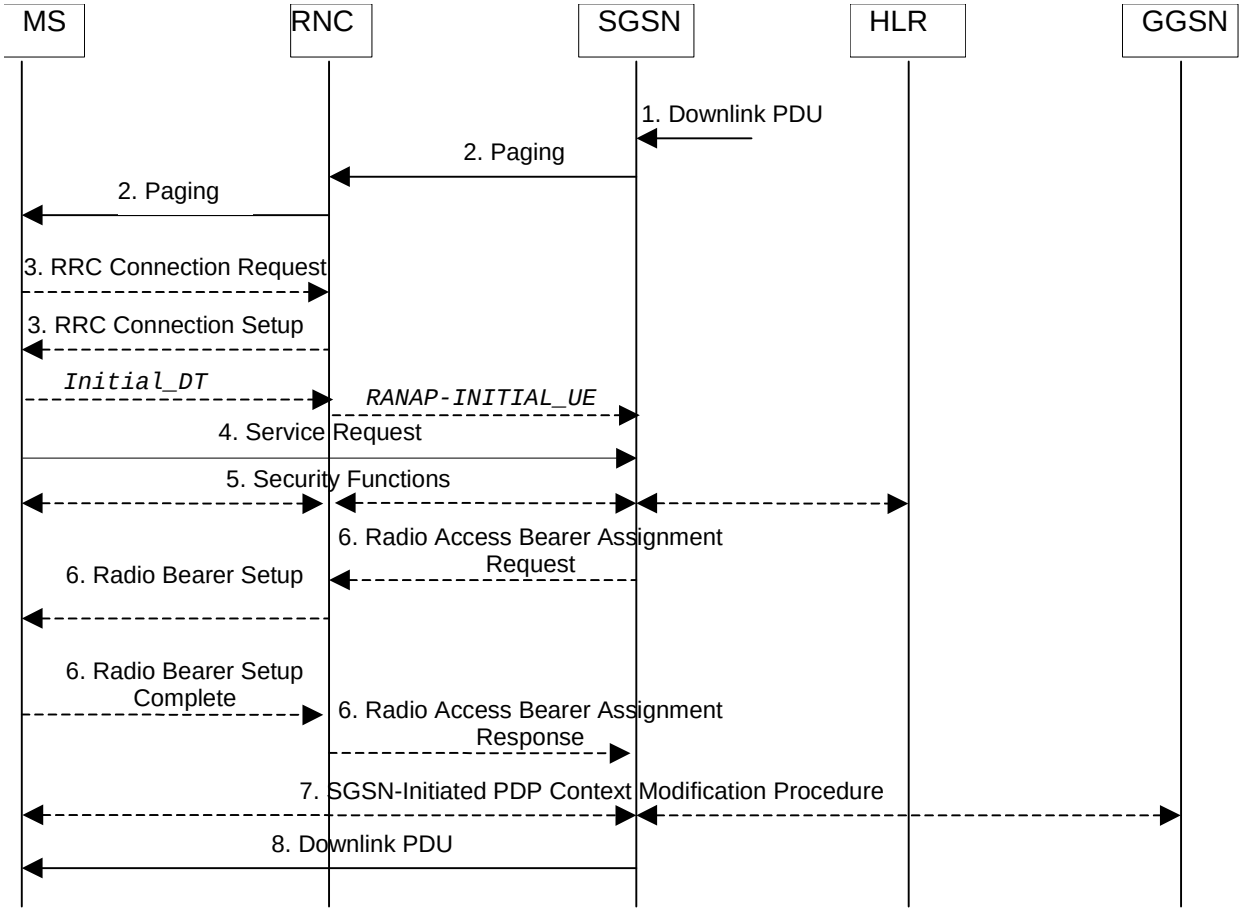
6) SRNC responds with the Radio Access Bearer Assignment Response (RAB ID(s), TEID(s), QoS Profile(s), RNC IP Address(es)) message. The GTP tunnel(s) are established on the Iu interface. If the RNC returns a Radio Access Bearer Assignment Response message with a cause indicating that the requested QoS profile(s) can not be provided, e.g., "Requested Maximum Bit Rate not Available", the SGSN may send a new Radio Access Bearer Assignment Request message with different QoS profile(s). The number of re-attempts, if any, as well as how the new QoS profile(s) values are determined is implementation dependent.

7) For each RAB re-established with a modified QoS profile, the SGSN initiates a PDP Context Modification procedure to inform the MS and the GGSN of the new negotiated QoS profile for the corresponding PDP context.

8) The MS sends the uplink packet.

7.3.2 Service Request initiated by network

The service request procedure initiated by the network is shown in the figure below.



1) The SGSN receives a downlink PDP PDU for an MS in PMM-IDLE state.

2) The SGSN sends a Paging message to the RNC. The RNC pages the MS by sending a Paging message to the MS. See subclause "PS Paging Initiated by 3G-SGSN without RRC Connection for CS" of 23.060 for details.

3) The MS establishes an RRC connection if none exists for CS traffic.

4) The MS sends a Service Request (P-TMSI, RAI, CKSN, Service Type) message to the SGSN. Service Type specifies Paging Response. The Service Request is carried over the radio in an RRC Direct Transfer message. *The RNC selects an SGSN to serve the MS as described in 7.1.3 and relays the Service Request to the SGSN in the Initial UE message (RANAP).* At this point, the SGSN may perform the authentication procedure. The SGSN knows whether the downlink packet requires RAB establishment (e.g., downlink PDU) or not (e.g., Request PDP Context Activation or MT SMS).

5) The SGSN shall perform the security mode procedure.

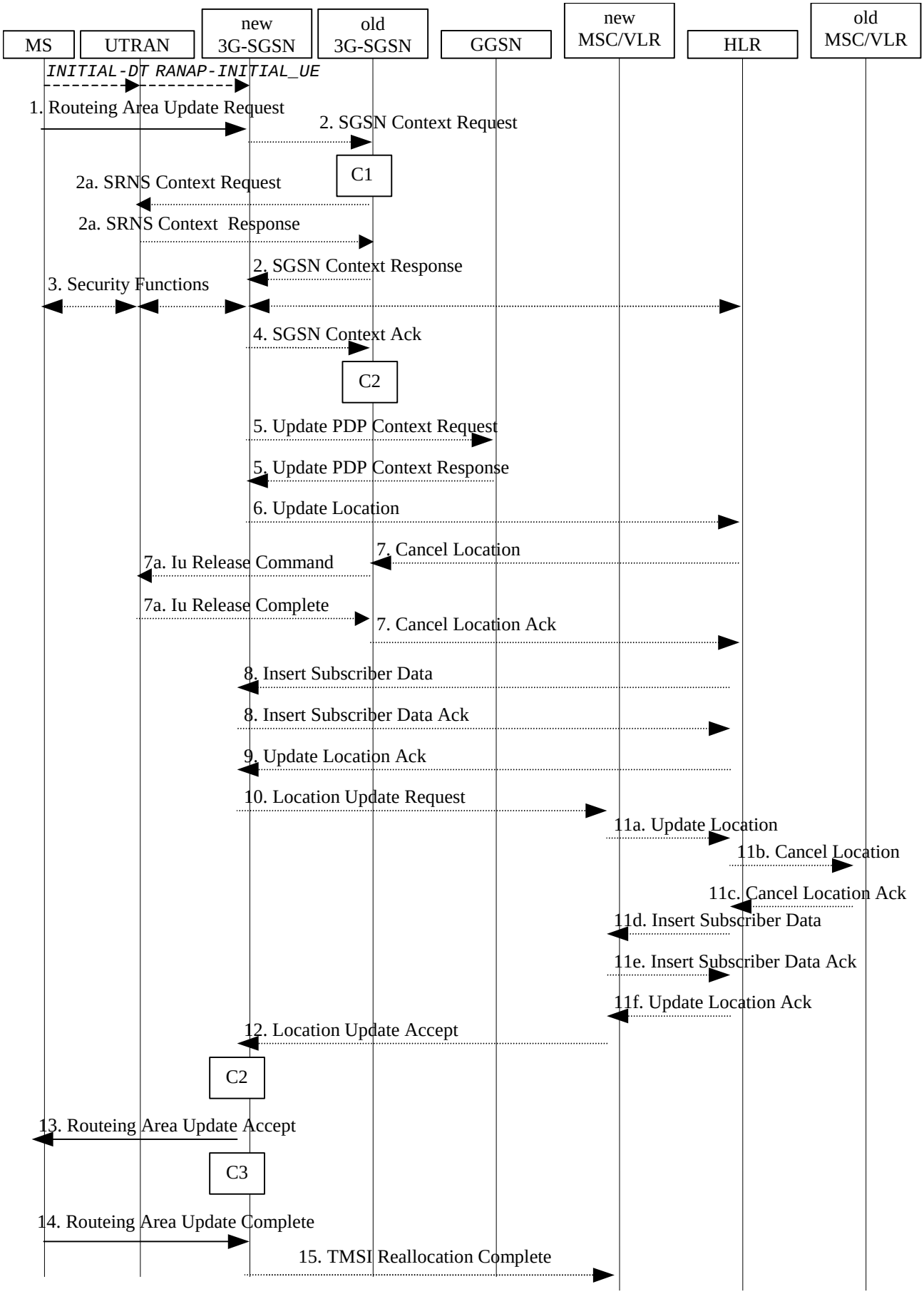
6) If resources for the PDP contexts are re-established, the SGSN sends a Radio Access Bearer Assignment Request (RAB ID(s), TEID(s), QoS Profile(s), SGSN IP Address(es)) message to the RNC. The RNC sends a Radio Bearer Setup (RAB ID(s)) to the MS. The MS responds by returning a Radio Bearer Setup Complete message to the RNC. The RNC sends a Radio Access Bearer Assignment Response (RAB ID(s), TEID(s), RNC IP Address(es)) message to the SGSN in order to indicate that GTP tunnels are established on the Iu interface and radio access bearers are established between the RNC and the MS. If the RNC returns a Radio Access Bearer Assignment Response message with a cause indicating that the requested QoS profile(s) can not be provided, e.g., "Requested Maximum Bit Rate not Available", the SGSN may send a new Radio Access Bearer Assignment Request message with different QoS profile(s). The number of re-attempts, if any, as well as how the new QoS profile(s) values are determined is implementation dependent.

7) For each RAB re-established with a modified QoS profile, the SGSN initiates a PDP Context Modification procedure to inform the MS and the GGSN of the new negotiated QoS profile for the corresponding PDP context.

8) The SGSN sends the downlink packet.

7.4 Signalling flow for Routing Area Update (Iu interface mode)

The routing area update procedure is shown in the figure below.


MS
UTRAN
new 3G-SGSN
old 3G-SGSN
GGSN
new MSC/VLR
HLR
old MSC/VLR
INITIAL-DT RANAP-INITIAL_UE
1. Routeing Area Update Request
2. SGSN Context Request
C1
2a. SRNS Context Request
2a. SRNS Context Response
2. SGSN Context Response
3. Security Functions
4. SGSN Context Ack
C2
5. Update PDP Context Request
5. Update PDP Context Response
6. Update Location
7. Cancel Location
7a. Iu Release Command
7a. Iu Release Complete
7. Cancel Location Ack
8. Insert Subscriber Data
8. Insert Subscriber Data Ack
9. Update Location Ack
10. Location Update Request
11a. Update Location
11b. Cancel Location
11c. Cancel Location Ack
11d. Insert Subscriber Data
11e. Insert Subscriber Data Ack
11f. Update Location Ack
12. Location Update Accept
C2
13. Routeing Area Update Accept
C3
14. Routeing Area Update Complete
15. TMSI Reallocation Complete

1) The RRC connection is established, if not already done. The Routeing Area Update Request (old P-TMSI, old RAI, old P-TMSI Signature) is carried in the Initial Direct Transfer message (RRC) from the MS to the RNC. The RNC selects an SGSN to serve the MS as described in 7.1.3 and relays the Routeing Area Update Request to the SGSN in the Initial UE message (RANAP).

2) If the RA update is an Inter-SGSN Routeing area update and if the MS was in PMM-IDLE state, the new SGSN sends an SGSN Context Request message (old P-TMSI, old RAI, old P-TMSI Signature) to the old SGSN to get the MM and PDP contexts for the MS. *The new SGSN selects the old SGSN as described in 7.1.4.* The old SGSN validates the old P-TMSI Signature and responds with an appropriate error cause if it does not match the value stored in the old SGSN. This should initiate the security functions in the new SGSN. If the security functions authenticate the MS correctly, the new SGSN shall send an SGSN Context Request (IMSI, old RAI, MS Validated) message to the old SGSN. MS Validated indicates that the new SGSN has authenticated the MS. If the old P-TMSI Signature was valid or if the new SGSN indicates that it has authenticated the MS, the old SGSN responds with SGSN Context Response (Cause, IMSI, MM Context, PDP contexts). If the MS is not known in the old SGSN, the old SGSN responds with an appropriate error cause. The old SGSN starts a timer. The new SGSN shall ignore the MS Network Capability contained in MM Context of SGSN Context Response only when it has previously received an MS Network Capability in the Routeing Area Request.

2a) If the MS is PMM-CONNECTED in the old 3G-SGSN, the old SGSN shall send an SRNS Context Request (IMSI) message to the old SRNS to retrieve the sequence numbers for the PDP context for inclusion in the SGSN Context Response message from the SRNS. Upon reception of this message, the SRNS buffers and stops sending downlink PDUs to the MS and returns an SRNS Context Response (IMSI, GTP-SNDs, GTP-SNUs, PDCP-SNUs) message. The SRNS shall include for each PDP context the next in-sequence GTP sequence number to be sent to the MS and the GTP sequence number of the next uplink PDU to be tunnelled to the GGSN. For each active PDP context using acknowledged mode, the SRNS also includes the uplink PDCP sequence number (PDCP-SNU). PDCP-SNU shall be the next in-sequence PDCP sequence number expected from the MS (per each active radio bearer).

3) Security functions may be executed. These procedures are defined in subclause "Security Function" of 23.060. If the security functions do not authenticate the MS correctly, the routeing area update shall be rejected, and the new SGSN shall send a reject indication to the old SGSN. The old SGSN shall continue as if the SGSN Context Request was never received.

4) If the RA update is an Inter-SGSN Routeing area update, the new SGSN sends an SGSN Context Acknowledge message to the old SGSN. The old SGSN marks in its context that the MSC/VLR association and the information in the GGSNs and the HLR are invalid. This triggers the MSC/VLR, the GGSNs, and the HLR to be updated if the MS initiates a routeing area update procedure back to the old SGSN before completing the ongoing routeing area update procedure.

5) If the RA update is an Inter-SGSN RA Update and if the MS was in PMM-IDLE state, the new SGSN sends Update PDP Context Request (new SGSN Address, QoS Negotiated, Tunnel Endpoint Identifier) to the GGSNs concerned. The GGSNs update their PDP context fields and return an Update PDP Context Response (Tunnel Endpoint Identifier). Note: If the RA update is an Inter-SGSN routeing area update initiated by an MS in PMM-CONNECTED state, the Update PDP Context Request message is sent as described in subclause "Serving RNS Relocation Procedures" of 23.060.

6) If the RA update is an Inter-SGSN RA Update, the new SGSN informs the HLR of the change of SGSN by sending Update Location (SGSN Number, SGSN Address, IMSI) to the HLR.

7) If the RA update is an nter-SGSN RA Update, the HLR sends Cancel Location (IMSI, Cancellation Type) to the old SGSN with Cancellation Type set to Update Procedure. If the timer described in step 2 is not running, the old SGSN removes the MM context. Otherwise, the contexts are removed only when the timer expires. It also ensures that the MM context is kept in the old SGSN in case the MS initiates another inter SGSN routeing area update before completing the ongoing routeing area update to the new SGSN. The old SGSN acknowledges with Cancel Location Ack (IMSI).

7a) If the MS is PMM-CONNECTED in the old 3G-SGSN, the old 3G-SGSN sends an Iu Release Command message to the old SRNC. The SRNC responds with an Iu Release Complete message.

8) If the RA update is an inter-SGSN RA Update, the HLR sends Insert Subscriber Data (IMSI, subscription data) to the new SGSN. The new SGSN validates the MS's presence in the (new) RA. If due to regional subscription restrictions the MS is not allowed to be attached in the RA, the SGSN rejects the Routeing Area Update Request with an appropriate cause, and may return an Insert Subscriber Data Ack (IMSI, SGSN Area Restricted) message to the HLR. If all checks are successful, the SGSN constructs an MM context for the MS and returns an Insert Subscriber Data Ack (IMSI) message to the HLR.

9) If the RA update is an Inter-SGSN RA Update, the HLR acknowledges the Update Location by sending Update Location Ack (IMSI) to the new SGSN.

10) If Update Type indicates combined RA / LA update with IMSI attach requested, or if the LA changed with the routeing area update, the association has to be established*. The VLR number is determined as described in 7.1.6. The new SGSN sends a Location Update Request (new LAI, IMSI, SGSN Number, Location Update Type) to the VLR.* Location Update Type shall indicate IMSI attach if Update Type in step 1 indicated combined RA / LA update with ISI attach requested. Otherwise, Location Update Type shall indicate normal location update. The SGSN starts the location update procedure towards the new MSC/VLR upon receipt of the first Insert Subscriber Data message from the HLR in step 8). The VLR creates or updates the association with the SGSN by storing SGSN Number.

11) If the subscriber data in the VLR is marked as not confirmed by the HLR, the new VLR informs the HLR. The HLR cancels the old VLR and inserts subscriber data in the new VLR (this signalling is not modified from existing GSM signalling and is included here for illustrative purposes):

    a) The new VLR sends an Update Location (new VLR) to the HLR.

    b) The HLR cancels the data in the old VLR by sending Cancel Location (IMSI) to the old VLR.

    c) The old VLR acknowledges with Cancel Location Ack (IMSI).

    d) The HLR sends Insert Subscriber Data (IMSI, GSM subscriber data) to the new VLR.

    e) The new VLR acknowledges with Insert Subscriber Data Ack (IMSI).

    f) The HLR responds with Update Location Ack (IMSI) to the new VLR.

12) The new VLR allocates a new TMSI and responds with Location Update Accept (VLR TMSI) to the SGSN. VLR TMSI is optional if the VLR has not changed. *An IuFlex aware VLR includes one of its (CS-)NRIs as part of VLR TMSI. The SGSN creates an association with the VLR by storing VLR number.*

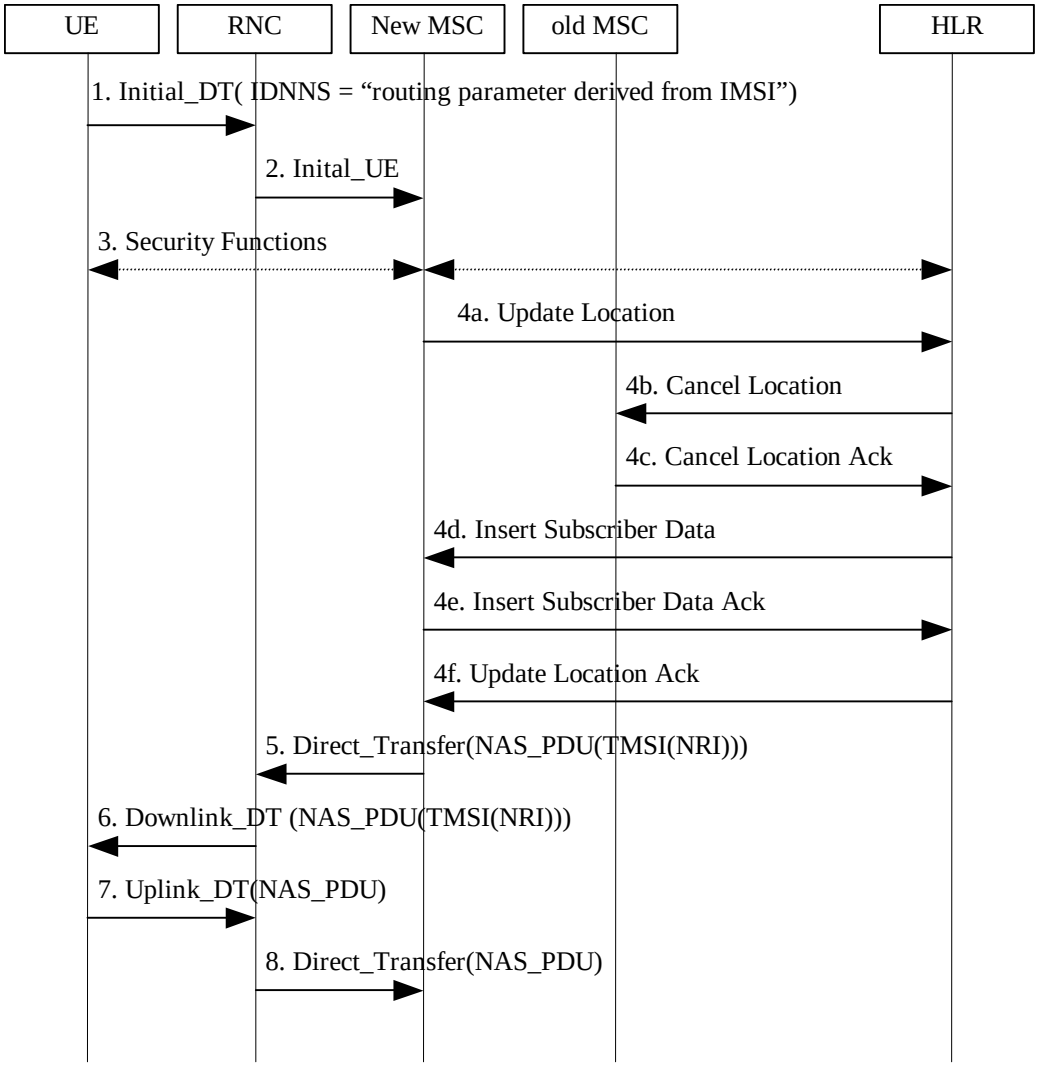
13) The new SGSN validates the MS's presence in the new RA. If due to roaming restrictions the MS is not allowed to be attached in the SGSN, or if subscription checking fails, the SGSN rejects the routeing area update with an appropriate cause. If all checks are successful, the new SGSN establishes MM context for the MS. The new SGSN responds to the MS with Routeing Area Update Accept (P-TMSI, VLR TMSI, P-TMSI Signature*). An IuFlex aware SGSN includes one of its (PS-)NRIs as part of P-TMSI.*

14) The MS confirms the reallocation of the TMSIs by returning a Routeing Area Update Complete message to the SGSN.

15) The new SGSN sends a TMSI Reallocation Complete message to the new VLR if the MS confirms the VLR TMSI.

7.5 IMSI attach procedure / Location area update with IMSI

This signalling flow shows the basic IMSI attach or location update procedure when a UMTS UE registers to a pool-area by mobile identity type IMSI.



1. UE requests the setup of the RRC connection and sends the Initial_DT including the Intra Domain NAS Node Selector (IDNNS). The IDNNS indicates that the routing parameter is derived from IMSI.
2. The RNC selects the MSC as described in 7.1.3. The Initial-UE message is generated on RANAP and sent via Iu-CS to the selected MSC/VLR.
3. The optional security functions can be executed
4. Since the UE wasn’t registered in the MSC before the Map Update-location procedure to HLR is invoked by the MSC
    a. The update-location is sent to HLR
    b. In case the UE was registered in another VLR the HLR sends cancel location procedure to old VLR
    c. The old VLR acknowledges with Cancel location Ack
    d. The HLR sends insert-subscriber data to the new VLR
    e. The new VLR acknowledges with insert-subscriber data Ack
    f. After finishing the location update procedure the HLR responds with Update-location to the new VLR
5. The MSC/VLR assigns a new TMSI to the UE and sends this TMSI value in the location-update accept to the UE. The TMSI contains the NRI of the VLR. The location update accept is carried in the NAS-PDU of the RANAP direct-transfer over Iu interface.

6. The RNC transparently forwards the NAS-PDU to the UE in the RRC downlink-DT message.
7. In the UE the new TMSI (including the NRI) and the LA are stored on SIM and the TMSI-reallocation complete is generated. This NAS message is returned to CN in the Uplink-DT via RRC. The mobile shall use this new TMSI next time it performs a mobile originating procedure.
8. The RNC forwards the NAS-PDU transparently to the MSC/VLR in the NAS-PDU of a Direct-transfer on Iu interface. If the TMSI-reallocation complete is received in the MSC/VLR the TMSI is considered as valid for the UE. From then on the UE will be addressed using this TMSI value.

Annex A (informative): Network configuration examples

Editor's note: This annex contains the examples for network configurations that have been discussed during the drafting meetings.

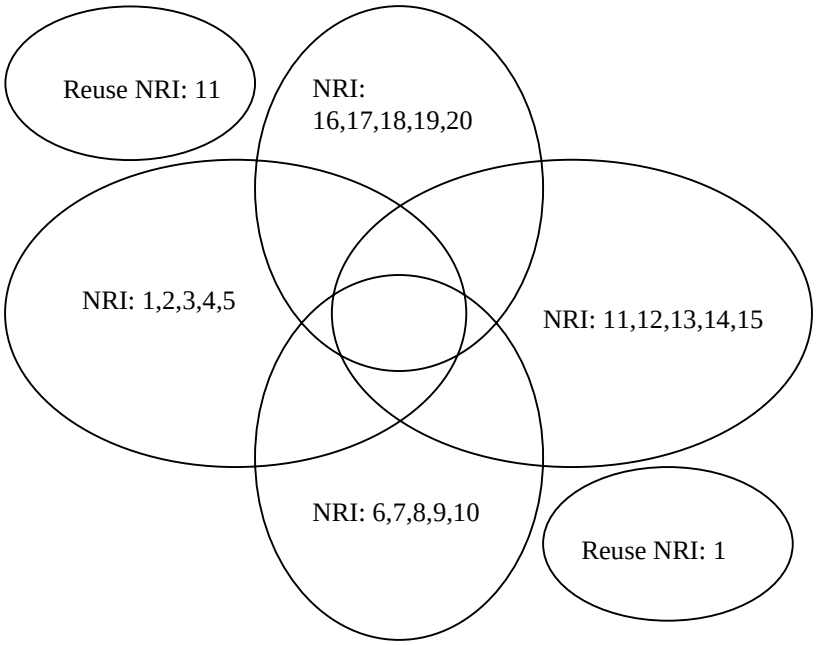
A.1: One city centre surrounded by residential areas

Assumptions:

This example shows a network covering one city centre surrounded by residential areas. The city centre is covered by all 4 pool-areas while the residential areas are covered by one pool-area only. Once a subscriber „found" its pool-area, he will not change the pool-area while commuting between the city centre and his residential area.
Each of the pool-areas is served by 5 MSCs, indicated by the 5 NRI values in the figure below.

The example in the figure configures 4 overlapping pool-areas;

- City centre with 12 Mio subscribers (with context in VLR, attached or detached)
- One switch office/building with 5 MSCs (5 NRIs) per pool-area
- Capacity of one MSC/VLR up to 1 Mio subscribers in VLR
- 4 bits are assumed for the VLR-restart counter
- Only distinct NRI values are used, so a UE changing between pool-areas will always be allocated to a new MSC by the NAS node selection function



TMSI calculation:

For addressing in the CS domain 30 bits for can be used (Bit 30&31 are reserved).

- The assumption is that 4 bits are used for the restart counter.

- To differentiate the 20 MSC in the city area 5 bits are needed for the NRI (12 NRI values remain unused; these 12 NRIs are left for additional MSCs in the whole area, NRIs can also be re-used as indicated in the figure)
- This leaves 30-4-5 = 21 bits for every MSC to address the subscriber data records in the VLR. (This give address space for 2 Mio TMSIs unique over all LAs of the MSC)
- The 4 pool-areas sum up to 20 Mio subscriber, allowing for some unbalanced load distribution

A.2: 3 Neighbouring large city centres

This documents provides some calculations for 'pool-identification alternative B' in case that 3 huge city centres are covered by pool-areas with direct contacts.

Assumptions:

The calculations are based on the following assumptions:

- 3 neighbouring pools with capacity of 32 M non-purged subscribers each
- Maximum capacity of a paging channel is 1 M pagings/hour per LA
- 0.25 pagings / hour are assumed per subscriber → 2M TMSI/LA can be realized
- For the 'VLR-restart' counters a number of bits need to be reserved. Working assumption is that 5 bit should be sufficient for any implementation, in the examples these 5 bits are reserved on the upper part of the TMSI. (This is of course implementation specific and not part of Iu-Flex.)
- The calculations are based on a node capacity of up to 1M (2^20) non-purged subscribers this results in:
    - Minimum 32 nodes are needed per pool-area (5-bit NRI)
    - Minimum is 16 LA's per pool-area

Basic configuration needed for 1 pool:

- To address the 32M TMSI per pool the total number of 25 bits are needed in the TMSI.
- For a node capacity of 1M non-purged TMSIs 20 Bits have to be reserved for TMSI per NRI and 5 bit for the NRI value.
- The NRI is located bit 14-23 (configurable). It is assumed that the bits 19-23 are used for the NRI.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CS/ PS		'VLR-restart'						used NRI range																							

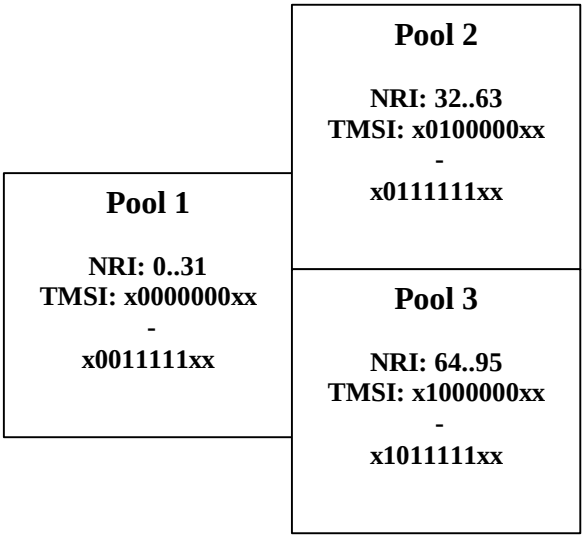
Figure 4: Example of a TMSI structure with 5 bit 'VLR-restart counter' and 5 bits NRI-length;

'3 pool configuration' – no sharing of NRI values:

- This example assumes that the 3 pool-areas have independent NRI values, so the available TMSI range has to be shared between the pools. All TMSI's from other pool-areas can be detected – best load distribution in the pools.

- So 3*32 = 96 NRI values are needed for all 3 pools. The NRI-length has to be increased to 7 bit. (not an optimum configuration since 32 NRI values are unused). In the example the NRI now uses bits 23-17.

- Since still for each NRI value 20 bits are needed to address 1M TMSIs there is a conflict with the assumed VLR-restart field length of 5 bit. The VLR-restart field has to be reduced to a 3 bit field in order to free sufficient addressing space in the TMSI structure!



NRI: 96..127
TMSI: x1100000xx - x1111111xx
are unused

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CS/ PS		‘VLR-restart’						used NRI range																							

Figure 5: Modified TMSI structure 7 bits NRI-length; VLR-restart field must be reduced to 3 bit.

- In this example configuration 32M TMSI values are wasted! So it would be more efficient to assign these TMSI ranges to the 3 pools rather than leave them unused. Alternatively these values could be used for sharing with nodes in the ‘outside world’.

- The major drawback of this solution is the reduction of the VLR-restart field to 3 bits only!

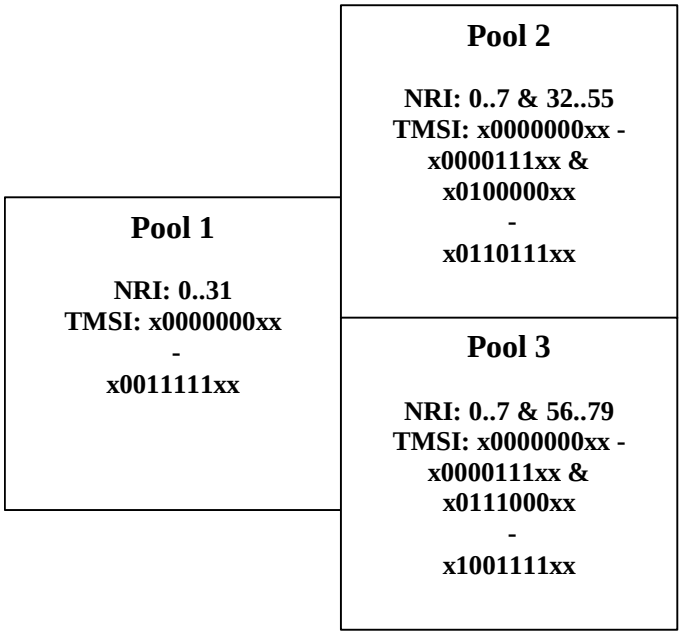
‘3 pool configuration’ – 25% of NRI values shared between the pools:

- Now the pool configurations are changed in a way that 25% of the NRI values are the same in all the 3 pools. This means that for ¼ of subscribers pool-changes cannot be detected. The traffic generated by these subscribers will not be distributed, but is routed by the NAS node selection function to the specific node with this NRI value in the new pool.

- The total range of needed NRI values is reduced by this to:
8 (the shared NRI’s) + 3 * 24 = 80

- To code this NRI’s still 7 bit are needed. So there is no gain in terms of addressing space in this example.

- In the example the NRI values 0..7 are shared and so are the TMSI ranges x0000000xx .. x0000111x



NRI: 80..127
TMSI: x1010000xx - x1111111xx
are unused

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CS/ PS		‘VLR-restart’						used NRI range																							

Figure 6: Modified TMSI structure 7 bits NRI-length; VLR-restart field must remain 3 bit.

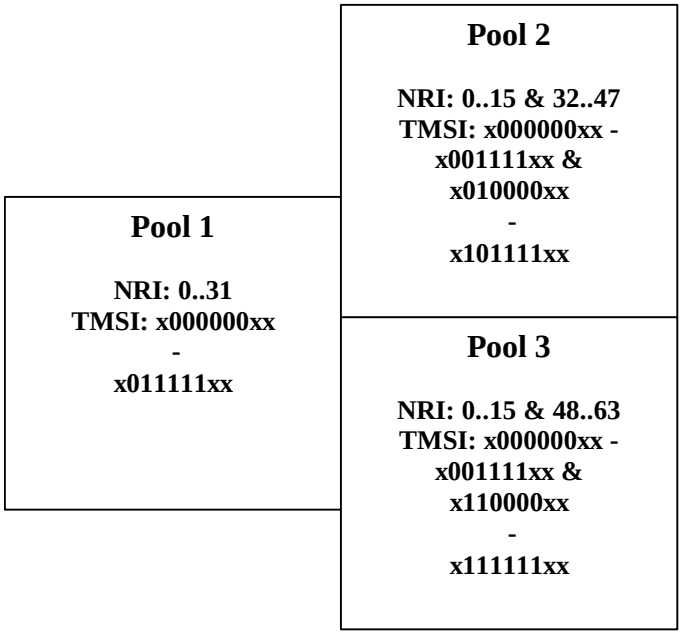
‘3 pool configuration’ – 50% of NRI values shared between the pools:

- The percentage of the shared NRIs is now increased to 50%. So ½ of the NRI values are the same in all the 3 pools. This means that for ½ of subscribers pool-changes cannot be detected. The traffic generated by these subscribers will not be distributed, but is routed by the NAS node selection function to the specific node with this NRI value in the new pool.

- The total range of needed NRI values is reduced by this to:
16 (the shared NRI’s) + 3 * 16 = 64

- This reduction of NRI saves 1 bit in NRI length. So the VLR-restart can be slightly increased to 4 bit (still 1 bit less than in the original assumption)

- In the example the NRI values 0..15 are shared and so are the TMSI ranges x000000xx .. x001111x

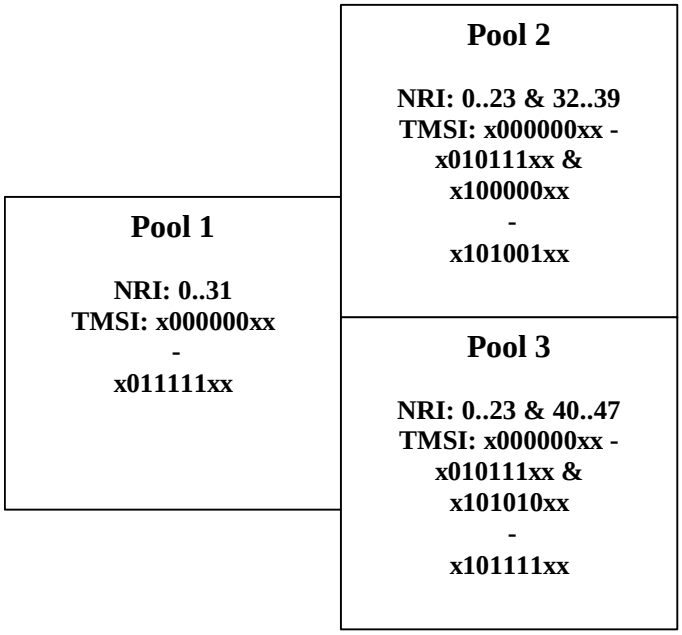


31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CS/ PS		‘VLR-restart’						used NRI range																							

Figure 7: NRI-length can be reduced by 1 bit; VLR-restart field can increase to 4 bit.

‘3 pool configuration’ – 75% of NRI values shared between the pools:

- Next step is to even increase the shared part of the NRI to ¾. This means that only 25% of the incoming traffic in a pool-area is distributed.
- The total range of needed NRI values is reduced by this to:
  24 (the shared NRI’s) + 3 * 8 = 48
- Like the first step this doesn’t free any addressing space in the TMSI. But some NRI values are now available in case it is wanted to share them with other nodes outside the ‘3 pool area’.
- In the example the NRI values 0..23 are shared and so are the TMSI ranges x000000xx .. x010111x



31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CS/ PS		'VLR-restart'						used NRI range																							

Figure 8: NRI-length can be reduced by 1 bit; VLR-restart field can increase to 4 bit.

'3 pool configuration' – full sharing of NRIs between the pools:

- The last variant of these configurations is a full sharing is all NRI values between all neighbouring pools. In this case no detection of pool area changes is possible. Consequently no distribution of load can be achieved. This results necessarily in the need to have a 'forced redistribution' mechanism to resolve heavy unbalance of load.
- The NRI and TMSI ranges will then be the same as in the 'single pool' example in the beginning.

Result:

The examples above show that it is basically not possible to configure the example configuration (32M non-purged subscribers; 1M per MSC) with a VLR-restart field as put in the assumptions, except that the full range of NRI is shared between the pools.
Taking it literally it could be possible with 3 pools when sharing the remaining quarter of the NRI (the part that would be unused otherwise), but latest if 4 pool-areas with this capacity have to be supported this reaches the limit.

An alternative to overcome this could be to apply the TMSI's on a per LA basis as it is already foreseen on the A/Iu interface specifications.

TMSI per LA:

Taking the example configuration mentioned above but changing the TMSI allocation per LA would result in an increase of the addressing space. Then the same TMSI value can be used multiple times in the same VLR. A specific subscriber data record can then only be addressed by LA&TMSI.

For the 32 MSCs this means that that each of them supports an equal share of TMSI of a LA. So each MSC handles 2M/32 = 32k TMSI of a specific LA.

The required TMSI addressing space id thereby reduced to 15 bit per MSC.

If, like before, 96 NRI values are needed to address all nodes in the 3 pools then 7 bit are needed for this. This leaves 5 bit for the VLR-restart counters (plus 3 unused bits).

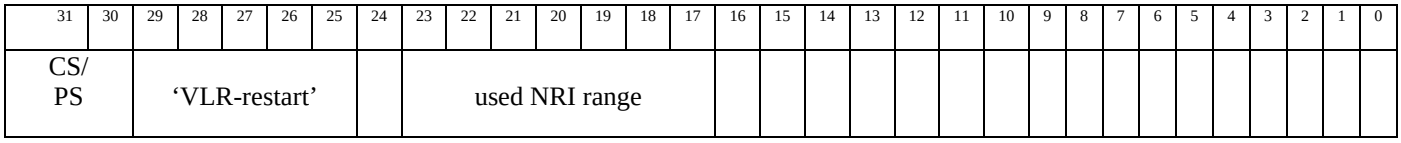


Figure 9: TMSI example for TMSI allocation per VLR; 32M TMSI/pool;

Without sharing NRI values the pool size can even be increased (Factor 8 – since 3 bit spare).

A number of aspects however remain to be looked at with this TMSI per LA approach:

- It requires an equal distribution of UE's of a certain LA over all nodes in the pool. This contradicts the wish for a flexible routing where e.g. a new attach should be routed to the closest node in order to save transmission resources.
- Attach requests in a LA may be rejected by one node because this node has already a fully booked TMSI table for this LA. At the same time the node may have in total still capacity left to serve subscribers…..
- The total load of TMSI re-allocations may increase since every change of LA must result in a TMSI reallocation.
- MAP on VLR-VLR I/F must be updated, otherwise subscriber confidentially decreases because for every change to other MSCs the IMSI has to be fetched via the air I/F. (At the same time node changes should only occur when changing the pool-area – so maybe never?)
- Can it happen that if NRI are shared there are several subscribers with the same TMSI in a certain LA? FFS
  If yes then a paging-request there will trigger several page-response messages per LA….

Annex B (informative): Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
					Version 0.0.0 Initial Proposal		
2001-04-20	Iu-flex drafting				Updates after drafting meeting		
2001-05-17	SA2#18				Adding S2-011369r1 chapter 5.3.1; alternative B chosen, A moved to annex and affected paragraphs updated accordingly; example network configurations added in annex C; some minor editorial corrections	0.1.0	0.2.0
2001-06-17	SA#12				Raised to version 1.0.0 (same technical content as v.0.2.0)	0.2.0	1.0.0
2001-08-15	Iu-Flex drafting	S2-011737, S2-011741, S2-011743, S2-011744, S2-011752, S2-011754rev1, S2-011755, S2-011756, S2-011757, S2-011758, S2-011759, S2-011760, S2-011762rev1, S2-011763, S2-011764, S2-011765			Updated with tdocs approved by Iu-Flex drafting July 3&5, 2001	1.0.0.	1.1.0
2001-08-21					References in chapter 2 adjusted to correct format Chapter 4.6.; 3rd paragraph first 'not' deleted (this change to tdoc S2-011741 was agreed in the drafting – but missing in v1.1.0)	1.1.0	1.1.1
2001-08-30	SA2#19	S2-012157, S2-012378, S2-012383, S2-012407, S2-012408, S2-012409			Updated with approved tdocs; Some additional editorial updates	1.1.1	1.2.0
2001-09-23	SA#13				Updated to v.2.0.0 (same technical content as v.1.2.0)	1.2.0	2.0.0
2001-09-25	SA#13				Updated to v.2.1.0 to delete all references of Iu-flex between CN nodes belonging to different operators (to fit to the scope and to the approved WID)	2.0.0	2.1.0

3GPP TS 23.236 V2.~~0~~1.0 (2001-~~08~~09)

Technical Specification

3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Intra Domain Connection of RAN Nodes to Multiple CN Nodes;

(Release 5)

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Foreword

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

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.

Introduction

UMTS will build on the success of GSM and is likely to become even more widespread, increasing the importance of a flexible network structure which the different operational configurations in which these networks will be deployed. The requirements to have a RNC or BSC controlled by a single MSC server or SGSN lead to certain limitations. Allowing the BSCs and RNCs to connect to a number of MSC servers or SGSNs increases the networks performance in terms of scalability, distributing the network load amongst the serving entities, and reducing the required signalling as the user roams.

1 Scope

This document covers the details for the Intra Domain Connection of RAN Nodes to Multiple CN Nodes for GSM and UMTS systems. In particular, it details the impacts to GSM and UMTS systems and the stage 2 procedures for the support of connecting a RNC or BSC to multiple MSC servers or SGSNs. The overall solution is described, and the detailed impacts on the existing specifications are identified.

The reference model to which these procedures apply can be found within 3GPP TS 23.002 [1]. Detailed architectural requirements within the subsystems are contained within the remainder of the 23 series of specifications e.g. the requirements for the Packet Switched (PS) domain are contained within 3GPP TS 23.060 [2] and the requirements for the Bearer Independent CS Core Network are contained in 3GPP TS 23.205[14].

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.

This specification may contain references to pre-Release-4 GSM specifications. These references shall be taken to refer to the Release 5 version where that version exists. Conversion from the pre-Release-4 number to the Release 4 (onwards) number is given in subclause 6.1 of 3GPP TR 41.001.

[1] 3GPP TS 23.002: "Network Architecture".

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

[3] 3GPP TS 23.012: “Location management procedures”.

[5] 3GPP TS 25.331: “Radio Resource Control (RRC) Protocol Specification”.

[6] 3GPP TS 25.301: “Radio interface protocol architecture”.

[7] 3GPP TS 25.303: “UE functions and inter-layer procedures in connected mode”.

[8] 3GPP TR 21.905: "3G Vocabulary".

[9] 3GPP TS 25.413: “UTRAN Iu interface RANAP signalling”.

[10] 3GPP TS 25.410: “UTRAN Iu Interface: General Aspects and Principles”.

[11] 3GPP TS 23.228: “IP Multimedia Subsystem – Stage 2”.

[12] 3GPP TS 43.051: “GSM/EDGE Radio Access Network (GERAN) overall description (Stage 2)”.

[13] 3GPP TS 23.153: "Out of Band Transcoder Control - Stage 2".

[14] 3GPP TS 23.205: “Bearer Independent CS Core Network – Stage 2”.

[15] 3GPP TR 25.931: “ UTRAN Functions, examples on signalling procedures”.

[16] GSM 08.18: “General Packet Radio Service (GPRS);Base Station System (BSS) -Serving GPRS Support Node (SGSN); BSS GPRS Protocol (BSSGP):.

[17] 3GPP TS 48.008: “Mobile-services Switching Centre - Base Station System(MSC - BSS) interface; Layer 3 specification”.

[18] 3GPP TS 23.003: “Numbering, addressing and identification”.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms defined in 3GPP TR 21.905 [8] apply:

NAS node selection Function: The function used to assign specific network resources (i.e. MSC or SGSN) to serve a mobile station and subsequently route the traffic to the assigned network resource.

Network Resource Identifier A specific parameter used to identify the CN node assigned to serve a mobile station.

Pool-area: A pool area is an area within which a MS may roam without need to change the serving CN node. A pool area is served by one or more CN nodes in parallel. All the cells controlled by a RNC or BSC belong to the same one [or more] pool area[s].

RAN node service area: This area contains all the cells controlled by the RAN node (RNC or BSC).

3.2 Symbols

For the purposes of the present document, the following symbols apply:

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AS	Access Stratum
BSC	Base Station Controller
BVCI	BSSGP Virtual Connection Identifier
CN	Core Network
CS	Circuit Switched
CS-MGW	Circuit Switched Media Gateway
DNS	Directory Name Server
IDNNS	Intra Domain NAS Node Selector
LA	Location Area
LAI	Location Area Identity
MS	Mobile Station
MSC	Mobile Switching Centre
NAS	Non Access Stratum
NRI	Network Resource Identifier
O&M	Operation and Maintenance
PS	Packet Switched
RA	Routing Area
RAI	Routing Area Identity
RAN	Radio Access Network
RNC	Radio Network Controller

SRNS	Serving Radio Network Subsystem
TMSI	Temporary Mobile Station Identity
TLLI	Temporary Logical Link Identifier
UE	User Equipment

4 General Description

4.1 Iu Flex Technical Requirements

This provides a (non-exhaustive) set of technical requirements:

1. IuFlex capable RAN nodes such as the RNC/BSC should be able to select any CN node such as the SGSN/MSC-Server within a pool area
2. IuFlex capable RAN nodes and CN nodes should be able to co-exist with pre release-5 RAN nodes and pre release-5 CN nodes.
3. The network should provide the CN node routing information to the UE and the UE should store it.
4. During the initial non-access stratum signalling, the UE should provide to the RAN node the routing information for the current serving CN.

~~5.The solution should not preclude the support of multiple core networks (from different PLMNs/operators) connected to a single RNS or BSS.~~

~~6.~~5. The solution shall enable the reduction of signalling within the core network (e.g reduction of the HLR signalling traffic).

~~7.~~6. The solution shall enable an improved scaling between radio access nodes and the core network nodes.

4.2 Overview

Note: Clarification is required in order to remove RAN nodes and CN node terminology and to capture that this is referring to the control signalling aspects.

The Intra Domain Connection of RAN Nodes to Multiple CN Nodes overcomes the strict hierarchy which restricts the connection of a RAN node to just one CN node. This restriction results from routing mechanisms in the RAN nodes which differentiate only between information to be sent to the PS or to the CS domain CN nodes and which do not differentiate between multiple CN node in each domain. The Intra Domain Connection of RAN Nodes to Multiple CN Nodes introduces a routing mechanism (and other related functionality), which enables the RAN nodes to route information to different CN nodes within the CS or PS domain, respectively.

The Intra Domain Connection of RAN Nodes to Multiple CN Nodes introduces further the concept of “pool-areas” which is enabled by the routing mechanism in the RAN nodes. A pool-area is comparable to an MSC or SGSN service area as a collection of one or more RAN node service areas. In difference to an MSC or SGSN service area a pool-area is served by multiple CN nodes (MSCs or SGSNs) in parallel which share the traffic of this area between each other. Furthermore, pool-areas may overlap which is not possible for MSC or SGSN service areas.

The Intra Domain Connection of RAN Nodes to Multiple CN Nodes enables a few different application scenarios with certain characteristics. The service provision by multiple CN nodes within a pool-area enlarges the served area compared to the service area of one CN node. This results in reduced inter CN node updates, handovers and relocations and it reduces the HLR update traffic. The configuration of overlapping pool-areas allows to separate the overall traffic into different MS moving pattern, e.g. pool-areas where each covers a separate residential area and all the same city centre. Other advantages of multiple CN nodes in a pool-area are the possibility of capacity upgrades by additional CN nodes in the pool-area or the increased service availability as other CN nodes may provide services in case one CN node in the pool-area fails.

An MS is served by one dedicated CN node of a pool-area as long as it is in radio coverage of the pool-area. Figure 1 shows most of the possible pool-area configurations. It contains CS pool-area 1 (RAN area 1, 2, 5, 6 served by MSCs 1, 2, 3), CS pool-areas 2 (RAN area 2, 3, 6, 7 served by MSCs 4, 5, 6), PS pool-area 1 (RAN area 1, 5 served by SGSNs 1, 2) and PS pool-area 2 (RAN area 2, 3, 6, 7 served by SGSNs 3, 4, 5). In addition the RAN areas 4 and 8 are served by MSC 7 and SGSN 6 without any usage of the Intra Domain Connection of RAN Nodes to Multiple CN Nodes. The possibility to configure overlapping pool-areas is shown by the CS pool-areas 1 and 2. The PS pool-areas 1 and 2 are configured non-overlapping. The pool-areas of the CS and the PS domain may be configured identical as CS pool-area 2 and PS pool-area 2 or they may be configured differently as shown by CS pool-area 1 and PS pool-area 1. The number or capacity of CN nodes is configured independently for each pool-area. The usage of the Intra Domain Connection of RAN Nodes to Multiple CN Nodes may be configured in parts of the network only. It co-exists with other areas not using this feature as shown in the figure with RAN areas 4 and 8 which are served by MSC 7 and SGSN 6.

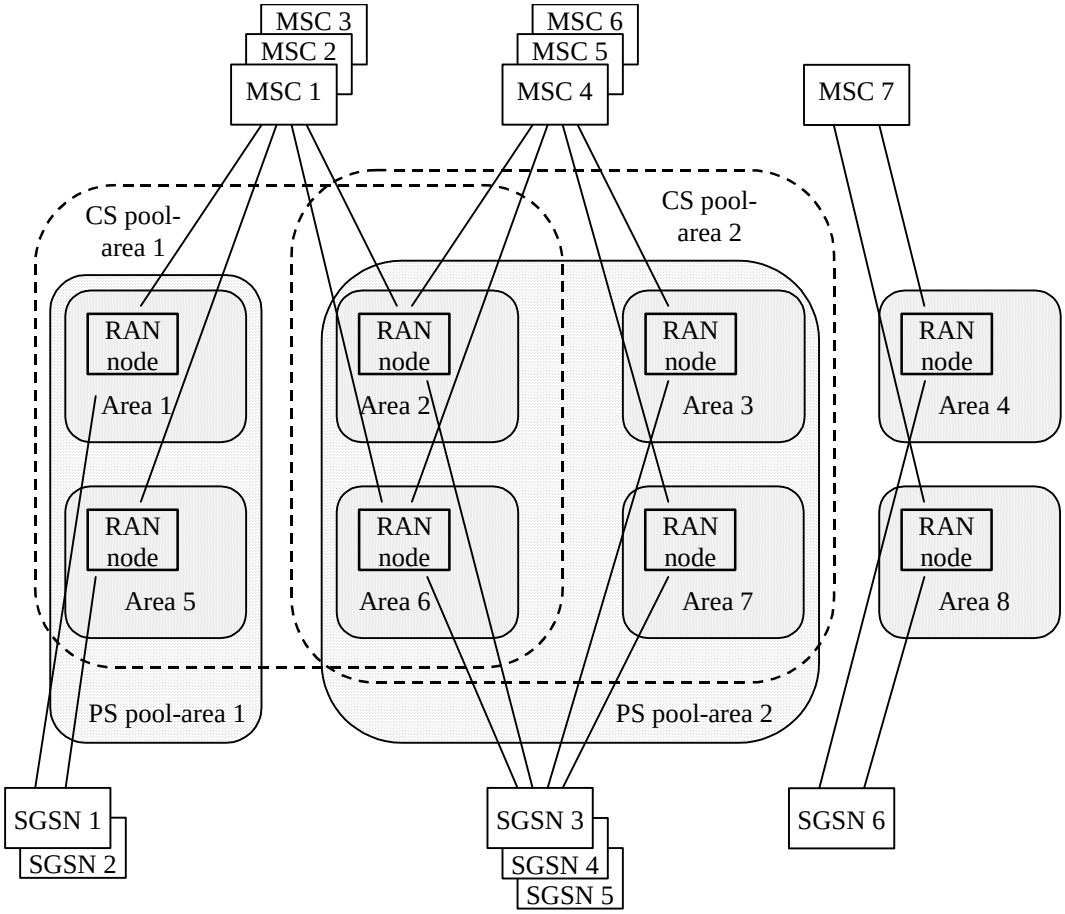


Figure 1: Pool-area configuration example

4.3 Pool-Area and Network Resource Identification

A pool-area is an area within which an MS may roam without a need to change the serving CN node. A pool-area is served by one or more CN nodes in parallel. The complete service area of a RAN node (RNC or BSC) belongs to the same one or more pool-area(s). A RAN node service area may belong to multiple pool-areas, which is the case when multiple overlapping pool-areas include this RAN node service area. The pool-areas of the CS and of the PS domain are configured independently with the granularity of RAN node service areas. Therefore, all uniqueness statements below apply to each of the domains (CS/PS) separately. If LAs or RAs span over multiple RAN node service areas then all these RAN node service areas have to belong to the same pool-area.

The Network Resource Identifier (NRI) identifies uniquely an individual CN node out of all CN nodes which serve in parallel a pool-area. In areas where pool-areas overlap the NRI identifies uniquely a CN node out of all CN node which serve all these overlapping pool-areas, i.e. an NRI identifies uniquely a CN node within a RAN node. Note again, that the NRIs of the CS and the PS domain are independent of each other as the PS and the CS domain CN nodes are addressed independently. More than one NRI may be assigned to a CN node.

The NRI is part of the temporary identity TMSI (CS domain) or P-TMSI (PS domain) which is assigned by the serving CN node to the MS. Each CN node which support the "Intra Domain Connection of RAN Nodes to Multiple CN Nodes" is configured with its specific one or more NRI(s). The (P-)TMSI allocation mechanism in the CN node generates (P-)TMSIs which contain a configured NRI in the relevant bit positions. The NRI has a flexible length between 10 and 0 bits (0 bits means the NRI is not used and the feature is not applied).

In Iu mode the MS provides an Intra Domain NAS Node Selector (IDNNS) [5] in the AS part of the RRC-Initial-direct-transfer message to the RAN node (RNC or BSC). The IDNNS contains a routing parameter with a fixed length of 10 bits. This routing parameter transports the NRI value. In addition the IDNNS contains an indication from which identity (TMSI, IMSI, IMEI, ...) the routing parameter is derived. The RAN node masks the significant bits out of the routing parameter part of the IDNNS to determine the NRI which is relevant to identify the CN node.

In A/Gb-mode for the A interface the RAN node derives the NRI from any initial NAS signalling message. The RAN node masks the significant bits out of the TMSI to determine the NRI which identifies the CN node. In A/Gb-mode for the Gb interface the RAN node derives the NRI from the TLLI. The RAN node masks the significant bits out of the TLLI to determine the NRI which identifies the CN node. For all three cases, Iu, A interface and Gb mode, it is configured in the RAN node which bits out of the information elements provided by the MS are significant for the NRI.

The whole network may be configured as one pool-area, a network may configure multiple pool-areas and the configuration of pool-areas may be combined with MSC or SGSN service areas which are not belonging to pool-areas. The change of a pool-area is not visible to the MS. In general there is no need to detect a pool-area change. It may be advantageous for load balancing purposes to detect pool-area changes in the network to distribute MSs entering a pool-area to CN nodes with an appropriate load status. MSs changing a pool-area may be detected by configuration of different NRI values for adjacent pool-areas. The pool-area change information potentially provided in the IDNNS by an MS in Iu mode is ignored by the network.

4.4 NAS Node Selection Function

This function is used in RAN nodes and potentially in CN nodes. In the RAN node the function selects the specific CN node (i.e. MSC or SGSN) to which initial NAS signalling messages or LLC frames are routed. The NRI identifies the specific CN node. If the NAS Node Selection Function has a CN node address configured for the NRI derived from the initial NAS signalling message or from the LLC frame then this message or frame is routed to this address. If no CN node address is configured for the derived NRI or if no NRI can be derived (e.g. the MS indicated an identity which contains no NRI) then the NAS Node Selection Function selects an available CN node (e.g. according to load balancing) and routes the message or LLC frame to the selected CN node.

The pool-area has no influence on the decisions of the NAS Node Selection Function as pool-areas may overlap. The NAS Node Selection Function in the RAN node derives the NRI from the IDNNS when the

MS is supported in Iu mode. When the MS is supported in Gb mode the NRI is derived from the TLLI and for A interface mode the NRI is derived from the TMSI.

In case a MSC/VLR sends a paging-request/paging with IMSI, the NAS node selection function in the BSC/RNC shall upon reception temporarily store the MSC/VLR-identity of the node that issued the paging-request/paging message. If the MSC/VLR initiates the paging procedure via Gs-interface the SGSN has to add the MSC/VLR-identity to the paging-request/paging message.

If the NAS node selection function receives a paging-response with an IMSI then it should check the temporarily stored MSC/VLR-identities on entries matching this IMSI and forward the paging-response to the node identified by this MSC/VLR-identity.

An MS will return an Attach Request containing the IMSI parameter as a response to a PS IMSI paging. Also, a PS IMSI paging is not time supervised from the SGSN sending the message. Therefore the RAN node receiving such a paging request does not have to buffer the associated SGSN identity. This again means that the NAS Node Selection Function in the RAN node selects an available SGSN (e.g. according to load balancing) when it receives an Attach Request containing the IMSI parameter.

4.5 Load Balancing

Preferably, the NAS Node Selection Function in the RAN node balances the load between the available CN nodes. This is performed by an appropriate selection of the CN node for an MS which was not yet assigned to a CN node, i.e. when there is no CN node configured for the NRI indicated by the MS, when no NRI can be derived or in exceptional cases, e.g. when the CN node corresponding to an NRI cannot be reached. The load-balancing algorithm is implementation specific.

In case of handover/relocation a load balancing between the CN nodes serving the same pool-area is gained by configuration. For each of the handover/relocation targets in a pool-area another CN node is configured as the target CN node. CN nodes which do not support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes configure only one CN node per handover/relocation target. CN nodes which do support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes may improve the availability by configuring multiple target CN nodes for each handover/relocation target in a pool-area. The mechanism for distribution of the traffic between the handover target CN nodes is implementation specific. This load balancing is complemented by the NAS Node selection Function in the RAN, which distributes MSs between the CN nodes when these MSs enter the pool-area in idle mode.

As more than one SGSN may send downlink data at the same time for a cell or a BVCI the total possible downlink traffic has to shared between the SGSNs as described in chapter 5.3.2 “Gb mode”.

4.6 Mobility Management

An MS performs LA or RA Updates and Attachments, which may result in a change of the serving CN node. In these procedures the new CN node requests from the old CN node MS specific parameters. If multiple CN nodes are configured in the new CN node for the old RA or LA indicated by the MS then the new CN node derives the NRI from the old (P-)TMSI indicated by the MS. The new CN node uses the old RA or LA together with the NRI to derive the signalling address of the old CN node from its configuration data. If the network contains nodes that cannot derive the old CN node from LAI/RAI and NRI a default CN node for each RA or LA (as described below) shall be used to resolve the ambiguity of the multiple CN nodes serving the same area.

4.7 Default CN node and Backwards Compatibility

CN nodes that can only derive one CN node from the LAI or RAI (e.g. because they do not support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes, or no detailed knowledge of the NRIs is configured) are not aware, that multiple CN nodes may serve a LA or RA. These nodes can therefore

contact only one CN node per LA or RA, respectively. This node will further on be referred to as default node.

A default node that supports the Intra Domain Connection of RAN Nodes to Multiple CN nodes resolves the ambiguity of the multiple CN nodes per LA or RA by deriving the NRI from the TMSI and P-TMSI. The default node relays the signalling between the new CN node and the old CN node.

Note that the default node is configured per LA or RA. So different CN nodes in a network might have configured different default nodes for a LA or RA. With this approach more than one of the CN nodes that serve a pool-area can be used as default-node, so load concentration on one node and a single point of failure can be avoided.

Note further, that it may be required to keep information on ongoing MAP/GTP dialogues in the default nodes.

The handover/relocation from CN nodes which do support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes to CN nodes not supporting this features does not need a NAS Node Selection Function in the originating CN node as there is only one target CN node. The originating CN node discovers from its configuration data, that there is only one target CN node for the requested handover/relocation target ID.

4.8 Support of combined mobility management procedures

Attach

In case of 'combined GPRS/IMSI attach' or 'GPRS attach when already IMSI attached', the SGSN sends the Location Update Request message to the MSC/VLR. The SGSN selects an MSC/VLR from the available MSC/VLRs which serve the current LA of the MS. The selection bases on a hash value derived from the IMSI. It is configured in the SGSN which range of the hash values relates to which MSC/VLR. This selection mechanism avoids a random change of the MSC/VLR for MSs using combined procedures when an SGSN fails. The new SGSN will select the same MSC/VLR.

Routing area update

The CN node changes in the following considerations result from pool-area changes (when pool-areas are configured) or from CN node service area changes (when no pool-areas are configured). For each domain (PS or CS) it is configured independently whether pool-areas are used or not.

When neither the MSC nor the SGSN are changed, the association for an MS between both CN nodes will also not change.

When the MSC changes but the SGSN does not change, the SGSN selects a new MSC because the new LA is not served by the old MSC/VLR. The selection mechanism is as described for the attach above.

When the SGSN changes but the MSC does not change, the new SGSN selects the old MSC to establish a Gs association because the new SGSN uses the same selection mechanism as described above for the attach with the same parameters as configured in the old SGSN.

When both the MSC and the SGSN change, the new SGSN selects a new MSC to establish a Gs association. The selection mechanism is as described for the attach above.

~~4.9Multiple Core Networks connected to a single BSS or RNS~~

~~The NAS Node Selection Function in the RAN nodes differentiates between CN nodes, which may be of different operators. Preferably, the available NRI values are split between the operators. The NAS Node Selection Function in the RAN node is configured to know which NRI values belong to which operator. An MS which is not yet assigned to a CN node, i.e. there is no CN node configured for the NRI indicated~~

by the MS, is assigned to an available CN node of that operator which uses the indicated NRI value. When no NRI can be derived the MS is assigned to a CN node selected from all available CN nodes.

The selection of a CN node may result in the assignment to a CN node of a "wrong" operator as, for example, the NRI may be derived from a TMSI which was allocated by a CN node of another network or by a CN node of an area which does not use the Intra Domain Connection of RAN Nodes to Multiple CN Nodes. The CN node derives and evaluates the IMSI. If evaluation of the IMSI shows that the MS should be served by one of the other CNs sharing the RAN, then the CN node rejects the attach or update request. The NAS Node Selection Function in the RAN node selects then an available CN node of another operator.

Once the MS is assigned to a CN node of the "right" operator it is always again assigned to a CN node of the same operator as long as the MS moves within a pool-areas where the same NRI value split and CN nodes of the same operators are configured.

5 Functional Description

5.1 MS Functions

In Iu mode the MS provides the IDNNS to the RNC in the access stratum part of the *RRC_initial_DT* message as described in [5].

No changes are expected in the MS for Gb or A interface mode.

5.2 RNC Functions

The RNC provides the NAS Node Selection Function. It masks the significant number of bits out of the IDNNS provided by the MS together with the initial NAS signalling message. The significant number of bits is configured in the RNC. The NAS Node Selection Function derives from the NRI the address of the specific CN node for the relevant domain (CS or PS). The association between NRI values and CN node addresses is configured in the RNC (O&M).

The RNC routes the initial NAS signalling messages according to the NRI and the “domain indicator” (CS or PS) to the relevant CN node if a CN node address is configured in the RNC for the specific NRI and the requested domain (CS or PS).

If no CN node address is configured in the RNC for the requested NRI or if the provided identity contains no NRI then the RNC routes the initial NAS signalling message to a CN node selected from the available CN nodes which serve the related domain (CS or PS). The selection mechanism is implementation dependent and should enable load balancing between the available CN nodes.

In case a MSC sends a paging with IMSI, the RNC shall upon reception temporarily store the MSC/VLR-identity of the node that issued the paging message. If the MSC/VLR initiates the paging procedure via Gs-interface the SGSN has to add the MSC/VLR-identity to the paging message.

5.3 BSC Functions

5.3.1 A interface mode

The BSC provides the NAS Node Selection Function. It is aware whenever a new RR connection is established. In particular, the BSC always examines the content of the Initial Layer 3 message sent by the MS in order to determine the position of the MS Classmark and to extract its contents. The examination of the Initial Layer 3 message content allows the BSC to observe the TMSI+LAI or IMSI or IMEI.

The BSC derives from Initial Layer 3 messages the NRI from the TMSI. It is configured in the BSC (O&M) which bits of the TMSI are significant for the NRI. The BSC routes the Initial Layer 3 message according to the NRI to the relevant MSC if an MSC address is configured in the BSC for the specific NRI. The association between NRI values and MSC addresses is configured in the BSC (O&M).

If no MSC address is configured in the BSC for the requested NRI or if no TMSI is sent by the MS (e.g. an IMSI or IMEI) then the BSC routes the initial NAS signalling message to an MSC selected from the available MSCs. In addition, the BSC may route the initial NAS signalling message to an MSC selected from the available MSCs if this message is a Location Update Request messages and the PLMN ID in the LAI is not one of the PLMN IDs served by the BSC (FFS). The selection mechanism is implementation dependent and should enable load balancing between the available MSCs.

In case a MSC sends a paging-request with IMSI, the NAS node selection function in the BSC shall upon reception temporarily store the MSC/VLR-identity of the node that issued the paging-request message.

5.3.2 Gb mode

The BSC provides the NAS Node Selection Function. The MS sends the TLLI to the BSC. The NRI is part of the P-TMSI and therefore also contained in the 'local TLLI' or in the 'foreign TLLI'. The number of bits out of the TLLI which are significant for the NRI is configured in the BSC (O&M).

A 'local TLLI' indicates to the BSC that the TLLI is derived from a P-TMSI which was assigned for the current RA, i.e. the 'local TLLI' contains an NRI which is valid for routing to an SGSN. A 'foreign TLLI' indicates to the BSC that the TLLI is derived from a P-TMSI which was assigned for another RA than the current RA. The BSC does not know whether the other RA and therefore the related P-TMSI belongs to the same pool-area or not unless this is configured in the BSC (which is not intended). Consequently, the BSC assumes, that the 'foreign TLLI' contains a NRI which is valid for routing to an SGSN.

For 'local TLLIs' and for 'foreign TLLIs' the BSC masks the NRI out of the TLLI which is indicated in each LLC frame. The BSC routes the uplink LLC frame to the relevant SGSN if an SGSN address is configured in the BSC for the specific NRI. The association between NRI values and SGSN addresses is configured in the BSC (O&M).

If no SGSN address is configured in the BSC for the requested NRI, which may happen for NRIs masked out of a 'foreign TLLI', or if the BSC received a 'random TLLI' which contains no NRI at all then the RNC routes the uplink LLC frame to an SGSN selected from the available SGSNs. The selection mechanism is implementation dependent and should enable load balancing between the available SGSNs.

Note: For the selection mechanism in the BSC it is probably sufficient, that the algorithm is ‘slow moving’. If the selection algorithm changes the SGSN to be assigned for 'random TLLIs' or for ’foreign TLLIs’ whose NRI value is not used in the current SGSN pool area during a MS’s Attach procedure or RA update procedure, then the Attach procedure or RA update procedure is likely to fail, but the MS will reattempt the procedure at T3310/T3330 expiry (=15 seconds).

As more than one SGSN may send downlink data at the same time for a cell or a BVCI, the BSC has to share the total possible downlink traffic between the SGSNs that can access a cell. The BSC should use the existing flow control procedure on cell level to control each of the SGSNs in a way not to violate the total possible traffic for the cell. How the BSC decides to share the downlink traffic between each of the SGSNs is an implementation specific issue; e.g. the possible downlink traffic can be equally shared between the SGSNs, or the share of each SGSN can be proportional to the capacity of the SGSN. In case a MSC sends a paging-request with IMSI via Gs-interface the SGSN has to add the MSC/VLR-identity to the paging-request message. The NAS node selection function in the BSC/RNC shall upon reception temporarily store the MSC/VLR-identity.

5.3.3 Iu mode

To support MSs in Iu mode the BSC provides the same functionality as described under "RNC Functions".

5.4 MSC Functions

TMSI Allocation

Every MSC is configured with its one or more specific NRI (O&M). One of these specific NRIs is part of every temporary identity (TMSI) which the MSC assigns to an MS. The TMSI allocation mechanism in the MSC generates TMSIs which contain one of the specific NRIs in the relevant bit positions. An NRI has a flexible length between 10 and 0 bits (0 bits means the NRI is not used and the feature is not applied). The use of the bits not used to encode the NRI is implementation dependent (e.g. to extent the TMSI space).

Mobility Management and Handover/Relocation

For MAP signalling between two MSCs which both support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes the new MSC derives the address of the old MSC from the old LAI and the NRI contained in the old TMSI. The MSC addresses for each LAI and NRI combination are configured in the MSC (O&M). If the network contains MSCs that cannot derive the old MSC from LAI and NRI the default MSC per LAI as described below shall be used (e.g. to reduce the configuration effort). Some redundancy may be required as the default MSC is a single point of failure.

The load balancing between multiple target MSCs at handover/relocation into a pool area is described in "Load Balancing~~4.5 Load Balancing~~". The handover/relocation from an MSC that supports the Intra Domain Connection of RAN Nodes to Multiple CN Nodes to an MSC not supporting the feature needs no new functionality, as there is only one MSC that serves the handover/relocation target.

Backward Compatibility and Default MSC

If a default MSC that is serving a pool-area receives MAP signalling (e.g. to fetch the IMSI or to get unused cipher parameters) it has to resolve the ambiguity of the multiple MSCs per LAI by deriving the NRI from the TMSI. The MSC relays the MAP signalling to the old MSC identified by the NRI in the old TMSI unless the default MSC itself is the old MSC. For every NRI value that is used in the pool-area an MSC address is configured in the default MSC (O&M).

Note, that it might be required to keep information on ongoing MAP dialogues in the default MSC.

Support of Combined Procedures

If the SGSN does not support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes then only one default out of the MSCs serving the related LA can be used for the combined procedures. A relaying or diverting from the default MSC to another is FFS. Distributing the associations of the combined procedures according to the LAs would result in MSC changes when the MS is still in the old MSC service area.

5.5 SGSN Functions

P-TMSI Allocation

Every SGSN is configured with its specific one or more NRI (O&M). One of these specific NRIs is part of every temporary identity (P-TMSI) which the SGSN assigns to an MS. The P-TMSI allocation mechanism

in the SGSN generates P-TMSIs which contain one of the specific NRIs in the relevant bit positions. An NRI has a flexible length between 10 and 0 bits (0 bits means the NRI is not used and the feature is not applied). The use of the bits not used to encode the NRI is implementation dependent (e.g. to extent the TMSI space).

Mobility Management and Handover/Relocation

For the GTP signalling between two SGSNs supporting the Intra Domain Connection of RAN Nodes to Multiple CN Nodes the new SGSN derives the address of the old SGSN from the old RAI and the NRI contained in the old P-TMSI/TLLI. The SGSN addresses are configured in the SGSN (O&M) or in DNS for each RAI and NRI combination. If the network contains SGSNs that cannot derive the old SGSN from RAI and NRI the default SGSN per RAI as described below shall be used (e.g. to reduce the configuration effort).

The load balancing between multiple target SGSNs at handover/relocation into a pool area is described in "Load Balancing~~4.5 Load Balancing~~". The handover/relocation from an SGSN that supports the Intra Domain Connection of RAN Nodes to Multiple CN Nodes to an SGSN not supporting the feature needs no new functionality, as there is only one SGSN that serves the handover/relocation target.

Backward Compatibility and Default SGSN

If a default SGSN that is serving a pool-area receives GTP signalling (e.g. to fetch the IMSI or to get unused cipher parameters) it has to resolve the ambiguity of the multiple SGSNs per RAI by deriving the NRI from the P-TMSI. The SGSN relays the GTP signalling to the old SGSN identified by the NRI in the old P-TMSI unless the default SGSN itself is the old SGSN. For every NRI value that is used in the pool-area an SGSN address is configured in the relaying SGSN (O&M) or in DNS.

Note, that it might be required to keep information on ongoing GTP dialogues in the default SGSN.

Support of Combined Procedures

The SGSN has to select an MSC at the Gs interface for the combined procedures if multiple MSCs are configured for the relevant LAI. Preferably, the MSC out of the available MSCs is selected based on the IMSI. This prevents an MSC change for many MSs if an SGSN fails and the re-attaching MSs would get assigned another MSC by the new SGSN. Two HLR updates instead of one would be the result. In addition the SGSN may perform load balancing at the Gs interface if this is required as the load balancing at the RAN - CN interface might be sufficient if not all MSs are attached to PS and CS (FFS).

Note, that the algorithm based on which the SGSN derives the MSC from the IMSI needs to be unique in all SGSNs and therefore should be standardized.

CS Paging

If a CS paging is received via the Gs interface from MSC with mobile identity type IMSI then the SGSN should include the MSC/VLR-id in the paging / paging-request message to RNC/BSC.

6 Application Examples

This clause describes some application examples for networks using the intra domain NAS node selection. In these examples, pool-areas are depicted by boxes or ellipses, while the core network elements which serve the pool-areas are depicted by the NRIs they have been assigned.

6.1 Network configuration example 1

This example configures 9 pool-areas each with 3 CN nodes serving within a pool-area. When a MS moves from one (NRI:1,2,3) to another pool-area (NRI:4,5,6). It indicates the old NRI (3) derived from its old TMSI to the RNC in the new pool-area (NRI:4,5,6). This NRI 3 is not configured in the RNC of the pool-area (NRI:4,5,6). The RNC selects a CN node out of the available NRIs 4,5,6 and establishes the signalling connection for the MS with the selected CN node. This new CN nodes allocates a new TMSI to the MS and thereby the new NRI for the new pool-area.

In this example, the NRIs can be re-used in a pattern where adjacent pool areas do not use the same NRI. Every pool area change will initiate a new selection of a new CN node.

NRI: 19, 20, 21	NRI: 22, 23, 24	NRI: 25, 26, 27
NRI: 16, 17, 18	NRI: 1, 2, 3	NRI: 4, 5, 6
NRI: 13, 14, 15	NRI: 10, 11, 12	NRI: 7, 8, 9

Figure 23: Network configuration example 1

6.2Network configuration example 2

In this example one RAN serves two CNs. For this purpose the NRI space is divided between the CNs. The example configures only one CN node per CN within a pool area. After the initial assignment to a CN every MS is assigned again to CN nodes of the same CN when the pool area is changed. The example corresponds to an overlay of two CNs each without Iu Flex as per CN only one CN node serves a pool area. This configuration can be extended by multiple CN nodes per CN serving a pool area.

NRI: 1, 2	NRI: 1, 2	NRI: 1, 2
NRI: 1, 2	NRI: 1, 2	NRI: 1, 2
NRI: 1, 2	NRI: 1, 2	NRI: 1, 2

Figure 4: Network configuration example 2

6.36.2 Network configuration example 23

This example shows a network covering one city centre surrounded by residential areas. The city centre is covered by all 4 pool-areas while each of the residential areas is covered by one pool-area only. Once a MS „found“ its pool-area, it will not change the pool-area while commuting between the city centre and its

residential area. Each of the pool-areas is served by 5 MSCs, indicated by the 5 NRI values in the figure below, which share the load within the pool-area. Only distinct NRI values are used for the overlapping pool-areas. Therefore, a MS changing between these pool-areas will always be allocated to a new MSC by the NAS node selection function. In addition it is shown, that the NRIs can be re-used in other pool-areas as indicated in the figure by the smaller areas with only one NRI. Also at a change to these areas the MSs will always be allocated to a new MSC by the NAS node selection function as adjacent areas do not use the same NRI values.

A calculation for the possible number of subscribers in this scenario is in Annex A.1: One city centre surrounded by residential areas C.1: One city centre surrounded by residential areas

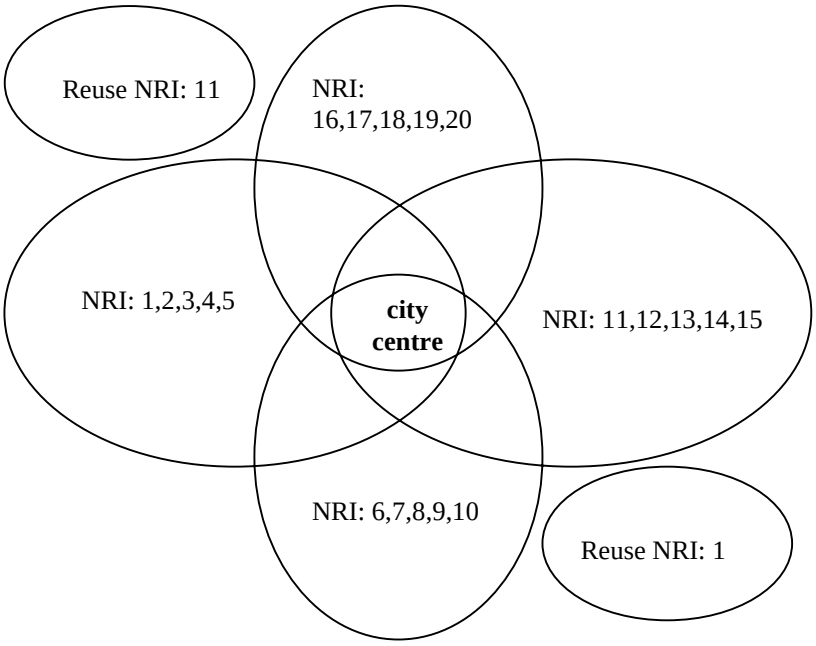


Figure 45: Network configuration example 3

7 Specific Examples

This chapter describes specific examples of IuFlex. First, building blocks of IuFlex are described in 7.1. These building blocks are then used in signalling flows starting from 7.2.

The changes to the signalling flows are indicated in *italic.*

7.1 Building blocks for signalling flows

7.1.1 RAN node selecting CN node in A interface mode

7.1.2 RAN node selecting CN node in Gb interface mode

7.1.3 RAN node selecting CN node in Iu interface mode

7.1.4 New CN node selecting old CN node

This building block describes how a new CN node selects the old CN node which was previously serving the MS. The new CN node has been allocated to serve the MS, and it may have to communicate with the old CN node e.g. in order to get IMSI of the MS or to get MM and PDP contexts of the MS.

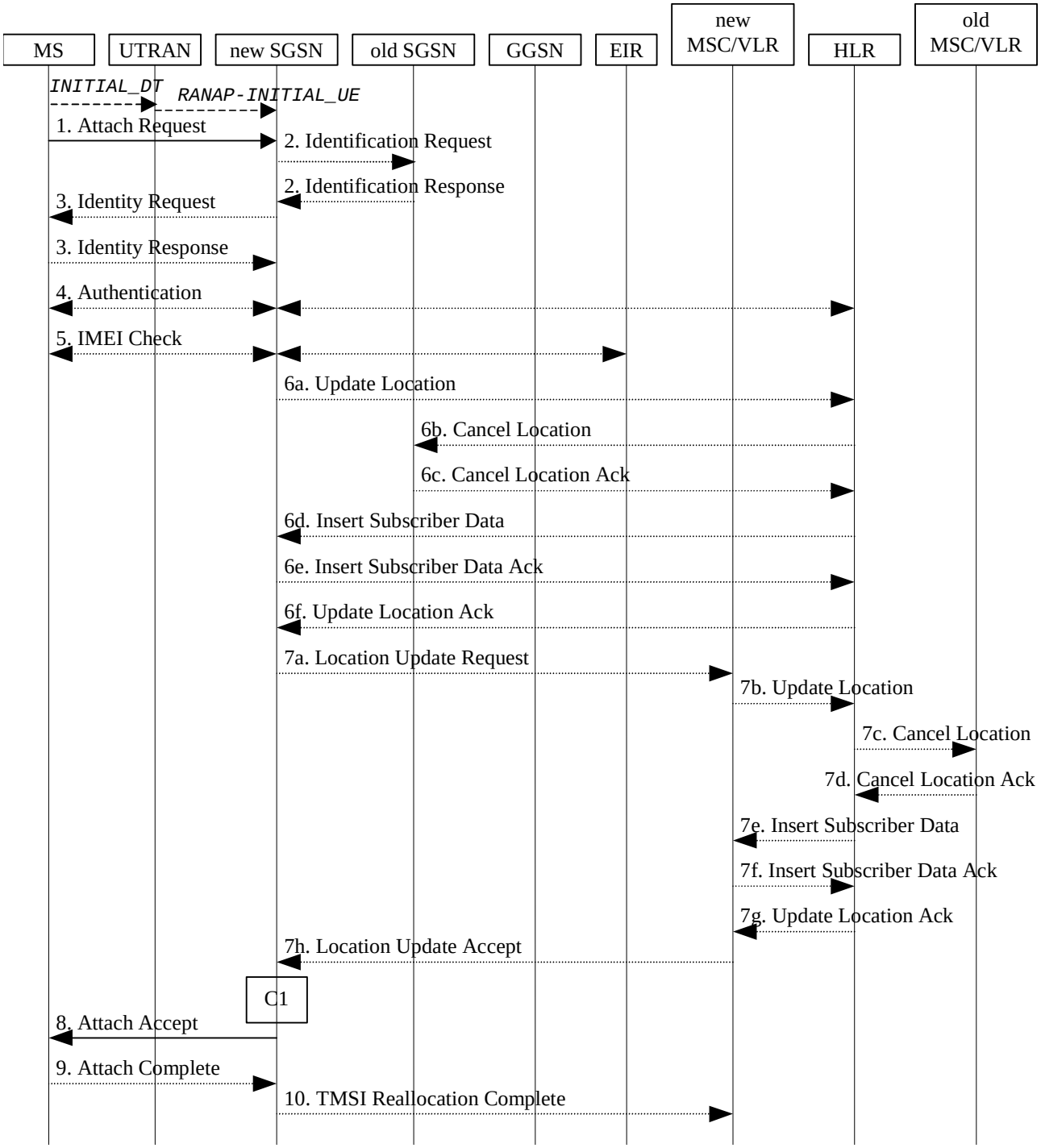
7.1.5 Old CN node selecting new CN node

This building block describes how the old CN node selects a new CN node which starts to serve the MS. The old CN node has to select a new CN node e.g. when performing handover.

7.1.6 SGSN selecting MSC

7.2 Signalling flow for Attach (Iu interface mode)

At attach, the RNC selects an SGSN to serve the MS. The attach procedure is shown in the figure below.



1) The Attach Request (old P-TMSI, old RAI, old P-TMSI Signature) is carried in the Initial Direct Transfer message (RRC) from the MS to the RNC. The RNC selects an SGSN to serve the MS as described in 7.1.3 and relays the Attach Request to the SGSN in the Initial UE message (RANAP).

2) If the MS identifies itself with P-TMSI and the SGSN has changed since detach, the new SGSN sends an Identification Request (P-TMSI, old RAI, old P-TMSI Signature) to the old SGSN to request the IMSI. *The new SGSN selects the old SGSN as described in 7.1.4.* The old SGSN responds with Identification Response (IMSI, Authentication Triplets (for GPRS) or Authentication Vectors (for UMTS)). If the MS is not known in the old SGSN, the old SGSN responds with an appropriate error cause. The old SGSN also validates the old P-TMSI Signature and responds with an appropriate error cause if it does not match the value stored in the old SGSN.

3) If the MS is unknown in both the old and new SGSN, the SGSN sends an Identity Request (Identity Type = IMSI) to the MS. The MS responds with Identity Response (IMSI).

4) The authentication functions are defined in the subclause "Security Function" of 23.060. If no MM context for the MS exists anywhere in the network, then authentication is mandatory. Ciphering procedures are described in subclause "Security Function" of 23.060. If P-TMSI allocation is going to be done and the network supports ciphering, the network shall set the ciphering mode.

5) The equipment checking functions are defined in the subclause "Identity Check Procedures" of 23.060. Equipment checking is optional.

6) If the SGSN number has changed since the GPRS detach, or if it is the very first attach, then the SGSN informs the HLR:

   a) The SGSN sends an Update Location (SGSN Number, SGSN Address, IMSI) to the HLR.

   b) The HLR sends Cancel Location (IMSI, Cancellation Type) to the old SGSN with Cancellation Type set to Update Procedure.

   c) The old SGSN acknowledges with Cancel Location Ack (IMSI). If there are any ongoing procedures for that MS, the old SGSN shall wait until these procedures are finished before removing the MM and PDP contexts.

   d) The HLR sends Insert Subscriber Data (IMSI, GPRS Subscription Data) to the new SGSN.

   e) The new SGSN validates the MS's presence in the (new) RA. If due to regional subscription restrictions the MS is not allowed to attach in the RA, the SGSN rejects the Attach Request with an appropriate cause, and may return an Insert Subscriber Data Ack (IMSI, SGSN Area Restricted) message to the HLR. If subscription checking fails for other reasons, the SGSN rejects the Attach Request with an appropriate cause and returns an Insert Subscriber Data Ack (IMSI, Cause) message to the HLR. If all checks are successful then the SGSN constructs an MM context for the MS and returns an Insert Subscriber Data Ack (IMSI) message to the HLR.

   f) The HLR acknowledges the Update Location message by sending an Update Location Ack to the SGSN after the cancelling of old MM context and insertion of new MM context are finished. If the Update Location is rejected by the HLR, the SGSN rejects the Attach Request from the MS with an appropriate cause.

7) If Attach Type in step 1 indicated GPRS Attach while already IMSI attached, or combined GPRS / IMSI attached, then the VLR shall be updated if the Gs interface is installed. *The VLR number is determined as described in 7.1.6.* The SGSN starts the location update procedure towards the new MSC/VLR upon receipt of the first Insert Subscriber Data message from the HLR in step 6d). This operation marks the MS as GPRS-attached in the VLR.

   a) The SGSN sends a Location Update Request (new LAI, IMSI, SGSN Number, Location Update Type) message to the VLR. Location Update Type shall indicate IMSI attach if Attach Type indicated combined GPRS / IMSI attach. Otherwise, Location Update Type shall indicate normal location update. The VLR creates an association with the SGSN by storing SGSN Number.

   b) If the LA update is inter-MSC, the new VLR sends Update Location (IMSI, new VLR) to the HLR.

   c) If the LA update is inter-MSC, the HLR sends a Cancel Location (IMSI) to the old VLR.

   d) The old VLR acknowledges with Cancel Location Ack (IMSI).

   e) If the LA update is inter-MSC, the HLR sends Insert Subscriber Data (IMSI, GSM subscriber data) to the new VLR.

   f) The VLR acknowledges with Insert Subscriber Data Ack (IMSI).

   g) After finishing the inter-MSC location update procedures, the HLR responds with Update Location Ack (IMSI) to the new VLR.

   h) The VLR responds with Location Update Accept (VLR TMSI) to the SGSN*. An IuFlex aware VLR includes one of its (CS-)NRIs as part of VLR TMSI. The SGSN creates an association with the VLR by storing VLR number.*

8) The SGSN selects Radio Priority SMS, and sends an Attach Accept (P-TMSI, VLR TMSI, P-TMSI Signature, Radio Priority SMS) message to the MS. P-TMSI is included if the SGSN allocates a new P-TMSI. *An IuFlex aware SGSN includes one of its (PS-)NRIs as part of P-TMSI.*

9) If P-TMSI or VLR TMSI was changed, the MS acknowledges the received TMSI(s) by returning an Attach Complete message to the SGSN.

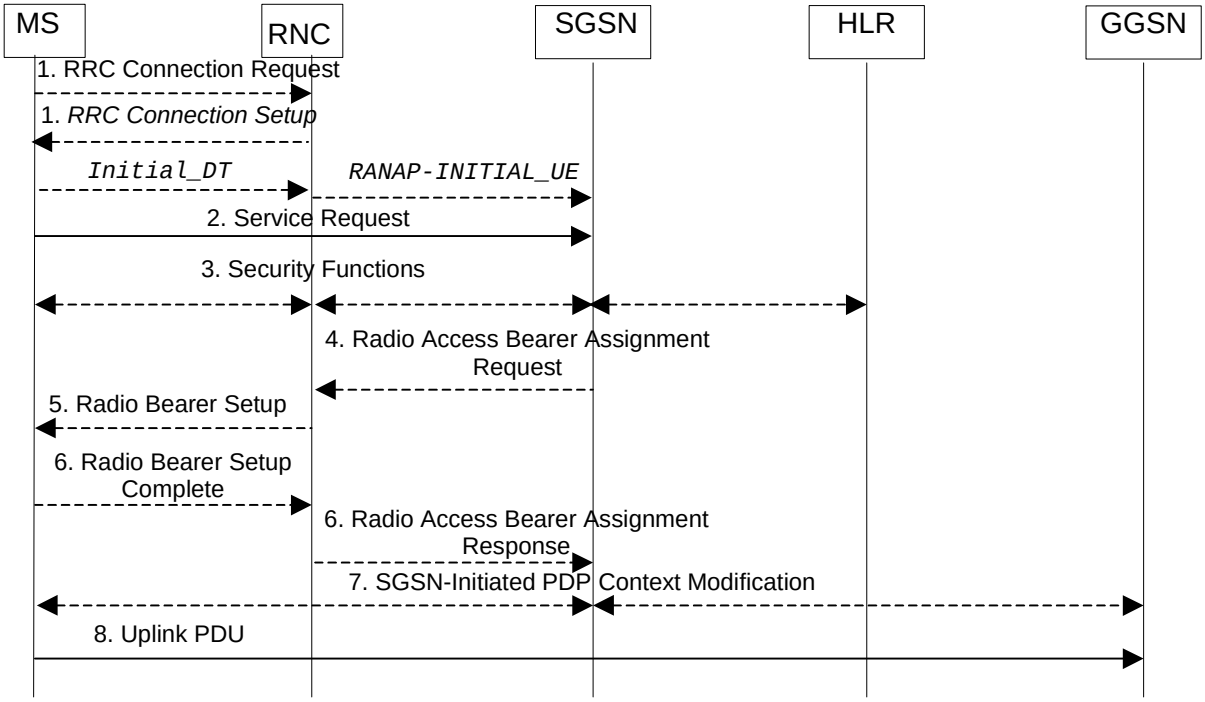
10) If VLR TMSI was changed, the SGSN confirms the VLR TMSI re-allocation by sending a TMSI Reallocation Complete message to the VLR.

7.3 Signalling flows for Service Request (Iu interface mode)

When performing service request, the signalling connection between the MS and the SGSN is re-established.

7.3.1 Service Request initiated by MS

The service request procedure initiated by the MS is shown in the figure below.



1) The MS establishes an RRC connection, if none exists for CS traffic.

2) The MS sends a Service Request (P-TMSI, RAI, CKSN, Service Type) message to the SGSN. Service Type specifies the requested service. Service Type shall indicate one of the following: Data or Signalling. *The Service Request is carried in the Initial Direct Transfer message (RRC) from the MS to the RNC. The RNC selects an SGSN to serve the MS as described in 7.1.3 and relays the Service Request to the SGSN in the Initial UE message (RANAP).* At this point, the SGSN may perform the authentication procedure.

If Service Type indicates Data, a signalling connection is established between the MS and the SGSN, and resources for active PDP context(s) are allocated, i.e., RAB establishment for the activated PDP context(s).

If Service Type indicates Signalling, the signalling connection is established between the MS and the SGSN for sending upper-layer signalling messages, e.g., Activate PDP Context Request. The resources for active PDP context(s) are not allocated.

3) The SGSN shall perform the security functions if the MS in PMM-IDLE state initiated the service request.

4) If the network is in PMM-CONNECTED state and the Service Type indicates Data, the SGSN shall respond with a Service Accept message towards the MS, in case the service request can be accepted. In case Service Type indicates Data, the SGSN sends a Radio Access Bearer Assignment Request (NSAPIRAB ID(s), TEID(s), QoS Profile(s), SGSN IP Address(es)) message to re-establish radio access bearer for every activated PDP context.

5) The RNC indicates to the MS the new Radio Bearer Identity established and the corresponding RAB ID with the RRC radio bearer setup procedure.

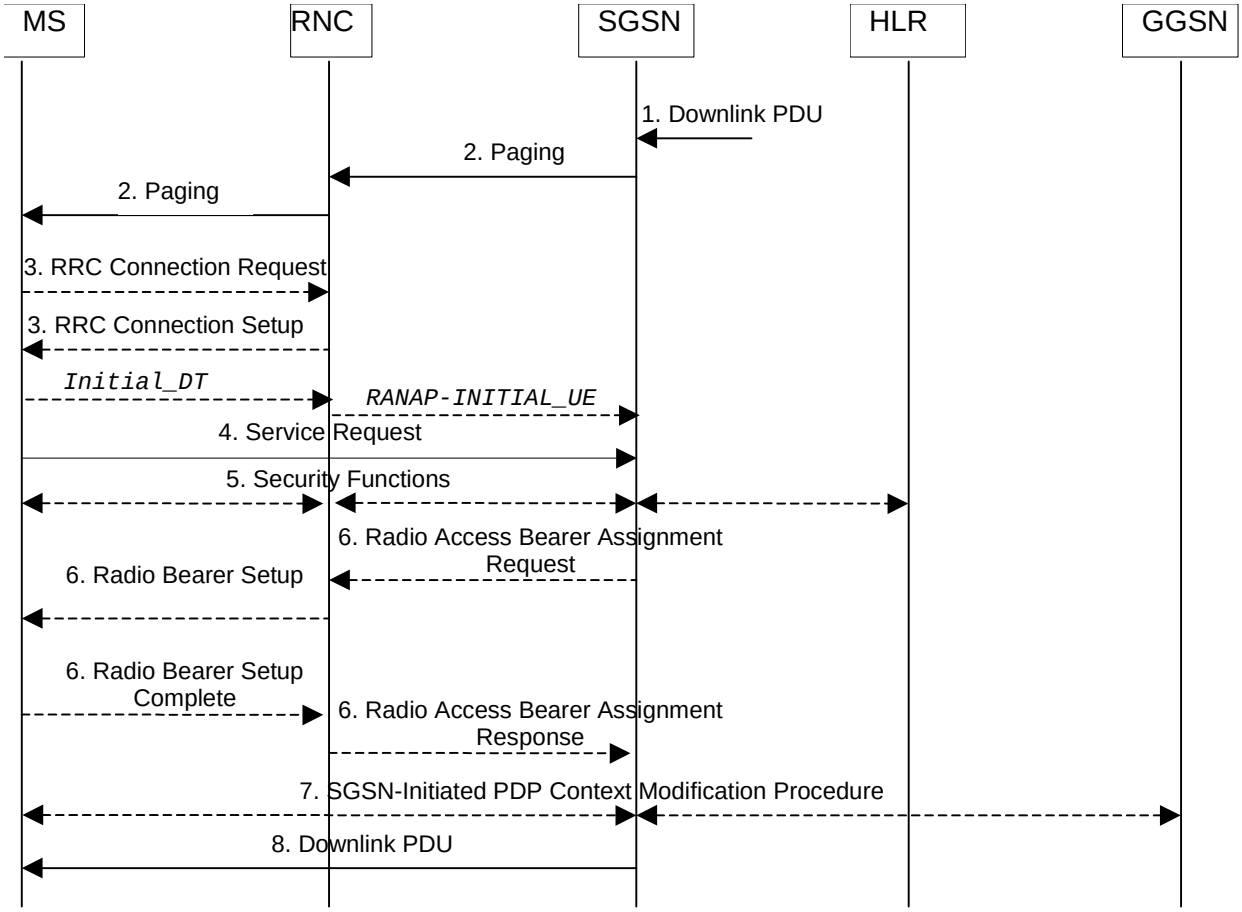
6) SRNC responds with the Radio Access Bearer Assignment Response (RAB ID(s), TEID(s), QoS Profile(s), RNC IP Address(es)) message. The GTP tunnel(s) are established on the Iu interface. If the RNC returns a Radio Access Bearer Assignment Response message with a cause indicating that the requested QoS profile(s) can not be provided, e.g., "Requested Maximum Bit Rate not Available", the SGSN may send a new Radio Access Bearer Assignment Request message with different QoS profile(s). The number of re-attempts, if any, as well as how the new QoS profile(s) values are determined is implementation dependent.

7) For each RAB re-established with a modified QoS profile, the SGSN initiates a PDP Context Modification procedure to inform the MS and the GGSN of the new negotiated QoS profile for the corresponding PDP context.

8) The MS sends the uplink packet.

7.3.2 Service Request initiated by network

The service request procedure initiated by the network is shown in the figure below.



1) The SGSN receives a downlink PDP PDU for an MS in PMM-IDLE state.

2) The SGSN sends a Paging message to the RNC. The RNC pages the MS by sending a Paging message to the MS. See subclause "PS Paging Initiated by 3G-SGSN without RRC Connection for CS" of 23.060 for details.

3) The MS establishes an RRC connection if none exists for CS traffic.

4) The MS sends a Service Request (P-TMSI, RAI, CKSN, Service Type) message to the SGSN. Service Type specifies Paging Response. The Service Request is carried over the radio in an RRC Direct Transfer message. *The RNC selects an SGSN to serve the MS as described in 7.1.3 and relays the Service Request to the SGSN in the Initial UE message (RANAP).* At this point, the SGSN may perform the authentication procedure. The SGSN knows whether the downlink packet requires RAB establishment (e.g., downlink PDU) or not (e.g., Request PDP Context Activation or MT SMS).

5) The SGSN shall perform the security mode procedure.

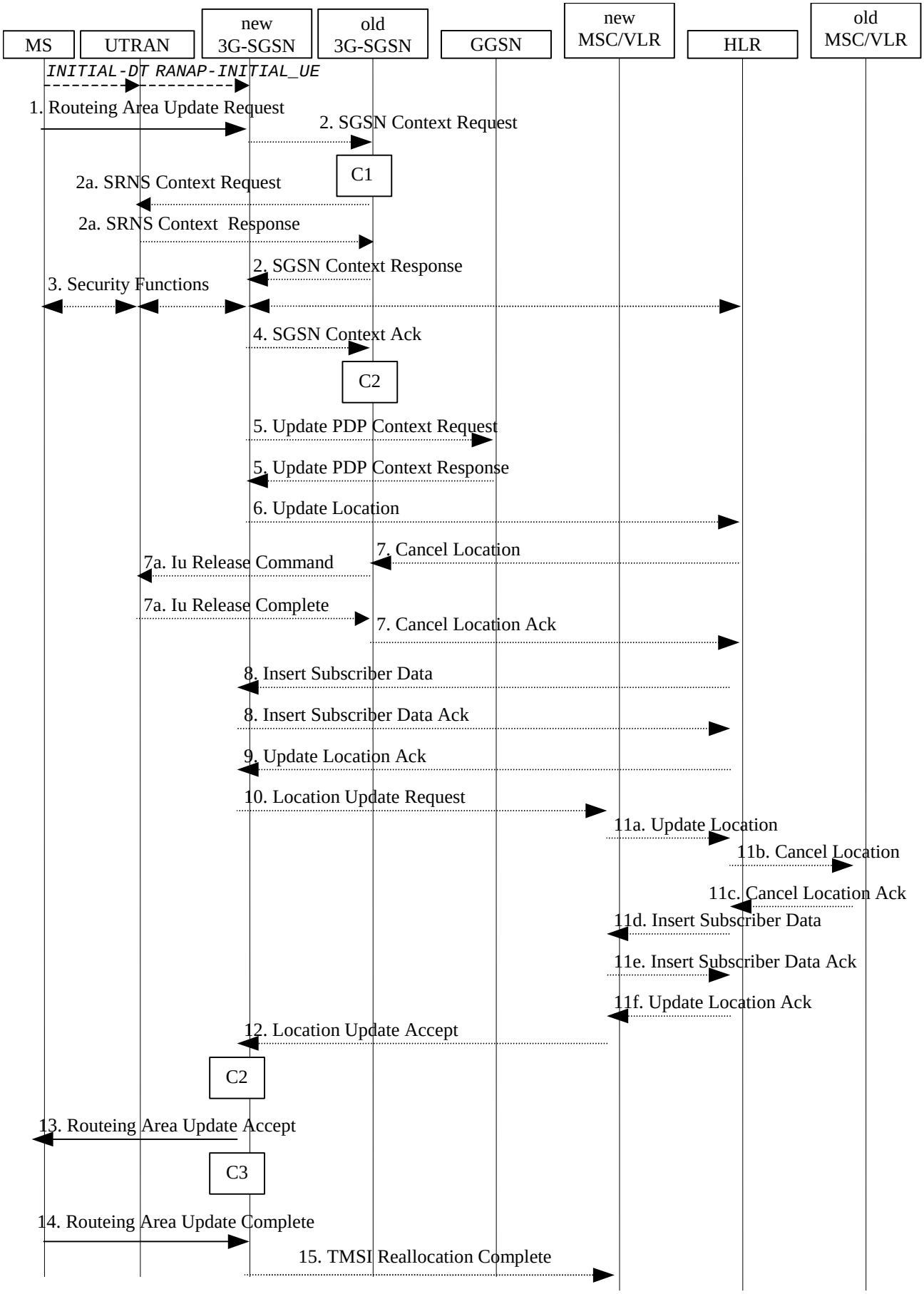
6) If resources for the PDP contexts are re-established, the SGSN sends a Radio Access Bearer Assignment Request (RAB ID(s), TEID(s), QoS Profile(s), SGSN IP Address(es)) message to the RNC. The RNC sends a Radio Bearer Setup (RAB ID(s)) to the MS. The MS responds by returning a Radio Bearer Setup Complete message to the RNC. The RNC sends a Radio Access Bearer Assignment Response (RAB ID(s), TEID(s), RNC IP Address(es)) message to the SGSN in order to indicate that GTP tunnels are established on the Iu interface and radio access bearers are established between the RNC and the MS. If the RNC returns a Radio Access Bearer Assignment Response message with a cause indicating that the requested QoS profile(s) can not be provided, e.g., "Requested Maximum Bit Rate not Available", the SGSN may send a new Radio Access Bearer Assignment Request message with different QoS profile(s). The number of re-attempts, if any, as well as how the new QoS profile(s) values are determined is implementation dependent.

7) For each RAB re-established with a modified QoS profile, the SGSN initiates a PDP Context Modification procedure to inform the MS and the GGSN of the new negotiated QoS profile for the corresponding PDP context.

8) The SGSN sends the downlink packet.

7.4 Signalling flow for Routing Area Update (Iu interface mode)

The routing area update procedure is shown in the figure below.


MS
UTRAN
new 3G-SGSN
old 3G-SGSN
GGSN
new MSC/VLR
HLR
old MSC/VLR
INITIAL-DT RANAP-INITIAL_UE
1. Routeing Area Update Request
2. SGSN Context Request
C1
2a. SRNS Context Request
2a. SRNS Context Response
2. SGSN Context Response
3. Security Functions
4. SGSN Context Ack
C2
5. Update PDP Context Request
5. Update PDP Context Response
6. Update Location
7. Cancel Location
7a. Iu Release Command
7a. Iu Release Complete
7. Cancel Location Ack
8. Insert Subscriber Data
8. Insert Subscriber Data Ack
9. Update Location Ack
10. Location Update Request
11a. Update Location
11b. Cancel Location
11c. Cancel Location Ack
11d. Insert Subscriber Data
11e. Insert Subscriber Data Ack
11f. Update Location Ack
12. Location Update Accept
C2
13. Routeing Area Update Accept
C3
14. Routeing Area Update Complete
15. TMSI Reallocation Complete

1) The RRC connection is established, if not already done. The Routeing Area Update Request (old P-TMSI, old RAI, old P-TMSI Signature) is carried in the Initial Direct Transfer message (RRC) from the MS to the RNC. The RNC selects an SGSN to serve the MS as described in 7.1.3 and relays the Routeing Area Update Request to the SGSN in the Initial UE message (RANAP).

2) If the RA update is an Inter-SGSN Routeing area update and if the MS was in PMM-IDLE state, the new SGSN sends an SGSN Context Request message (old P-TMSI, old RAI, old P-TMSI Signature) to the old SGSN to get the MM and PDP contexts for the MS. *The new SGSN selects the old SGSN as described in 7.1.4.* The old SGSN validates the old P-TMSI Signature and responds with an appropriate error cause if it does not match the value stored in the old SGSN. This should initiate the security functions in the new SGSN. If the security functions authenticate the MS correctly, the new SGSN shall send an SGSN Context Request (IMSI, old RAI, MS Validated) message to the old SGSN. MS Validated indicates that the new SGSN has authenticated the MS. If the old P-TMSI Signature was valid or if the new SGSN indicates that it has authenticated the MS, the old SGSN responds with SGSN Context Response (Cause, IMSI, MM Context, PDP contexts). If the MS is not known in the old SGSN, the old SGSN responds with an appropriate error cause. The old SGSN starts a timer. The new SGSN shall ignore the MS Network Capability contained in MM Context of SGSN Context Response only when it has previously received an MS Network Capability in the Routeing Area Request.

2a) If the MS is PMM-CONNECTED in the old 3G-SGSN, the old SGSN shall send an SRNS Context Request (IMSI) message to the old SRNS to retrieve the sequence numbers for the PDP context for inclusion in the SGSN Context Response message from the SRNS. Upon reception of this message, the SRNS buffers and stops sending downlink PDUs to the MS and returns an SRNS Context Response (IMSI, GTP-SNDs, GTP-SNUs, PDCP-SNUs) message. The SRNS shall include for each PDP context the next in-sequence GTP sequence number to be sent to the MS and the GTP sequence number of the next uplink PDU to be tunnelled to the GGSN. For each active PDP context using acknowledged mode, the SRNS also includes the uplink PDCP sequence number (PDCP-SNU). PDCP-SNU shall be the next in-sequence PDCP sequence number expected from the MS (per each active radio bearer).

3) Security functions may be executed. These procedures are defined in subclause "Security Function" of 23.060. If the security functions do not authenticate the MS correctly, the routeing area update shall be rejected, and the new SGSN shall send a reject indication to the old SGSN. The old SGSN shall continue as if the SGSN Context Request was never received.

4) If the RA update is an Inter-SGSN Routeing area update, the new SGSN sends an SGSN Context Acknowledge message to the old SGSN. The old SGSN marks in its context that the MSC/VLR association and the information in the GGSNs and the HLR are invalid. This triggers the MSC/VLR, the GGSNs, and the HLR to be updated if the MS initiates a routeing area update procedure back to the old SGSN before completing the ongoing routeing area update procedure.

5) If the RA update is an Inter-SGSN RA Update and if the MS was in PMM-IDLE state, the new SGSN sends Update PDP Context Request (new SGSN Address, QoS Negotiated, Tunnel Endpoint Identifier) to the GGSNs concerned. The GGSNs update their PDP context fields and return an Update PDP Context Response (Tunnel Endpoint Identifier). Note: If the RA update is an Inter-SGSN routeing area update initiated by an MS in PMM-CONNECTED state, the Update PDP Context Request message is sent as described in subclause "Serving RNS Relocation Procedures" of 23.060.

6) If the RA update is an Inter-SGSN RA Update, the new SGSN informs the HLR of the change of SGSN by sending Update Location (SGSN Number, SGSN Address, IMSI) to the HLR.

7) If the RA update is an nter-SGSN RA Update, the HLR sends Cancel Location (IMSI, Cancellation Type) to the old SGSN with Cancellation Type set to Update Procedure. If the timer described in step 2 is not running, the old SGSN removes the MM context. Otherwise, the contexts are removed only when the timer expires. It also ensures that the MM context is kept in the old SGSN in case the MS initiates another inter SGSN routeing area update before completing the ongoing routeing area update to the new SGSN. The old SGSN acknowledges with Cancel Location Ack (IMSI).

7a) If the MS is PMM-CONNECTED in the old 3G-SGSN, the old 3G-SGSN sends an Iu Release Command message to the old SRNC. The SRNC responds with an Iu Release Complete message.

8) If the RA update is an inter-SGSN RA Update, the HLR sends Insert Subscriber Data (IMSI, subscription data) to the new SGSN. The new SGSN validates the MS's presence in the (new) RA. If due to regional subscription restrictions the MS is not allowed to be attached in the RA, the SGSN rejects the Routeing Area Update Request with an appropriate cause, and may return an Insert Subscriber Data Ack (IMSI, SGSN Area Restricted) message to the HLR. If all checks are successful, the SGSN constructs an MM context for the MS and returns an Insert Subscriber Data Ack (IMSI) message to the HLR.

9) If the RA update is an Inter-SGSN RA Update, the HLR acknowledges the Update Location by sending Update Location Ack (IMSI) to the new SGSN.

10) If Update Type indicates combined RA / LA update with IMSI attach requested, or if the LA changed with the routeing area update, the association has to be established. *The VLR number is determined as described in 7.1.6. The new SGSN sends a Location Update Request (new LAI, IMSI, SGSN Number, Location Update Type) to the VLR.* Location Update Type shall indicate IMSI attach if Update Type in step 1 indicated combined RA / LA update with ISI attach requested. Otherwise, Location Update Type shall indicate normal location update. The SGSN starts the location update procedure towards the new MSC/VLR upon receipt of the first Insert Subscriber Data message from the HLR in step 8). The VLR creates or updates the association with the SGSN by storing SGSN Number.

11) If the subscriber data in the VLR is marked as not confirmed by the HLR, the new VLR informs the HLR. The HLR cancels the old VLR and inserts subscriber data in the new VLR (this signalling is not modified from existing GSM signalling and is included here for illustrative purposes):

   a) The new VLR sends an Update Location (new VLR) to the HLR.

   b) The HLR cancels the data in the old VLR by sending Cancel Location (IMSI) to the old VLR.

   c) The old VLR acknowledges with Cancel Location Ack (IMSI).

   d) The HLR sends Insert Subscriber Data (IMSI, GSM subscriber data) to the new VLR.

   e) The new VLR acknowledges with Insert Subscriber Data Ack (IMSI).

   f) The HLR responds with Update Location Ack (IMSI) to the new VLR.

12) The new VLR allocates a new TMSI and responds with Location Update Accept (VLR TMSI) to the SGSN. VLR TMSI is optional if the VLR has not changed. *An IuFlex aware VLR includes one of its (CS-)NRIs as part of VLR TMSI. The SGSN creates an association with the VLR by storing VLR number.*

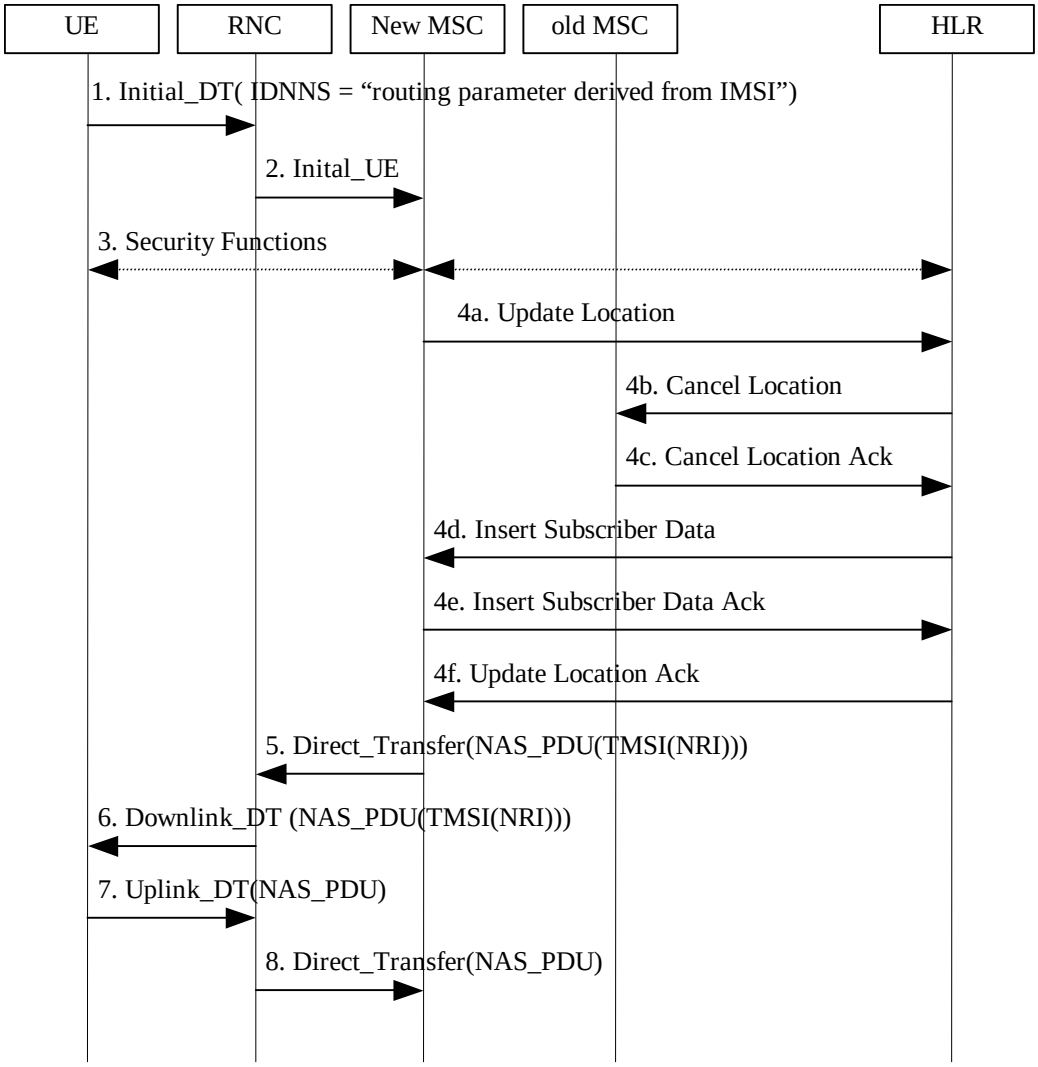
13) The new SGSN validates the MS's presence in the new RA. If due to roaming restrictions the MS is not allowed to be attached in the SGSN, or if subscription checking fails, the SGSN rejects the routeing area update with an appropriate cause. If all checks are successful, the new SGSN establishes MM context for the MS. The new SGSN responds to the MS with Routeing Area Update Accept (P-TMSI, VLR TMSI, P-TMSI Signature*). An IuFlex aware SGSN includes one of its (PS-)NRIs as part of P-TMSI.*

14) The MS confirms the reallocation of the TMSIs by returning a Routeing Area Update Complete message to the SGSN.

15) The new SGSN sends a TMSI Reallocation Complete message to the new VLR if the MS confirms the VLR TMSI.

7.5 IMSI attach procedure / Location area update with IMSI

This signalling flow shows the basic IMSI attach or location update procedure when a UMTS UE registers to a pool-area by mobile identity type IMSI.



1. UE requests the setup of the RRC connection and sends the Initial_DT including the Intra Domain NAS Node Selector (IDNNS). The IDNNS indicates that the routing parameter is derived from IMSI.
2. The RNC selects the MSC as described in 7.1.3. The Initial-UE message is generated on RANAP and sent via Iu-CS to the selected MSC/VLR.
3. The optional security functions can be executed
4. Since the UE wasn’t registered in the MSC before the Map Update-location procedure to HLR is invoked by the MSC
    a. The update-location is sent to HLR
    b. In case the UE was registered in another VLR the HLR sends cancel location procedure to old VLR
    c. The old VLR acknowledges with Cancel location Ack
    d. The HLR sends insert-subscriber data to the new VLR
    e. The new VLR acknowledges with insert-subscriber data Ack
    f. After finishing the location update procedure the HLR responds with Update-location to the new VLR
5. The MSC/VLR assigns a new TMSI to the UE and sends this TMSI value in the location-update accept to the UE. The TMSI contains the NRI of the VLR. The location update accept is carried in the NAS-PDU of the RANAP direct-transfer over Iu interface.

6. The RNC transparently forwards the NAS-PDU to the UE in the RRC downlink-DT message.
7. In the UE the new TMSI (including the NRI) and the LA are stored on SIM and the TMSI-reallocation complete is generated. This NAS message is returned to CN in the Uplink-DT via RRC. The mobile shall use this new TMSI next time it performs a mobile originating procedure.
8. The RNC forwards the NAS-PDU transparently to the MSC/VLR in the NAS-PDU of a Direct-transfer on Iu interface. If the TMSI-reallocation complete is received in the MSC/VLR the TMSI is considered as valid for the UE. From then on the UE will be addressed using this TMSI value.

Annex A (informative): Network configuration examples

Editor's note: This annex contains the examples for network configurations that have been discussed during the drafting meetings.

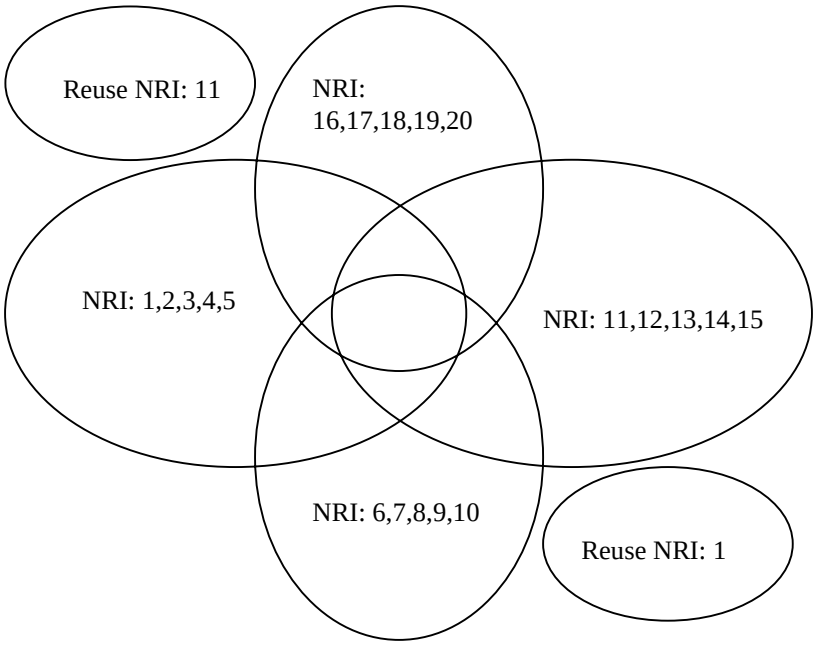
A.1: One city centre surrounded by residential areas

Assumptions:

This example shows a network covering one city centre surrounded by residential areas. The city centre is covered by all 4 pool-areas while the residential areas are covered by one pool-area only. Once a subscriber „found" its pool-area, he will not change the pool-area while commuting between the city centre and his residential area.
Each of the pool-areas is served by 5 MSCs, indicated by the 5 NRI values in the figure below.

The example in the figure configures 4 overlapping pool-areas;

- City centre with 12 Mio subscribers (with context in VLR, attached or detached)
- One switch office/building with 5 MSCs (5 NRIs) per pool-area
- Capacity of one MSC/VLR up to 1 Mio subscribers in VLR
- 4 bits are assumed for the VLR-restart counter
- Only distinct NRI values are used, so a UE changing between pool-areas will always be allocated to a new MSC by the NAS node selection function



TMSI calculation:

For addressing in the CS domain 30 bits for can be used (Bit 30&31 are reserved).

- The assumption is that 4 bits are used for the restart counter.

- To differentiate the 20 MSC in the city area 5 bits are needed for the NRI (12 NRI values remain unused; these 12 NRIs are left for additional MSCs in the whole area, NRIs can also be re-used as indicated in the figure)
- This leaves 30-4-5 = 21 bits for every MSC to address the subscriber data records in the VLR. (This give address space for 2 Mio TMSIs unique over all LAs of the MSC)
- The 4 pool-areas sum up to 20 Mio subscriber, allowing for some unbalanced load distribution

A.2: 3 Neighbouring large city centres

This documents provides some calculations for 'pool-identification alternative B' in case that 3 huge city centres are covered by pool-areas with direct contacts.

Assumptions:

The calculations are based on the following assumptions:

- 3 neighbouring pools with capacity of 32 M non-purged subscribers each
- Maximum capacity of a paging channel is 1 M pagings/hour per LA
- 0.25 pagings / hour are assumed per subscriber → 2M TMSI/LA can be realized
- For the 'VLR-restart' counters a number of bits need to be reserved. Working assumption is that 5 bit should be sufficient for any implementation, in the examples these 5 bits are reserved on the upper part of the TMSI. (This is of course implementation specific and not part of Iu-Flex.)
- The calculations are based on a node capacity of up to 1M (2^20) non-purged subscribers this results in:
    - Minimum 32 nodes are needed per pool-area (5-bit NRI)
    - Minimum is 16 LA's per pool-area

Basic configuration needed for 1 pool:

- To address the 32M TMSI per pool the total number of 25 bits are needed in the TMSI.
- For a node capacity of 1M non-purged TMSIs 20 Bits have to be reserved for TMSI per NRI and 5 bit for the NRI value.
- The NRI is located bit 14-23 (configurable). It is assumed that the bits 19-23 are used for the NRI.

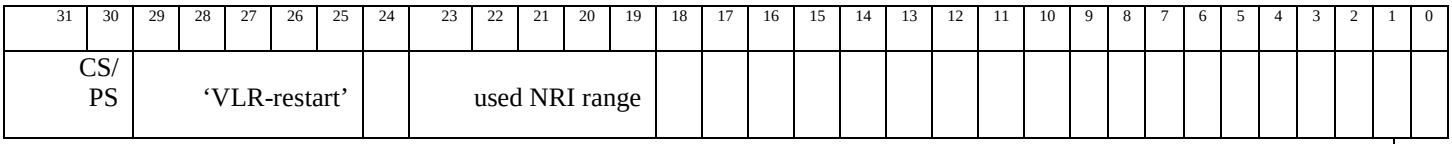


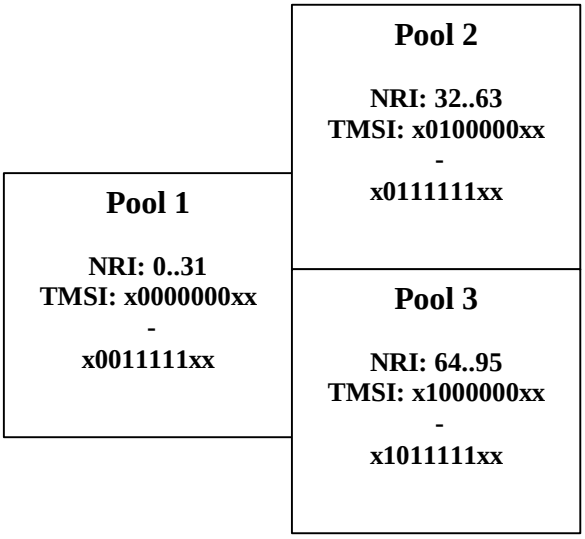
Figure 56: Example of a TMSI structure with 5 bit 'VLR-restart counter' and 5 bits NRI-length;

'3 pool configuration' – no sharing of NRI values:

- This example assumes that the 3 pool-areas have independent NRI values, so the available TMSI range has to be shared between the pools. All TMSI's from other pool-areas can be detected – best load distribution in the pools.

- So 3*32 = 96 NRI values are needed for all 3 pools. The NRI-length has to be increased to 7 bit. (not an optimum configuration since 32 NRI values are unused). In the example the NRI now uses bits 23-17.

- Since still for each NRI value 20 bits are needed to address 1M TMSIs there is a conflict with the assumed VLR-restart field length of 5 bit. The VLR-restart field has to be reduced to a 3 bit field in order to free sufficient addressing space in the TMSI structure!



NRI: 96..127
TMSI: x1100000xx - x1111111xx
are unused

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CS/ PS		‘VLR-restart’						used NRI range																							

Figure 67: Modified TMSI structure 7 bits NRI-length; VLR-restart field must be reduced to 3 bit.

- In this example configuration 32M TMSI values are wasted! So it would be more efficient to assign these TMSI ranges to the 3 pools rather than leave them unused. Alternatively these values could be used for sharing with nodes in the ‘outside world’.

- The major drawback of this solution is the reduction of the VLR-restart field to 3 bits only!

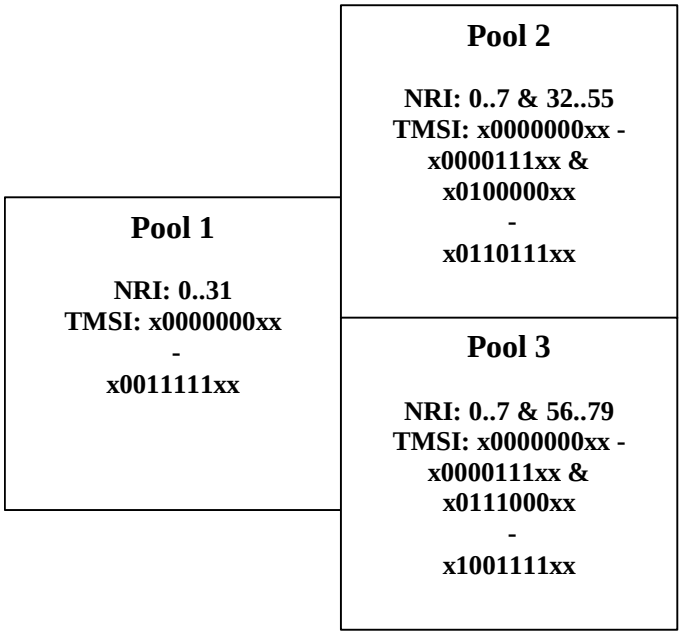
‘3 pool configuration’ – 25% of NRI values shared between the pools:

- Now the pool configurations are changed in a way that 25% of the NRI values are the same in all the 3 pools. This means that for ¼ of subscribers pool-changes cannot be detected. The traffic generated by these subscribers will not be distributed, but is routed by the NAS node selection function to the specific node with this NRI value in the new pool.

- The total range of needed NRI values is reduced by this to:
8 (the shared NRI’s) + 3 * 24 = 80

- To code this NRI’s still 7 bit are needed. So there is no gain in terms of addressing space in this example.

- In the example the NRI values 0..7 are shared and so are the TMSI ranges x0000000xx .. x0000111x



NRI: 80..127
TMSI: x1010000xx - x1111111xx
are unused

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CS/ PS		‘VLR-restart’						used NRI range																							

Figure 7~~8~~: Modified TMSI structure 7 bits NRI-length; VLR-restart field must remain 3 bit.

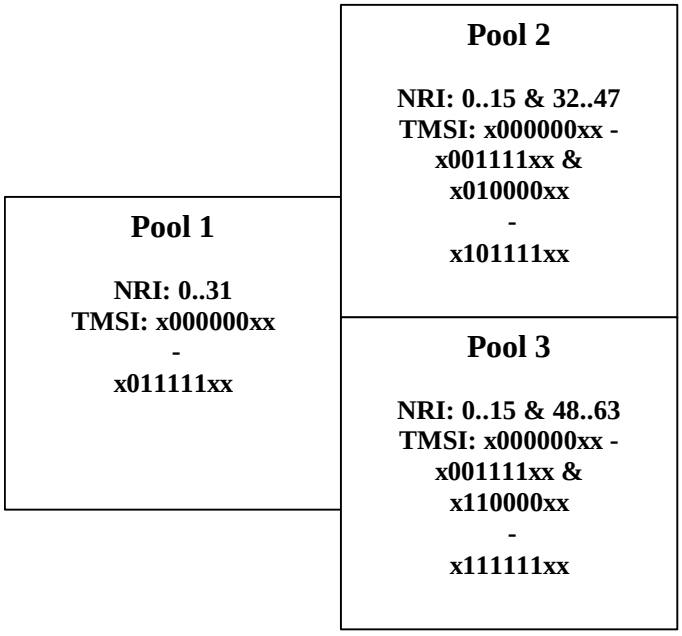
‘3 pool configuration’ – 50% of NRI values shared between the pools:

- The percentage of the shared NRIs is now increased to 50%. So ½ of the NRI values are the same in all the 3 pools. This means that for ½ of subscribers pool-changes cannot be detected. The traffic generated by these subscribers will not be distributed, but is routed by the NAS node selection function to the specific node with this NRI value in the new pool.

- The total range of needed NRI values is reduced by this to:
16 (the shared NRI’s) + 3 * 16 = 64

- This reduction of NRI saves 1 bit in NRI length. So the VLR-restart can be slightly increased to 4 bit (still 1 bit less than in the original assumption)

- In the example the NRI values 0..15 are shared and so are the TMSI ranges x000000xx .. x001111x

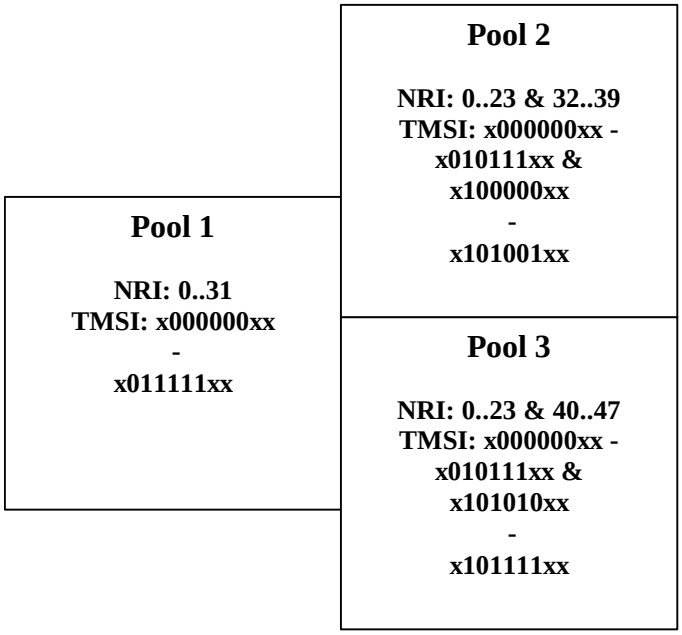


31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CS/ PS		‘VLR-restart’						used NRI range																							

Figure 8~~9~~: NRI-length can be reduced by 1 bit; VLR-restart field can increase to 4 bit.

‘3 pool configuration’ – 75% of NRI values shared between the pools:

- Next step is to even increase the shared part of the NRI to ¾. This means that only 25% of the incoming traffic in a pool-area is distributed.
- The total range of needed NRI values is reduced by this to:
  24 (the shared NRI’s) + 3 * 8 = 48
- Like the first step this doesn’t free any addressing space in the TMSI. But some NRI values are now available in case it is wanted to share them with other nodes outside the ‘3 pool area’.
- In the example the NRI values 0..23 are shared and so are the TMSI ranges x000000xx .. x010111x



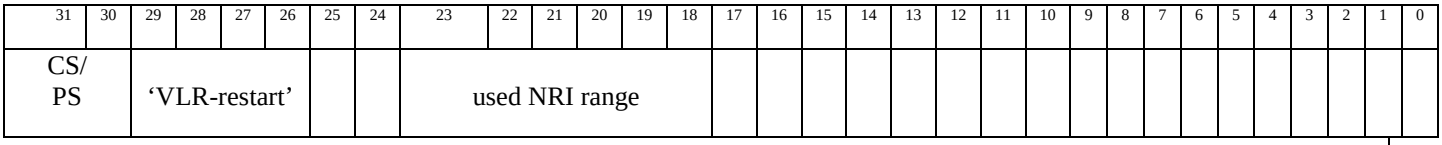


Figure 9~~10~~: NRI-length can be reduced by 1 bit; VLR-restart field can increase to 4 bit.

'3 pool configuration' – full sharing of NRIs between the pools:

- The last variant of these configurations is a full sharing is all NRI values between all neighbouring pools. In this case no detection of pool area changes is possible. Consequently no distribution of load can be achieved. This results necessarily in the need to have a 'forced redistribution' mechanism to resolve heavy unbalance of load.
- The NRI and TMSI ranges will then be the same as in the 'single pool' example in the beginning.

Result:

The examples above show that it is basically not possible to configure the example configuration (32M non-purged subscribers; 1M per MSC) with a VLR-restart field as put in the assumptions, except that the full range of NRI is shared between the pools.
Taking it literally it could be possible with 3 pools when sharing the remaining quarter of the NRI (the part that would be unused otherwise), but latest if 4 pool-areas with this capacity have to be supported this reaches the limit.

An alternative to overcome this could be to apply the TMSI's on a per LA basis as it is already foreseen on the A/Iu interface specifications.

TMSI per LA:

Taking the example configuration mentioned above but changing the TMSI allocation per LA would result in an increase of the addressing space. Then the same TMSI value can be used multiple times in the same VLR. A specific subscriber data record can then only be addressed by LA&TMSI.

For the 32 MSCs this means that that each of them supports an equal share of TMSI of a LA. So each MSC handles 2M/32 = 32k TMSI of a specific LA.

The required TMSI addressing space id thereby reduced to 15 bit per MSC.

If, like before, 96 NRI values are needed to address all nodes in the 3 pools then 7 bit are needed for this. This leaves 5 bit for the VLR-restart counters (plus 3 unused bits).

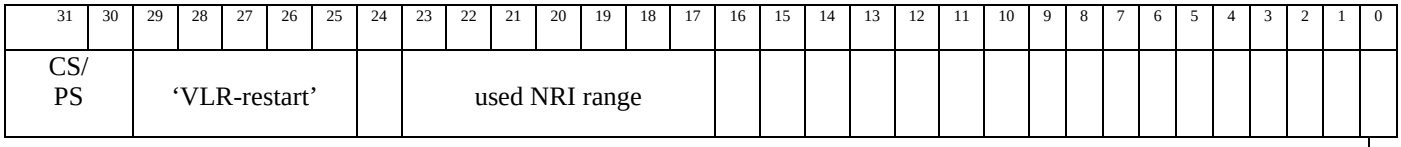


Figure 10~~11~~: TMSI example for TMSI allocation per VLR; 32M TMSI/pool;

Without sharing NRI values the pool size can even be increased (Factor 8 – since 3 bit spare).

A number of aspects however remain to be looked at with this TMSI per LA approach:

- It requires an equal distribution of UE's of a certain LA over all nodes in the pool. This contradicts the wish for a flexible routing where e.g. a new attach should be routed to the closest node in order to save transmission resources.
- Attach requests in a LA may be rejected by one node because this node has already a fully booked TMSI table for this LA. At the same time the node may have in total still capacity left to serve subscribers…..
- The total load of TMSI re-allocations may increase since every change of LA must result in a TMSI reallocation.
- MAP on VLR-VLR I/F must be updated, otherwise subscriber confidentially decreases because for every change to other MSCs the IMSI has to be fetched via the air I/F. (At the same time node changes should only occur when changing the pool-area – so maybe never?)
- Can it happen that if NRI are shared there are several subscribers with the same TMSI in a certain LA? FFS
  If yes then a paging-request there will trigger several page-response messages per LA….

Annex B (informative): Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
					Version 0.0.0 Initial Proposal		
2001-04-20	Iu-flex drafting				Updates after drafting meeting		
2001-05-17	SA2#18				Adding S2-011369r1 chapter 5.3.1; alternative B chosen, A moved to annex and affected paragraphs updated accordingly; example network configurations added in annex C; some minor editorial corrections	0.1.0	0.2.0
2001-06-17	SA#12				Raised to version 1.0.0 (same technical content as v.0.2.0)	0.2.0	1.0.0
2001-08-15	Iu-Flex drafting	S2-011737, S2-011741, S2-011743, S2-011744, S2-011752, S2-011754rev1, S2-011755, S2-011756, S2-011757, S2-011758, S2-011759, S2-011760, S2-011762rev1, S2-011763, S2-011764, S2-011765			Updated with tdocs approved by Iu-Flex drafting July 3&5, 2001	1.0.0.	1.1.0
2001-08-21					References in chapter 2 adjusted to correct format Chapter 4.6.; 3rd paragraph first 'not' deleted (this change to tdoc S2-011741 was agreed in the drafting – but missing in v1.1.0)	1.1.0	1.1.1
2001-08-30	SA2#19	S2-012157, S2-012378, S2-012383, S2-012407, S2-012408, S2-012409			Updated with approved tdocs; Some additional editorial updates	1.1.1	1.2.0
2001-09-23	SA#13				Updated to v.2.0.0 (same technical content as v.1.2.0)	1.2.0	2.0.0
2001-09-25	SA#13				Updated to v.2.1.0 to delete all references of Iu-flex between CN nodes belonging to different operators (to fit to the scope and to the approved WID)	2.0.0	2.1.0