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**Digital cellular telecommunications system (Phase 2+) (GSM);
Universal Mobile Telecommunications System (UMTS);
LTE;
Intra-domain connection of Radio Access Network (RAN)
nodes to multiple Core Network (CN) nodes
(3GPP TS 23 236 version 17.0.0 Release 17)**

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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 to permit 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.

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1 Scope

This document covers the details for the Intra Domain Connection of RAN Nodes to Multiple CN Nodes for GERAN and UTRAN based 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 description of a broadly similar concept for E-UTRAN based systems is not described in the document: instead, it is described in TS 23.401 [22].

NOTE: The specified solution impacts RAN nodes. In case an upgrade of radio networks is not performed, the solutions for deploying NNSF functionality above RAN nodes described in TR 23.924 [23] may be used as a guideline for connecting RAN nodes to multiple MSC servers.

The reference model to which these procedures apply can be found within 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 TS 23.060 [2] and the requirements for the Bearer Independent CS Core Network are contained in 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. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

- [1] 3GPP 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".
- [19] 3GPP TS 43.068: "Voice Group Call Service (VGCS); Stage 2".
- [20] 3GPP TS 43.069: "Voice Broadcast Service (VBS); Stage 2".
- [21] 3GPP TS 23.251: "Network Sharing; Architecture and functional description".
- [22] 3GPP TS 23.401: "General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access".
- [23] 3GPP TS 924: "Feasibility Study on NAS Node Selection Function above BSC/RNC".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

CN node: for the purpose of this specification, and unless otherwise stated, a CN node is either an MSC or an SGSN.

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.

Non-broadcast LAI/RAI: Each CN node in a pool have to be assigned one unique non-broadcast LAI/RAI that it use in case it want to be offloaded. Each CN node in the pool has to be aware of the non-broadcast LAI/RAI assigned to the other CN nodes in the pool, because in case of re-distribution the 'target CN node' will retrieve data (e.g. IMSI, security context, MM & PDP contexts) from the offloaded CN node based on non-broadcast LAI/RAI.

Null-NRI: A 'null-NRI' indicates to a radio node (BSC/RNC) that the NAS Node Selection Function shall be used for selecting a CN node to receive a message. There is one unique 'null-NRI' in a PLMN supporting pool functionality. In MOCN shared networks (see TS 23.251 [21]) with multiple CN Operators, there is one unique 'null-NRI' per CN operator. That is, in MOCN networks the RAN Operator handles multiple 'null-NRIs'.

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: for the purpose of this specification, and unless otherwise stated, a RAN node is either an RNC or a BSC.

RAN node service area: This area contains all the cells controlled by the 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 abbreviations given in TR 21.905 [8] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [8].

AS	Access Stratum
BSC	Base Station Controller
BVCI	BSSGP Virtual Connection Identifier

CN	Core Network
CS	Circuit Switched
CS-MGW	Circuit Switched Media Gateway
DCN	Dedicated Core Network
DNS	Directory Name Server
IDNNS	Intra Domain NAS Node Selector
LA	Location Area
LAI	Location Area Identity
MOCN	Multi-Operator Core Network
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. Iu Flex capable RAN nodes such as the RNC/BSC shall be able to select any CN node such as the SGSN/MSC-Server within a pool area.
2. Iu Flex capable RAN nodes and CN nodes shall be able to co-exist with pre Release 5 RAN nodes and pre Release 5 CN nodes.
3. The network shall provide the CN node routing information to the UE and the UE shall store it.
4. The UE shall provide the routing information received from the serving CN node to the RAN node. In some cases, this serving CN node may be an Evolved Packet Core MME.
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

Editor's 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 nodes 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. From a RAN perspective a pool-area comprises all LA(s)/RA(s) of one or more RNC/BSC that are served by a certain group of CN nodes in parallel. One or more of the CN nodes in this group may in addition serve LAs/RAs outside this pool-area or may also serve other pool-areas. This group of CN nodes is also referred to as MSC pool or SGSN pool respectively.

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.

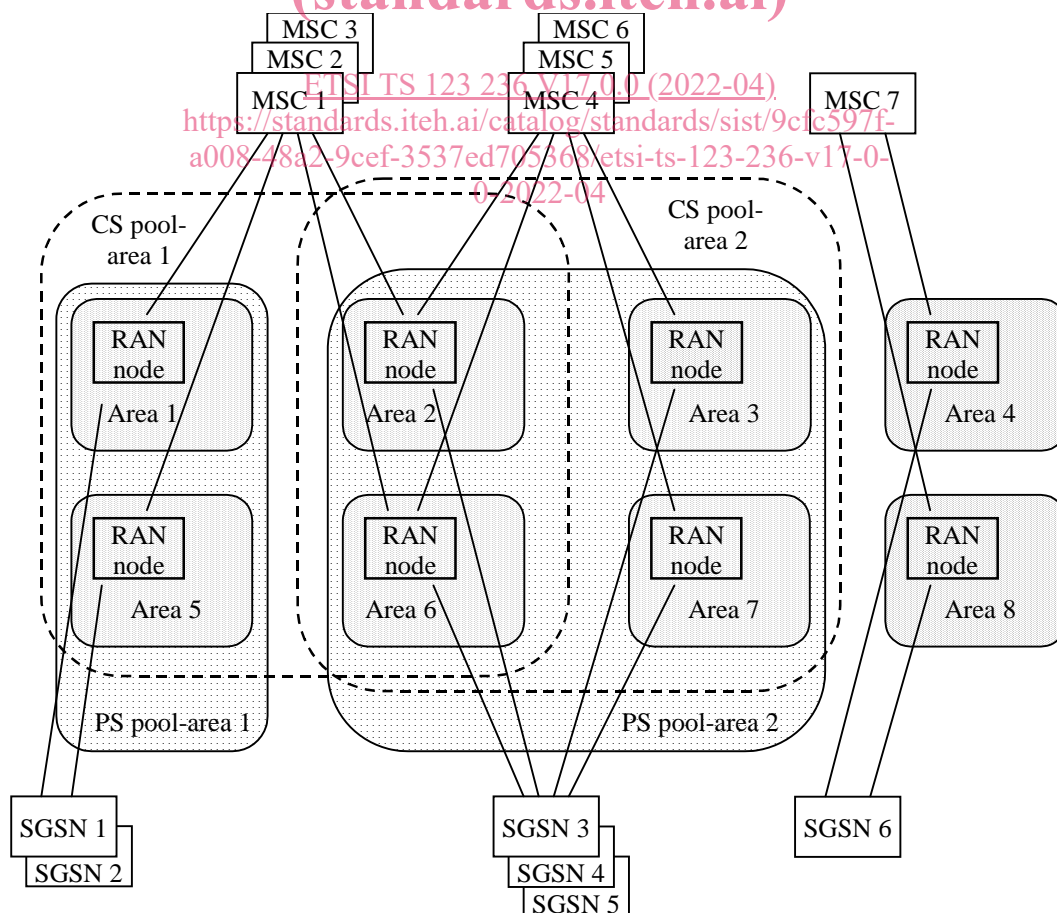


Figure 1: Pool-area configuration example

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. The length of the NRI shall be the same in all nodes of a domain in one pool-area. In areas where pool-areas overlap the NRI identifies uniquely a CN node out of all CN nodes, which serve all these overlapping pool-areas, i.e. an NRI identifies uniquely a CN node within a RAN node. In case of overlapping pool-areas the NRI length shall be configured to be the same in all the nodes of a specific domain serving these pool-areas. 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 supports 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) TS 25.331 [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. The most significant bit of the NRI shall correspond with the most significant bit of the routing parameter in the IDNNS. When the IDNNS is derived from the IMSI, the IDNNS has a value (V) from the range 0 to 999 as defined in TS 25.331 [5]. The RAN node shall be configured to use the value (V) to select a CN node. Each value (V) corresponds a single CN node. Typically many values of (V) may point to the same CN node. In A/Gb mode.

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 NRI is coded in bits 23 to 14 of TMSI or P-TMSI. Regardless of the NRI length the most significant bit of the NRI is always in bit 23 of TMSI or P-TMSI (examples of NRI position are given in annex A.2), see also TS 23.003 [18].

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.

NOTE: A routing-area update after SRNS relocation is not an initial NAS signalling message, thus it is routed along the existing Iu-connection to the SGSN.

In A/Gb mode in case a MSC/VLR sends a paging-request/paging with IMSI (i.e. the paging message does not contain a TMSI), the NAS node selection function in the BSC shall upon reception temporarily store the Global-CN-ID of the node that issued the paging-request/paging message. If the NAS node selection function in A/Gb mode receives a paging-response with an IMSI then it should check the temporarily stored Global-CN-ID on entries matching this IMSI and forward the paging-response to the node identified by this Global-CN-ID.

In Iu mode in case a MSC/VLR sends a paging-request/paging with IMSI (i.e. the paging message does not contain a TMSI), the NAS node selection function in the BSC/RNC may upon reception temporarily store the Global-CN-ID of the node that issued the paging-request/paging message. If the NAS node selection function in Iu mode receives an Initial Direct Transfer message with an IDNNS derived from IMSI as a result of IMSI paging:

- and if BSC/RNC has temporarily stored the Global-CN-ID then it should check the temporarily stored Global-CN-ID on entries matching this IDNNS and forward the paging-response to the node identified by this Global-CN-ID or
- the BSC/RNC shall use the IDNNS derived from IMSI to select a CN node. In this case the IDNNS has a value (V) from the range 0 to 999 as defined in TS 25.331 [5]. The RAN node shall be configured to use the value (V) to select a CN node. Each value (V) corresponds a single CN node. Typically many values of (V) may point to the same CN node.

In UMTS, an MS answering a paging with IMSI includes in its response an IDNNS derived from its TMSI, if the MS has a valid TMSI. Temporarily storing the IMSI in the RNC increases the success rate to reach the MS that have both lost their TMSI and are paged with IMSI. In GSM, an MS paged with IMSI always answers with IMSI.

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.

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 a 'random TLLI' is received (Gb-mode BSC), 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.

When the NAS Node Selection Function in the RAN (or, if using Network Mode of Operation I, the SGSN) receives an indication that the MS is configured for low access priority (e.g. because it is used for Machine Type Communication), the NAS Node Selection Function may take this indication into account when selecting the CN node (e.g. to select an MSC that has a particularly large VLR capacity or an SGSN that is optimized to handle UEs configured for low access priority).

In case of handover/relocation into a pool-area a load balancing between all the target CN nodes serving this pool-area is gained by configuration. Source CN nodes which support Intra Domain Connection of RAN Nodes to Multiple CN Nodes may be configured with all possible target CN nodes for each handover/relocation target. Source CN nodes which do not support the Intra Domain Connection of RAN Nodes to Multiple CN Nodes can configure only one target CN node per handover/relocation target. In this case each of source CN nodes which handover/relocate to the same pool-area may be configured with another target CN node out of all target CN nodes serving the same

handover/relocation target. The mechanism for distribution of the traffic between the handover/relocation 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 be shared between the SGSNs as described in clause 5.3.2.

When dedicated core networks (DCNs) are used, load balancing by RNC/BSC is only performed between SGSNs that belong to the same DCN within the same SGSN pool area. Load balancing may also be performed per DCN in the case of an SGSN serving multiple DCNs when one DCN is supported by multiple SGSNs. The DCN Load Balancing functionality permits UEs that are entering into a pool area and being re-directed to an appropriate DCN to be distributed in a manner that achieves load balancing between the core network nodes of the same DCN within the same SGSN pool area. An example of NRI configuration that can achieve this is when DCNs are used is provided in clause A.3.

In case of CS domain subsequent handover/relocation, if the controlling MSC supports Intra Domain Connection of RAN Nodes to Multiple CN Nodes then it should check the target indicated by the serving MSC. If it is in its own pool area then the handover/relocation is handled as one back to the controlling MSC (the target MSC indicated by the serving MSC is not taken into account). If the target location is not in its own pool area then the target MSC indicated by the serving MSC is taken into account as normal (handover/relocation to a third MSC).

If the controlling (anchor) MSC is not in the same pool as target third MSC and if the controlling MSC does not support Intra Domain Connection of RAN Nodes to Multiple CN nodes, because the serving MSC can select any third MSC in the target pool area, the operator should configure the addresses of all possible third MSCs within the controlling MSC.

4.5a Load Re-Distribution

4.5a.1 General

There are situations where a network operator will wish to remove load from one CN node in an orderly manner (e.g. to perform scheduled maintenance, or, to perform load re-distribution to avoid overload) with minimal impact to end users and/or additional load on other entities. The re-distribution procedure does not require any new functionality in the terminal, that is, all terminals can be moved.

Re-distribution of UEs is initiated via an O&M command in the CN node, which needs to be off-loaded. In a first phase (a couple of Periodic LU/RAU periods long), UEs doing LU/RAU or Attach are moved to other CN nodes in the pool. When the CN node receives the Location Update, Routing Area Update or Attach request, it returns a new TMSI/P-TMSI with a null-NRI, and a non-broadcast LAI/RAI in the accept message.

In CS domain the non-broadcast LAI will cause the terminal to immediately send a new Location Update, which the RAN node then will route to a new MSC due to the null-NRI. In the PS domain, a new Routing Area Update is triggered by setting the periodic routing area update timer to a sufficiently low value (recommended value is 4 seconds) in the accept message. The UE will shortly after send a new Routing Area Update that the RAN node then will route to a new SGSN due to the presence of a null-NRI.

In a second phase (PS domain specific), the SGSN requests all UEs trying to set up PDP Contexts to detach & reattach. When they reattach, the SGSN moves them as in the first phase described above.

A third phase includes scanning through remaining UEs and initiating a move of them to other CN nodes. In the PS domain UEs are requested to detach and reattach, which will cause them to be moved. In case of CS domain a new TMSI is allocated to these UEs using the TMSI re-allocation procedure (with null-NRI and non-broadcast LAI) so that a Location Update is triggered when the ongoing CM transaction ends, which will cause them to be moved.

UEs being moved from one CN node are stopped from registering to the same CN node again by an O&M command in BSCs and RNCs connected to the pool. UEs moving into a pool area may also be stopped from registering into a CN node being off-loaded in the same manner.

In network configurations using MOCN network sharing, re-distribution is always done between CN nodes within the same CN Operator. This is ensured by each CN Operator using his own unique null-NRI. The RAN node is preconfigured with the null-NRIs for the different CN Operators, and it uses the null-NRI to select a CN node within the same CN Operator.