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Technical Report

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Foreword

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x the first digit:

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Introduction

UMTS will build on the success of GSM and is likely to become even more widespread. In addition, the continued growth of international travel for business and leisure means that the number of roaming UMTS and GSM subscribers is set to increase significantly.

Every time a subscriber moves to a location area served by a different MSC/VLR or SGSN, the subscriber data must be downloaded from the HLR in the home PLMN to the new entity serving the user and deleted in the old MSC/VLR or SGSN. If the coverage areas associated with these entities are small or the subscriber frequently moves between location areas the subscriber will represent a large signalling load. This is equally applicable to subscribers moving within their home network and roaming subscribers except in the latter case international signalling costs are incurred.

The Turbo-Charger concept provides an architecture that is scalable to compensate for loading levels and able to service any subscriber distribution. This is achieved by modifying the subscriber data management to reduce the signalling load associated with mobility. The reduction in signalling load is achieved without introducing a new node but does require new functionality within the network.

1. Scope

This Technical Report describes the use of Turbo-Charger mechanism in UMTS to reduce the signalling traffic associated with mobility. This document provides a technical proposal and example uses of the Turbo-Charger concept but also identifies issues that require further study. Finally, this document highlights the advantages and disadvantages, and identifies the UMTS procedures that would require enhancing to support his functionality.

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.
- A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] GSM 01.04: "Digital cellular telecommunications system (Phase 2+); Abbreviations and acronyms".

3. Definitions and Abbreviations

3.1 Definitions

Turbo-Charged Network	A UMTS network in which the Turbo-Charger mechanism is being used to optimise mobility management signalling.
Turbo-Charger Routeing Function	The function used to assign specific network resources (i.e. MSC/VLR and/or SGSN) to serve a mobile station and subsequently route C-Plane traffic to the associated network resource
Network Resource Identifier	A specific parameter used to identify the core network resource assigned to serve a mobile station.

3.2 Abbreviations

NRI	Network Resource Identifier
TMSI	Temporary Mobile Station Identity
TRF	Turbo-Charger Routeing Function
URA	UTRAN Routeing Area

4. General Description

The aims of the Turbo-Charger concept are to reduce the intra and inter-PLMN mobility management costs and to provide automatic load-sharing between available core network resources i.e. the MSC/VLR and/or SGSN.

The Turbo-Charger constitutes a change to the network architecture. Despite this, the Turbo-Charger enhancement should not require significant modifications of the UMTS standards.

The current network philosophy is to geographically divide the region between the available core network resources. An alternative architectural philosophy is to equally divide the subscribers between the available core network resources, irrespective of their location. The consequence of this new philosophy is the virtual elimination of handovers and location updates. Hence, signalling associated with mobility management is reduced. This reduction in signalling is equally applicable to subscribers moving within their home network and roaming subscribers.

In addition, this philosophy provides scalability by enabling operators to introduce new network resources without tying the new capacity to a particular geographical area. This is extremely important for new entrants wishing to minimise the initial deployment costs while maximising coverage.

Within a Turbo-Charged network, a Turbo-Charger Routeing Function (TRF) is placed between the RNCs and the 'pool' of network resources, i.e. MSC/VLR and SGSN. The purpose of the TRF is to assign specific network resources to serve a mobile station and to subsequently route Iu-interface messages to the assigned MSC/VLR and/or SGSN, respectively.

The TRF may use a TMSI (Temporary Mobile Subscriber Identity) partitioning scheme or a new parameter to identify the serving MSC/VLR for signalling. The TMSI partitioning scheme would allocate a sub-set of the TMSI range to each MSC/VLR, see Figure 1. The Iu-interface signalling traffic is then routed to the correct MSC/VLR based on the TMSI or the value of a new parameter defined specifically for this purpose. Similarly, a TLLI (Temporary Logical Link Identity) partitioning scheme could be used.

In Turbo-Charger, each 3G-MSC/VLR/SGSN acts as if it serves the whole network coverage area. Therefore, all the 3G-MSC/VLR/SGSN must know of all the LA/RA and cells within the Turbo-Charged Area.

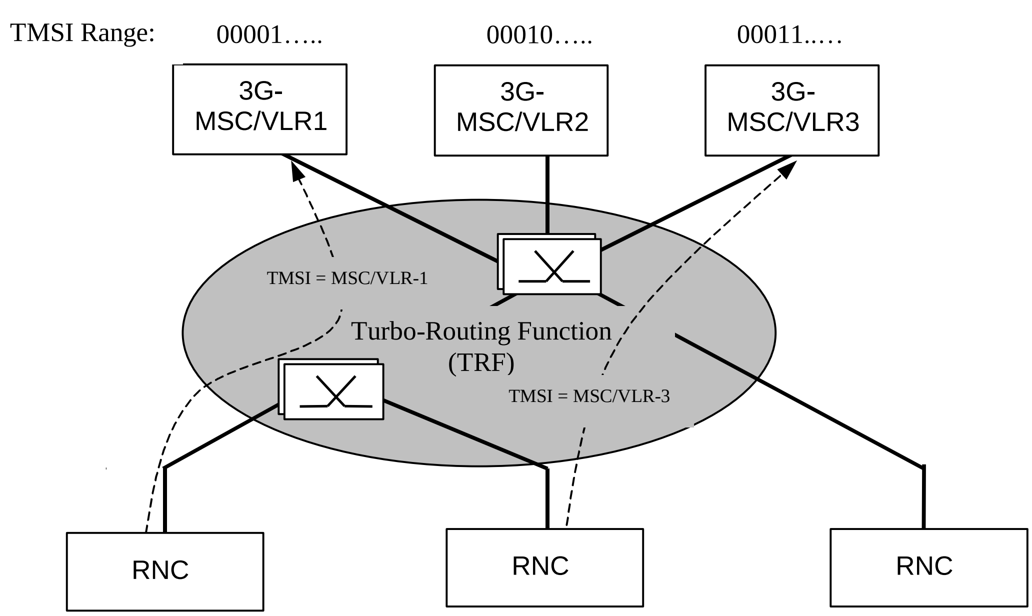

Figure 1: An example Turbo-Charged Network Architecture

In large metropolitan areas where subscribers are currently served by multiple MSC/VLRs, some MSC/VLRs may be very busy while others are not fully utilised. Since the TRF would route all Iu interface traffic and it can participate in load-sharing and balancing based on the current loading of the network. Two mechanism to assign network resources to serve a particular subscriber and provide load-sharing are envisaged, random load-sharing and dynamic load-sharing.

- Random load-sharing requires the TRF to randomly assign a MSC/VLR and/or SGSN to serve a particular mobile station when it first comes in to the network.

- Dynamic load-sharing requires the implementation of an intelligent router or appropriate signalling to determine the current loading of the network. Using this information the TRF can assign network resources to the mobile and potentially redistribute traffic as required.

Once network resources have been assigned further update requests are not required because the service area of each MSC/VLR and SGSN could potentially incorporate the whole network. The access network continues to store the mobile station's location at the URA and cell level.

5. Functional Description

Turbo-Charger introduces a flexible mechanism to assign network resources to serve a particular mobile station that is independent of the geographical location.

The Turbo-Charger mechanism proposes the following modifications to the Iu-interface procedures:
- An optional new parameter i.e. "network resource identifier (NRI)" in Iu signalling that may be used to identify the network resource assigned to serve the mobile station.
- The introduction of an optional Turbo-Charger Routeing Function (TRF), which assigns a specific network resource to serve a mobile station and optionally uses the temporary mobile identity or "network resource identifier" to route C-Plane traffic to the assigned core network resource.
- Enhanced core network functionality to assign temporary mobile identities from a specific range, e.g. TMSI partitioning scheme, P-TMSI or TLLI partitioning scheme, and/or NRIs.

5.1 Turbo-Charger Routeing Function

The Turbo-Routeing Function (TRF) performs two functions:

- Selection of the specific core network resources i.e. MSC/VLR or SGSN to serve the subscriber,
- Routes C-plane traffic to the correct serving entity.

The TRF assigns specific network resources to serve each mobile station to provide load-sharing among the available network resources. In determining the network resource assignment, the TRF takes into account the current loading of the network and other system considerations that may affect the suitability of the assignment.

A possible mechanism for determining the current network loading might be to periodically query network entities to determine their loading or to query network entities when assignment is required. Alternatively, the TRF may randomly select an appropriate network resource to serve the mobile station.

Following the allocation of network resources to serve the mobile station by the TRF, the core network assigns a temporary mobile identity, and optionally a "network resource identifier (NRI)" to identify the serving entity.

The TRF uses the identifiers to route signalling to the correct network entity at the SCCP or IP layer. Although the NRI is optional, specifying a NRI provides separation between the mobile identity and the network resource. Figure 3 provides an example flow diagram for the TRF.

The receipt of a Location Update Request message or other signalling messages containing a mobile identifier that is not recognised by the TRF would typically trigger network resource assignment. After network resources have been assigned to serve a particular mobile station, the standard UMTS location updating procedures are used towards the HLR. The serving entity or entities will then handle all signalling for the associated mobile subscriber and initiate the establishment of U-Plane channels.

UMTS is sufficiently flexible to provide load-sharing for traffic channels and allows the core network to specify the AAL2, AAL5 or IP address and binding identity to be used by the RNC to establish radio bearers. Consequently, in the U-Plane there is no permanent association between the mobile station and core network entities.

The TRF may be implemented within the Core Network as a centralised entity or in a distributed fashion, as part of the SGSN and/or MSC/VLR.

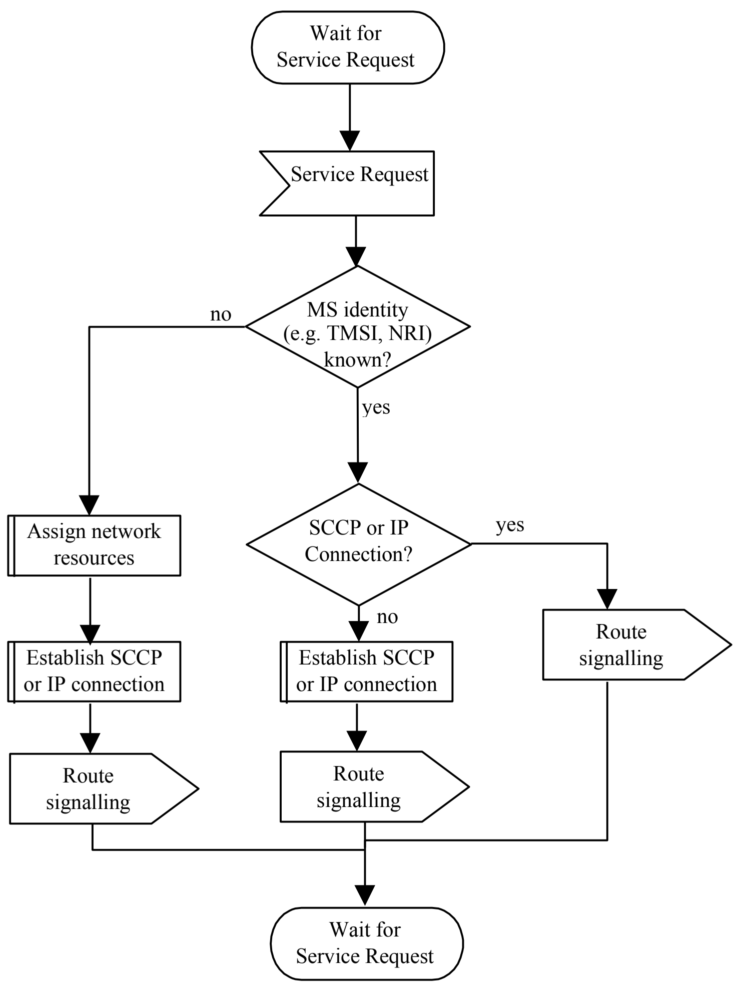

Figure 3: Example flow diagrams for a Turbo-Charger Routeing Function (TRF)

6. Specific Examples

This section describes the operations of a Turbo-Charged network. The examples make no assumptions about the location of the TRF within the network as a whole.

6.1 Network Registration and Location Updating Procedures

Figure 4 provides the message flow for a mobile station registering in the CS-domain.

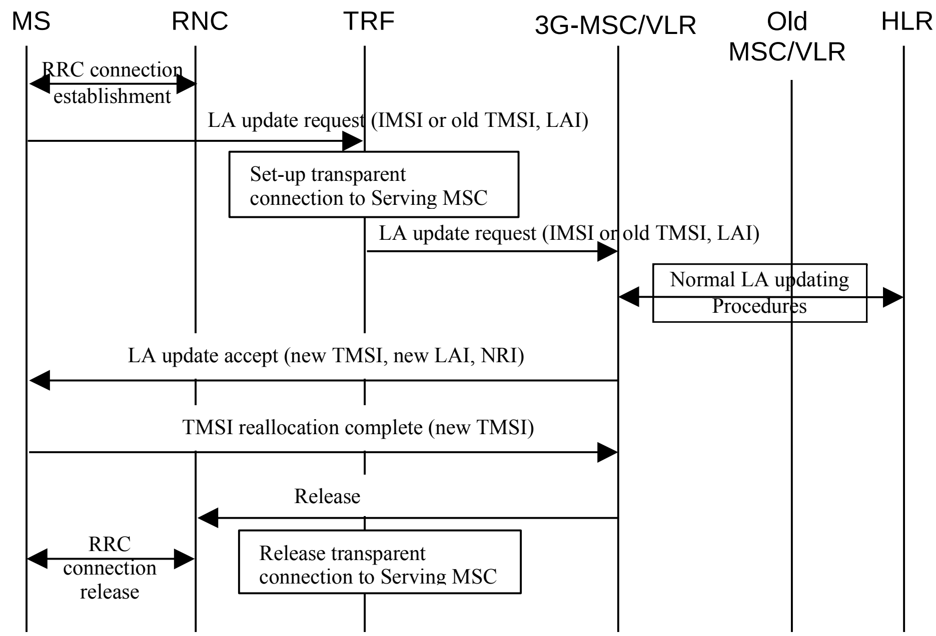

Figure 4: The message flow for a mobile station registering in a Turbo-Charged network.

In mobile network registration, the mobile station will send a LA update request with the IMSI or old TMSI and LAI. The TRF does not recognise the LAI to belong to any MSC/VLR in the current network. Therefore, the TRF selects a serving 3G-MSC/VLR for the mobile station either randomly or based on the network loading conditions and forwards the message to the serving 3G-MSC/VLR.

The serving 3G-MSC/VLR then completes the location update procedures for the mobile station according to the normal UMTS location update procedures. The HLR is informed that the 3G-MSC/VLR is now the new serving MSC/VLR for the mobile station.

If the Location Updating procedure is successful, the MSC/VLR assigns a TMSI (from the range of allocated TMSIs) to the mobile station and optionally a NRI. The serving MSC/VLR sends a Location Update accept message to the MS, which includes the TMSI+LAI and optionally a NRI to the MS. The mobile station stores these identifiers at a register inside the mobile station. The mobile station will use the identifiers in future requests sent to the MSC/VLR.

After the LA update has been accepted, the serving MSC/VLR sends a Release message to the RNC. The RNC releases the signalling link, which results in the termination of the SCCP connection between the RNC and MSC/VLR.

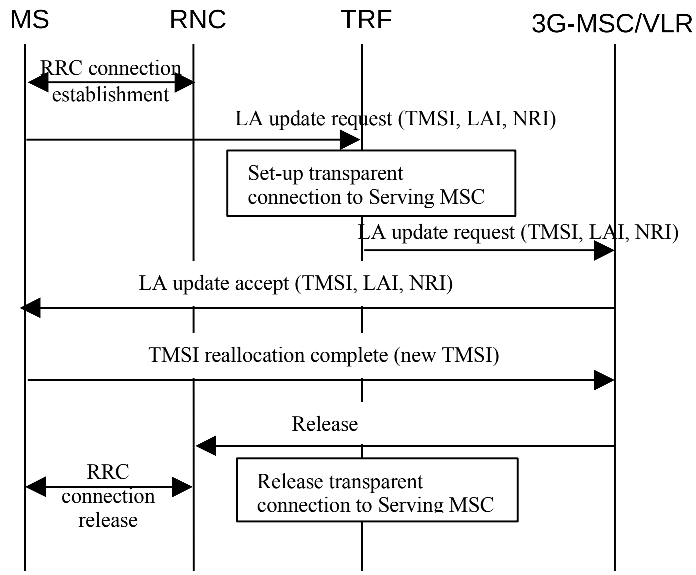

Figure 4: The message flow for a mobile station location updating within a Turbo-Charged network.

In the case where the MS moves location areas within the Turbo-Charged network, the serving MSC/VLR does not need to perform a location updating procedure. The TRF intercepts the LA update request message from the MS, and based on the TMSI+LAI or, if available, NRI forwards the message to the serving MSC/VLR. The serving MSC/VLR updates the VLR with the new LAI and may choose to assign a new TMSI. The identifiers are included in the LA update accept message to the MS. From the MSs point of view, a Location update procedure has been completed successfully.

Within a Turbo-Charged network, the MSC/VLRs know which location areas they serve. Consequently, the serving 3G-MSC/VLR knows, based on the LAI, when and when not to perform a location updating procedure towards the HLR.

6.2 Mobile Terminating Call Set-up

Figure 5 provides the message flow diagram for the case when a call is terminated to a mobile.

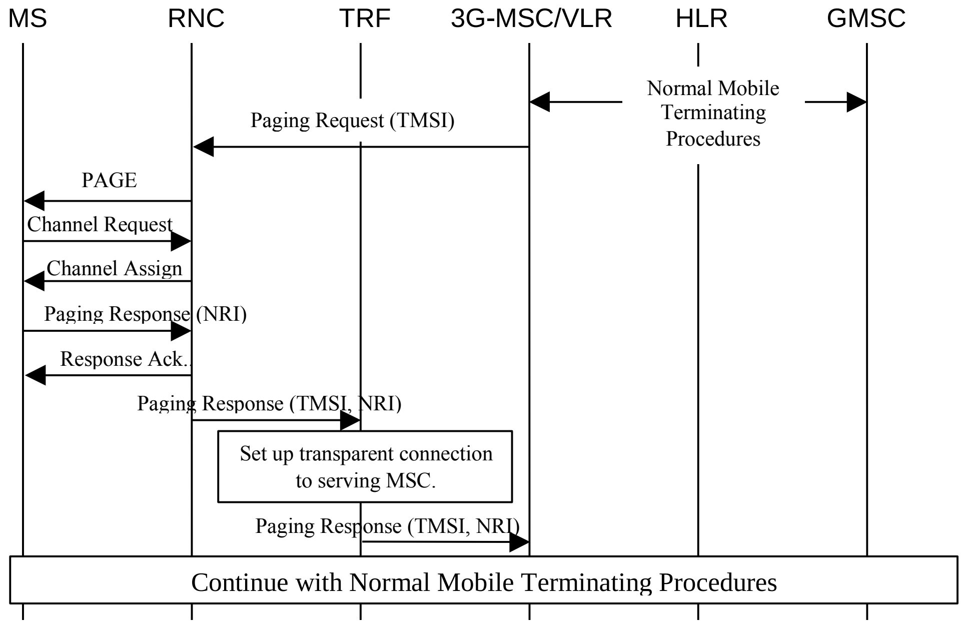

Figure 5: Mobile terminating call set-up procedure in a Turbo-Charged network.

Upon receipt of a mobile terminated call, the gateway MSC initiates normal mobile terminating procedures to the HLR and MSC/VLR.

The serving MSC/VLR routes the message to the serving RNC, and the RNC pages the mobile station. In response to the Page, the mobile station makes a channel request to which the RNC responds with a channel assignment. The mobile station then sends a Paging response message to the RNC in the form of a SABM Paging response message on the SDCCH Uplink. The RNC acknowledges this message and subsequently sends a Paging response message.

The TRF based upon the TMSI and/or, if available, NRI sets up an internal transparent SCCP connection between the RNC and the serving MSC/VLR (previously assigned by TRF). After this path has been established the TRF forwards the paging response to the serving MSC/VLR. The system then continues with the remainder of the normal mobile terminated call set-up sequence.

No inter-working problems have been identified with using Pre-Paging in a Turbo-Charged Network.

6.3 Mobile Originating Call Set-up

Figure 6 provides the message flow diagram for the case when a mobile station originates a call.

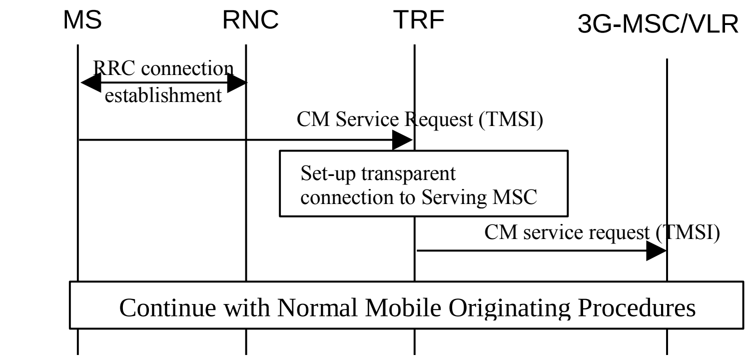

Figure 6: Mobile originating call set-up procedure in a Turbo-Charged Network

When a mobile station originates a call within a Turbo-Charged network, it sends a CM Service request message to the TRF. The TRF based upon the TMSI and/or, if available, NRI sets up an internal transparent SCCP connection between the RNC and the serving MSC/VLR (previously assigned by the TRF). After this path has been established the TRF forwards the CM service request message to the serving MSC/VLR. The system then continues with the remainder of the normal mobile originating call set-up sequence.

6.4 SRNS Relocation Update

Figures 7 and 8 are taken from UMTS 23.121 and modified to show the introduction of the TRF within a Turbo-Charged network.

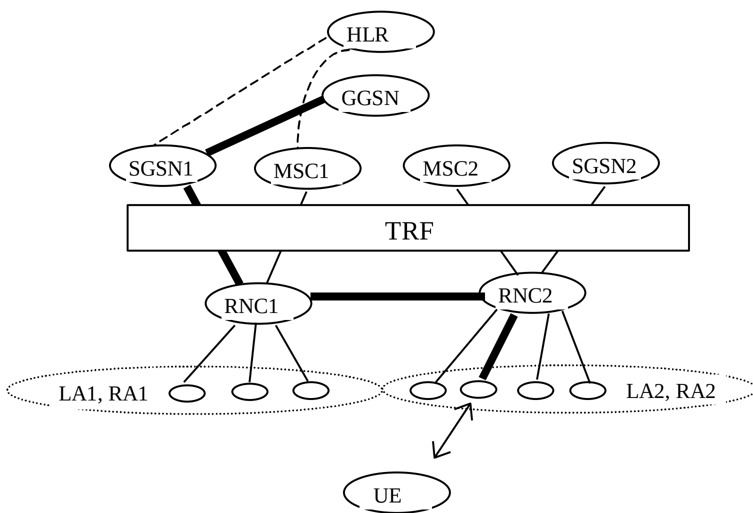

Figure 7: Before SRNS relocation and location registration in a Turbo-Charged Network

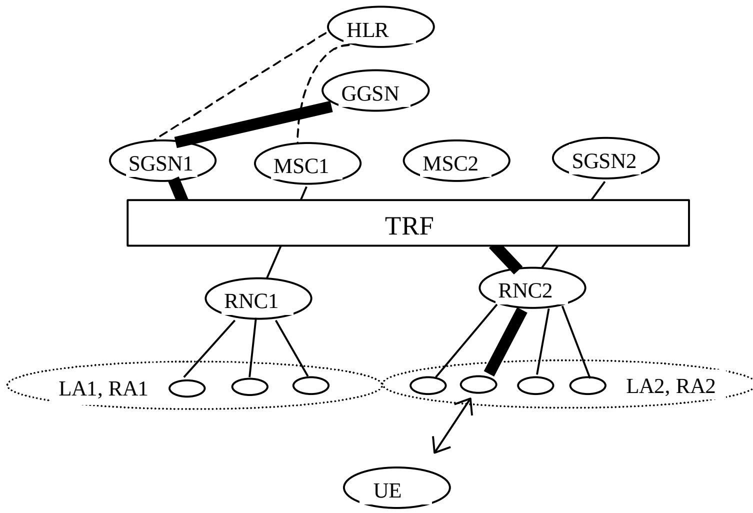

Figure 8: After SRNS relocation and location registration in a Turbo-Charged Network

Within a Turbo-Charged network the UE is registered in the same SGSN and MSC before and after SRNS relocation.

Figure 9 is taken from UMTS 23.121 and modified to show an example message flow for the SRNS relocation update procedure when a UE changes SGSN area within a Turbo-Charged network. The following signalling reductions and modifications are made to the SRNS relocation update procedure for Turbo-Charger:

- Addition of TRF.
- Removal of all messages needed between SGSN1 and SGSN2.
- All messages sent to/from SGSN2 will be sent to/from SGSN1.

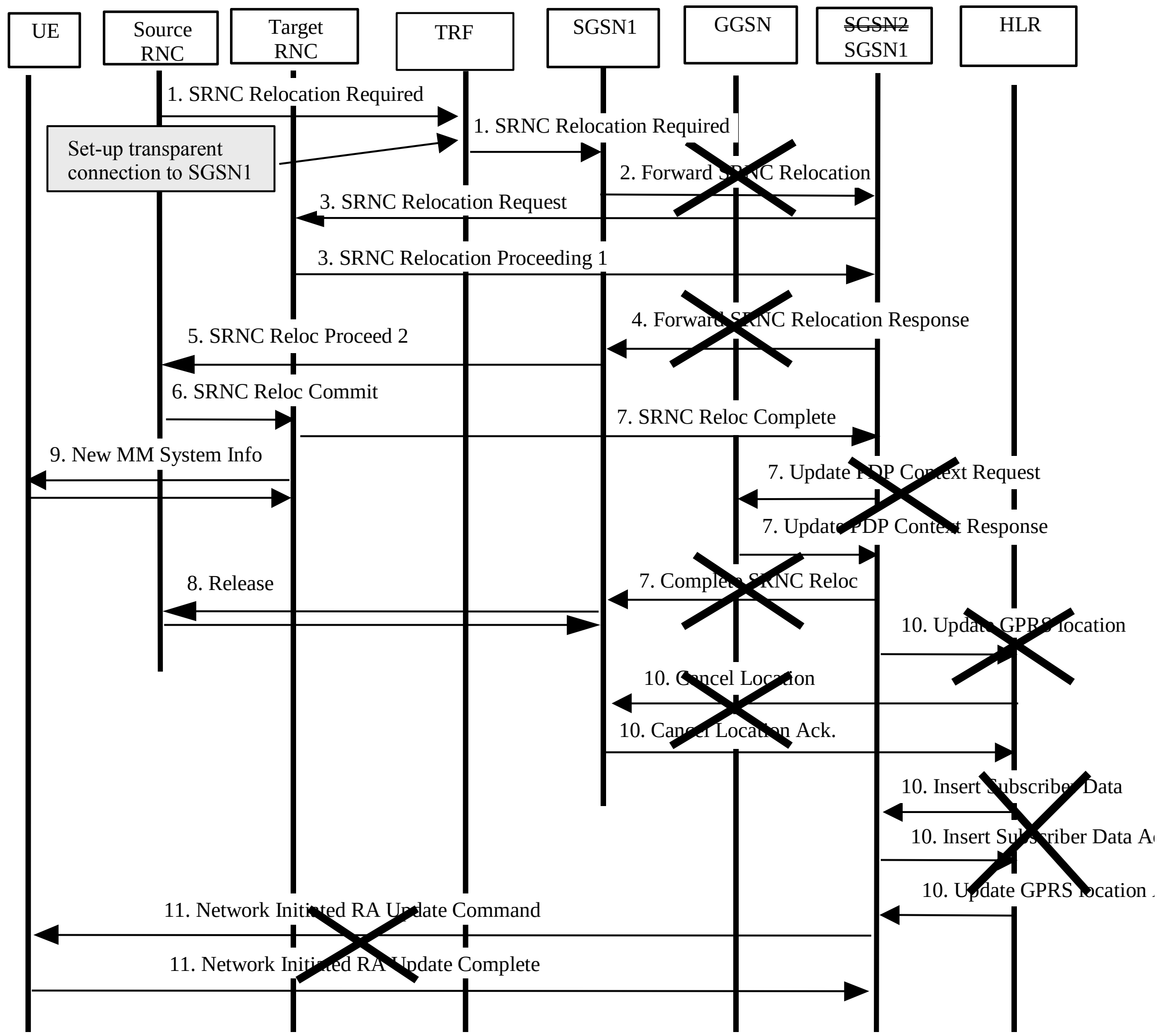

Figure 9: Information transfer for SRNS relocation update when changing SGSN area in a Turbo-Charged network

6.5 Modification of Subscription Data

The Insert Subscriber Data and Delete Subscriber Data procedures are not impacted by the Turbo-Charger concept.

6.6 Cancel Location

The Cancel Location procedure is not impacted by the Turbo-Charger concept.

6.7 Reset

The Reset procedures between the HLR and VLR/SGSN are not impacted by the Turbo-Charger concept.

6.8 Short Message Service

The Short Message Service is not impacted by the Turbo-Charger concept.

7. Benefits and Drawbacks

7.1 Advantages

- Turbo-Charger reduces mobility management signalling at source.
- Turbo-Charger reduces mobility management costs for both home and roaming subscribers moving within the Turbo-Charged Network.
- A Turbo-Charged network reduces international signalling in roaming scenarios, which is of benefit to the home network.
- Subscribers are only required to authenticate once, upon arriving in a turbo-charged network, removing the need for subsequent authentication procedures towards the home network.
- A Turbo-Charged Network does not require additional inter-working MSCs and GSNs as the HLR continues to track the location of the subscriber at the MSC/VLR and SGSN level.
- The Turbo-Charger philosophy benefits new entrants by enabling operators to introduce new network resources without tying the new capacity to a particular geographical area. In the initial deployment of a system, an overall goal is to support the highest number of subscribers with the smallest infrastructure. This initial deployment not only minimises the initial cost of deployment but also reduces the networking overhead that results from subscriber mobility.
- The Turbo-Charger philosophy provides scalability by enabling operators to introduce new network resources without tying the new capacity to a particular geographical area. For example when an MSC (or multiple MSCs) serving a system become overloaded, additional MSCs must be deployed. In deploying additional MSCs within a system, the area served by the system is typically geographically partitioned to equalise loading among the MSCs. As the number of deployed MSCs increases, each served area becomes smaller and the number of boundaries between serving MSCs increases. The additional boundaries cause an increase in subscriber mobility between MSCs, the subscriber mobility consuming additional MSC CPU capacity. Consequently, as additional MSCs are added within a system, the marginal benefit of each MSC deployment is reduced as the total number of deployed MSCs increases. In a Turbo-Charged network the addition of network resources benefits the network as a whole and does not require further subdivision of location areas.

7.2 Disadvantages

- Potentially limits the number of subscribers that can be registered in a network as a consequence of the TMSI/TLLI partitioning scheme.
- The Turbo-Charger concept introduces complexity to existing network architecture and maintenance:
  - All RNC/BSC must be accessible from all MSC/VLR/SGSN (and conversely) for signalling and user traffic and, because of combined procedures, all MSC/VLRs must be accessible from all SGSN.
  - TRF is needed between the RNC and MSC/VLR/SGSN and between the SGSN and MSC/VLR.
  - Between RNC and MSC, ATM-AAL2 switching nodes are required for user traffic of CS domain.
  - All the LA/RA and cells within the turbo-charged area and LA for the MSC/VLRs adjacent to the turbo-charged area must be known by all the MSC/VLR/SGSN of this area. This may not be manageable for large Turbo-charged areas.
  - All the LA/RA within the turbo-charged area must be known by the TRF.
  - When a cell, LA/RA, or BSC/RNC is added / suppressed all the MSC/VLR/SGSN within the turbo-charged area need to be updated. The data update has to be synchronized at the network level. Although, one data update can apply to all.

- TRF is not so simple:
  - TRF is a less efficient SCCP relay function since it needs to interpret MM messages and retrieve the destination address.
  - If TRF is implemented in a new node, then operators will have to buy and manage a new type of node.
  - TRF must have redundancy and defence mechanisms. In case of failure, calls and packet transmissions cannot be performed in the MSC/VLR/SGSN served by the TRF.
- Some inefficient use of transport resources may happen when the distance between the BSC/RNC and MSC/VLR/SGSN becomes important, i.e. in large turbo-charged area. This is a network configuration issue. It is possible to configure the network to avoid this.
- If dynamic load sharing is used for choosing the MSC/VLR/SGSN, the signalling messages used between the MSC/VLR/SGSN and the TRF node to indicate the load must be standardized in order to enable interoperability between different manufacturers.
- The TRF node and the MSC/VLR/SGSN can be from different manufacturer. If the TMSI/TLLI is used for routing, a part of the TMSI/TLLI may have to be standardized. In addition, partitioning limits capacity of the MSC/VLR/SGSN when the restart indicator and time stamp are used.
- Supplementary Service interactions will continue to use the HLR in the home network and consequently incur international signalling charges in roaming scenarios.
- CAMEL services will continue to require signalling to the home network and consequently incur international signalling charges in roaming scenarios.
- In case of mixed UMTS+GSM network, the MS moves frequently between GSM and UMTS coverage. If Turbo Charger does not apply to GSM, then it is inefficient because when the MS moves between the 2 coverage types, the MS will perform registration in a new MSC/VLR/SGSN.
- Additional disadvantages if Turbo-Charger is applied to GSM
  - In GPRS, for each transmitted packet, the TRF has to retrieve the SGSN from either the TLLI or NRI, which may delay packet transmission and decreases performance.
  - The BSC must be connected to an STP and be able to handle all messages coming from STP. This is currently not mandatory.
  - All the MSC need to be linked by point-to-point circuit trunks to all the BSC. This is because there can not be switching nodes between the MSC/VLR and the BSC since no protocol like ISUP, QAAL2 exist between them.
  - The links between the BSC and all the MSC/VLR must be over-dimensioned because all the user traffic may not be equally distributed on the MSC/VLR.
  - GSM MSs cannot send and receive the optional NRI parameter.

7.3 Open Issues

- Evaluate the signaling reduction in Turbo-Charger in comparison to the Super-Charger feature, which is simpler and possibly at a lower cost.
- Clarify in the technical report which parameters, NRI or TMSI/TLLI, the TRF function will use as criterion for routing. The NRI should be used preferably instead of the TMSI/TLLI but this raises the issue of the old MS that cannot send and receive the NRI.
- Clarify the following impacts in the UTRAN:
  - In case of Reset, Block/unblock, and overload procedures triggered by the MSC/SGSN, the BSC/RNC has to identify the MSC/SGSN and only affect the transactions related to this MSC/SGSN.
  - With Turbo Charger, how are Reset messages sent to all the MSC/SGSN? Does the BSC/RNC send several Reset messages? Does the TRF node duplicate the Reset messages sent by the BSC/RNC into several messages towards all the MSC/SGSN?
  - If Turbo-Charger is applicable to GSM, then the MSC address should also probably be used by the BSC to identify a circuit, instead of only the CIC.

- When the MS moves from a Turbo charged area to a non Turbo charged area, as the new SGSN cannot deduce any more the old SGSN address from the RA , clarify how the SGSN contexts can be retrieved from the old SGSN. It is not acceptable for the subscriber to reactivate all active PDP contexts and restart all sessions and operations related to these PDP contexts.
- In case of combined Attach procedure when the subscriber is already attached for CS services, clarify how the SGSN can find the correct MSC/VLR as this information cannot be deduced any more from the RA.
- How will the TRF function send messages to the MSC/VLR/SGSN where the MS is registered if the TMSI or TLLI or NRI cannot be sent by the MS? For example, after restart of the MSC/VLR/SGSN, the paging is done with IMSI only and the MS answers with IMSI.
- With the Turbo Charger, the BSC/RNC is accessible from several SGSNs. So how is the flow control of packets coming from the SGSNs handled? Is it handled by the TRF? How are distributed between the SGSNs the amounts of flow allowed?
- After an HLR failure, if the VLR number in which the MS is registered is wrong because a backup database has been done, no Reset message will be sent to the VLR. As no update location is done towards the HLR as long as the MS stays within the Turbo Charged area, the MS will not receive any terminated call or terminated short message. This needs to be solved.
- In case of Search procedure, the MSC/VLR (SGSN) sends paging messages to all the BSC/RNC, the BSC/RNC sends paging messages in all LA (RA) of the Turbo Charged area. This leads to a heavy load of the MSC/VLR (SGSN) and the radio network in signalling and processing. Clarify how it can be handled?

8. Impact on UMTS Specifications

8.1 Stage 2 Functional Description

A Stage 2 Service Description in necessary to describe the Turbo-Charger concept. This technical report can serve as a basis for the Stage 2.

8.2 Procedures

Turbo-Charger does not impact the RANAP specifications or the GTP protocols.

The following procedures are impacted by Turbo-Charger:

- GPRS attach and Combined Attach procedure
- LA update, RA update, and Combined RA update procedure
- Paging and Search procedures
- Reset RNC, Reset MSC, Reset SGSN, Reset circuit, Reset NS-VC procedures
- Block/Unblock procedures
- Overload procedures
- Flow control of packets coming from SGSN

These messages are intercepted by the TRF and the optional Network Resource Identifier (NRI) parameter needs to be added to the following mobility management messages in UMTS 24.008:

- LA update request,
- Attach request,
- RA update request,
- Paging response,
- CM service request, and
- CM Re-establishment request.

The following procedures may be impacted by Turbo-Charger: Activate PDP Context and Activate AA PDP Context.

8.3 Terminals

Support of the optional NRI parameter.

9. Conclusions

Weighing the advantages versus disadvantages is very difficult therefore no firm conclusion can be made on the technical feasibility at this stage. CN1 has concluded that Turbocharger is not feasible for R99 for lack of time.

Document history		
0.0.1	Nortel Networks	Presented to CN1#6 for information
0.0.2	Nortel Networks	Revisions to incorporate comments made at CN1#6. Presented to CN1#7 for approval.
0.0.3	Nortel Networks	Revisions to incorporate comments made at CN1#8.
0.1.0	Nortel Networks	Revisions to incorporate Alcatel's comments at CN1#8.
0.1.1	Nortel Networks	Revisions to incorporate comments made at CN1#8.
1.0.0	Nortel Networks	Approved at CN1#9, presented for information at TSGN#6