# Presentation of Specification to TSG or WG

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| **Presentation to:** | **TSG-RAN Meeting #14** |
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## Abstract of document:

This document is for part of the Rel-5 study item “Improvement of RRM across RNS and RNS/BSS”. This study report describes the techniques to improve the RRM across RNS and RNS/BSS. It also deals with the feasibility of the techniques that are described in this document and their benefits.

## Changes since last presentation to TSG-RAN Meeting #13:

Detail information of approach 1 in the TR was added.

## Outstanding Issues:

## Contentious Issues:

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*(Proposed Technical Report)*

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***3GPP***

Postal address

3GPP support office address

650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

http://www.3gpp.org

# Contents

# Foreword

This Technical Report 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.

# 1 Scope

This document is for part of the Rel 5 study item "Improvement of RRM across RNS and RNS/BSS".

This study report describes the techniques to improve the RRM across RNS and RNS/BSS. It also deals with the feasibility of the techniques which are described in this document and their benefits.

# 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.

[1] TR 101 112 V3.2.0, Universal Mobile Telecommunications System (UMTS); Selection procedures for the choice of radio transmission technologies of the UMTS (UMTS 30.03 version 3.2.0)

[2] 3GPP TS 25.423: "RNSAP Specification".

[3] 3GPP TS 25.433: "NBAP Specification".

# 3 Definitions, symbols and abbreviations

## 3.1 Definitions

For the purposes of the present document, the following terms and definitions apply.

**Example:** text used to clarify abstract rules by applying them literally.

## 3.2 Symbols

## 3.3 Abbreviations

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

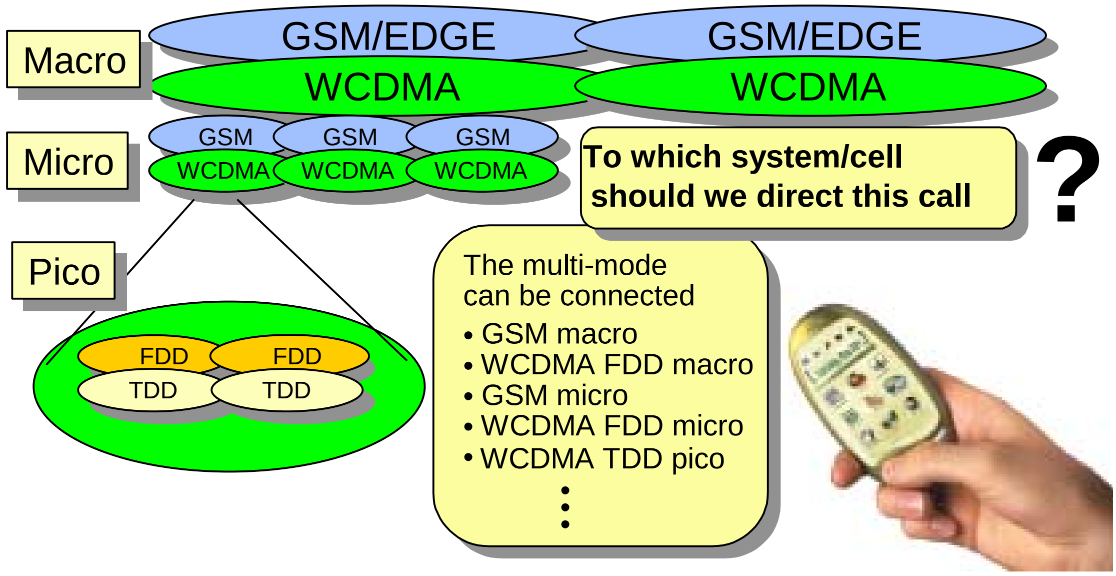
| | |
|---|---|
| RRM | Radio Resource Management |
| IRNSAP | Inter Radio Network Subsystem Application Part |

# 4 Introduction

In 3GPP TSG RAN #11, it was decided to create Rel 5 SI, "Improvement of RRM across RNS and RNS/BSS" to invest Multiradio Support study area.

This chapter introduces the background of this study and the reason why RRM is important in multi-radio environment.

In the future, the mobile network configurations will not be as simple as in nowadays. Multiple cells from different radio technologies will be overlapped in the same area and multiple layers will co-exist. In this complicating environment, multi-mode mobile can be connected to different cell and unless there is knowledge about each cell it would be very difficult to optimise




network performance and to manage resources properly.

**Figure 1. Future Mobile Network Environment**

In addition, it would be reasonable to direct different services with different QoS classes to the most suitable radio accesses.

To consider the above situation, it is necessary to invest a study to provide optimal resource management in multi-radio environment and to optimise network performance.

# 5 Requirements

## 5.1 General

To provide optimal resource management and to optimise network performance in multi-radio environment, any solution(new/enhanced) should enable the followingperformance improvements:

**Trunking gain:** Less blocking from real time services. Higher throughput and lower delay for non real-time services. Lower possibility of handover failure in case of load sharing /inter system handover.

**Lower interference:** Managing the average interference to be lower.

**QoS Management:** As a service can be realised in several systems, the call can be directed to the system which can best obtain the requested QoS with least cost for the operator.

## 5.2 Open Interfaces

If there is a need to define a new interface, then this interface shall be open:

**Multi-vendor operation:** An operator with for example GERAN equipment from vendor X and UTRAN equipment from vendor Y will have the possibility to steer and to control traffic between the systems.

## 5.3 Backward Compatibility

**Backward compatibility**: The solution shall be backward compatible and shall affect to existing interface as little as possible.

**Transparency to UE/MS:** The solution for providing optimal resource management across RNS and RNS/BSS shall be transparent for UE/MS functionality.

# 6 Study Areas

Currently 2 approaches has been proposed and the evaluation of both solution should be carried on in the future.

## 6.1 CRRM Server

### 6.1.1 Introduction

This chapter introduces the concept of Common Radio Resource Management server (CRRM Server), as a new logical node in UTRAN and GERAN. The purpose of the CRRM Server is to collect resource management functionality that can be related to multi-system functionality, so that this can be processed in the same algorithm (i.e. handover, load control, QoS control, etc).

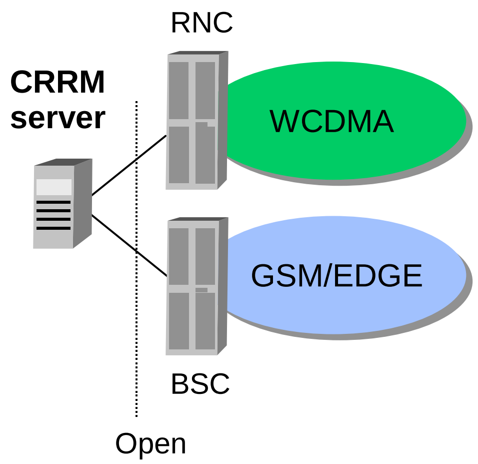



**Figure 2. CRRM server relationship to the UTRAN/GERAN architecture.**

With the introduction and integration of several systems with several modes and several layers, resource management becomes a more and more complicated task.

For example handover and load sharing algorithms shall not only maintain the connection at a reasonable quality, they should also consider whether it would be beneficial to move the connection to another system/layer/mode. This decision is not solely because of changing radio propagation, but also factors such as system load, operator priorities and service quality play an important role.

Although possibilities to gain information on other systems (e.g. inter system measurements GSM/UTRAN) are built in, the general understanding is that the respective algorithms shall execute in their respective system, and it is up to the operator to tune both systems to avoid ping-ponging, and to achieve optimal system performance.

In order to improve this situation, the introduction of a Common Radio Resource Management Server with an open interface towards both UTRAN RNS and GERAN BSS would make it possible to collect information from several systems/modes/layers and make a more optimal decision. CRRM server is not supposed to be be consulted for channel switching or for soft handover, since the RRM in RNC shall handle these kind cases. CRRM server will be used only for inter system/modes/layers HO.

### 6.1.2 Technical Details

Common Resource Management Server acts as a policy manager for the access to the cells and the radio bearer resources within UTRAN and GERAN, by performing the Radio Resource Management algorithms that are based on dynamic status information per cell from all the cells in the system. CRMS is also connected to other radio access network than UTRAN/GERAN in the future, allowing dynamic intersystem RRM.

One CRMS collects the information about the cell status in one area from RNSs or BSSs and, based on this, prioritises handover candidate lists.

#### 6.1.2.1 CRMS Interfaces

The CRMS shall provide or ask for services to the logical entities(i.e. RNC, BSC and CRMS) that are connected to it. There are three main groups of services related to the CRMS:

1) Cell Measurement Gathering: This group of services is needed between CRMS and they are used to provide measurements related to the cells controlled by the RNC/BSC. This group of services may also be used by a CRMS to forward measurement to another CRMS (Edge Cell Measurement Gathering), which may be necessary in case the two CRMS control neighbouring cells.

2) Prioritisation of the list of candidate cells of a UE for a specific operation (handover, network controlled cell reselection...), This group of services is only needed between CRMS and RNC/BSC.

3) Error indication: this service is used by one entity to report detected errors in a received message, provided they cannot be reported by an appropriate response message. The error indication procedure can be used either between a CRMS and a RNC/BSC or between a CRMS and a CRMS.

These interfaces shall be standardised.

##### 6.1.2.1.1 Cell Measurement Gathering

The measurement reporting procedures are based on the UTRAN Iub Common Measurement procedures [3] and/or on the Iur Common Measurement procedures [2]. Both of them, and also this interface, support on-demand (immediate), periodical or event-triggered reporting methods.

The CRMS shall select and set the reporting method for one, a group or all of the elements to be measured using just one requesting message. The reporting of the measurements shall be done in the same way as the request was done (individually or grouped)

Measurements can be expressed with parameters independent of the radio technology.

Four elementary procedures are defined for this purpose:

| Elementary Procedure | Initiating Message | Response message | |
|---|---|---|---|
| | | Successful Outcome | Unsuccessful Outcome |
| Measurement Initiation | MEASUREMENT INITIATION REQUEST | MEASUREMENT INITIATION RESPONSE | MEASUREMENT INITIATION FAILURE |
| Measurement Reporting | MEASUREMENT REPORT | | |
| Measurement Termination | MEASUREMENT TERMINATION REQUEST | | |
| Measurement Failure | MEASUREMENT FAILURE INDICATION | | |

#### 6.1.2.1.2 Prioritisation of the list of candidate cells

The RNC/BSC sends to the CRMS the list of candidate cells of a UE for a specific operation (handover, cell change order...), including (when available) the mobile measurements for these cells and information about the quality of service that the user requires. The CRMS, after applying some algorithms, returns the prioritised list.

One 'class 1' elementary procedure will be defined for this interface.

| Elementary Procedure | Initiating Message | Response message | |
|---|---|---|---|
| | | Successful Outcome | Unsuccessful Outcome |
| Prioritised Cell List | PRIORITISED CELL LIST REQUEST | PRIORITISED CELL LIST RESPONSE | PRIORITISED CELL LIST FAILURE |

#### 6.1.2.1.3 Error Indication

The error indication procedure is initiated to report detected errors in a received message and same with the one defined in [2] or [3].

### 6.1.2.2 Example Scenario

#### 6.1.2.2.1 UTRAN ⇔ GERAN

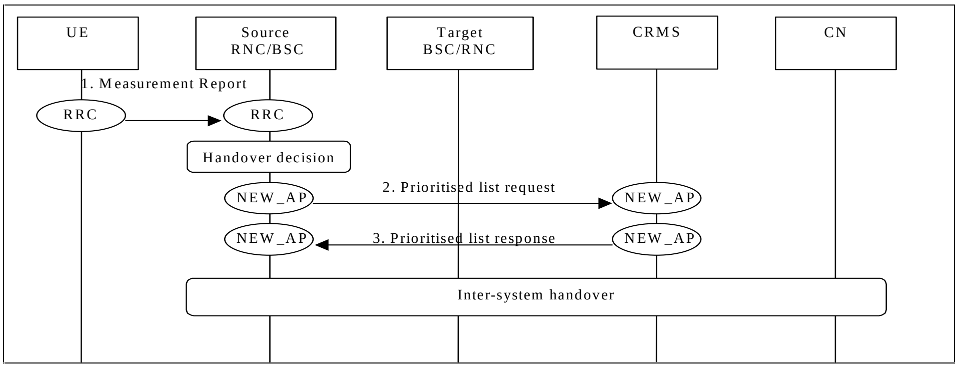



**Figure 3. UTRAN ⇔ GERAN Intersystem HO with CRMS**

1. Source RNC/BSC receives the neighbour cell measurements from UE and executes the handling for them.
2. The handover decision based on neighbour cell measurements is made. RNC/BSC sends the target cell proposal via Prioritised Cell List procedure in order to find the most optimal cell. Target cell list proposal is sent to the CRMS using the *Prioritised List Request* message..
3. The CRMS makes the prioritisation and returns the reordered candidate cell list using one *Prioritised List Response* message.

After target cell is decided, the procedure is same with the inter-system handover.

#### 6.1.2.2.2 DRNC Covered by Another CRMS

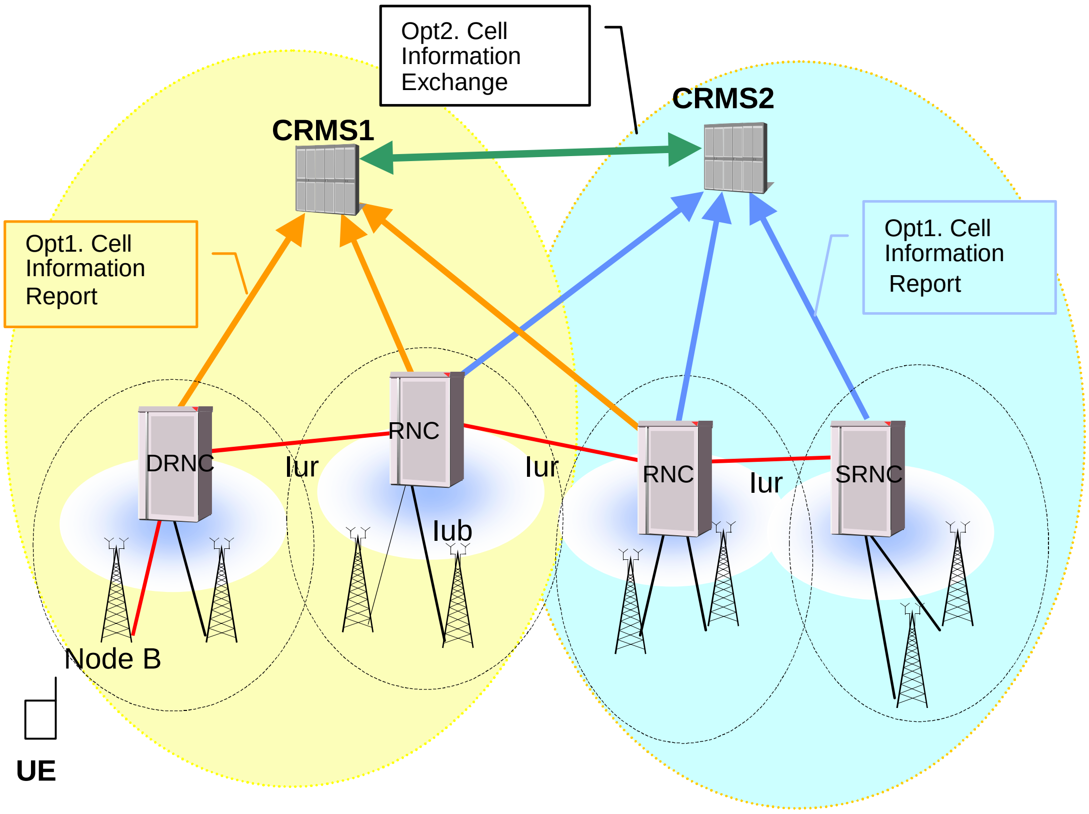



**Figure 4. UTRAN Architecture with CRMS**

Each CRMS will gather the cell load information under its coverage. For the neighbouring cells of the CRMS coverage, each CRMS can be provided the cell load information in 2 ways; Opt 1-CRMS can request cell load information of neighbouring cell or Opt 2-CRMSs can exchange the border cell load information.

It's up to each manufacture to choose which option to implement.

In case the DRNC is covered by another CRMS than the one covers SRNC as in [Figure 4], during RL Setup procedure DRNC will provide the address of CRMS1. Once SRNC decides HO and needs to consult CRMS covering the DRNC, SRNC will request the HO prioritised list from CRMS1.

### 6.1.2.2.3 UE in Soft Handover

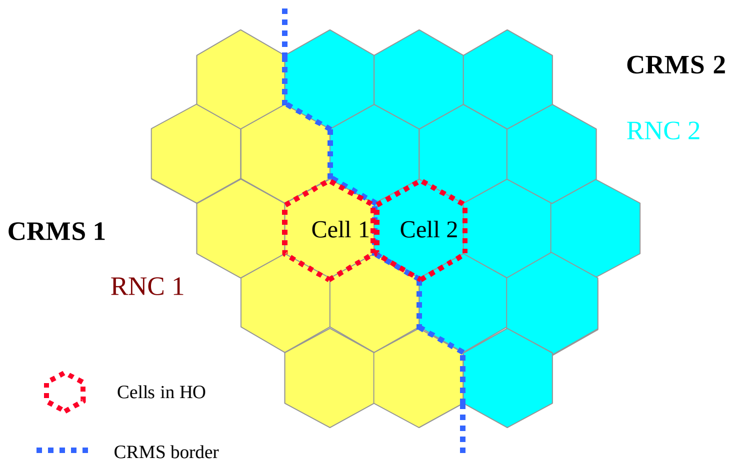



**Figure 5. Border Cell SHO Case**

If there are more than one CRMSs exist, then depending on the network planing each CRMS will keep the cell load information not only under its own coverage but also the neighbouring cells of CRMS border as described in 6.1.2.2.2. Therefore in case border cells are participating in SHO and each cell belongs to different CRMS coverage as [Figure 5], either CRMS can decide HO prioritised list because both CRMSs are having the border cell load information.

### 6.1.3 Open Issues

- CRMS-CRMS open interface. Is this interface needed ?

- The relationship between CRMS and RNC. In case there are DRNCs and more than one CRMSs, to which CRMS does SRNC ask the prioritized list ?

- If UE is in SHO and multiple CRMSs are involved in, which CRMS will decide prioritized list ?

## 6.2 Integrated CRRM

### 6.2.1 Introduction

An alternative approach to achieve a CRRM functionality is to use the existing Iur and Iur-g interfaces, i.e. the CRRM functionality is integrated into the existing UTRAN nodes. As matter of fact many CRRM functionalities, such as Intra-RAT/Inter-frequency Handover, Directed retry, Service Handover, etc. are already supported in the current standard. The Iur and the proposed Iur-g interfaces already include almost all the required ingredients to support the CRRM functionality. Therefore, a natural approach is to continue this path and improve the exiting CRRM functionality.

The main benefit of the Integrated CRRM is that with limited changes and already existing functionality it is possible to achieve optimal system performance. Most importantly, this is achieved without introducing additional delay which will deteriorate the delay sensitive procedures at call setup, handover and channel switching.

Furthermore, the additional delay will have adverse impact on the truncking gain specially for the bursty traffic which will cause reduced radio resource utilisation. In addition, delayed handover decision and execution will have negative impact on power control and thus reduced system capacity.

The delay requirement on the channel switching would in practice limit the possibility to interrogate the external CRMS, thus reducing the possibility to achieve a optimal system performance. Whereas, in the Integrated CRRM, the SRNC or BSC, based on its intra and inter system knowledge and the capacity, makes decision on whether to perform channel switching, inter-layer, inter-frequency or inter-RAT handover.

It is the general understanding that the RRM algorithms can not completely moved to an external CRRM. Some part of functionality will anyway reside in the RNS and BSS, which will result in that all three systems need to be tuned to achieve optimal performance, making the system tuning more cumbersome.

## 6.2.2 Technical Details

In order to improve the integrated CRRM functionality, the following additions have been identified to the existing interfaces:

1. Common measurements
2. Cell relation
3. Cell capability

### 6.2.2.1 Common measurements

The measurements such as load information of the neighbouring UMTS and GSM cells is an important input to the CRRM algorithm.

The cell load measurement has been already introduced on Iur in Rel-4 for UMTS cell load measurements between the neighbouring RNSs.

The measurements between the BSC and RNC could be transferred in two different ways, via Iur-g or Iu.

#### 6.2.2.1.1 Common measurements over Iur-g

Similar procedure as the RNSAP Common measurement procedures are introduced.

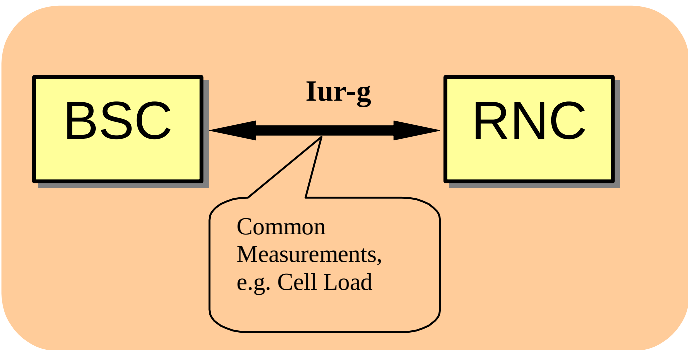



Figure 6.: Common Measurements over Iur-g

#### 6.2.2.1.2 Common measurements over Iu/A-interface

The cell load measurement is included in the transparent container IEs in the messages used by the RANAP Relocation procedures and BSSMAP Handover procedures.

Since the load measurements has short validity, this method is not as efficient as the method 1. However, during high traffic the Inter-RAT handover is executed more often between the UTRAN and BSS which gives more frequent measurements which will result in more reliable load information. This method is an alternative specially if the Iur-g is not required for other reasons than cell load measurements.

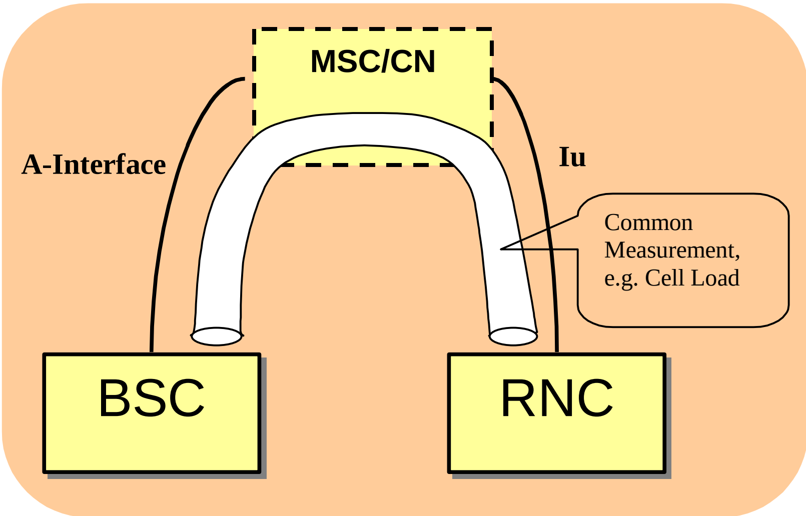



Figure **7.** : Common measurements in transparent containers over Iu/A-Interface

#### 6.2.2.1.3 IRNSAP

It is proposed to define a new interface between an RNC and a BSC that allows to exchange these information.

This interface should allow a connection towards a BSC supporting A/Gb mode i.e. not be linked to the support of GERAN Iu mode. Nevertheless, in order to anticipate the GERAN evolution in Iu mode and the interface called Iurg, it is proposed that the interface between a RNC and a 2G BSC remains compatible with Iurg. It means that this interface should be based on RNSAP. Furthermore the underlying transport should also be compatible with legacy 2G BSC equipments.

It is proposed to call IRNSAP (for inter Radio Network Subsystem Application Part) the protocol on this interface.

##### 6.2.2.1.3.1 Signalling Transport

Since the transport solution should be compatible with legacy 2G BSC equipments, B-SS7 cannot be used. Thus, it is proposed to use the IP stack that will be defined in release 5 for the Iur interface.

##### 6.2.2.1.3.2 IRNSAP functions

The following functions, taken from the R4 RNSAP protocol, are needed:

- Measurement on Common Resources.
- Information Exchange.

This would be handled by defining the Common Measurement Initiation, Common Measurement Reporting, Common Measurement Termination and Common Measurement Failure procedures as well as the Information Exchange Initiation, Information Exchange Reporting, Information Exchange Termination and Information Exchange Failure procedures as they have been defined in RNSAP in Release 4 but for the information described in the sub-section 3 of this contribution.

#### 6.2.2.2 Cell relation

The knowledge about the cell relations, i.e. overlapped, Macro/Micro cells or in general Hierarchical Cell Structure (HCS) is valuable in the SRNC in order to direct the traffic to the most optimal cell. Furthermore, the SRNC may not perform Inter-frequency CM measurements if the neighbouring cell is overlapped with the serving cell, and thereby avoiding capacity loss due to the CM measurements. In addition, the delays in the handover procedure will be reduced as the CM measurements are omitted.

The information about cell coverage area is proposed to be indicated to the SRNC by including the Cell GAI IE in the UMTS and GSM neighbouring cell information in the RADIO LINK SETUP RESPONSE and RADIO LINK ADDITION RESPONSE messages. The Cell GAI is already included in a number of the RNSAP messages from DRNC to SRNC, such as RADIO LINK SETUP RESPONSE for the UE cell-based positioning method.

Other HCS specific parameters such as HCS Prio (similar to HCS in RRC) may be required. Which parameters to include is FFS.

#### 6.2.2.3 Cell capability

The GSM neighbouring cell information is normally setup via management interface in the CRNC. However, currently the SRNC does not receive all the necessary information over Iur about the neighbouring GSM cell capability. By the GSM cell capability, it is meant the information whether the GSM neighbouring is capable of, e.g. GPRS, HSCSD, EDGE, GERAN(Iu, Gb/A-interface), etc. This information is necessary for the CRRM algorithm in the SRNC in the cell candidate selection at call setup and handover.

#### 6.2.2.4 Proposed Parameters for RRM improvements across RNS/BSS

These two lists are preliminary and non-exhaustive, they should be completed in future meetings.

The following information would be useful in an RNC for a decision on 3G to 2G handovers:

- 2G Cell Capacity for CS Domain (e.g. number of available Time Slots),
- 2G Cell Capacity for PS Domain (e.g. number of available Time Slots),
- 2G Cell load in CS Domain (e.g. Percentage of 2G Cell Capacity for CS Domain),
- 2G Cell load in PS Domain (e.g. Percentage of 2G Cell Capacity for PS Domain),
- Available QoS in PS Domain (e.g. Average Buffer Delay per Priority, Available Maximum Bit Rate per priority).

The following information already available in RNSAP would be useful in a BSC for 2G to 3G handovers:

- 3G Cell Capacity,
- 3G Cell load (e.g. Percentage of 3G Cell Capacity),

Possibly, UMTS specific information such as those already available in RNSAP could also be useful:

- transmitted carrier power,
- received total wide band power,
- UL timeslot ISCP (for a TDD Cell),

# 6.3 CRRM Performance Analysis

## 6.3.1 Introduction

The target of this document is to quantify some of the benefits of Common Radio Resource Management (CRRM) for traffic management in an environment where several different radio access technologies co-exist with cells on several hierarchical layers.

One of the benefits comes from uniform distribution of traffic, which is desirable to maximise the trunking gain in network and to minimise the probability to make needless traffic reason handovers (see Figure 8). This also results in more uniform distribution of interference. This is achieved from the knowledge of the status of each cell, e.g. load in order to share the information of each cell.

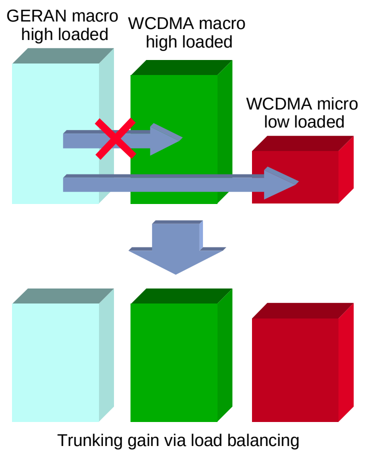



**Figure 8. Trunking gain via load balancing**

The trunking gain can be achieved by:

- directing a real time user to another system (or layer or frequency) by inter-system handover (IS-HO) or directed retry (DR) if the cell is full - resulting in less blocking
- directing a non-real time user to another system (or layer or frequency) by inter-system network controlled cell reselection (IS-NCCRS) if the cell throughput is below threshold (high delay) – resulting in a higher average throughput (smaller average delay).

In this document the capacity (trunking) gains from CRRM concept are studied by relatively simple Matlab ® simulations. Only the load of the cells is considered as an input to cell prioritisation process. The simulations are carried out for both real-time (RT) and non-real-time (NRT) traffic. The simulation assumptions for RT traffic apply to both conversational and streaming traffic classes, whereas NRT assumptions apply only to interactive traffic class.

## 6.3.2 System Model

The simulation models are built on top of Matlab ® simulation tool. The simulation area consists of 5x4 hexagonal grid of cells. The border effects are alleviated by using wrap-around method (no UE enters or leaves the area). The left and right borders of the hexagon grid are connected to each other as well as the top to the bottom, thus each cell has 6 intra-layer neighbours.

There can be up to *n* layers on top of the first layer. Each layer has same properties, such as maximum bandwidth, i.e., no specific radio system specific features/limitations (e.g. timeslots) are considered, a layer can be WCDMA, GSM, etc. No propagation model is modelled.

In the simulations the position of a UE is not defined strictly, but as a membership to a certain cell. As with the call duration distributions these speed distributions are assumed from the information available. In Figure 9 the UE speed distribution used in the simulations is depicted.

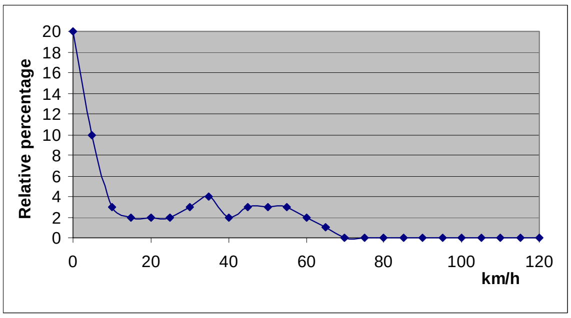



**Figure 9. UE speed distribution**

The direction of the movement is randomly determined. The border crossings between cells within the same system are treated as probabilities arising from the speed distribution of UE according to function

$$P_{MS\_BC} = \tanh\left[\frac{timestep \cdot UE\_Speed}{2 \cdot 3.6 \cdot L}\right], \qquad (1)$$

where *timestep* is one simulation step in [s], *UE_Speed* is speed of UE from the distribution in [km/h], and *L* equals to cell radius in [m].

The factor 3.6 in the denominator is a unit conversion from [km/h] to [m/s]. The factor 2 is needed as an adjustment, so that the border crossing probability is about 0.5, if *UE* moves one cell radius in one timestep. Tanh-function is used to make sure that the border crossing probability of a *UE* never exceeds 1, even if *timestep* or *UE_Speed* are set to a very high value.

## 6.3.2.1 RT Model and Algorithms

In this section the simulation assumptions for real-time simulations are described. RT simulations do not distinguish between conversational and streaming traffic classes.

### 6.3.2.1.1 Traffic Model

The air interface of the RT simulations consists of capacity definitions for each layer. In the model only hard capacity limits are used, such as maximum capacity for all cells in kbits/s. Thus, If the limits are exceeded, the UE is either handed over to another layer or the call is dropped.

For each single real-time call a certain duration time was chosen. The call duration distribution follows the formula

$$f(x) = \frac{1}{d} e^{-dx} \qquad (2)$$

where the mean duration of a call is 120s (d=1/120). All terminals are supposed to be multi-mode, so they can operate in all systems/layers. The traffic model is a constant bit rate model, with 100 % of activity, hence no silent periods are modeled.

The call arrival process has been modelled simply as

$$NumNewCalls = \frac{timestep}{average\ call\ length} \cdot Total\ number\ of\ active\ UE \qquad (3)$$

On the average the number of active calls remain constant during the simulation. Also with this approach it is assumed that no queuing occurs. Although for a real time services calls could be generated according to a Poisson process, it does not have much impact on the average capacity results.

#### 6.3.2.1.2 Reference IS-HO algorithm

Without CRRM only very little information about the target cell can be obtained. It is possible that there is no direct information available in one system about the load situation in the other system. So, an inter-system handover (IS-HO) attempt can fail due to high load in the target cell just not being known. In this case, the UE remains in its original cell. In these simulations the load reason HO triggering thresholds are located at 80% load for each cell. Above it the *UE*'s are handed over to another system because of load reason.

As the load reason IS-HO is triggered a number of users causing excess load are commanded to make inter-layer/system HO to randomly chosen target cells. If the target cell load is less than 80% the intra-system/layer HO is proceeded, but in contrary case ISHO is failed and call is kept in original cell. The procedure is illustrated in Figure 10 (left). If both current cell and target cell are fully loaded the call is dropped.

In initial access (call setup) same load thresholds are used as in case of handovers. If the load of the source cell is over 80% directed retry (DR) is performed to randomly chosen target cell. See Figure 10.

Note that only one DR is allowed in RT call setup and HO to randomly selected target cell among *n* layers.

#### 6.3.2.1.3 CRRM ISHO Algorithms

Basically the same procedure is used in CRRM simulations as without CRRM. The only difference is that the cell capabilities are known by CRRM. Thus, the most optimum cell can be chosen among *n* parallel cells in both call setup and inter-system/layer HO. In Figure 10 (right) procedure with CRRM is illustrated. Note that the target cell prioritisation is based only on the cell load and no QoS issues are considered.

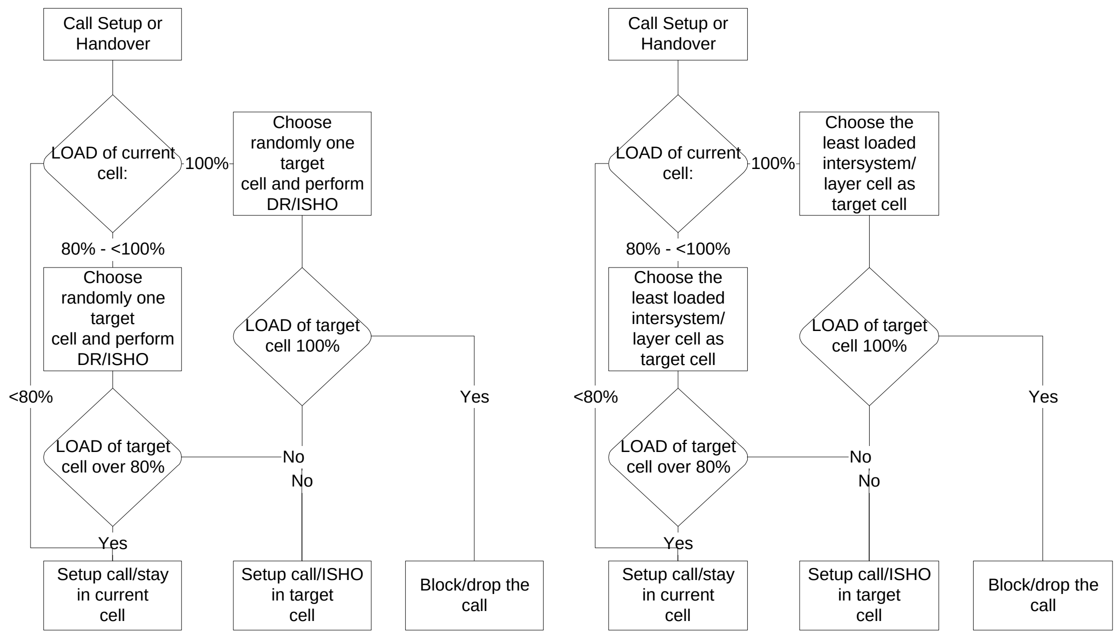



**Figure 10. Call setup and traffic reason HO procedure without CRRM (left) and with CRRM (right)**

### 6.3.2.2 NRT Model and Algorithms

In this section the simulation assumptions for non-real-time simulations are described. Here NRT simulations refer only to interactive traffic class.

#### 6.3.2.2.1 Packet traffic model

In NRT simulations a typical WWW browsing model based on [1] is used. In the packet generating model one browsing session consists of a sequence of packet calls, and a packet call corresponds the downloading of a WWW document. After the document is entirely arrived to the terminal, the user is consuming certain amount of time for studying the information. This time interval is called **reading time**.

The user initiates a packet call when requesting an information entity. During a packet call several packets may be generated, which means that the packet call constitutes of a bursty sequence of packets (Figure 11). This phenomenon is not taken into account in the traffic model, since only the capacity or trunking gain results are in scope of these simulations. Therefore, the packet calls are not divided to smaller segments of data (packets), neither the TCP/IP rate adaptation mechanisms to include the packet arrival process within a packet call is included.

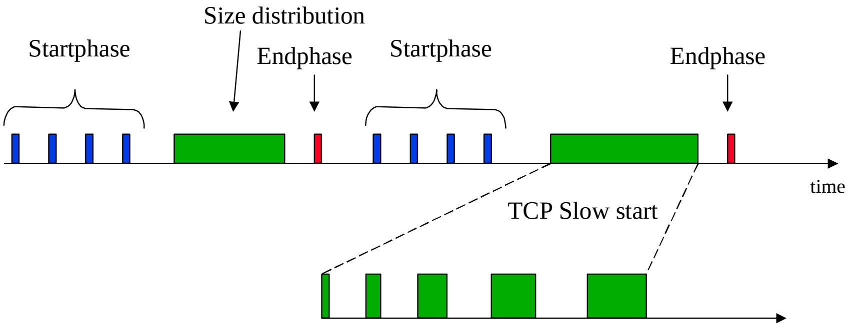



**Figure 11. Generic model for NRT traffic.**

Hence, only the following are modelled in order to catch the typical behaviour of WWW-browsing (see Figure 12): Session arrival process, Number of packet calls per session (***$N_{pc}$***), Reading time between packet calls (***$D_{pc}$***), and Size of a packet call (***$S_d$***). Note that the session length is modelled implicitly by the number of events during the session.

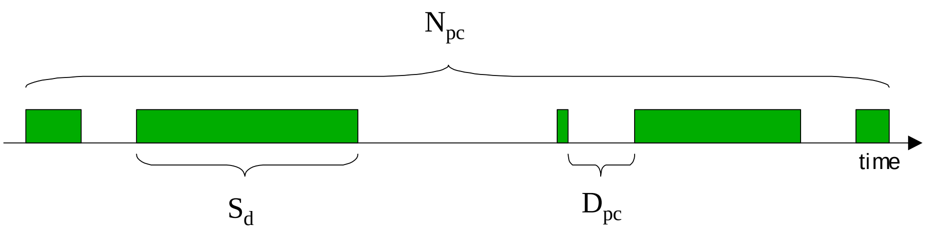



**Figure 12. A packet session**

Next it is described how these four different events are modelled. The geometrical distribution is used (discrete representation of the exponential distribution), since the simulations are using discrete time scale [1].

***Session arrival process:*** The arrival of session set-ups to the network is modelled as a Poisson process. It is important to note that this process only generates the time instants when service calls begin and it has *nothing to do with call termination*.

***The number of packet call requests per session, $N_{pc}$:*** This is a geometrically distributed random variable with a mean $\mu_{Npc}$ [packet calls], i.e.,

$$N_{pc} \in Geom(\mu_{Npc}).$$

***The reading time between two consecutive packet call requests in a session, $D_{pc}$: :*** This is a geometrically distributed random variable with a mean $\mu_{Dpc}$ [model time steps], i.e.,

$$D_{pc} \in Geom(\mu_{Dpc}).$$

Note that the reading time starts when the last packet of the packet call is completely received by the user. The reading time ends when the user makes a request for the next packet call.

***Packet call size, $S_d$:*** The traffic model can use such packet call size distribution that suits best for the traffic case under study. Pareto distribution is used.

**The Pareto distribution is defined by:**

$$\begin{cases} f_x(x) = \dfrac{\alpha \cdot k^{\alpha}}{x^{\alpha+1}}, x \geq k \\ F_x(x) = 1 - \left(\dfrac{k}{x}\right)^{\alpha}, x \geq k \\ \mu = \dfrac{k\alpha - m \cdot \left(\dfrac{k}{m}\right)^{\alpha}}{\alpha - 1}, \alpha > 1 \end{cases}$$

In Table 1 default mean values for the distributions of typical www service are given. According to the values for α and k in the Pareto distribution, the average packet call size is set to 25 kbytes. The parameters of heavy-tailed Pareto distribution (packet call size) has been tailored to reduce the simulation time, thus packet call size can vary between 4.5 kbytes and 2Mbytes.

| Process | Random Variable | Parameters |
|---|---|---|
| Packet Call Size | Pareto with cutoff | α=1.1, k=4.5Kbytes, m=2 Mbytes, μ=25Kbytes |
| Mean number of packet calls per session | Geometric | 5 |
| Mean reading time | Geometric | 5 s |

**Table 1. Default mean values for the distributions of typical www service**

### 6.3.2.2.2 Channel model and packet scheduling

The simulation setup is simplified by assuming each cell to have same capacity (bandwidth). Generated packet traffic is led through a time divided shared channel (e.g. DSCH, HSDPA) utilising the whole cell bandwidth. Each cell has a buffer where packet calls are scheduled in 'first in first out' basis (see Figure 13), and hence, each cell buffer is reduced by timestep*bandwidth kbytes in each simulation step.

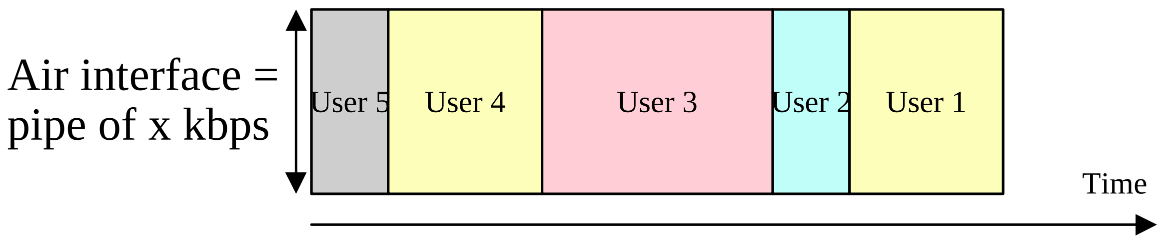



**Figure 13. First in first out scheduling**

### 6.3.2.2.3 Reference case

In reference case (no CRRM) simulations the inter-system network controlled cell reselection (IS-NCCRS) due to delay reason is not implemented for NRT data, and thus each layer/system generates and processes packet traffic separately.

###### 6.3.2.2.4 IS-NCCRS algorithms for NRT simulations

In simulations with CRRM a delay reason Inter-system/layer network controlled cell reselection is triggered if the delay in cell buffer exceeds certain time in seconds (MaxDelayTreshold). CRRM checks if there is significant difference (MinDelayDifference) between current cell and the parallel IS cell having smallest buffer delay. The last packet calls in buffer are moved to parallel cell having smallest buffer delay such that the delay is balanced between cells. The purpose of these thresholds (MaxDelayTreshold and MinDelayDifference) is to reduce unnecessary cell reselection/signalling, and obviously there's trade-off between optimum performance and the amount of signalling.

Also in call setup a call can be directed to a cell where the buffer size is the smallest by directed retry. However, this is not very easy to implement, since in reality it would require measurements from other cells before call setup, and hence, cause much more delay.

Initial access cell change in call setup (directed retry DR) can also be understood so that the idle mode control of UEs is optimal, and new calls are always started in optimal layer.

#### 6.3.2.3 Simulation Results

In this chapter the simulations results for both RT and NRT data are presented.

##### 6.3.2.3.1 Real-time (conversational and streaming traffic) simulations

Main parameters for NRT simulations are shown in Table 2.

| | |
|---|---|
| Channel bandwidth | 800 kbps |
| Service kbps | 32 kbps, 144kbps and 384 kbps |
| Max connections per cell/layer | 25 (32 kbps), 5 (144 kbps), 2 (384 kbps) |
| Load threshold | 650 kbps (~80%) |
| ExamineMinutes (simulation time) | 20-40 minutes |

**Table 2. RT simulation parameters**

In Figure 14 two examples of blocking as a function of 144kbps user traffic without and with CRRM algorithms are shown. The number of users at 2% blocking is collected and plotted in Figure 16.

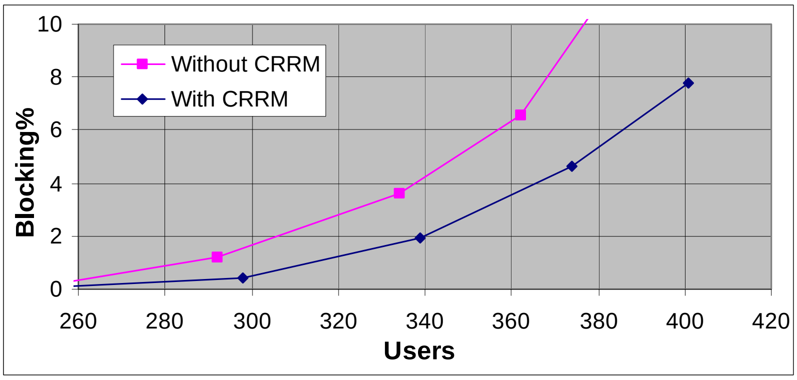



**Figure 14. An example of blocking as a function of 144kbps user traffic without and with CRRM algorithms (5 layers)**

In following Figure 15 – Figure 17 the system capacity and capacity improvements from different algorithms are plotted for different RT services. The abbreviations of simulation cases used in figures are explained in Table 3. In all cases the total number of users per each layer is equal on average.

| | |
|---|---|
| Ideal ISHO/DR | Maximum capacity by ideal inter-system/layer handover and DR with all cells in same |

| | |
|---|---|
| | channel pool. Values obtained from Erlang B formula. |
| No ISHO/DR | Inter-system/layer handovers or DR not used. Traffic in each layer handled separately. Values obtained from Erlang B formula. |
| Full CRRM control | Inter-system/layer handovers with CRRM algorithms. See section 6.3.2.1.3 for more details. Values obtained from simulations. |
| Reference | Reference Inter-system/layer handover algorithm without CRRM. See section 6.3.2.1.2 for more details. Values obtained from simulations. |

**Table 3. The abbreviations of RT simulation cases.**

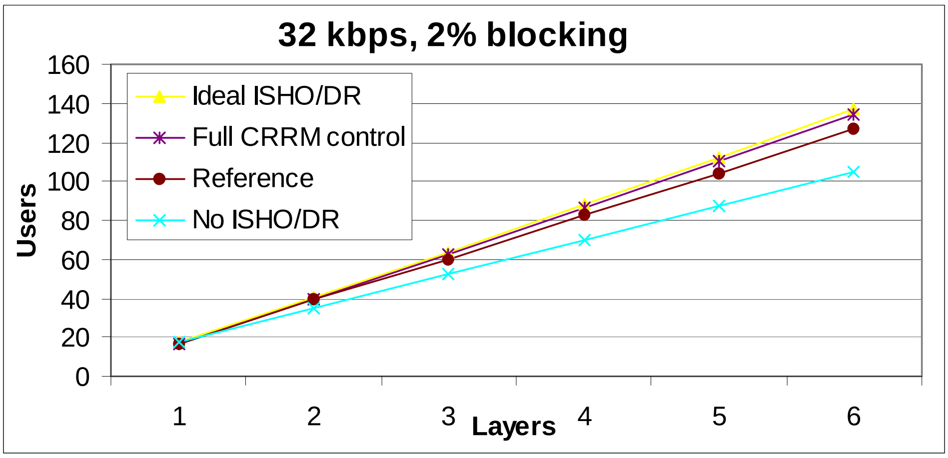



**Figure 15. Number of 32 kbps users per hexagonal cell area as a function of layers**

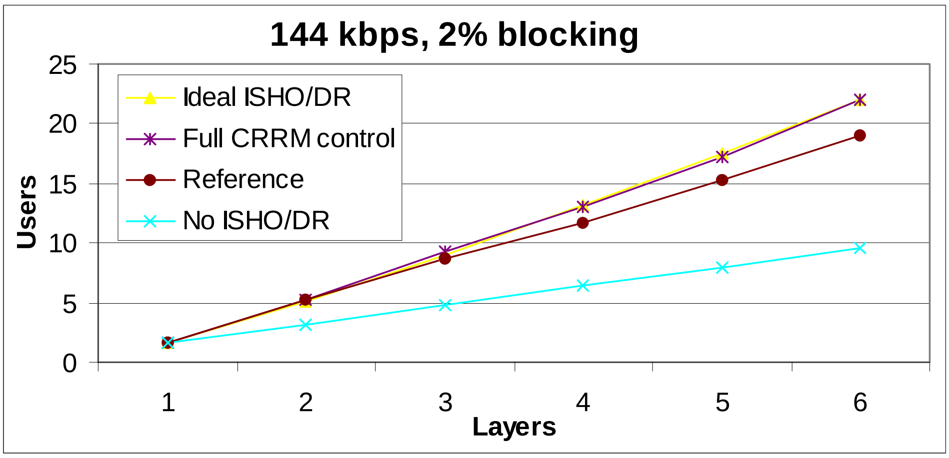



**Figure 16. Number of 144 kbps users per hexagonal cell area as a function of layers**

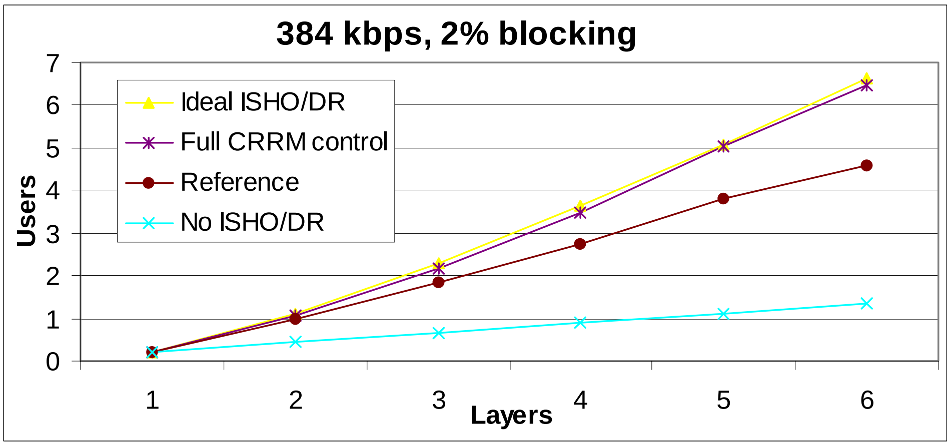



**Figure 17. Number of 384 kbps users per hexagonal cell area as a function of layers**

Previous figures can be summarised so that the higher the bit rate (less capacity), the more trunking gain can be obtained from CRRM when compared to the reference case. For example the number of 384kbps users with 4 layers can be increased by 27% (11% for 144kbps, 4% for 32 kbps) with CRRM as compared to reference case.

### 6.3.2.3.2 Non-real-time (interactive traffic) simulations

Main parameters for NRT simulations are shown in Table 4.

| | |
|---|---|
| Channel bandwidth | 40 kBps (320 kbps) and 200 kBps (1.6 Mbps) |
| MaxDelayTreshold | 5 seconds |
| MinDelayDifference | 50% |
| ExamineMinutes | 40-80 minutes |

**Table 4. NRT simulation parameters**

The abbreviations of NRT simulation cases used in figures are explained in Table 5.

| | |
|---|---|
| No IS-NCCRS, unbalanced traffic | No cell reselections between layers/systems. Unbalanced idle mode: Layer *n* has *n* times more users than layer 1. |
| No IS-NCCRS, balanced traffic | No cell reselections between layers/systems. Users distributed equally between layers = CRRM balances users in idle mode |
| CRRM, DR only | CRRM directs new NRT user to lowest loaded layer (smallest cell buffer = delay) |
| CRRM, IS-NCCRS only | CRRM moves user from highest to lowest loaded layer if difference >50%. See section 6.3.2.2.3 for more details. |
| CRRM, DR and IS-NCCRS | Both initial access direction and load reason cell re-selection used |

**Table 5. The abbreviations of NRT simulation cases.**

### 6.3.2.3.3 Channel bandwidth 320 kbps

In Table 6 an example of results from CRRM simulations with both initial access and IS-NCCRS algorithms (6 layers) is shown. Correspondingly, cumulative distribution function of packet delay for the same case is plotted in Figure 18. The number of active users at 95% and 90% outage (delay less or equal than 5s) are collected (**bold**) and plotted in Figure 19 and Figure 20, respectively.

| *New calls/s* | *Average actUEs* | *Users in buffer (ave)* | *Average buffer delay [s]* | *Number of packet sessions* | *Number of DRs* | *Number of packet calls* | *Delay reason IS-NCCRS* | *IS-NCCRS rate %* |
|---|---|---|---|---|---|---|---|---|
| 20 | 599 | 184 | 3.6 | 46588 | 38278 | 232940 | 7964 | 3.42 |
| 23.33 | **723** | 236 | 4.2 | 54359 | 44760 | 271795 | 10895 | 4.01 |
| 26.67 | 875 | 316 | 5.1 | 62997 | 51922 | 314985 | 15296 | 4.86 |
| 30 | **1056** | 430 | 6.3 | 70236 | 58033 | 351180 | 20684 | 5.89 |

**Table 6. An example of results from packet data simulations with CRRM (DR + IS-NCCRS, 6 layers, 320 kbit/s channel, 40 min simulation)**

Note that DR rate is roughly 5/6 of total number of packet sessions, because the probability that other layer cell is less loaded than original cell is 5/6 (with 6 layers) in these simulations. This could be greatly reduced by introducing similar delay trigger and MinDelayDiff parameter as in case of IS-NCCRS. However, this could possibly reduce the CRRM gain down to same level as in 'IS-NCCRS only' case (see Figure 19 and Figure 20).

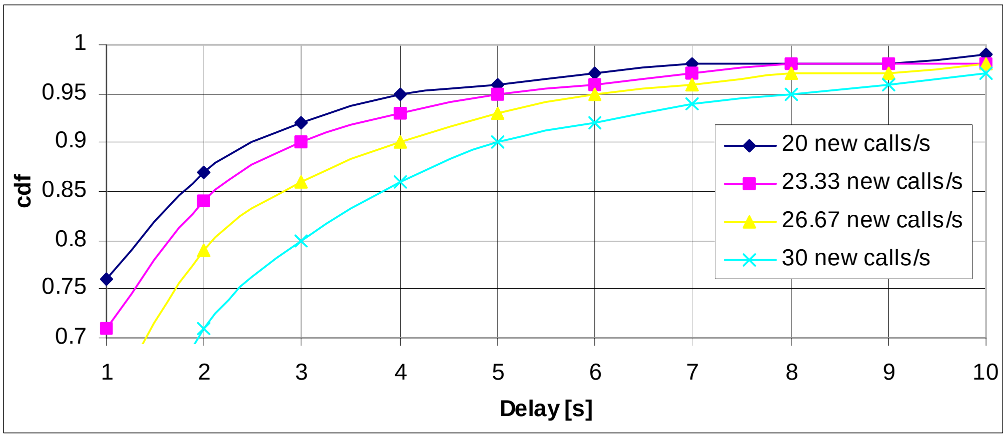



**Figure 18. Example of cumulative distribution function of packet delay from simulations with CRRM utilising both IS-NCCRS and Initial Access cell reselection (6 Layers)**

In following Figure 19 the system capacity and capacity improvements from different algorithms are plotted for interactive web surfing traffic through 320 kbit channel bandwidth, when 95% of users experience less or equal than 5seconds of delay.

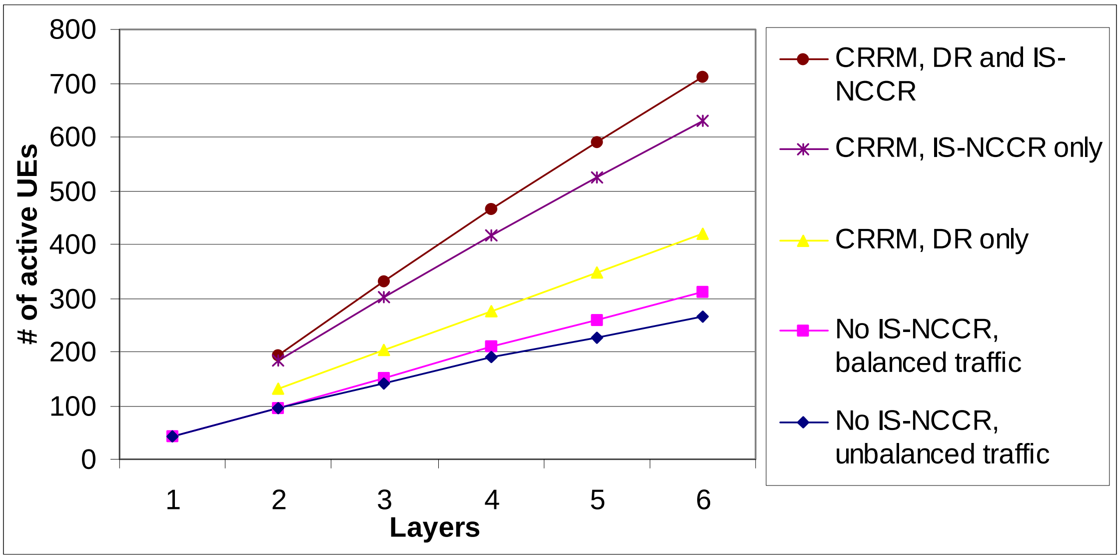



**Figure 19. NRT simulations (channel bandwidth 320 kbps), 95% of users experience less than 5s delay**

Also 90% outage values are plotted in Figure 20 in order to study how much the observed outage point affects the results.

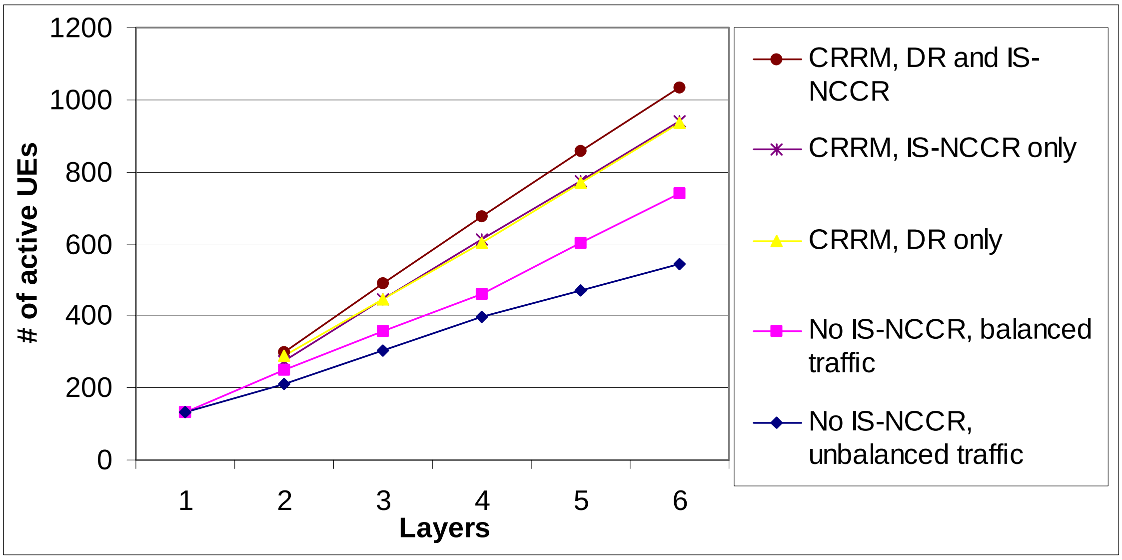



**Figure 20. NRT simulations (channel bandwidth 320 kbps), 90% of users experience less than 5s delay**

When comparing Figure 19 and Figure 20 it can be noted that the relative improvement by CRRM is higher with 95% outage than with 90%. The gain can be up to 150% with 95% outage and up to 100% with 90% outage. Thus, CRRM seems to provide more gain with stricter packet delay requirements.

### 6.3.2.3.4 Bandwidth 200kBps (1.6Mbps)

The same simulation were run with five times higher bandwidth (1.6Mbps). In Table 7 an example of results from CRRM simulations with both IS-NCCRS and DR (4 layers, 1.6 Mbit/s channel) is shown. Correspondingly, cumulative distribution function of packet delay for the same case is plotted in Figure 21. The number of active users at 95% outage (delay less or equal than 5s) is collected (**bold**) and plotted in Figure 22.

| *New calls/s* | *Average actUEs* | *Users in buffer (ave)* | *Average buffer delay [s]* | *Number of packet sessions* | *Number of DRs* | *Number of packet calls* | *delay reason IS-NCCRS* | *IS-NCCRS rate %* |
|---|---|---|---|---|---|---|---|---|
| 75 | 2043 | 499 | 1.3 | 40379 | 30540 | 201895 | 7288 | 3.61 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 91.67 | 2626 | 727 | 1.8 | 49399 | 37466 | 246995 | 13046 | 5.28 |
| 108.33 | 3384 | 1125 | 2.6 | 58607 | 44478 | 293035 | 21728 | 7.41 |
| 116.67 | **3744** | 1395 | 3.1 | 62207 | 47364 | 311035 | 26800 | 8.62 |
| 125 | 4801 | 2307 | 4.7 | 67613 | 51815 | 338065 | 39793 | 11.77 |

**Table 7. An example of results from packet data simulations with CRRM (DR + IS-NCCRS, 4 layers, 1.6 Mbit/s channel, 10 min simulation)**

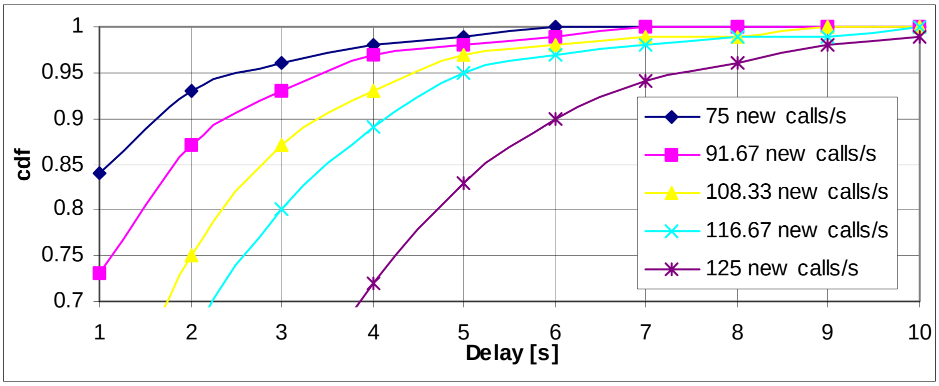



**Figure 21. Example of cumulative distribution function of delay from simulations with CRRM utilising both IS-NCCRS and DR in cell reselection (4 Layers)**

In Figure 22 the system capacity and capacity improvements from different algorithms are plotted for interactive web surfing traffic through 1.6 Mbps channel bandwidth.

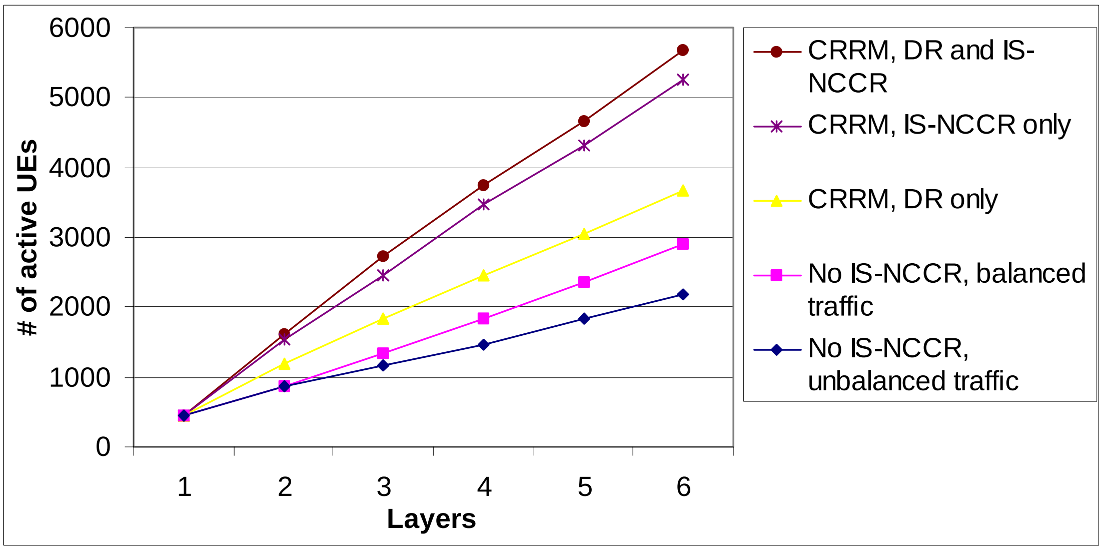



**Figure 22. NRT simulations (channel BW 1.6Mbps), 95% of users experience less than 5s delay**

Again, when observing Figure 22 it is seen that the CRRM gain in 1.6Mbps channel can be up to 150% with 95% outage. Earlier in Figure 19 similar gains in 320 kbps channel were shown. Thus, it can be concluded that the throughput of one system does not heavily affect CRRM gain in case of NRT data.

#### 6.3.2.3.5 Bandwidth efficiency with and without CRRM

In Table 8 an example of bandwidth efficiency of a cell with and without CRRM is shown for 4 layers. The CRRM efficiency (with both IS-NCCRS and DR) is compared with efficiency of no CRRM case.

The efficiency values are calculated by:

(NumOfNewUsers/s * AveKBpsPerUser * AveTxTimePerUser / NumberOfCells) / BandwidthPerCell

| Channel Bandwidth | 5s Outage Percentage | Bandwidth efficiency with CRRM | Bandwidth efficiency without CRRM |
|---|---|---|---|
| 320 kbps | 90% | 0.61 | 0.34 |
| | 95% | 0.47 | 0.18 |
| 1.6 Mbps | 95% | 0.73 | 0.31 |

**Table 8. Bandwidth efficiency of a cell with and without CRRM, CRRM with IS-NCCRS + DR, no CRRM case with traffic unbalance, 4 layers**

In these values the same CRRM capacity gain is seen as in Figure 19 - Figure 22. Also it is seen that 1.6 Mbps channel provide significant trunking gain as compared to 5 times smaller bandwidth.

#### 6.3.2.4 Conclusions

The simulation results can be summarised in Table 9 as follows:

| QoS class | Capacity gain with 2 layers | Capacity gain with 4 layers | Capacity gain with 6 layers |
|---|---|---|---|
| Conversational & Streaming | 32 kbps: -<br>144 kbps: -<br>384 kbps: - | 32 kbps: 4%<br>144 kbps: 11%<br>384 kbps: 27% | 32 kbps: 6%<br>144 kbps: 16%<br>384 kbps: 40% |
| Interactive | 40 - 100% | 70 - 140% | 90 – 180% |

**Table 9. Summary of CRRM gains for RT and NRT traffic classes**

As a summary, the reason for CRRM gains are:

- RT traffic: only one DR is allowed for a user in call setup and handover, thus the gain comes from directing the call to most optimum cell/layer.
- NRT traffic: no load reason inter-system cell reselection used without CRRM

Note that CRRM gains for interactive non-real-time traffic depend heavily on required delay outage percentage, 90% vs. 95%.

CRRM gains for background traffic is more difficult to quantify. However, the average delay can be also minimised for background traffic, and thus the average throughput can be maximised, if the rest of the traffic is distributed equally between systems/layers.

It can be concluded that CRRM is most important for:

- high bit rate (>32 kbps) conversational and streaming connections
- interactive connections

It must be noted that the gains of these simulations are fairly ideal and assume no delays in signalling, etc.

Note 1: In the non-realtime simulation, the IS-NCCR case without CRRM. As a result, it is not possible to differentiate between the gain obtained by introducing IS-NCCR (e.g. load based without CRRM), and IS-NCCR with CRRM.

Note 2: In the simulations, each layer has the same properties. As a result, the cost when moving between 2 layers is always identical. However in cases of multi-system networks (e.g. GSM/UTRAN), the cost (=signalling overhead, delay,..) for mobility in between layers of the same system (e.g. one UTRAN carrier to another carrier) is normally less significant than for mobility between layer of different systems.

Note 3. This simulation only considered the case of no CRRM for any layers or the case of CRRM between all layers. i.e. the case that CRRM is hierarchical is not considered. In case of an operator with a GSM and a UTRAN network, typically each system will already provide "CRRM" for the layers within that system.

# 7 Agreements and associated contributions

# 8 Specification Impact and associated Change Requests

*This section is intended to list the affected specifications and the related agreed Change Requests. It also lists the possible new specifications that may be needed for the completion of the Work Task.*

# 9 Project Plan

## 9.1 Schedule

| Date | Meeting | Scope | [expected] Input | [expected]Output |
|---|---|---|---|---|
| | | | | |
| | | | | |

## 9.2 Work Task Status

| | Planned Date | Milestone | Status |
|---|---|---|---|
| 1. | | | |
| 2. | | | |

# History

| Document history | | |
|---|---|---|
| **Date** | **Version** | **Comment** |
| 07/2001 | 0.1.0 | TR template |
| 08/2001 | 0.2.0 | Introduction, requirement, approach 1 are added |
| 08/2001 | 0.3.0 | Approach 2 and Simulation result are added |
| 11/2001 | 0.4.0 | Detail information of approach 1 was added. |
| 12/2001 | 1.0.0 | This was updated to version 1.0.0. |

Editor for 3G TR 25.881 is Woonhee Hwang, Nokia :

Tel. : +358 9  5113 0149
Fax :  +358 9 5113 0163
Email : woonhee.hwang@nokia.com

This document is written in Microsoft Word version.

# Annex <X>: Change history

| Change history | | | | | | | |
|---|---|---|---|---|---|---|---|
| Date | TSG # | TSG Doc. | CR | Rev | Subject/Comment | Old | New |
| | | | | | | | |
| | | | | | | | |
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