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Reconfigurable Radio Systems (RRS); Use Cases for Reconfigurable Radio Systems operating in IMT bands and GSM bands for intra-operator scenarios

Reference
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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Reconfigurable Radio Systems (RRS).

Introduction

The present document describes how Reconfigurable Radio Systems can be exploited in IMT bands and GSM bands to increase the efficiency of the radio resource management in the intra-operator scenarios for which the spectrum resources are assigned to and managed by a single operator.

1 Scope

The present document collects operating network scenarios - to be described in the form of system use cases - for Reconfigurable Radio Systems operating in IMT bands and GSM bands i.e. licensed spectrums allocated to IMT and GSM systems.

Use cases will focus on intra-operator scenarios for which the spectrum resources are assigned to and managed by a single operator.

Use cases will be described at the system functionality level and do not have to be confused with the features/requirements of the system under consideration. A use case may be related to one or more features/requirements, a feature/requirement may be related to one or more use cases. Moreover, the use cases will identify actors and information flows, and will form the basis of system requirements work at TC RRS for Software Defined Radio (SDR) systems and Cognitive Radio (CR) systems.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 102 683: "Reconfigurable Radio Systems (RRS); Cognitive Pilot Channel (CPC)".

3 Definitions and abbreviations

3.1 Definitions

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

Cognitive Radio System (CRS): radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained

Reconfigurable Radio Systems (RRS): generic term for radio systems encompassing Software Defined and/or Cognitive Radio Systems

Software Defined Radio (SDR): radio transmitter and/or receiver employing a technology that allows the RF operating parameters including, but not limited to, frequency range, modulation type, or output power to be set or altered by software, excluding changes to operating parameters which occur during the normal pre-installed and predetermined operation of a radio according to a system specification or standard

use case: description of a system's behaviour as it responds to a request that originates from outside of that system

NOTE: In other words, a use case describes "who" can do "what" with the system in question. The use case technique is used to capture a system's behavioural requirements by detailing scenario-driven threads through the functional requirements.

3.2 Abbreviations

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

3GPP	Third Generation Partnership Project
BCCH	Broadcast Control Channel
BSC	Base Station Controller
CPC	Cognitive Pilot Channel
CRS	Cognitive Radio System
DSP	Digital Signal Processor
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplex
FFR	Fractional Frequency Reuse
FPGA	Field Programmable Gate Array
GPRS	General Packet Radio Service
GSM	Global System for Mobile communication
HPR	Hardware Processing Resources
HSPA	High Speed Packet Access
IMB	Integrated Mobile Broadcast
IMT	International Mobile Telecommunications
ISM	Industrial, Scientific and Medical
LTE	Long Term Evolution
MD	Mobile Device
MNO	Mobile Network Operator
O&M	Operation & Maintenance
PS	Packet Switch
QoS	Quality of Service
RAT	Radio Access Technology
RBS	Reconfigurable Base Station
RF	Radio Frequency
RNC	Radio Network Control
RRM	Radio Resource Management
RRS	Reconfigurable Radio Systems
RU	Radio Unit
SDR	Software Defined Radio
TC	Technical Committee
TDD	Time Division Duplex
TR	Technical Report
TS	Time Slot
UE	User Equipment
UMTS	Universal Mobile Telecommunication System
VHO	Vertical Hand-Over

4 Motivation and goals

Due to the rapidly increasing of the Internet/data traffic and the need for broader bandwidths, IMT bands and GSM bands are getting heavily used. RRS may in the future be used as one method to address such problem by facilitating e.g. a more efficient use of the Radio Resources owned and managed by the operators. In fact, exploiting RRS capabilities, a network operator owning two or more RATs could utilise the new opportunity to dynamically and jointly manage the resources of the deployed RATs, in order to adapt the network to the dynamic behaviour of the traffic and to globally maximize the capacity. On these bases, different Use Cases, describing how RRS can be exploited in IMT bands and GSM bands in intra-operator scenarios, will be depicted.

5 Use Cases

5.1 Overview

Use Cases according to the definition in clause 3.1 will describe the system behaviour according to the specific Scenario considered. Use Cases and related Scenarios are then used for deriving the potential System Requirements. For this purpose each Use Case described in the following clauses is documented in the same way by using the same structure:

- General Use Case Description
- Stakeholders
- Scenario
- Information Flow

An initial set of potential System Requirements is grouped in a dedicated clause.

Hereafter the list of Use Case (described in detail in the next clauses) with the aim to serve as a short summary is reported. The Use Cases considered in the present document are the following:

- Radio Resource optimization
- Spectrum refarming
- Upgrading a pre-existing RAT and deploy of a new RAT to a pre-existing network:
  - Upgrade of an existing RAT
  - Deploy a new RAT in frequency bands already supported by the RBS
  - Deploy a new RAT in frequency bands currently not supported by the RBS
- Addition of multiple standards modes
- LTE pico/femto cell reconfiguration
- Cognition Enabler

5.2 Detailed Use Cases

5.2.1 Radio Resource optimization

5.2.1.1 General Use Case Description

Considering a cell set in a certain area, the traffic of different services on a specified RAT may change from one sub-area to the other according to the day period. It could then happen that some cells may be congested (high blocking percentages) in some particular area (typically these portions are called hot-spots) in which the traffic is more consistent, while surrounding cells are less loaded or characterized by low blocking percentages. Moreover, in case of deployment of two or more RATs in the same area, the offered traffic of different services on each deployed RAT may also be differently distributed in time and space with respect to the ones of the other deployed RATs. Last but not least, due to the fact that some IMT bands are very close to license exempt bands (e.g. the 2,4 GHz ISM band), it could happen that in a certain area Mobile Devices may experience interference problems (reported to the network). In such contexts, in the longer term, RRS will give the MNOs the means for managing in an efficient way the radio resources (e.g. reducing of radio access blocking percentages, redistributing resources among different RATs and/or minimizing system interference problems) within its own licensed frequency bands.

5.2.1.2 Stakeholders

Mobile Network Operator (MNO): operates and maintains an heterogeneous mobile network deployed using reconfigurable radio nodes (e.g. RBSs) and provides mobile services (voice and data) to its customers.

Infrastructure Providers: provides the hardware and software of the radio nodes (e.g. RBS) (see note).

User: performs voice and/or data traffic through his/her Mobile Device.

Mobile Device Manufacturer: provides hardware and software of Mobile Devices and software components needed for the upgrade (see note).

NOTE: Actually for multi-standard radio nodes is assumed a vertical market (i.e. same provider for the hardware and software).

5.2.1.3 Scenario

A deployment of different RATs in a geographical area with a network deployed using reconfigurable nodes is considered. It is supposed that each reconfigurable node is equipped with a certain amount of Hardware Processing Resources (HPR) (see note) that are shared between the different managed RATs. On these bases, it is possible to perform two different typologies of reconfiguration according to the specific contexts: an intra-system reconfiguration that involves only one single RAT and/or an inter-system reconfiguration that involves two or more different RATs. For example, an intra-system reconfiguration could be necessary when the traffic on a specified RAT drastically changes from one sub-area to the other (e.g. some cells may be congested while the surrounding ones not). On the other side, the inter-system reconfiguration could be needed when different traffic loads are experienced by each RAT, in order to increase the percentage of Radio Resources (RR) devoted to the over-loaded system while decreasing the ones used by the others (supposed under-loaded). It should be noted that intra-system and inter-system reconfigurations can be simultaneously performed.

NOTE: HPR indicates the hardware of the reconfigurable node (e.g. constituted by DSPs and FPGAs) that is used to run the software that implements the specific RATs functionalities (e.g. Base Band operations). The RF part is supposed to be separate and managed by specific modules (e.g. Radio Units (RUs)) able to support more RATs at the same time with sufficient power capacity in order to respect the RF requirements of any single RAT.

In general, HPRs are shared among the different RATs whose cells are managed by a certain reconfigurable node. It is then not possible to share HPRs among RATs whose cells are managed by different reconfigurable radio nodes (e.g. RBSs). On the contrary, RRs can be shared among cells managed by different reconfigurable radio nodes.

As an example of intra-system reconfiguration, a GSM deployment is considered. In particular, a RBS uses its HPRs to manage the different cells in terms of RRs (e.g. carriers) allocated to each cell. Figure 1a depicts a possible initial configuration that foresees 3 cells (numbered from 1 to 3) initially configured by 3 carriers each for a total of 9 different frequencies (numbered from 1 to 9). Starting from this situation, let us suppose to have a high offered traffic situation in Cell1 (i.e. high blocking probability on new connections) and, at the same time, a low offered traffic situation for the other two cells (i.e. null blocking probability on new connections). In this context, it is then possible to reconfigure the RBS in order to add to the congested Cell1 more RRs (for example 3 more carriers) borrowed from Cell2 and Cell3 (being supposed under-loaded) performing all the controls needed in order to avoid interference problems to the system. Figure 1b shows a possible final configuration that foresees Cell1 with 6 carriers in total, Cell2 with 2 carriers and Cell3 with 1 carrier. More in general, RRs to be added to the congested cell can be borrowed also from cells managed by other RBSs. Finally, this example can be extended also to intra-system reconfiguration for UMTS and LTE systems taking into account their peculiarities such as the scrambling codes for UMTS and sub-carriers orthogonality for LTE. Figure 2 depicts an example of an LTE intra-system reconfiguration. In particular, the left part of figure 2 depicts a possible initial configuration in which each cell uses the whole band with a limited output power in the areas closer to the RBS, while the band is separated into different smaller parts with a higher output power for each cell (this has been studied in the framework of 3GPP as the Fractional Frequency Reuse concept). In this context, the RRS can exploit the FFR concept in a dynamic manner, for example according to the traffic variations, and reconfigure accordingly the LTE RRs between the different cells (right part of figure 2).

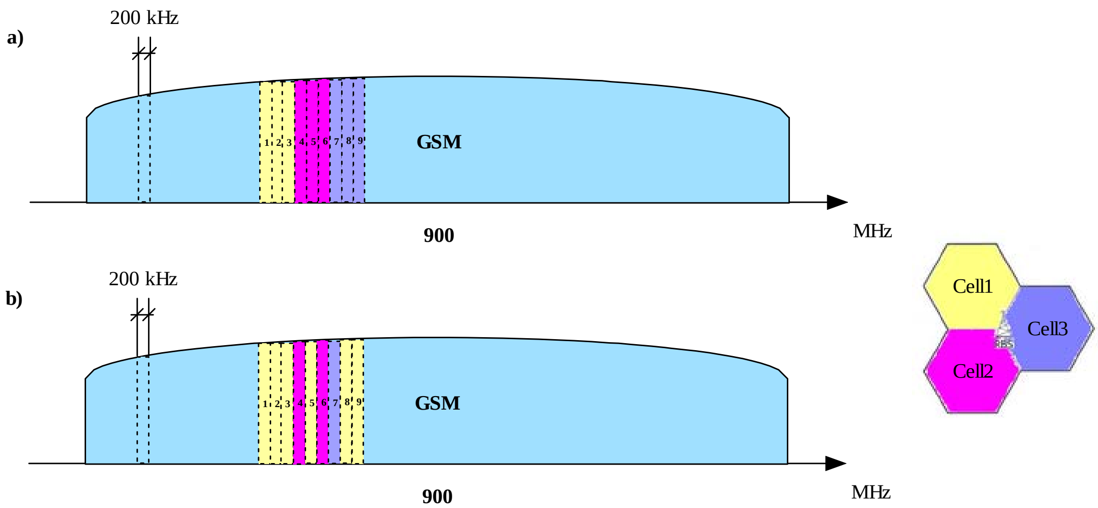

Figure 1: Example of GSM intra-system RRs reconfiguration

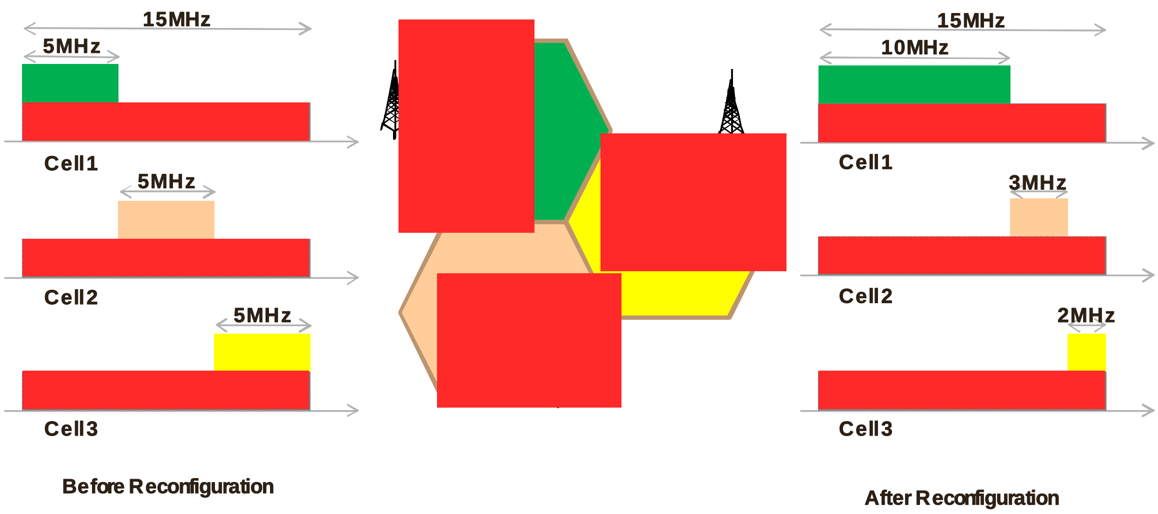

Figure 2: Example of LTE intra-system RRs reconfiguration

As an example of inter-system reconfiguration, let us consider a portion of a geographical area covered with two RATs such as GSM and UMTS. The initial configuration foresees a given percentage of HPRs devoted to UMTS system, a given percentage of HPRs is devoted to GSM system and the remaining HPRs are currently not used and free to be assigned. Depending on the quantity of HPRs devoted to the two systems, a certain related amount of RRs can be managed and assigned to UMTS (e.g. 5 MHz channel per carrier; one carrier per cell) and to the GSM (e.g. 200 kHz channel per carrier; one or more carriers per cell). Figure 3 shows an initial allocation (before reconfiguration) of the RRs assigned to the two systems.

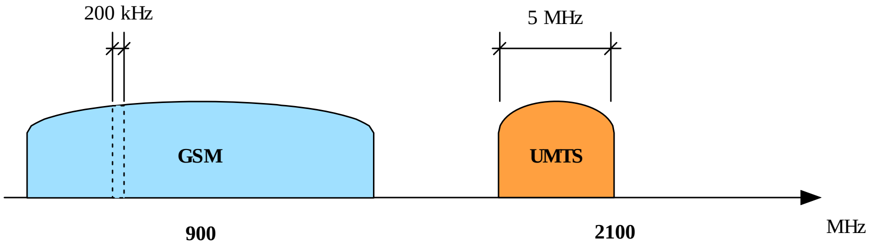

Figure 3: Example of RRs allocation of the GSM and UMTS systems before reconfiguration

Starting from the situation reported above, let us suppose to have an high offered traffic situation (i.e. overloading and congestion situation with high blocking probability on new connections) experienced by the UMTS system and, at the same time, a low offered traffic situation (i.e. null blocking probability on new connections) for the GSM system. In this context, it is then necessary to reconfigure accordingly the HPRs and RRs of the cells managed by the reconfigurable node in order to reserve to the UMTS system more processing capacity and, consequently, more RRs (e.g. one or more 5 MHz channels). It is possible to depict different ways to act for the reconfiguration depending, for example, on the amount of currently unused HPRs. Figure 4 shows the RRs allocation after the reconfiguration in the case of sufficient free HPRs to activate new UMTS channel. In this case the reconfiguration involves only the hardware part of the reconfigurable node, leaving the RRs assigned to the two systems unmodified. On the contrary, in the case there are not sufficient free HPRs, it is then necessary to free additional HPRs by reconfiguring also the GSM system. Being the GSM system under-loaded (as supposed), some RRs can be released leaving free HPRs that, added the ones already available, can be used in order to activate a new UMTS channel (figure 5). In this case the reconfiguration implicates to modify also the RRs assigned to the considered systems.

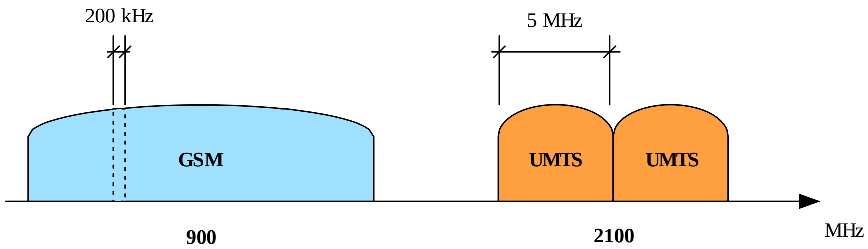

Figure 4: RRs allocation after reconfiguration in the case of sufficient free HPRs to activate a new UMTS channel

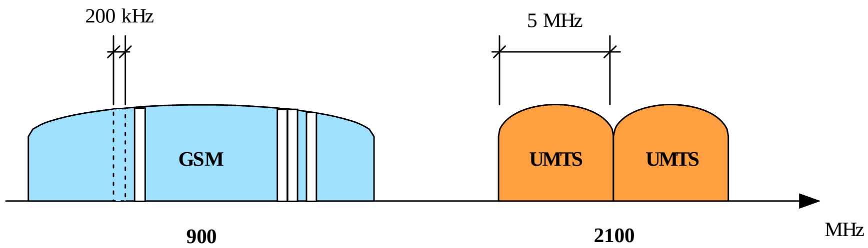

Figure 5: RRs allocation after reconfiguration in the case of not sufficient free HPRs to activate a new UMTS channel in which some RRs of the GSM system have been released in order to free the necessary additional HPRs

In addition to the examples reported above, more complex scenarios can be drawn, considering reconfigurations that implicate modifications to both HPRs and RRs, and, last but not least, taking into account also new RAT deployment such as LTE. As an example, figure 6a reports an initial RRs allocation considering GSM, UMTS and LTE systems where the LTE has a 5 MHz channel active at 2 600 MHz (GSM and UMTS have the same allocation reported in figure 3). According to the MNO needs (e.g. traffic variations, RRs reallocations, interference problems, etc.), the nodes can be accordingly reconfigured in order to add RRs to the LTE system (for a resulting 10 MHz channel), reallocate the UMTS ones releasing some RRs of the GSM system (figure 6b), supposing to have the sufficient HPRs to manage the reconfiguration.

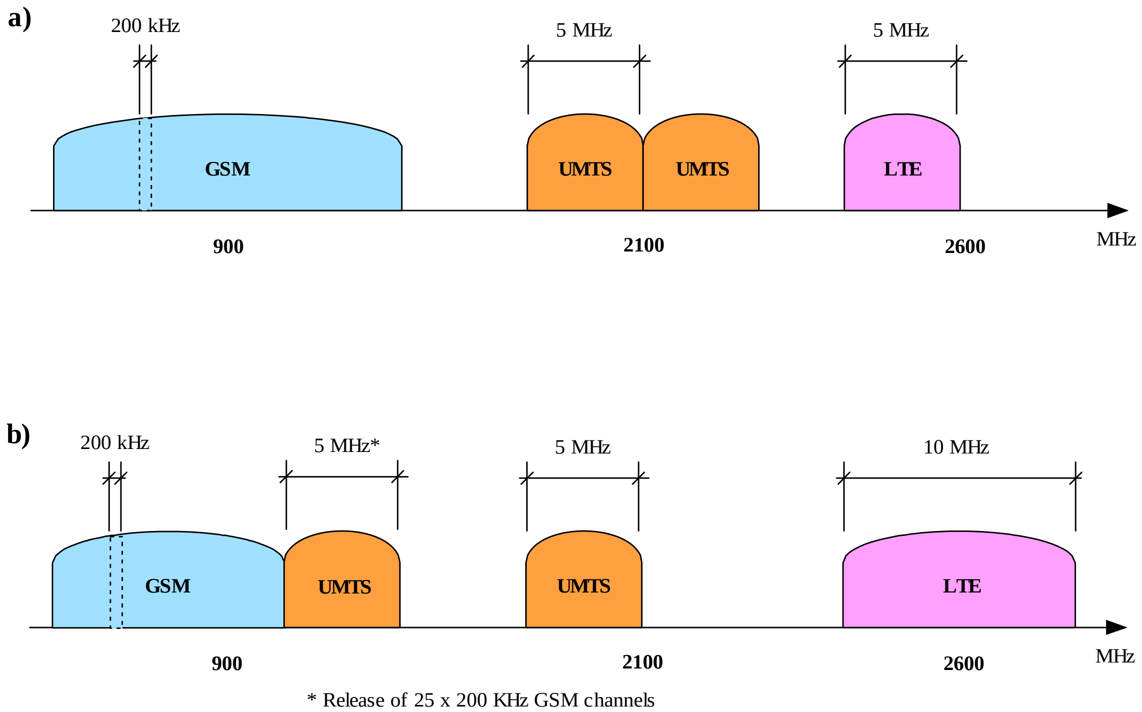

Figure 6: Example of a reconfigurations that implicates modifications to both HPRs and RRs

5.2.1.4 Information Flow

In this clause a high level information flow during a reconfiguration process is presented. As a simplified example, the information flow depicts a GSM intra-system RRs reconfiguration in the cases of i) adding a new carrier in a cell and ii) releasing a carrier in a cell.

The information flow considers the following logical/physical entities:

- Reconfigurable Base Station, that can be reconfigured in terms of percentage of HPRs devoted to each supported RAT and in terms of active RRs (e.g. frequency carriers) for each supported RAT.
- Radio Controller that includes the RRM (Radio Resource Management) entity which aim is to manage the request and the assignment of a radio channel to the Mobile Devices, and the Reconfiguration Entity that is running the Reconfiguration Algorithm devoted to monitor the activity status of the cells (for each supported RAT) in terms of number of the requests to the different systems; to execute the Reconfiguration Algorithm that decides which RBS are to be reconfigured; to control the reconfiguration by sending appropriate reconfiguration commands. Other secondary mechanisms for evaluating the need of a network reconfiguration could be possible (e.g. based on the reports sent by the Mobile Devices). Finally, it should to be noted that in the traditional systems (e.g. GSM and UMTS), the Radio Controller can be intended as the BSC (GSM) or the RNC (UMTS). In addition, in case of flat-architectures, the Radio Controller tasks could operate inside each eNodeB (LTE) or in a higher-order node (e.g. O&M).

Figure 7 shows the high level information flow occurring in the case of adding a new GSM carrier in a cell. In particular:

- The RRM indicates to the Reconfiguration Entity the results of the different Channel Requests coming from the Mobile Devices.
- At the end of the monitoring period T (see note), the Reconfiguration Entity runs the Reconfiguration Algorithm in order to evaluate a possible reconfiguration: in this case the algorithm decides to add a new GSM carrier in the cell having performed all the controls needed in order to avoid interference problems to the system. Such controls can be based on different possible approaches (e.g. exhaustive approach based on the application of real-time planning algorithms, fast approach based on a heuristic check of the reuse distances, physical approach based on RBS and Mobile Device measurements, etc.).

NOTE: Performing too many reconfigurations in a short time (e.g. small values of T) could require to send too many signalling messages for configuring and further reconfiguring RBSs and could lead the system to a unstable situation due to too fast modifications of the planning; performing too few reconfigurations in a long time (e.g. high values of T) could not be much effective, since the time elapsed between the need of a reconfiguration and the time of the reconfiguration itself could be too long. The MNO should then take into account said factors and evaluating the trade-off of them when setting the value of T.

- The Reconfiguration Entity sends to the RRM an Add Carrier Command indicating the carrier to be added in the cell.
- The RRM sends to the Reconfigurable Base Station the RBS Reconfiguration Command.
- Upon the reception of the RBS Reconfiguration Command, the RBS performs the reconfiguration by activating the new carrier in the cell and updating its operational parameters.
- After the reconfiguration is performed, the RBS sends to the RRM the RBS Reconfiguration Confirmation.
- Upon the reception of the RBS Reconfiguration Confirmation, the RRM updates accordingly the Cell Context and informs the Mobile Devices about the new cell configuration (e.g. updating the System Information on BCCH, sending the Frequency Redefinition message to the Mobile Devices with an ongoing voice call, sending a Reconfiguration Channel Command to the Mobile Devices having an active GPRS data connection).
- The RRM sends to the Reconfiguration Entity the Add Carrier Completed message.

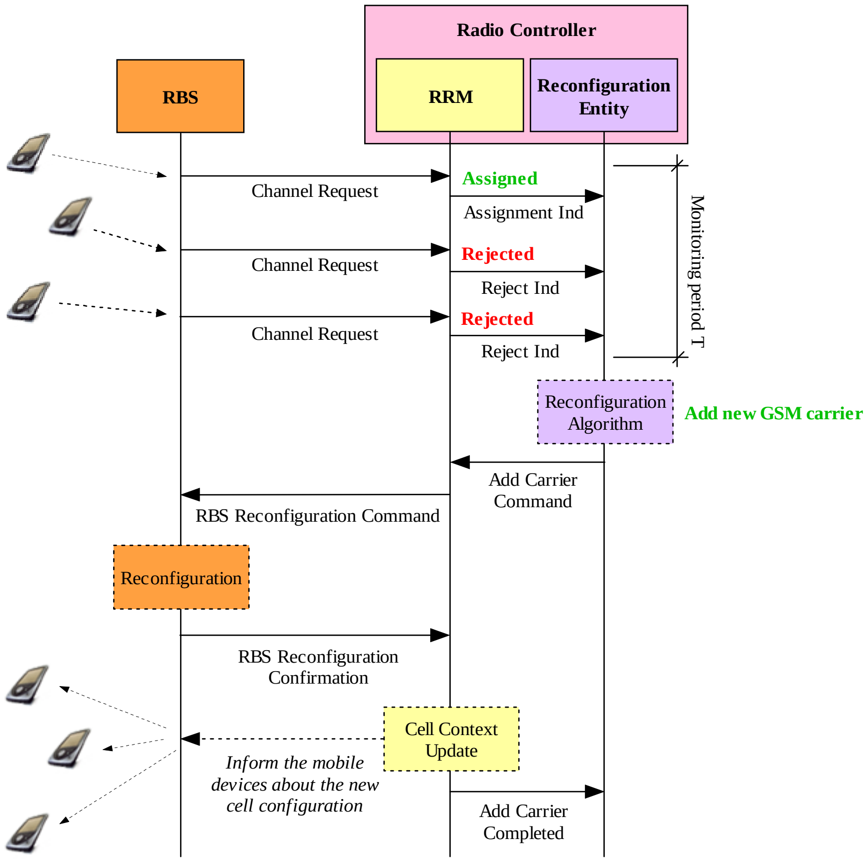

Figure 7: High level information flow related to the case of adding a new GSM carrier in a cell

Figure 8 shows the high level information flow occurring in the case of releasing a GSM carrier in a cell. In particular:

- The RRM indicates to the Reconfiguration Entity the results of the different Channel Requests coming from the Mobile Devices.
- At the end of the monitoring period T, the Reconfiguration Entity runs the Reconfiguration Algorithm in order to evaluate a possible reconfiguration: in this case the algorithm decides to drop a GSM carrier and sends to the RRM a Drop Carrier Command.
- Upon the reception of the Drop Carrier Command, the RRM perform the decision on which carrier to drop according to specific criterions. Having identified the carrier to be removed, the RRM commands the handover to the Mobile Devices allocated on that carrier. After the completion of the handovers, the RRM updates accordingly the Cell Context and informs the Mobile Devices about the new cell configuration (see the previous example for the details).
- The RRM sends to the Reconfigurable Base Station the RBS Reconfiguration Command.
- Upon the reception of the RBS Reconfiguration Command, the RBS performs the reconfiguration by releasing the carrier in the cell and updating its operational parameters.
- After the reconfiguration is performed, the RBS sends to the RRM the RBS Reconfiguration Confirmation.
- Upon the reception of the RBS Reconfiguration Confirmation, the RRM sends to the Reconfiguration Entity the Drop Carrier Completed message.

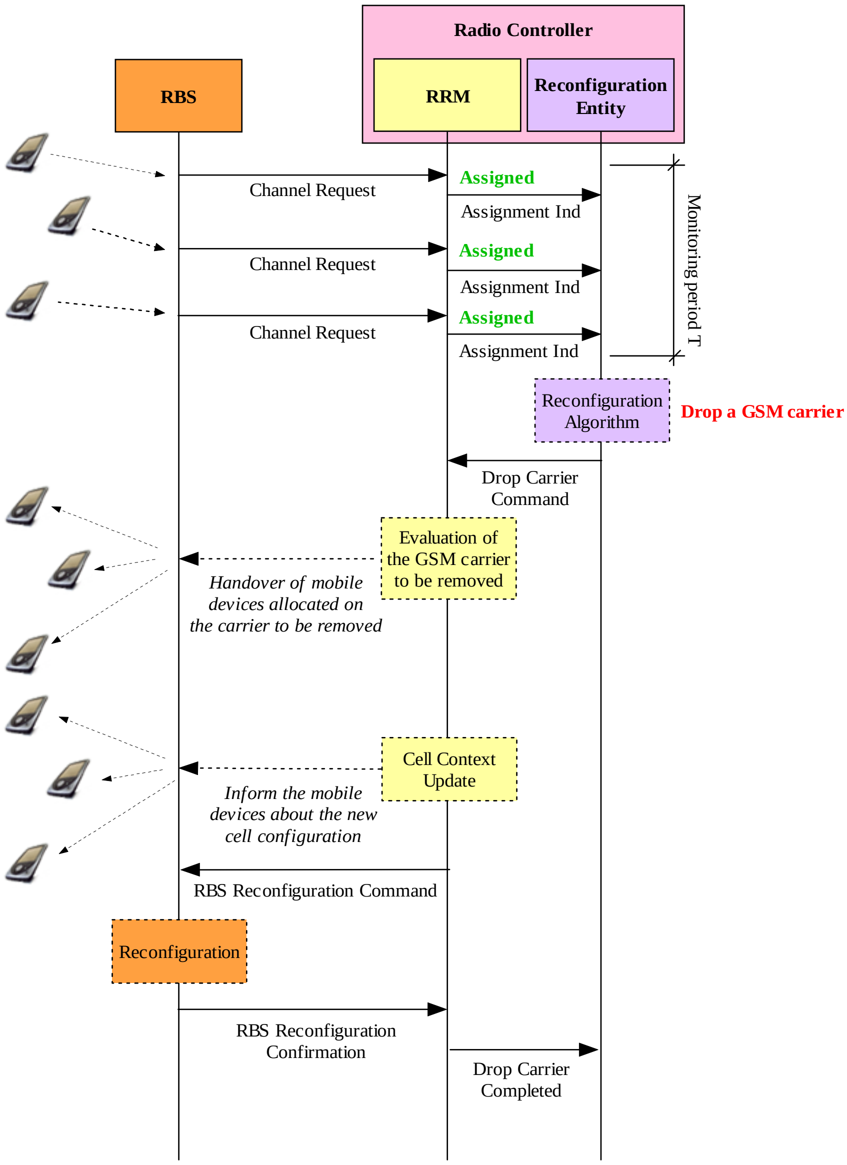

Figure 8: High level information flow related to the case of releasing a GSM carrier in a cell

As already reported, the information flows presented are just high level examples that refer to GSM intra-system RRs reconfiguration cases. The information flow may vary according to the RATs considered, to the heterogeneity of the system and to the type of reconfiguration.

5.2.2 Spectrum refarming

5.2.2.1 General Use Case Description

A particular situation is that of spectrum refarming in the context of technology evolution and periodical emergence of new families of standards. This implies their progressive introduction/coexistence in the legacy "bands" rather than a simple and quick switchover which is not appropriate due to the large amount of legacy Mobile Devices and the corresponding investments. RRS can allow a smooth refarming transition period in this case taking into account the traffic constraints and user requirements.

5.2.2.2 Stakeholders

Mobile Network Operator (MNO): operates and maintains an heterogeneous mobile network deployed using reconfigurable radio nodes (e.g. RBSs) and provides mobile services (voice and data) to its customers.

Infrastructure Providers: provides the hardware and software of the reconfigurable radio nodes.

User: performs voice and/or data traffic through his/her Mobile Device.

Mobile Device Manufacturer: provides hardware and software of Mobile Devices and software components needed for the upgrade.

5.2.2.3 Scenario

In this intra-operator scenario, the operator wants to update its network with a new RAT (RAT2) which is progressively introduced in the frequency band of the previous technology (RAT1), transparently and with no constraint for the customers. The deployment roadmap of this new technology is under CAPEX constraints and therefore progressive in terms of geographic coverage, targeting some specific "island" areas to begin with. During the refarming period (several months, more...), legacy Mobile Devices that only have access to RAT1 coexist with multi-mode Mobile Devices that are progressively introduced in the market. The multi-mode devices can access both RAT1 and RAT2.

The curves in figure 9, corresponding to the global network situation, propose a possible evolution of RAT2 coverage together with the dedicated spectrum/radio resources within the considered frequency band under refarming process. The appropriate route (global resource management illustrated by the two curves) to evolve the global network from situation A (only RAT1 before starting refarming process) to situation B (only RAT2 after finishing refarming process) may be affected by many unpredictable factors (e.g. market, environment/terrain or technology related) and may also be impacted by unexpected situations that may occur during the refarming period. This is the reason why the red and blue curves show some flexibility by intentionally being decreased at some point in time even if they follow a general increasing trend from point A to point B. Once the transforming process has reached point B, the refarming is completed and no base stations still operates RAT1 (Mobile Device supporting only RAT1 cannot get any connection). There is no reason to come back to a previous situation with both technologies.

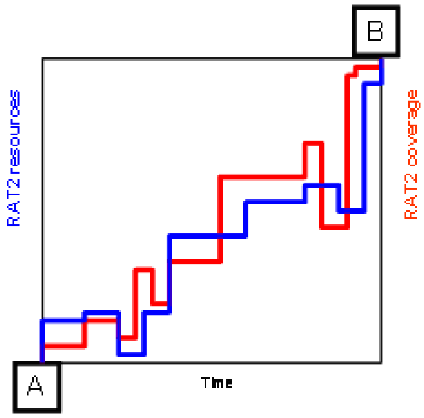

Figure 9: Global refarming process totally replacing RAT1 by RAT2 within a limited frequency band

Reconfigurable Base Stations (RBSs) can allow this kind of flexible evolution, provided that appropriate mechanisms are implemented to manage the radio resources.

In general, this evolution needs to be managed in accordance with the MNO strategy and in a transparent way for the customers with neither harmful interference occurrence nor capacity/throughputs bottlenecks resulting from the phased resource reallocations within the same frequency band (as described in figure 10).

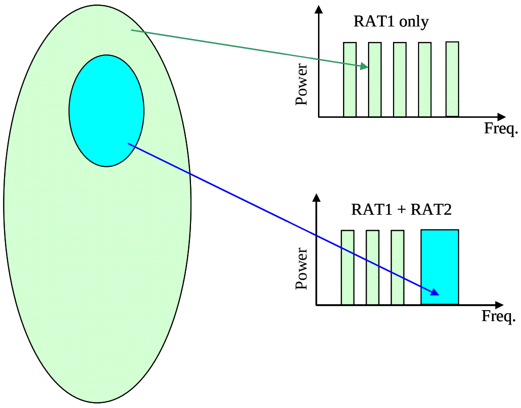

Figure 10: Local replacement of RAT1 channels by RAT2 resources in the same frequency band

To guarantee QoS, optimize the refarming route towards situation B and timely trigger activation/deactivation of the radio resources for RAT1/RAT2, reconfigurable elements are needed to introduce flexibility both at the Base Stations and Mobile Devices levels.

In other words, it is needed to match the activation/deactivation of RAT1/RAT2 resources to local cell load variations taking into account:

- The proportion of legacy and multi-mode Mobile Devices in the cell, and the Vertical Hand-Over (VHO) strategy.
- The type of service demand (if it impacts the choice between RAT1 and RAT2).
- Unexpected big events (or global customer movement) that may locally impact spectrum demand and cell loads.

5.2.2.4 Information Flow

This clause presents a high level information flow (depicted in figure 11) for the spectrum refarming scenario that involves two radio access technologies, namely RAT1 and RAT2.

The following nodes are considered:

- Reconfigurable Base Stations that can be reconfigured in terms of percentage of active Radio Resources (RR) from RAT1 and RAT2. Once the RBS has received the reconfiguration command and before performing the reconfiguration, all the Mobile Devices (including those in idle mode) are informed (if needed) of the new configuration (e.g. when removing a carrier).
- After reconfiguration, the Mobile Devices in the cell are informed by the RBS about the new configuration (e.g. update of the neighbouring list, in particular for the mobile in idle mode).
- The Reconfiguration Entity receives and analyses the refarming decisions and triggers the corresponding reconfigurations of the Base Stations that are concerned by the refarming process. Once all the reconfigurations are completed, the reconfiguration Entity is informed by each affected RBS that the process is completed.
- The Refarming Strategy Entity is a generic entity in the network forwarding the refarming step decisions to the Reconfiguration Entity. These decisions that follow a general scheduled roadmap can also be triggered by other reasons. As indicated in the scenario description, multiple factors may affect the refarming global process that can relate to market, technical or environmental context as well as unexpected specific events that may temporarily impact the capacity needs. When a refarming step is completed, the Refarming strategy Entity received an acknowledgement from the Reconfiguration Entity.

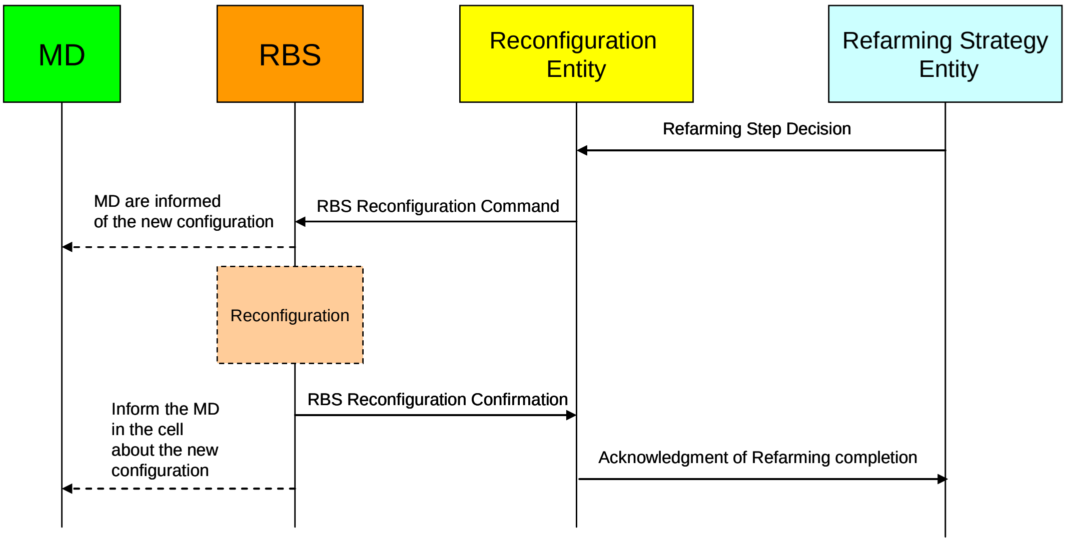

Figure 11: High level information flow related to the case of Spectrum Refarming

5.2.3 Upgrading a pre-existing RAT and deploy of a new RAT to a pre-existing network

5.2.3.1 General Use Case Description

This Use Case refers to two different possibilities for a Mobile Network Operator that operates and maintains an heterogeneous mobile network deployed using Reconfigurable Base Stations:

- To upgrade an existing RAT to include new functionalities (e.g. to add uplink HSPA+ to an UMTS network)
- To deploy a new RAT to a pre-existing network (e.g. to add LTE network to a 2G-3G network already deployed) and to commission and optimize it. Commission works include all activities, after equipment installation that should be done to make a node available to provide all specified functionalities, suitable connectivity with other RAT and PS nodes have to be included. Optimization refers to works needed to achieve the best performance of equipment inside de network.

In this context it is also supposed that Mobile Devices in the network are also reconfigurable and that their software can be upgradable from a network node that stores it.

5.2.3.2 Stakeholders

Mobile Network Operator (MNO): operates and maintains an heterogeneous mobile network deployed using reconfigurable radio nodes (e.g. RBSs) and provides mobile services (voice and data) to its customers.

Infrastructure Providers: provides the hardware and software of the reconfigurable radio nodes.

User: performs voice and/or data traffic through his/her Mobile Device.

Mobile Device Manufacturer: provides hardware and software of Mobile Devices and software components needed for the upgrade.

5.2.3.3 Scenario

Starting from the general Use Cases description reported above, three different scenarios can be depicted.

Upgrade of an existing RAT

The MNO upgrades a RAT managed by a RBS by downloading the necessary software packages from a network node, instead of changing the RBS hardware. A possible example could be the addition of HSPA+ functionalities to the UMTS system. The MNO activates procedures of self-optimization in the network.

Moreover, the Mobile Devices in the network with reconfiguration capabilities and upgradable software have to be informed of the availability of such new functionalities. It could be necessary to manage the download of new software for the interested Mobile Devices.

Deploy a new RAT in frequency bands already supported by the RBS

In this case, it is supposed that the hardware related to the RF part of the RBS (e.g. Radio Unit) supports the new RAT deployment from the frequency bands perspective. A possible example is the deployment of the UMTS in the GSM bands. The MNO then downloads the necessary software for the new RAT from a network node and activate procedures of self-commissioning and self-optimization in the network.

Moreover, the Mobile Devices in the network with reconfiguration capabilities and upgradable software have to be informed about the availability of the new RAT and, if the Mobile Device supports the related frequency band, a software download to reconfigure the Mobile Device has to be performed accordingly.

Deploy a new RAT in frequency bands currently not supported by the RBS

In this case, it is supposed that the hardware related to the RF part of the RBS (e.g. Radio Unit) or Base Band Unit (BBU) do not currently support the new RAT deployment from the frequency bands perspective. A possible example is the deployment of the LTE in the 2,6 GHz into a RBS currently managing GSM in the 800 MHz band. Two solutions are then possible:

- The Radio Unit can be accordingly reconfigured: MNO updates the Radio Unit software and activates the related procedures of self-commissioning and self-optimization in the network.
- The Radio Unit cannot be reconfigured or processing capability of BBU is not enough: a new Radio Unit has to be installed into the RBS to fulfil MNO requirements. This new Radio Unit can be configured accordingly by software. Or a new hardware should be installed to increase capabilities of RBS. Self-commissioning and self-optimization procedures need to be activated.

Moreover, the Mobile Devices in the network with reconfiguration capabilities and upgradable software have to be informed about the availability of the new RAT and, if the Mobile Device supports the related frequency band, a software download to reconfigure the Mobile Device has to be performed accordingly.

5.2.3.4 Information Flow

In this clause are presented three high level information flows:

- Upgrade of an existing RAT.
- Deploy a new RAT in frequency bands already supported by the RBS.
- Deploy a new RAT in frequency bands currently not supported by the RBS.

The information flow considers the following logical/physical entities:

- Reconfigurable Base Station: can be upgraded by software download from network and can be reconfigured in terms of percentage of HPRs devoted to each supported RAT and in terms of active Radio Resources (RR) allocated for each RAT. After the upgrade of an existing RAT or the deployment of new RAT, the mobiles allocated to the RBS are informed about the new cell configuration, available new functionalities and/or new RATs. RBS should support (self-)commissioning process that makes the RBS available for network and could be triggered by the RBS itself (if hardware upgrade is needed) or by the Reconfiguration Entity.
- Radio Resource Management: entity which aim is to manage the request and the assignment of radio channels to the Mobile Devices and to manage software download towards them. If Mobile Device requires support for new functionality or new RAT, RRM should behave as a bridge to establish a link between Mobile Device and Handset Manufacturer Service Server. In case of flat-architectures, the RRM tasks could operate inside each RBS.

- Reconfiguration Entity: is running the upgrading algorithm (that includes software download managing), the adding new RAT procedure (including software download), the commissioning process triggered from network, the optimization process and the Reconfiguration Algorithm for activation of new functionalities and new RAT. The commissioning process triggered from network, commands and enables all processes required to make new RAT available, this includes RRM and RBS. If the RBS does not require hardware upgrade, it also triggers the self-commissioning procedure in RBS. The self-optimization process commands all processes required to reach performance level required by operator, in particular at the RF level. Finally, it should to be noted that in case of flat-architectures, the Reconfiguration Entity tasks could be shared among RBS and higher-order nodes.

- Refarming/O&M Strategy Entity: is a generic entity in the network which forwards the refarming and upgrade step decisions to the Reconfiguration Entity. These decisions that follow a general scheduled roadmap can also be triggered by other reasons. As indicated in the scenario description, multiple factors may affect the refarming global process that can relate to market, technical or environmental context as well as unexpected specific events that may temporarily impact the capacity needs.

Figure 12 shows the high level information flow related to the case of upgrade of an existing RAT:

- The Refarming/O&M Strategy Entity indicates to the Reconfiguration Entity the decision to deploy new functionality.

- The Reconfiguration Entity runs the Upgrading Algorithm that provides software to RRM and RBS and triggers the upgrading of the nodes.

- The Reconfiguration Entity sends to the RRM software package and directives for new functionality deployment.

- The RRM sends to RBS software package for new functionality.

- After the reception of software package the RBS sends to RRM the RBS Software Download Confirmation.

- Upon the reception of the RBS Software Download Confirmation, the RRM sends a Download Completed to Reconfiguration Entity that triggers the Reconfiguration Algorithm to activate the new functionalities.

- The Reconfiguration Entity sends an Activation Command to RRM that consequently sends the Reconfiguration Command to the RBS.

- Upon the reception of the RBS Reconfiguration Command from RRM, the RBS performs the reconfiguration, activating new functionalities and updating operational parameters.

- After the reconfiguration is performed, the RBS sends to the RRM the RBS Reconfiguration Confirmation.

- The RRM sends to Reconfiguration Entity the message Deployment Of New Functionality Completed. This message triggers the Self-optimization Process.

- After the reception of Self-optimization Command the RRM sends the RBS Reconfiguration Command to the RBS that trigger its reconfiguration.

- Upon the reception of the RBS Reconfiguration Confirmation, the RRM sends Self-optimization Completed to the Reconfiguration Entity.

- The Reconfiguration Entity closes the deployment, sending the Acknowledgement to the Refarming/O&M Strategy Entity.

- The RRM informs the Mobile Devices about the new cell configuration and available new functionality.

- Mobile Devices could request support for new functionalities to Handset Manufacturer Service Server, by operator network.

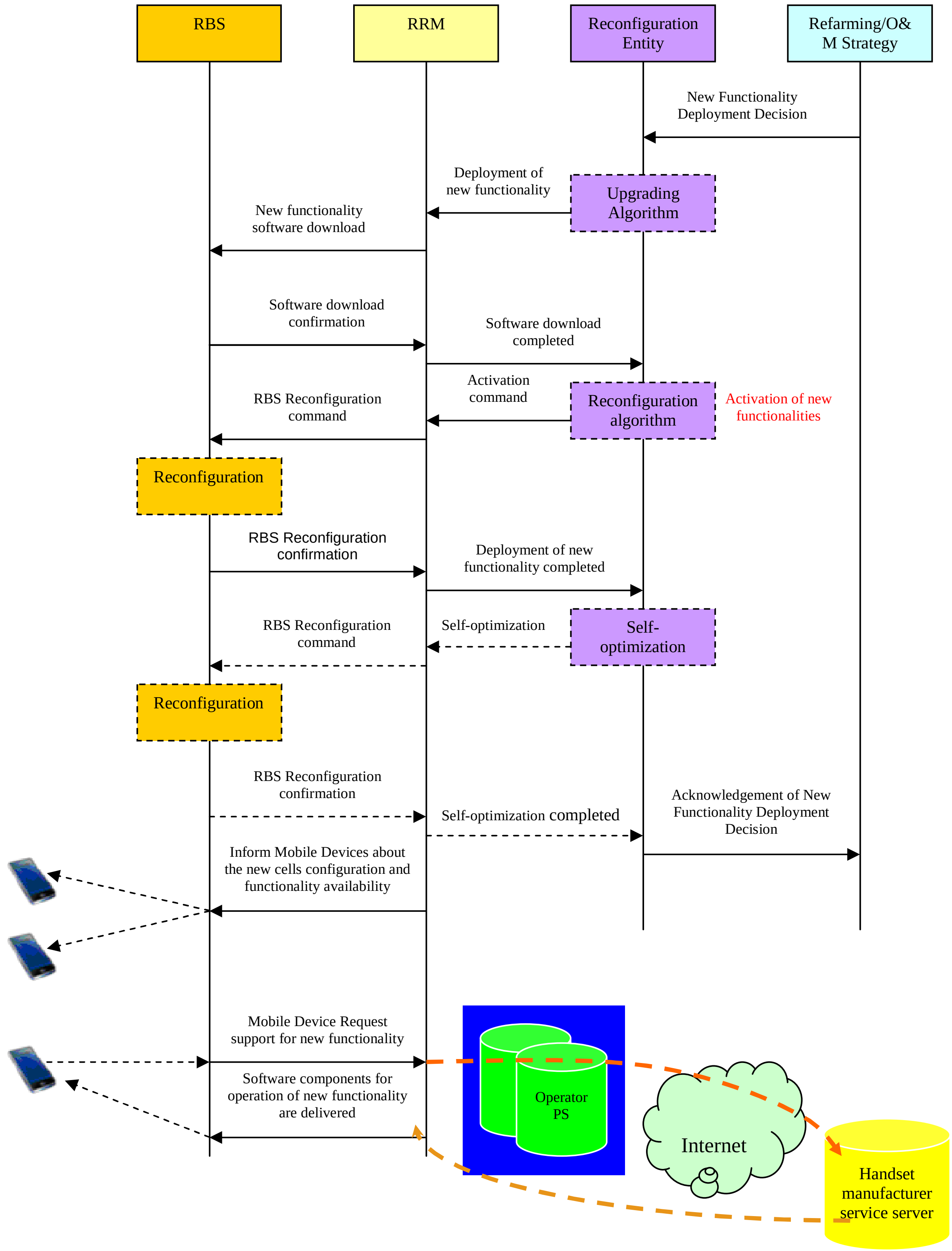

Figure 12: High level information flow related to the case of upgrade of an existing RAT

Figure 13 shows the high level information flow related to case of deploy a new RAT in frequency bands already supported by the RBS:

- The Refarming/O&M Strategy Entity indicates to the Reconfiguration Entity the decision to deploy a new RAT.
- The Reconfiguration Entity runs the Adding New RAT Procedure that provides software to RRM and RBS and triggers the Adding Procedure of the nodes.
- The Reconfiguration Entity sends to the RRM the software package and the directives for the new RAT deployment.
- The RRM sends to RBS the software package for the new RAT deployment.
- After the reception of the software package the RBS sends to RRM the RBS Software Download Confirmation.
- Upon the reception of the RBS Software Download Confirmation, the RRM sends a Download Completed message to the Reconfiguration Entity that triggers the Commissioning Process.
- After the reception of the Commissioning Command, the RRM sends to RBS the RBS Commissioning Command. This message triggers Self-commissioning Process.
- Upon the reception of the RBS Commissioning Confirmation message, the RRM sends the Commissioning Completed to the Reconfiguration Entity that triggers the Reconfiguration Algorithm for the Activation Of New RAT Process.
- The Reconfiguration Entity sends the Activation Command to RRM that sends the RBS Reconfiguration Command to the RBS.
- Upon the reception of the RBS Reconfiguration Command from RRM, the RBS performs the reconfiguration, activating the new RAT and updating operational parameters.
- After the reconfiguration is performed, the RBS sends to the RRM the RBS Reconfiguration Confirmation.
- The RRM sends to Reconfiguration Entity the Deployment Of New RAT Completed message that triggers the Self-optimization Process.
- After the reception of Self-optimization Command message from the Reconfiguration Entity, the RRM sends to the RBS the RBS Reconfiguration Command that triggers its reconfiguration.
- Upon the reception of the RBS Reconfiguration Confirmation from the RBS, the RRM sends the Self-optimization Completed message to the Reconfiguration Entity.
- The Reconfiguration Entity closes the Adding New RAT Procedure, sending the Acknowledgement message to the Refarming/O&M Strategy Entity.
- The RRM informs the Mobile Devices about the new cell configuration and new RAT availability.
- Mobile Devices could request support for new RAT to Handset Manufacturer Service Server through the operator network.

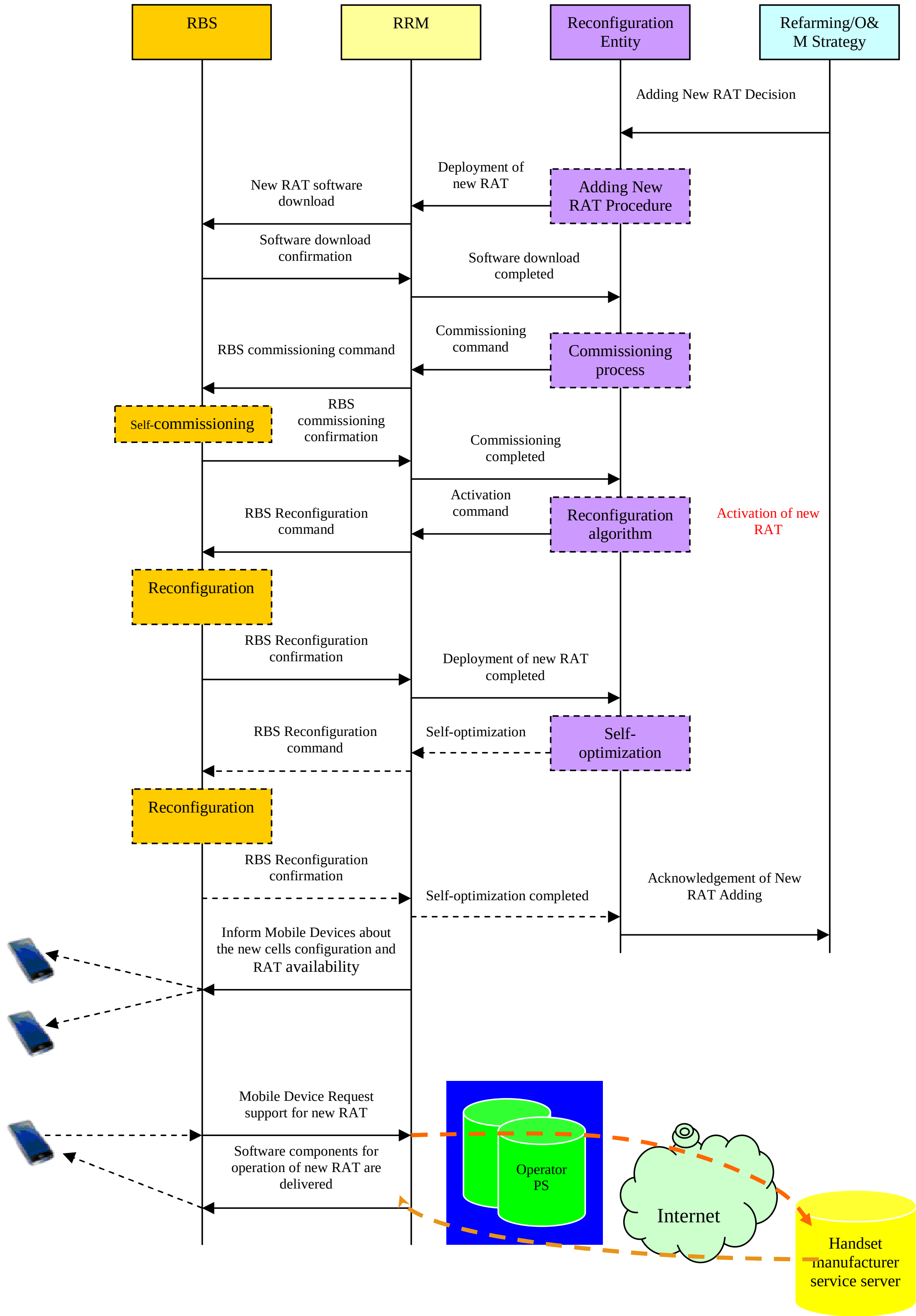

Figure 13: High level information flow related to the case of deploy a new RAT in frequency bands already supported by the RBS

Figure 14 shows the high level information flow related to case of deploy a new RAT in frequency bands currently not supported by the RBS:

- The Refarming/O&M Strategy Entity indicates to the Reconfiguration Entity the decision to deploy a new RAT.
- Since in this case it is supposed that the RBS does not currently support the frequency bands on which deploy the new RAT, a hardware upgrade of RBS is needed and an installation of a new equipment is required. After RBS upgrade, the RBS triggers the Self-commissioning Process.
- Upon the reception of the RBS Commissioning Confirmation message, the RRM sends the RBS Commissioning Completed message to the Reconfiguration Entity that runs the Commissioning Process.
- After the Commissioning Process, the Reconfiguration Entity starts the Adding New RAT Procedure that provides software to both RRM and RBS.
- The Reconfiguration Entity sends to the RRM software package and directives for new RAT deployment.
- The RRM sends to the RBS the software package for the new RAT deployment.
- After the reception of the software package, the RBS sends to the RRM the RBS Software Download Confirmation.
- Upon the reception of the RBS Software Download Confirmation, the RRM sends the Download Completed message to the Reconfiguration Entity that triggers the Commissioning Process.
- After the reception of Commissioning Command, the RRM sends to RBS the RBS Commissioning Command. This message triggers the Self-commissioning Process.
- Upon the reception of the RBS Commissioning Confirmation, the RRM sends the Commissioning Completed to Reconfiguration Entity that triggers the Reconfiguration Algorithm for the Activation Of New RAT Process.
- The Reconfiguration Entity sends an Activation Command message to the RRM that sends the RBS Reconfiguration Command message to the RBS.
- Upon the reception of the RBS Reconfiguration Command from the RRM, the RBS performs the reconfiguration, activating the new RAT and updating operational parameters.
- After the reconfiguration is performed, the RBS sends to the RRM the RBS Reconfiguration Confirmation message.
- The RRM sends to Reconfiguration Entity the Deployment Of New RAT Completed message that triggers the Self-optimization Process.
- After the reception of Self-optimization Command message from the Reconfiguration Entity, the RRM sends to the RBS the RBS Reconfiguration Command message that triggers its reconfiguration.
- Upon the reception of the RBS Reconfiguration Confirmation message from the RBS, the RRM sends the Self-optimization Completed message to the Reconfiguration Entity.
- The Reconfiguration Entity closes the Adding New RAT Procedure sending the Acknowledgement message to the Refarming/O&M Strategy Entity.
- The RRM informs the Mobile Devices about the new cell configuration and the new RAT availability.
- Mobile Devices could request support for the new RAT to Handset Manufacturer Service Server through the operator network.

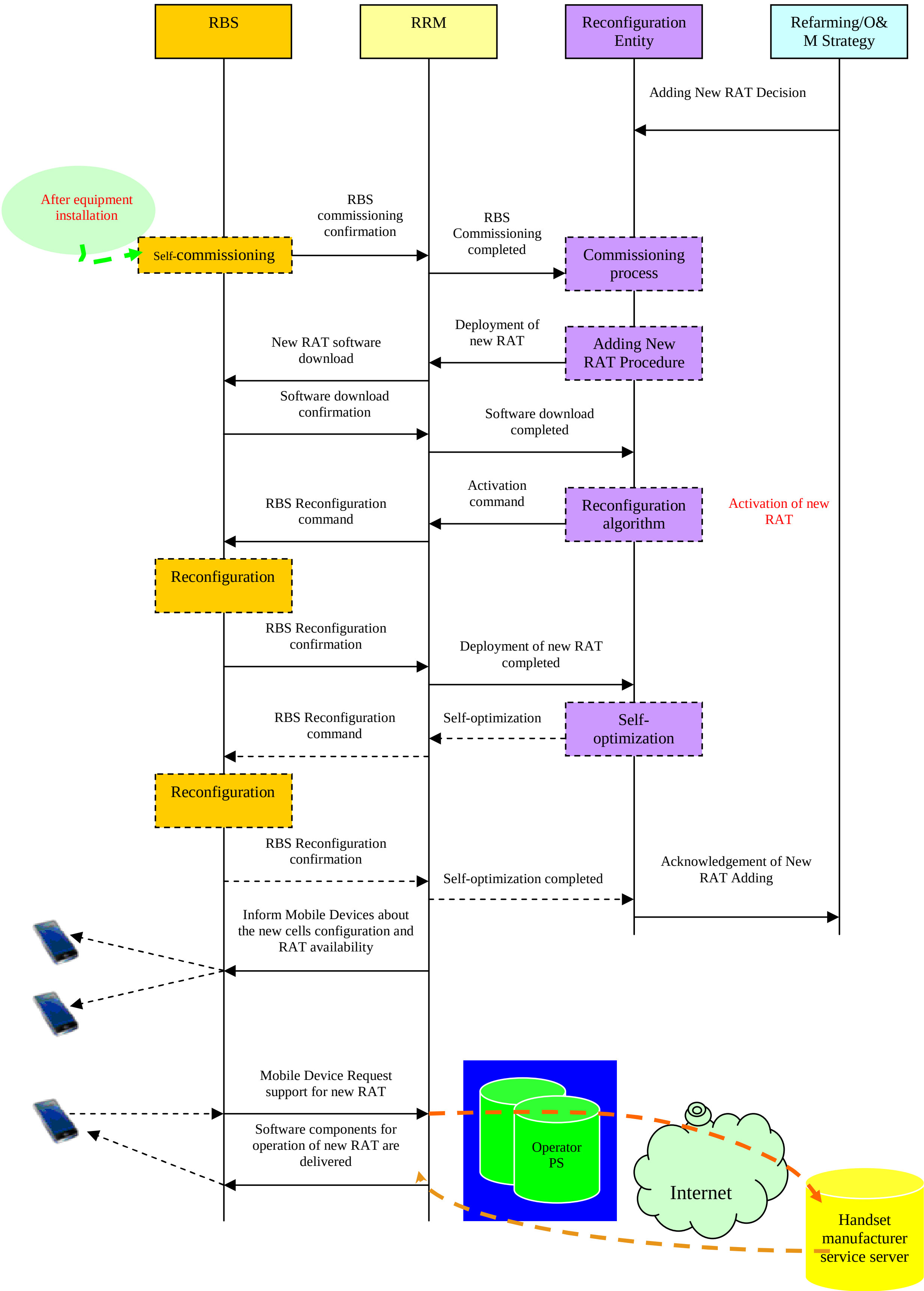

Figure 14: High level information flow related to the case of deploy a new RAT in frequency bands currently not supported by the RBS

5.2.4 Addition of multiple standards modes

5.2.4.1 General Use Case Description

The context in which the MNO needs to add capacity provided by FDD and TDD modes and to share dynamically services between such modes is considered. By monitoring services demands and traffic load, the RRS management entity can decide to allocate certain amount of network resources to FDD and TDD modes and the assignment of users to different radio access technologies in a dynamic manner. In this context, networks nodes are supposed to be reconfigurable (e.g. RBSs) as well as the Mobile Devices. Both have to be able to support FDD and TDD modes.

5.2.4.2 Stakeholders

Mobile Network Operator (MNO): operates and maintains an heterogeneous mobile network deployed using reconfigurable radio nodes (e.g. RBSs) and provides mobile services (voice and data) to its customers.

Infrastructure Providers: provides the hardware and software of the reconfigurable radio nodes.

User: performs voice and/or data traffic through his/her Mobile Device.

Mobile Device Manufacturer: provides hardware and software of Mobile Devices and software components needed for the upgrade.

5.2.4.3 Scenario

The scenario considers that the broadcast services (e.g. IMB) are provided by MNO using UMTS TDD mode. Voice, internet and other similar data service are provided by UMTS FDD and UMTS TDD modes. Finally, multimedia unicast services are provided by UMTS FDD mode. FDD and TDD modes can be considered also for LTE.

In an initial configuration (figure 15), the RBS provides UMTS in FDD and TDD modes and broadcast services are scheduled onto UMTS TDD. In the case the number of subscribers demanding certain multimedia content provided by broadcast service is lower than a certain threshold, a possible strategy is for instance to provide those low demand contents by unicast service scheduled onto FDD or TDD modes. More in general, the resources allocated to broadcast (spectrum and access node) can be dynamically shared with other voice and data services on UMTS TDD or just released for other UMTS FDD services (figure 16). In this final configuration, the RRS management entity has decided to allocate a more suitable (according to the traffic demand) spectrum and resources to support broadcast services in UMTS TDD mode and a new assignment of Mobile Devices to radio technologies and modes available.

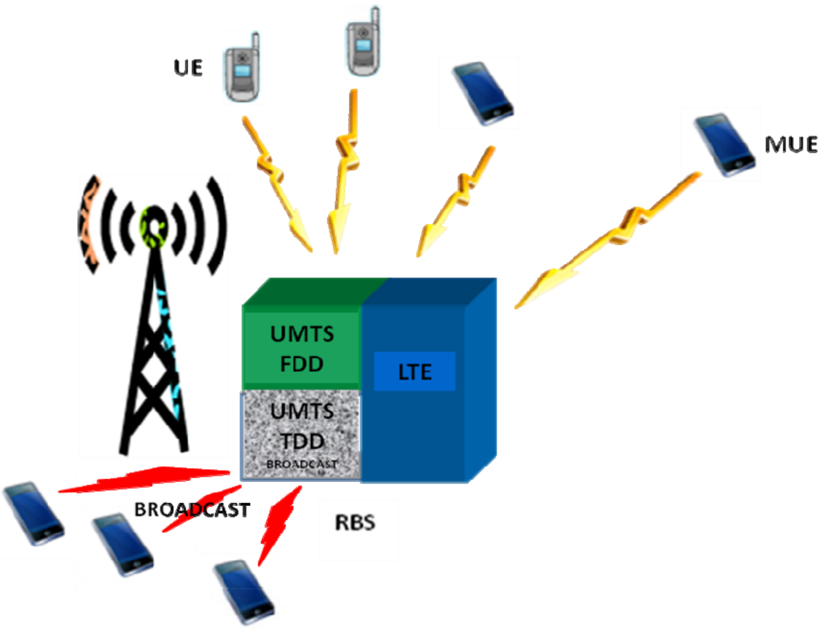

Figure 15: Initial configuration of the RBS

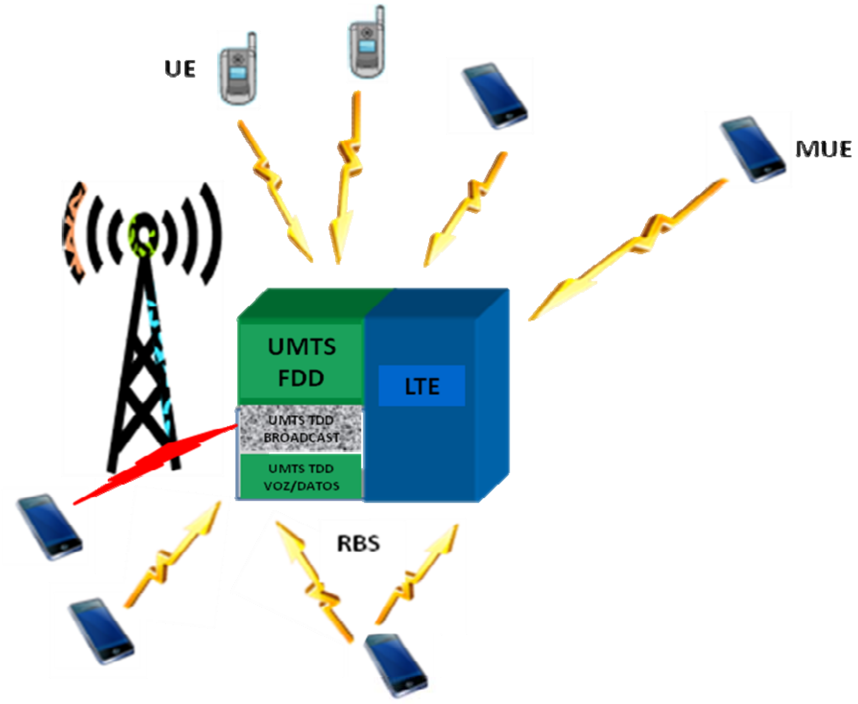

Figure 16: Final configuration of the RBS

5.2.4.4 Information Flow

In this clause a high level information flow during a re-assignment of resources (hereafter intended as HPRs and RRs) between FDD and TDD modes in one RBS is presented.

The information flow considers the following logical/physical entities:

- Reconfigurable Base Station: can be reconfigured in terms of percentage of HPRs devoted to each supported RAT and in terms of percentage of active Radio Resources (RR) allocated for TDD and FDD modes in one or multiple RATs. After the re-assignment of resources the RBS informs the Mobile Devices about the new cell configuration and services scheduling.

- Radio Resource Management: entity which aim is to manage the request and the assignment of radio channels to the Mobile Devices, to command re-assignment of resources of RBS and evaluate the impact of re-assignment. In case of flat-architectures, the RRM tasks could operate inside each RBS.

- Reconfiguration Entity: runs the Reconfiguration Algorithm devoted to monitor the activity status of the cells (for each supported RAT) in terms of number of the requests to the different systems and services, to define strategy and execute the re-assignment of resources inside each RBS; to execute the Reconfiguration Algorithm deciding which RBS are to be reconfigured and to control the reconfiguration by sending appropriate reconfiguration commands. Other secondary mechanisms for evaluating the need of a network reconfiguration and re-assignment of resources inside each RBS could be possible (e.g. based on the reports sent by the Mobile Devices). The re-assignment of resources would include, for instance, change of assignment of Time Slot (TS) for TDD mode for unicast (voice, data, multimedia) and broadcast (multimedia, massive downloads), RF power re-adjustment of FDD/TDD modes to balance coverage/interference requirements and power capabilities of equipment, antennas use optimization depending on coverage/interference and service requirements (broadcast, unicast, umbrella or directive coverage), re-assignment of HPRs inside each RBS and re-assignment of capacity/routing resources of links among Radio Access Subsystem, PS and Multimedia PS. Finally, it should to be noted that in case of flat-architectures, the Reconfiguration Entity tasks could be shared among RBS and higher-order nodes.

Figure 17 shows the high level information flow related to the case of re-assigning resources shared among multiple standards modes. In particular:

- The RRM indicates to the Reconfiguration Entity the results of the different Channel Requests coming from the Mobile Devices.
- At the end of the monitoring period, the Reconfiguration Entity runs the Reconfiguration Algorithm in order to evaluate a possible reconfiguration: in this case the algorithm decides to re-assign TDD resources used for broadcast purposes to unicast services and to change the RF and allocation of resources. Special care should be taken to prevent interference problems to the system. Information required about services demands of subscribers could be complemented by MNO from PS and should be an input to the Reconfiguration Algorithm.
- The Reconfiguration Entity sends to the RRM some directives for assignment of resources and re-assignment command performing controls in order to avoid interference problems to the system.
- The RRM triggers an Evaluation Process of impact of the re-assignment in terms of resources availability. The RRM commands handover to Mobile Devices affected by re-assignment of RRs.
- The RRM sends the RBS Reconfiguration Command message to RBS.
- Upon the reception of the RBS Reconfiguration Command, the RBS performs the reconfiguration by re-assigning RRs, activating new carriers in the cell and updating operational parameters.
- After the reconfiguration is performed, the RBS sends to the RRM the RBS Reconfiguration Confirmation.
- Upon the reception of the RBS Reconfiguration Confirmation, the RRM informs the Mobile Devices about the new cell configuration.
- The RRM sends to the Reconfiguration Entity the Re-assignment Resources Completed message.

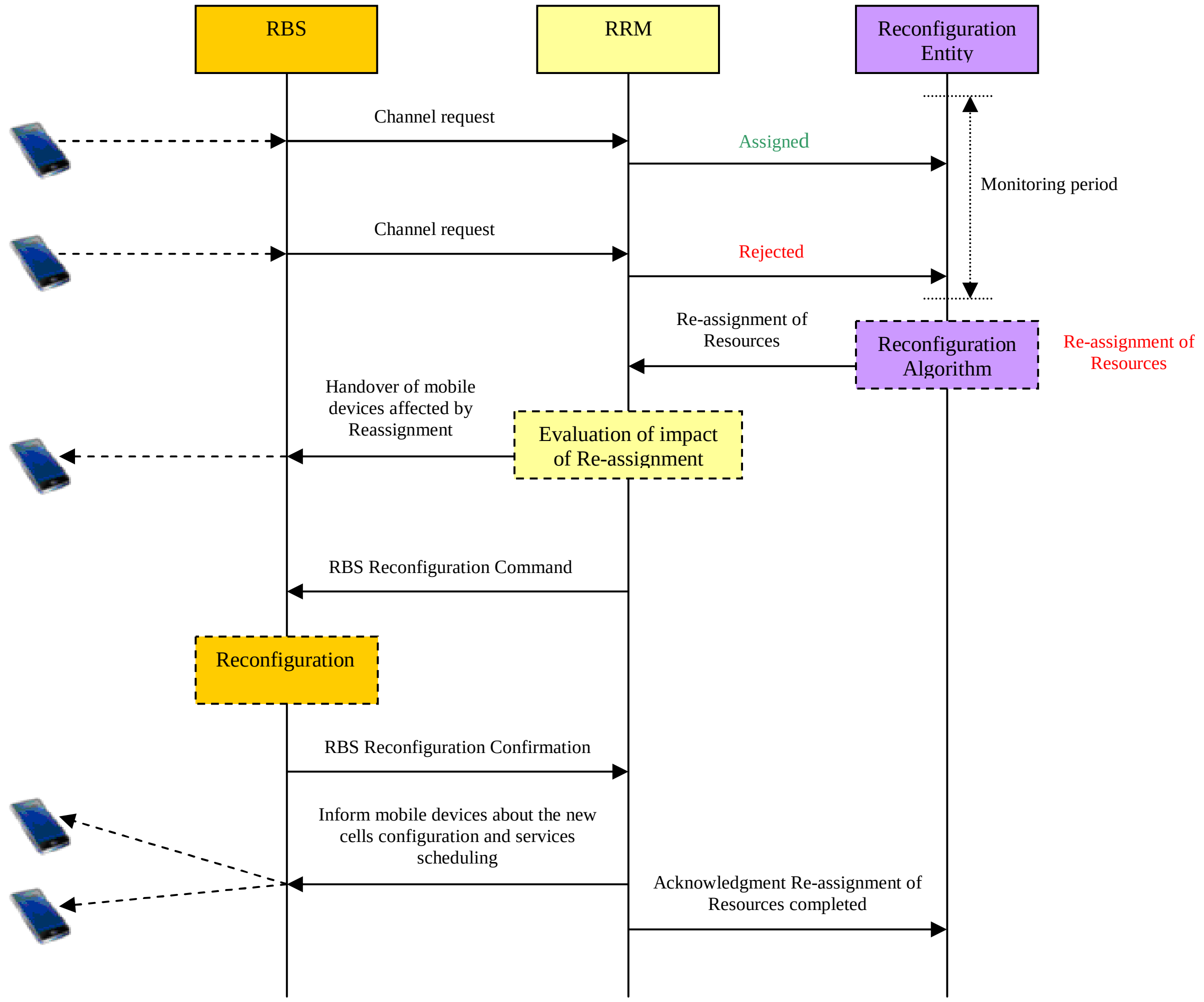

Figure 17: High level information flow related to the case of re-assigning resources shared among multiple standards modes

5.2.5 LTE pico/femto cell reconfiguration

5.2.5.1 General Use Case Description

For cellular systems like GSM, in order to ensure that the mutual interference among cells remains below a harmful level, adjacent cells use different frequencies. However in cells that are separated by a certain distance, frequencies can be reused. More in general, the correct behaviour of the system is assured when the SNR of each cell is above a certain level accordingly defined.

On this basis, considering an indoor LTE pico/femto cell within the coverage of a GSM macro cell, it could be possible to reuse appropriate GSM frequencies with a low transmission power in order to avoid harmful interference to the GSM system. This Use Case can be considered as a particular implementation for LTE pico/femto cell scenario of the more general Radio Resource Optimization approach reported in clause 5.2.4.

5.2.5.2 Stakeholders

Mobile Network Operator (MNO): operates and maintains an heterogeneous mobile network to which radio resource optimization schemes are performed dynamically in time.

Infrastructure Providers: provides the hardware and software of the reconfigurable radio nodes.

User: performs voice and/or data traffic through his/her Mobile Device (e.g. eUE).

Mobile Device Manufacturer: provides hardware and software of Mobile Devices and software components needed for the upgrade.

5.2.5.3 Scenario

In figure 18, the GSM frequency band is divided into three sub-sets (S1, S2, and S3) used in a cluster of three cells. Each sub-set is constituted by a certain number of GSM carriers. In this context, an LTE pico/femto eNodeB used inside a house within the coverage of a GSM cell could operate in the GSM band by using different GSM frequency band sub-sets at different low transmission power. Both GSM frequency band sub-sets and associated low transmission power need to be selected and set accordingly, in order to guarantee no harmful interference to the GSM system. For instance, as shown in figure 18, transmission power of carriers (S2, which is used by the closest GSM base station) could be less than the others (S1 and S3), being at a greater distance. To the extreme, LTE pico/femto eNodeB low transmission power on S2 could be reduced down to "0" to avoid interference to the GSM system. More likely, to be more conservative, the GSM frequency band sub-sets exploited by the LTE pico/femto eNodeB will be the ones not belonging to first tyre of GSM neighbouring cells in order to grant an opportune SNR. On top of that, GSM BCCH carriers are excluded from the frequencies that can be used by the LTE pico/femto eNodeB, in order to not impact on the GSM planning. Moreover, the LTE pico/femto eNodeB can use its bands and the GSM frequency band sub-sets together to get higher data rates, and in this case, the GSM frequency band sub-sets could be used as a secondary component carrier of CA.

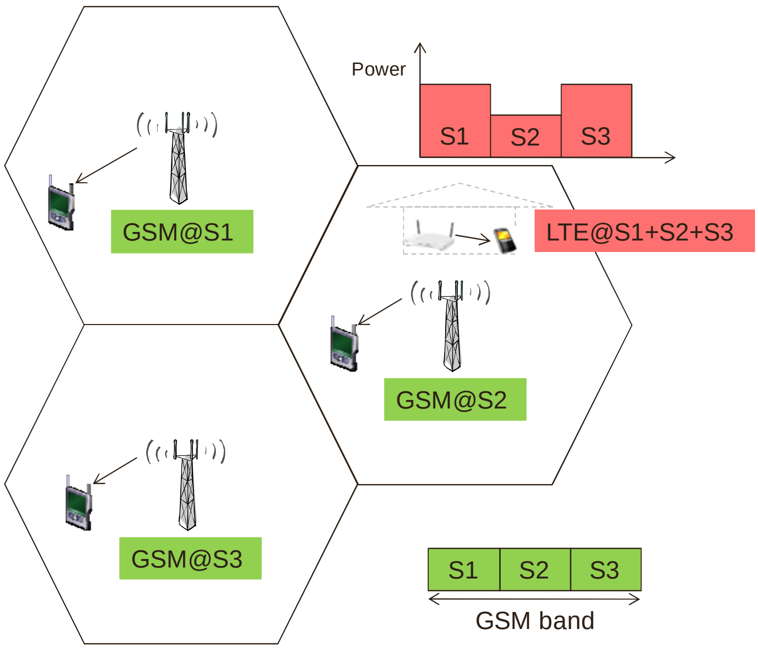

Figure 18: Frequency Reuse between RATs

In general, in order to maintain the interference level from LTE pico/femto eNodeB to GSM system below a predefined level, LTE pico/femto eNodeB has to obtain or decide the appropriate GSM frequency band sub-sets and optimum transmission power to be used. In general, two modes can be chosen to make decision on the LTE pico/femto eNodeB reconfiguration, depending on the Reconfiguration Entity location (please refer to clause 5.2.4 for more details):

- Centralized mode: for each LTE pico/femto eNodeB, the usable GSM frequency band sub-sets as well as maximum transmission power need to be acquired from the Reconfiguration Entity located externally to the LTE pico/femto eNodeB.
- Distributed mode: for each LTE pico/femto eNodeB, the usable GSM frequency band sub-sets as well as maximum transmission power are selected by the Reconfiguration Entity internal to the LTE pico/femto eNodeB based on its measurement results of the received power in the related bands from the surrounding GSM BSs/UEs. Interactions between the different LTE pico/femto eNodeB are applied for coordination purposes.

In addition, LTE eUEs under the pico/femto eNodeB has to be informed about the new operating frequency after the reconfiguration.

5.2.5.4 Information Flow

In this clause an example of high level information flow related to the reconfiguration of a LTE pico/femto eNodeB cell is presented.

The information flow considers the following logical/physical entities:

- Reconfigurable LTE pico/femto eNodeB that can be reconfigured in terms of active frequency carriers and optimum transmission power to be used by LTE.
- Reconfiguration Entity that provides to the LTE pico/femto eNodeB the usable GSM frequency band sub-sets and the related maximum transmission power, which could be used by the LTE pico/femto eNodeB directly. As reported in clause 5.2.4, the Reconfiguration Entity is a logical entity that could operate inside each LTE pico/femto eNodeB (distributed mode) or externally in a higher-order node (centralized mode).

Figure 19 shows an example of LTE pico/femto cell reconfiguration information flow. In particular:

- The LTE pico/femto eNodeB sends a Radio Resource Request message to the Reconfiguration Entity to request the GSM frequency band sub-sets that can be used. The LTE pico/femto eNodeB need to include its current location in the message.
- The Reconfiguration Entity evaluates and decides the GSM frequency band sub-sets and the related low transmission power that can be used in order to avoid harmful interference to the GSM system. After that sends the Reconfiguration Command message to the LTE pico/femto eNodeB.
- The LTE pico/femto eNodeB selects the mechanism to use the radio resources, e.g. as a secondary carrier for CA or as the primary carrier, and perform the reconfiguration.
- The LTE pico/femto eNodeB notifies the eUEs in its coverage about the change of the operating frequency. Broadcasting message may be used for IDLE eUEs and the eUE(s) with an ongoing communication could be informed via the dedicated RRC signalling.
- eUE(s) can access to the LTE pico/femto cell.

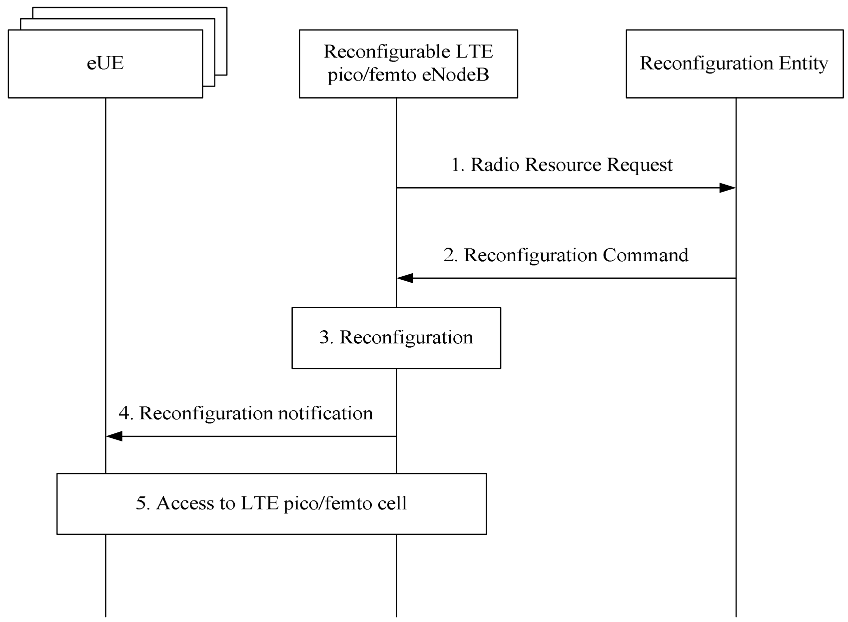

Figure 19: Example of LTE pico/femto cell reconfiguration information flow

5.2.6 Cognition enabler

5.2.6.1 General Use Case Description

This Use Case considers a heterogeneous or multi-RAT context managed by a single operator in which radio resource management schemes (e.g. load balancing, radio resource optimization, etc.) could be performed dynamically in time. Mechanisms to provide the information to the Mobile Devices for managing their operations appropriately are then needed. In this context, the concept of the in-band CPC (Cognitive Pilot Channel) can be exploited for this scope.

5.2.6.2 Stakeholders

Mobile Network Operator (MNO): operates and maintains an heterogeneous mobile network to which radio resource optimization schemes are performed dynamically in time.

Infrastructure Providers: provides the hardware and software of the reconfigurable radio nodes (e.g. RBS).

User: performs voice and/or data traffic through his/her Mobile Device.

Mobile Device Manufacturer: provides hardware and software of Mobile Devices and software components needed for the upgrade.

5.2.6.3 Scenario

In an intra-operator scenario, the in-band CPC solution foresees that one or more RATs composing the MNO network can be used as bearer for the related information. In fact, as reported in [i.1], in-band CPC information can be contextualized by different means such as context information exchanged between network and Mobile Devices, policies provided to the Mobile Devices e.g. in order to assist the decision making and reconfiguration mechanisms and their operations, and new operative software that can be downloaded on the Mobile Devices.

A possible example of scenario can consider the exploitation of the in-band CPC for policies provisioning to the Mobile Devices in the case of advanced radio resource management schemes, such as load balancing and radio resource optimization (see clause 5.2.4) to be performed by the MNO. Policies sent by the MNO to the Mobile Devices will permit to manage appropriately their operations in the context of the multi-RAT environment.

5.2.6.4 Information Flow

In this clause it is presented an example of in-band CPC information flow related to the scenario depicted in the previous clause. The information flow considers the following logical/physical entities:

- Mobile device(s).
- Multi-RAT environment constituted by RAT1, RAT2 and RAT3.
- RRM (Radio Resource Management) and Reconfiguration Entity described in clause 5.2.4.4.
- CPC Manager storing the up-to-dated information related to the policies.

Figure 20 shows the CPC information flow. In particular:

- After the Mobile Device is switched-on, it camps on the RAT1 following the common camping procedures.
- On the network side, a load balancing algorithm is performed inside the RRM entity that, according to specific parameters and network conditions (e.g. congestion situation), selects the RAT2 as the preferred one to which the Mobile Devices have to reselect on.
- Such decision, in the form of a new policy, is sent to the CPC Manager that updates its stored information. The updated policies are sent on the in-band CPC exploiting the available RATs in order to make it available to be sent to the Mobile Devices.
- The Mobile Device receives the policy on the in-band CPC (through RAT1). Then the Mobile Device applies the new policy operating a cell-reselection to RAT2.

- In a successive moment, on the network side, a radio resource optimization algorithm is performed by the Reconfiguration Entity that, according to the MNO needs (e.g. traffic variations, RRs reallocations decision), may add new RRs to the RAT3. Having now more capacity to be exploited, RAT3 can be selected as the preferred one e.g. for new data connection requests.

- Such decision, in the form of a new policy, is sent to the CPC Manager that updates its stored information. The updated policies are sent on the in-band CPC exploiting the available RATs in order to make it available to be sent to the Mobile Devices.

- The Mobile Device receives the policy on the in-band CPC (through RAT2). From this point on, in case the Mobile Device will need to start a data connection, it will first reselect on RAT3 and send the appropriate channel request on such RAT.

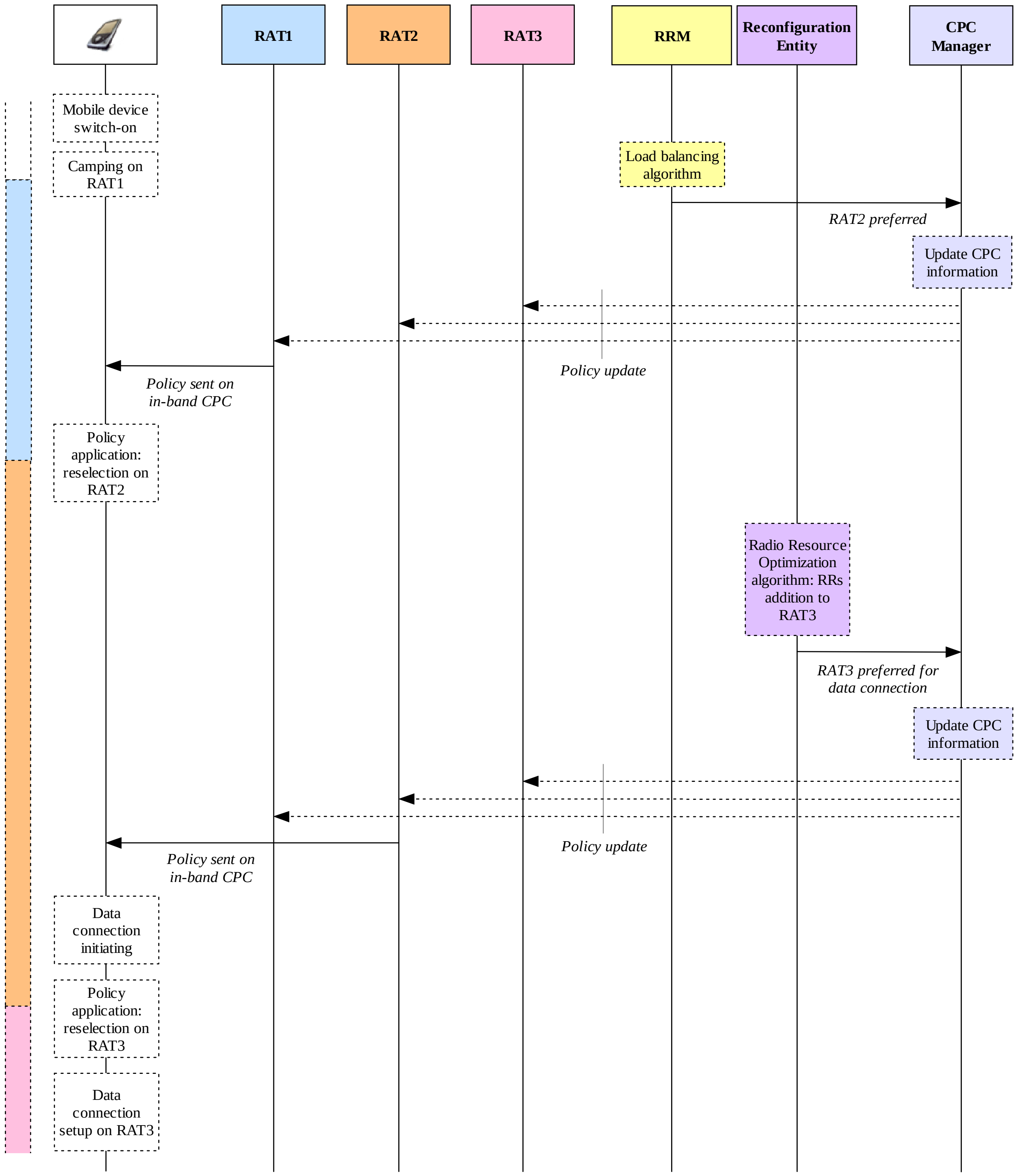

Figure 20: Example of in-band CPC information flow

6 Potential System Requirements

From the different Use Cases reported in the previous clauses, the following potential System Requirements can be drawn. It has to be noted that each Use Case does not necessarily require to fulfil all the potential System Requirements but only the ones related to the specific Scenarios. In general, further and more elaborated requirements will be drawn in the framework of the system requirements activities.

RBS - Multiple RATs and frequency bands support
The RBS should be multi-standard reconfigurable nodes supporting multiple RATS and the frequency bands of interest.

RBS - FDD and TDD modes support
The RBS should be able also to support FDD and TDD modes for the RATs and the frequency bands of interest.

RBS - Standard and regulatory restrictions compliance
All RATs implemented (e.g. by software) in the RBS should be fully compliance with the current existing standards (e.g. GSM, UMTS, LTE, WIMAX, etc.) and related regulatory restrictions (bands, frequencies, power levels, spectrum masks).

RBS - HPRs and RRs dynamic reconfiguration
The RBS should be able to be reconfigured in both HPRs and RRs for each supported RAT in the frequency band of interest. The percentage of HPRs devoted to each supported RAT can be dynamically modified. The number of RRs assigned to each supported RAT can be dynamically modified.

RBS - Real-time reconfiguration
The reconfiguration phase of a RBS is performed in real-time and/or in the fastest way without the necessity to shut down and restart the device (e.g. in case of multi-RAT operations/reconfigurations).

RBS - Reconfiguration based on network/users conditions
The RBSs are able to be reconfigured taking into account the experimented network and users conditions (e.g. traffic and/or interference conditions)

RBS - Reconfiguration based on MNO deployment strategies
The RBS is able to be reconfigured taking into account the MNO deployment strategies (e.g. refarming)

RBS - Common standardized interfaces
The RBS should be able to receive and execute reconfiguration commands coming from entities that manage the reconfiguration of the network via common standardized interfaces.

RBS - Remote upgrade
Remote upgrade of an existing RAT should be managed by the RBS in a fastest way in order to minimize the service unavailability.

RBS - (Self-)commissioning and (self-)optimization
The RBS should be able to manage and run commissioning procedures and optimization process triggered by the network or by the RBS itself (self-commissioning and self-optimization).

RBS - RRs management
The RBS could be able to manage operator's available spectrum to provide subscriber demands, considering behaviour of standard/services (coverage, capacity, mobility) in different frequency bands.

Reconfiguration management architecture
The Radio Controller should contain the entities that manage the reconfigurations (e.g. RRM and Reconfiguration Entity); however entities like Reconfiguration Entity could be also located in the core network, in the O&M nodes, or directly in the Base Stations for flat architectures (e.g. HSPA+ and/or LTE).

Reconfiguration management parameters
The Reconfiguration Entity should be able to know and manage the parameters (e.g. maximum channel capacity, expected channel capacity, bandwidths, power levels, etc.) to perform the reconfiguration of the different systems.

Common policy framework
A common policy framework should be defined for the implementation of information provisioning mechanisms to the Mobile Devices.

Efficient information provisioning mechanisms
Efficient mechanisms to inform (when needed) the Mobile Devices (including those in idle mode) about the new network configuration RBS (e.g. update of the neighbouring list, update of new available RATs, etc.) and derived new policies should be defined.

CPC Manager content update
Depending on the timing restrictions coming e.g. from the radio resource optimization mechanisms adopted, the CPC Manager content should be updated in a proper timeframe.

In-band CPC information delivery
Depending on the timing restrictions coming e.g. from the radio resource optimization mechanisms adopted, the time needed by the CPC to deliver the information should satisfy such timing restrictions.

In addition, to fully benefit from the depicted Use Cases and related Scenarios, Mobile Devices should be capable of:

MD - Multiple RATs and frequency bands support
The Mobile Devices should be reconfigurable and able to support multiple RATs and frequency bands of interest

MD - FDD and TDD modes support
The Mobile Devices should be reconfigurable and able to support FDD and TDD modes for the RATs and the frequency bands of interest.

MD - Software upgrade
The Mobile Devices should be upgradable with new functionalities and new supported RAT by software and commands received by the network.

MD - Policy management
Mobile Devices should be able to receive, store and correctly execute any policy sent from the network (e.g. via in-band CPC).

History

Document history		
V1.1.1	July 2011	Publication