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Reconfigurable Radio Systems (RRS); Use Cases for building and exploitation of Radio Environment Maps (REMs) 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).

1 Scope

The present document intends to identify use cases and provide system level functionality for building and exploiting evolutionary Radio Environment Maps (REMs) in a single or multi-RAT context in intra-operator scenarios.

Building the REM within an RRS context requires the enhancement of existing network entities, protocols and interfaces accomplishing the tasks of requesting, storing and processing geo-located measurements related to the radio environment.

It is expected that REMs will be exploited in an RRS context for network troubleshooting and radio resource management optimization. The present document includes a general description of the use cases and associated stakeholders as well as information flows and high level requirements. Technical challenges are also identified.

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] Report Recommendation ITU-R SM.2152 (2009): "Definitions of Software Defined Radio (SDR) and Cognitive Radio System (CRS)".

3 Definitions and abbreviations

3.1 Definitions

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

cognitive radio system: 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

NOTE: This is the current definition as given in [i.1].

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

NOTE: This is the current definition as given in [i.1]

use case: description of a system from a user's perspective

NOTE 1: Use cases treat a system as a black box, and the interactions with the system, including system responses, are perceived as from outside the system. Use cases typically avoid technical jargon, preferring instead the language of the end user or domain expert.

NOTE 2: Use cases should not 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.

NOTE 3: A brief use case consists of a few sentences summarizing the use case.

3.2 Abbreviations

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

BS	Base Station
CAPEX	CAPital EXpenditures
CR	Cognitive Radio
FDD	Frequency Division Duplex
GUI	Graphical User Interface
HO	HandOver
LTE	Long Term Evolution
MCD	Measurements Capable Device
MD	Mobile Device
MDT	Minimization of Drive Test
MME	Mobility Management Entity
MNO	Mobile Network Operator
NFC	Near Field Communication
OFDM	Orthogonal Frequency Division Multiplexing
PHY	Physical Layer
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RBS	Radio Base Station
REM	Radio Environment Map
RF	Radio Frequency
RFID	Radio Frequency Identification
RNC	Radio Network Controller
RRM	Radio Resource Management
RRS	Reconfigurable Radio System
RSRP	Reference Signal Received Power
SDR	Software Defined Radio
SINR	Signal to Interference plus Noise Ratio
TR	Technical Report
UMTS	Universal Mobile Telecommunications Service

4 Motivation, Goals

The cognitive radio concept offers, through radio environment awareness, opportunities for improving radio resource management as well as for easing network monitoring and troubleshooting.

The Radio Environment Map (REM) defines a set of network entities and associated protocols that trigger, perform, store and process geolocated radio measurements (received signal strength, interference levels, QoS measurements for e.g. femto cell deployment scenario and related radio resources management) and network performance indicators.

Such measurements are typically performed by user equipments, network entities or dedicated sensors.

The REM uses a dynamic database capable of tracking changes in the radio environment and, as such, necessitates a careful design depending on the scenarios of interest.

A generic description of the REM concept is provided in Figure 1. As shown in the Figure, Measurement Collection Modules (one for each RAT domain) request geo-located measurements from,Measurements Capable Devices (MCDs), such as Mobile Devices. The data collected from every RAT domain is stored and treated in the REM entity (encompassing REM management and storage modules). The post-treated REM data is then provided to the RRM entities for radio resources optimization purposes.

For MCDs, the following principles apply as far as MDs are concerned:

- The info in the REM is gathered by Mobile Devices that may not be the ones that benefit from the REM information in a specific scenario.
- The Mobile Device making field strength measurement, can measure in a frequency band which is not the band where the device is operating.
- As REM are, in principle, technology agnostic, measurements for the benefit of Mobile Devices operating on a particular RAT may be performed by Measurement Capable Devices (MCD) operating in another RAT.

In this context the REM is a powerful technology agnostic tool that encompasses any compliant reconfigurable radio access technology, which allows powerful cross-technology optimization algorithms to be implemented and provides a synthesized view of the networks for monitoring purposes through dedicated Graphical User Interfaces (GUIs).

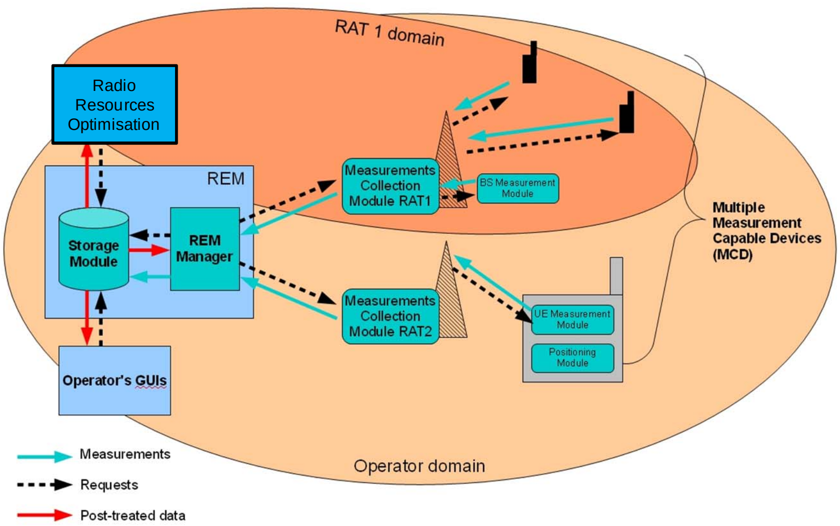

Figure 1: Generic REM description in intra-operator domain

5 Uses 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

Hereafter the list of Use Cases (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:

- In-band Coverage/Capacity Improvement by Relays
- Self-Configuration and Self-Optimization of Femto-Cells
- System Optimization
- Introduction of New Radio Access Technologies
- Vertical Handovers Optimization
- Intra-System Handovers Optimization

5.2 Detailed Use Cases

5.2.1 In-band Coverage/Capacity Improvement by Relays

5.2.1.1 General Use Case Description

In this scenario REM helps detecting and locating coverage and capacity problems by supplying geo-localized information on the coverage/capacity indicators. As a remedy, it provides a means to dynamically adjust the transmit power of the emitters (i.e. auto-configuration of relays).

Basically, the aim is to detect and solve coverage hole and traffic hotspot issues through introduction of relays. From the operator perspective, the problem detection is a key issue since it appears when customers complain. One way forward is then the necessity to perform specific measurement campaign to clearly understand the unsatisfying situation before deciding on solution implementations to improve it. In some scenarios (e.g. LTE) MDT concept is also a solution.

The relay solution appears to be efficient as it allows improving/extending the coverage zone, and at the same time also helps to handle more traffic. However, relays are deployed inband with radio backhauling, hence generating potential interference and also consuming radio resources. Their configuration has therefore to be optimized to avoid resource wastage.

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.

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

Base Station: The existing BSs provide the coverage and capacity foreseen by the network planning.

Relays: They are intended to improve coverage and capacity (low-cost solution to coverage/capacity adjustments).

REM: This entity stores geo-localized coverage/capacity information.

Mobile Device: MD reports measurements for the REM.

5.2.1.3 Scenario

Within a cellular network, areas that suffer from high shadowing receive the serving signal with strength much lower than what the initial planning forecasted. This is commonly referred to as a *dead zone* or a *coverage hole*. Possible causes are a hilly terrain or buildings of great dimensions. In these areas, the service quality is usually severely impacted. However, depending on the size of a coverage hole and traffic needs, the deployment of a new base station may not be a cost-effective solution.

On the other hand, some areas might have a significantly high traffic demand for short periods, which necessitates a provision of capacity increase in order not to cause a notable degradation in the planned service quality. A cost-effective solution to alleviate such problems is the use of relays, whose deployment is foreseen as one of the new features to be included in LTE-Advanced. Relays are small base stations that use the radio access spectrum for backhauling and they forward mobile messages to/from the Base Stations (BSs). Capacity/coverage improvement is obtained by properly configuring the relays (adjusting the transmitting power, antenna parameters, etc.). In this context, REMs can be used to reach the following objectives:

- Detect and locate the above mentioned situations that require coverage and capacity improvements.
- Trigger a cognitive engine to handle the issue.
- Help to configure and optimize the solution in a way that does not require a re-planning.

Figure 2 provides an example of a relay-based solution to coverage improvement. The figure depicts a situation where the green area requires better coverage due to propagation issues or more capacity due to traffic issues. The left-hand sub-figure highlights the weakness of a hand-made solution: the transmission power of the relay is not optimally adjusted to cover the intended zone. The blue area that is due to the overshoot in relay coverage causes high interference, degrading the QoS for the users in the vicinity. Besides, the relay coverage does not completely cover the intended zone, leaving the initial problem partially unsolved. On the right-hand side, the solution tailored with REM can be seen. The transmission power of the relay is optimally configured and its coverage matches the green area.

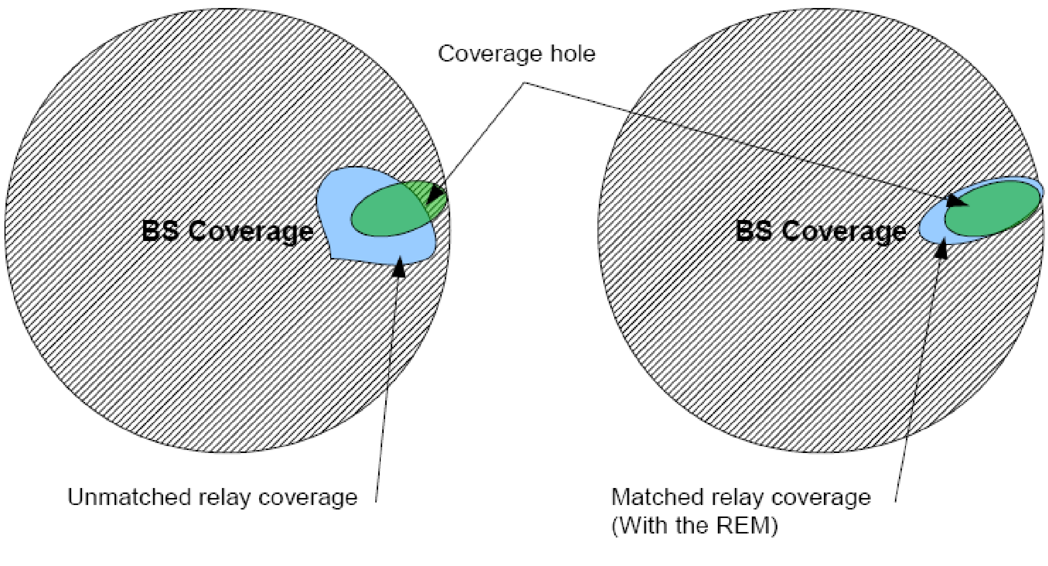

Figure 2: Relay scenario

5.2.1.4 Information Flow

This clause presents a high level information flow depicted in Figure 3 and Figure 4 for the Relay optimization scenario. The information flow considers the following nodes:

- Base Station: The existing BSs provide the coverage and capacity foreseen by the network planning.
- Relays: They are intended to improve coverage and capacity (low-cost solution to coverage/capacity adjustments).
- REM: This entity stores geo-localized coverage/capacity information.
- Mobile Device: MD reports measurements for the REM.

In the following, the situation has been split into the following main phases:

- Phase 1: REM helps detecting/identifying and locating coverage and/or capacity problems.
- Phase 2: A new relay is installed and commissioned at the appropriate location.
- Phase 3: REM helps optimizing the relay configuration parameters.

The phase 1 information flow is the following:

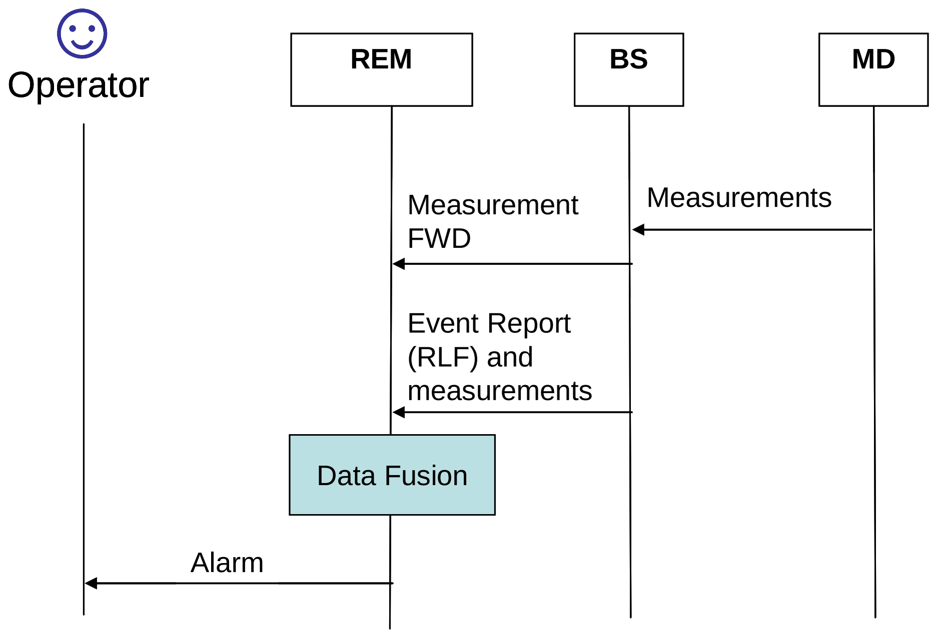

Figure 3: Phase 1 information flow

Phase 3 on Relay optimization takes place after the roll-out and initial configuration setting. MDs, BSs and Relays continuously monitor events and carry on relevant measurements. Based on those reports, REM detects whether the problem is solved or not and adjust the relay configuration, adjusting parameters related to e.g. remotely controllable mechanical downtilt, electrical downtilt, beamforming, transmitted power, allocated bandwidth and allocated timeslots. The corresponding high level information flow is given below.

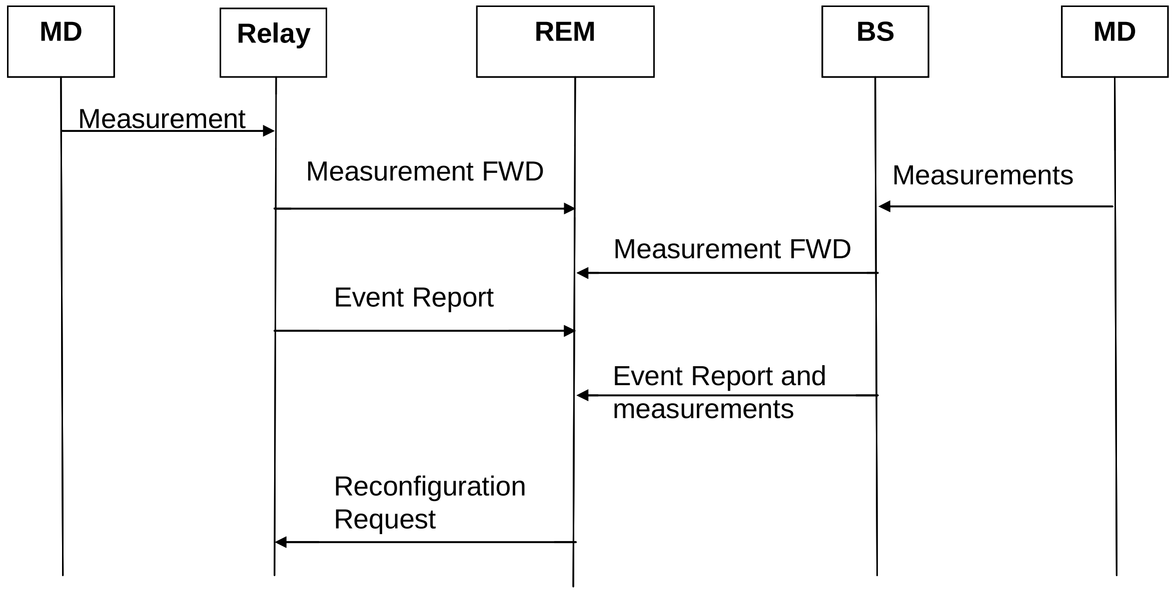

Figure 4: Phase 3 information flow

5.2.1.5 Potential System Requirements

From the Use Case presented above, the following system requirements can be derived:

REQ_01 Mobile Devices have the capability to perform geo-localized measurements.

REQ_02 Mobile Devices can report their location information with sufficient precision.

REQ_03 BSs and relays have a connection with the REM.

REQ_04 Relays are agile enough in configuration modifications (power adjustment, beamforming capability, etc.).

5.2.2 Self-Configuration and Self-Optimization of Femto-Cells

5.2.2.1 General Use Case Description

This clause addresses the use of REM to enable efficient self-configuration, self-optimization and self-healing of femto-cells (transmission parameters, admission/mobility/congestion/interference control, etc.)

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.

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

5.2.2.3 Scenario

The aim of this scenario is to use REM information to ease self-configuration, self-optimization and self-healing of femto-cells.

Femto-cells are very small base stations that are located in customers' premises and that are operated by the customers. Backhauling is provided by the landline internet access of the customer (ADSL, fiber, etc.) and radio access is achieved by the radio access technology that defines the femto-cell (3G or LTE). Since they are operated by the customers, they are typically plug-and-play type devices.

Besides, since the operator has no role in their installation and their operation, the initial network planning process does not exist in femto-cells. The operator does not exactly know how many femto-cells will be deployed and therefore cannot carry out an initial dimensioning and planning of the femto-cell network. Being plug-and-play type devices, femto-cells are completely autonomous in operations like transmission parameter settings (RF and antenna parameters, power levels, etc.), neighbour list definition, admission/congestion control parameter adjustment, mobility management (femto-femto as well as femto-macro), etc.

Furthermore, femto-cells are deployed in the same frequency band as the macro cells of the same radio access technology (3G or LTE) and therefore interference mitigation with the neighbouring macrocells is a challenging issue.

Finally, systems involving femtocells are expected to be highly dynamic; as consumer equipment the rate of deployment is uncertain, the devices might be powered down for substantial period of time, and devices might be moved geographically significant distances without advance warning. Taking into account all this, issues like self-configuration, self-optimization and self-healing are of primary importance for femto-cells.

To facilitate the plug-and-play of femto-cell deployment, both the network control element and femto-cell need to get and maintain the REM information. Therefore, a lot of effort is being spent to obtain some improvement in autonomously setting and tracking the optimum femto-cell parameters in order to guarantee the required QoS on their coverage area without deteriorating the performances of neighbouring femto- and macro-cells.

In this context, REMs can have a significant role in enhancing the self-x functionalities of the femto-cells.

5.2.2.3.1 Use of the REM to solve femto/macro interference

This scenario implies the availability of a bi-mode femto which can flexibly accommodate both 3G and LTE technologies with associated bi-mode mobile devices. In this context, the bi-mode definition indicates that the femto base station operates two different radio access technologies with a dynamic flexible percentage of radio resources devoted to each other.

Figure 6 depicts the situation where a mobile device which is connected to the femto cell on 3G mode operating in the 2,1GHz band, is getting harmful interference from the 3G macro cell which also operates in the same frequency band. To improve the situation, one possible solution is to benefit from the bi-mode femto capability, thus switching the interfered mobile device to LTE technology at 2,6 GHz within the femto cell. This solution is viable provided that the following conditions are satisfied:

- Condition 1: Radio resources on the LTE technology at the femto level are available, both in terms of hardware processing resources and available resource blocs at 2,6 GHz.
- Condition 2: The vertical handover process from 3G towards LTE, once performed, will not create any femto-LTE/macro-LTE interference situation due to the potential presence of an outdoor LTE macro cell in the femto cell vicinity. As highlighted in clause 5.2.2.3 above on the generic scenario introduction, the plug and play approach of introducing femto cells does not allow yet carrying out planning that includes the femto cell resources. Furthermore the reconfigurable bi-mode (3G-LTE) femto creates additional challenge for planning, In addition, interference situation is likely to occur as shown in Figure 5 where MD2 is not visible from the e-NodeB (dotted line), due to its location in cell edge with additional building penetration loss. Therefore, MD1 which is within the e-NodeB coverage may create potential collisions with MD2.

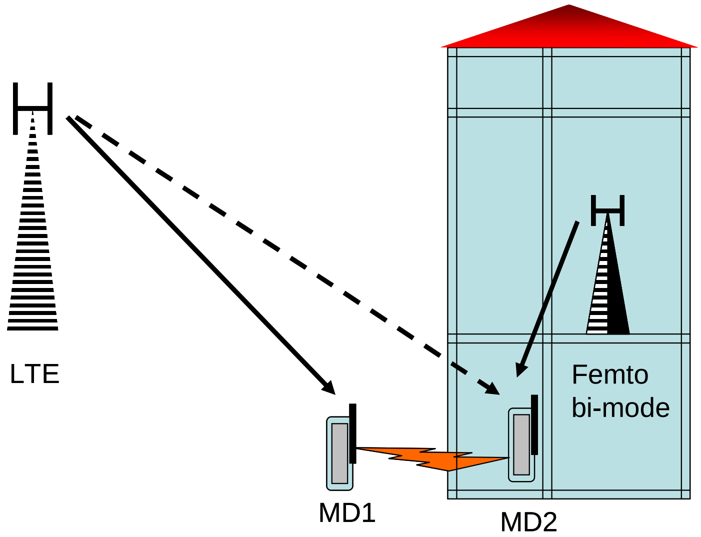

Figure 5: Femto-Macro Interference

The following process based on the capabilities offered by the Radio Environment Map concept and described in Figure 6 is therefore proposed:

- Initial situation: The Mobile Device (MD) is connected to the femto cell with 3G technology.
- Harmful interference due to the coexistence of the outdoor 3G cell is degrading the QoS of the MD-Femto link. Femto cell internal management reacts accordingly in a short time frame, checking whether the bi-mode Femto has enough resources in LTE technology to Hand Over the MD from 3G to LTE with seamless service continuity.
- Assuming the LTE resource availability is OK (in other terms satisfying condition 1 that can be done locally at the femto level), the bi-femto prepares the Hand-Over and needs to check whether the new connection will be satisfying for the MD. One key issue (which is the answer to condition 2) is the new interference situation in the LTE 2,6 GHz band. The answer can be provided using the REM dynamic database:
  - First the femto sends a request to the REM which can be located either at the femto cell or preferably at the HeNB GW, as shown in Figure 6.
  - Then the REM entity delivers a message to the femto cell, containing information on the level of received (interference) power from the LTE macro station throughout the femto coverage area.
- Based on this information, the femto cell is then able to take the appropriate Go-NoGo decision for the hand-over taking into account precise interference possibilities.

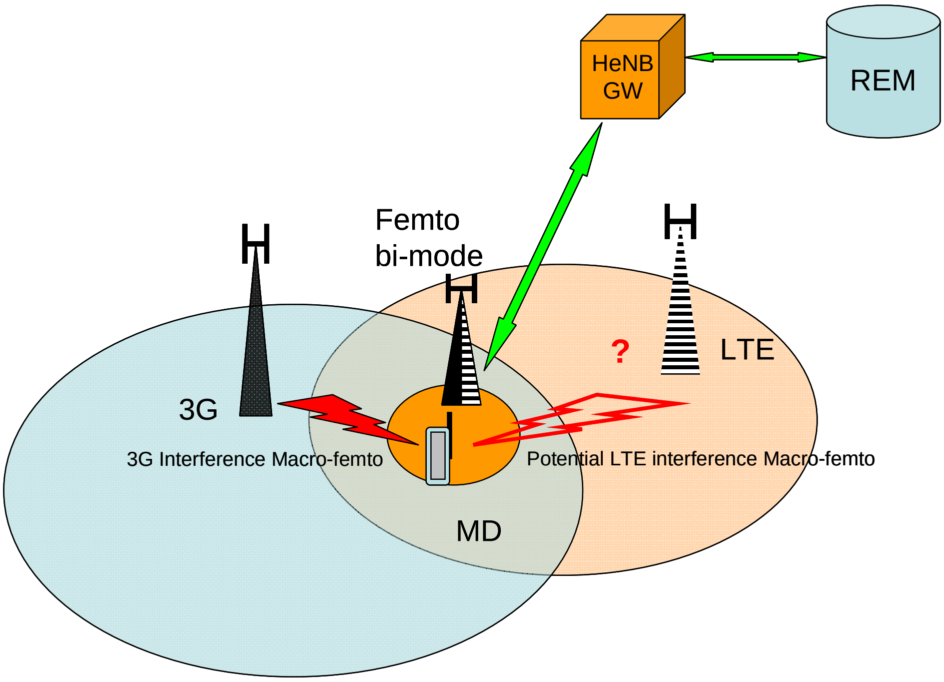

Figure 6: Scenario description

The corresponding high level information flow is depicted in Figure 7.

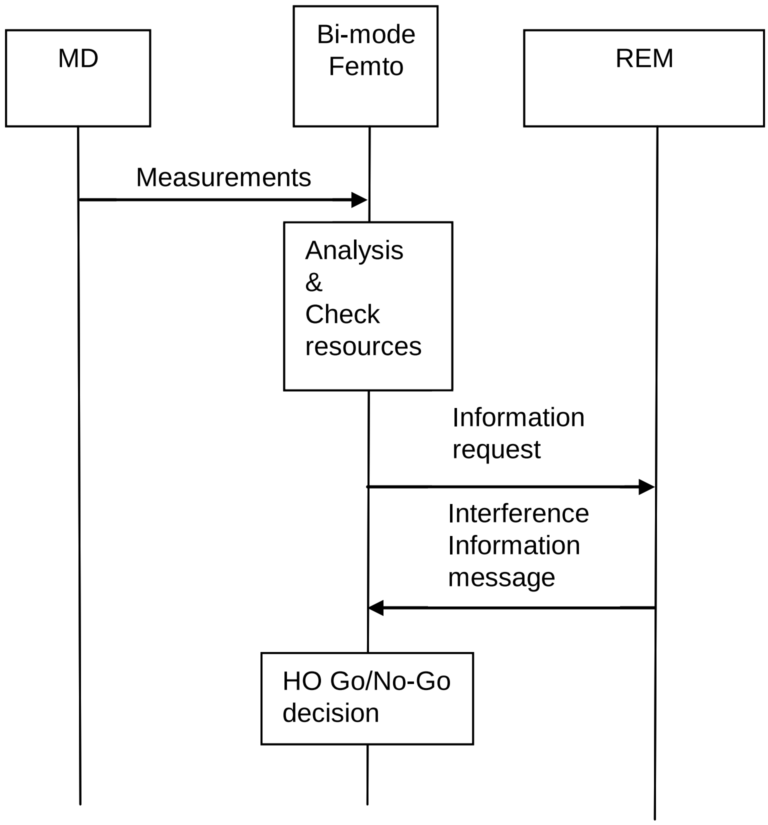

Figure 7: Information flow for the femto/macro interference scenario

5.2.2.4 Potential System Requirements

From the Use Case scenarios presented above, the following system requirements can be drawn:

REQ_01 Mobile Devices have the capability to perform geo-localized measurements.

REQ_02 Mobile Devices can report their location information with sufficient precision.

REQ_05 The femto-cells can communicate with the REM.

5.2.3 System Optimization

5.2.3.1 General Use Case Description

System optimization aims to enhance the performance of Radio Access Network(s) based on Key Performance Indicators (KPIs) in terms of:

- Throughput
- Coverage
- Capacity and outage probability

In system optimization, there are several goals to be attained, and/or several constraints to be respected, which are related to the above metrics. The operator can assign priorities to each of them and the aim is to attain these goals, respecting the constraints by adjusting the system parameters. These parameters can belong to any aspect/functionality of the access network, but here the focus is particularly on the Radio Resource optimization parameters. Optimization processes usually require some kind of knowledge about the radio conditions, the radio access network environment and topology. This knowledge is provided by the mobile measurements, for example the SINR experienced by the mobiles, the interference caused by a transmission, the traffic demand, etc.

An example could be an algorithm aimed at configuring automatically the power masks of BSs which use OFDM-based PHY layer and whose target is to maximize the aggregated throughput of one or more BSs. The optimum power mask configuration clearly depends on the spatio-temporal characteristics of environmental factors like traffic density and SINR distributions.

In such a context, REM can be of tremendous use by gathering and storing the required data, which is then available for use by the optimization processes. Obviously, issues like gathering relevant data, storing it, building the REM and retrieving the necessary information when necessary should be handled timely and efficiently without excessive signaling overhead.

REM is not involved in the radio resource optimization process in any active way. It is assumed that the radio resource optimization entity determines when to start or stop the optimization process and which RRM entities (e.g. BSs) should be involved in optimization.

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.

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

5.2.3.3 Scenarios

The scenarios for which the system optimization can be done are illustrated in Figure 8. In the first scenario mobile devices served by BS 1 are concentrated near the border area between BS1 and BS2, where the mobile devices experience low SINR. In the second scenario mobile devices are concentrated at the cell centre of BS1 in which case the terminals experience high SINR.

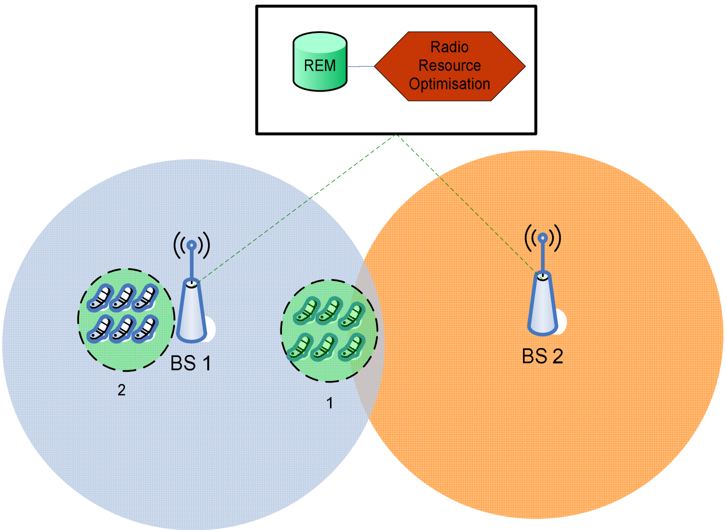

Figure 8: Scenarios where system optimization can be executed for improvement of user throughput

For both scenarios, the optimal overall system throughput for all the mobile devices, can be achieved through an optimization of the radio parameters of BSs (including power mask, antenna down-tilt and beam direction etc.), while taking into account the traffic distribution, as well as other system information.

The measurements reported and forwarded by BSs can be further processed by REM manager and stored in REM. BSs can report the cell related traffic information to REM. The REM can also provide the Radio Resources Optimization entity with information such as neighbouring relations, user terminal service characteristics and historical performance statistics. The Radio Resources optimization entity may involve other entities (e.g. BSs) in calculating optimal values for radio parameters e.g. power mask and provide these to the BSs.

5.2.3.4 Information Flow

This clause presents the high level information flow depicted in Figure 9 for the system optimization scenario.

1) MD provides the measurements (received power value) to REM via BS.

2) REM processes the measurements reported by MD and send processed information and other assisting information to the Radio Resources Optimization entity, including neighbouring-related information (i.e. information related to other BS) traffic distribution, user terminal service characteristics as well as historical performance statistics.

3) According to the information provided by REM, the Radio Resources Optimization entity identifies which BSs to be involved in the optimization process.

4) Depending on the information provided by REM, the Radio Resources Optimization entity determines parameters for optimization process, e.g. scaling factor, weighing factor, and adaptation speed/step size parameters.

5) In the case of distributed optimization, the Radio Resources Optimization entity starts the optimization process by sending start indicator and the optimization parameters to the involved BSs. The start decision is done through the comparison of network status with predefined thresholds which are also provided by REM.

   In the case of centralized optimization, the Radio Resources Optimization entity sends the optimization parameters to all BSs.

6) The Radio Resources Optimization entity monitors status of network through MD reported (and processed by REM) measurements.

7) For distributed optimization, the Radio Resources Optimization entity stops the optimization process by sending stop indicator to the involved BSs. The stop decision is made via comparison of network status with predefined thresholds.

8) Radio Resources Optimization entity sends optimization results to REM for the purpose of historical statistics.

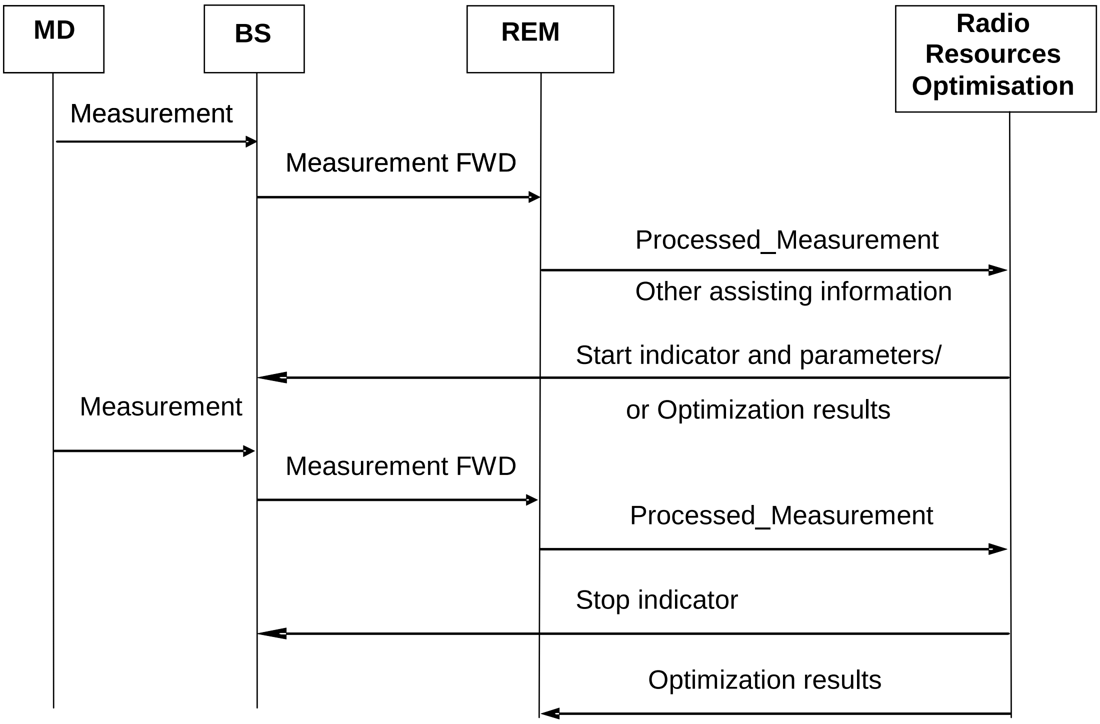

Figure 9: Information flow for the system optimization scenario

5.2.3.5 Potential System Requirements

From the Use Case scenarios presented above, the following system requirements can be drawn:

REQ_01 Mobiles Devices have the capability to perform geo-localized measurements.

REQ_06 Algorithms need slowly varying measurements.

5.2.4 Introduction of New Radio Access Technologies

5.2.4.1 General Use Case Description

Void.

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 costumers.

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

5.2.4.3 Scenario

An operator willing to update its network with a new technology rarely fully deploys the network at once because of the CAPEX required. Usually the coexistence of two mobile radio systems using different technologies is handled by leaving enough frequency guard bands between their radio channels or by using a less aggressive frequency reuse scheme hence longer guard distances. This inevitably wastes more resources than necessary, due to the required frequency or spatial margins. REM might be used to automatically find and set the optimum parameters (frequency reuse factor, guard band interval, etc.) (see Figure 10).

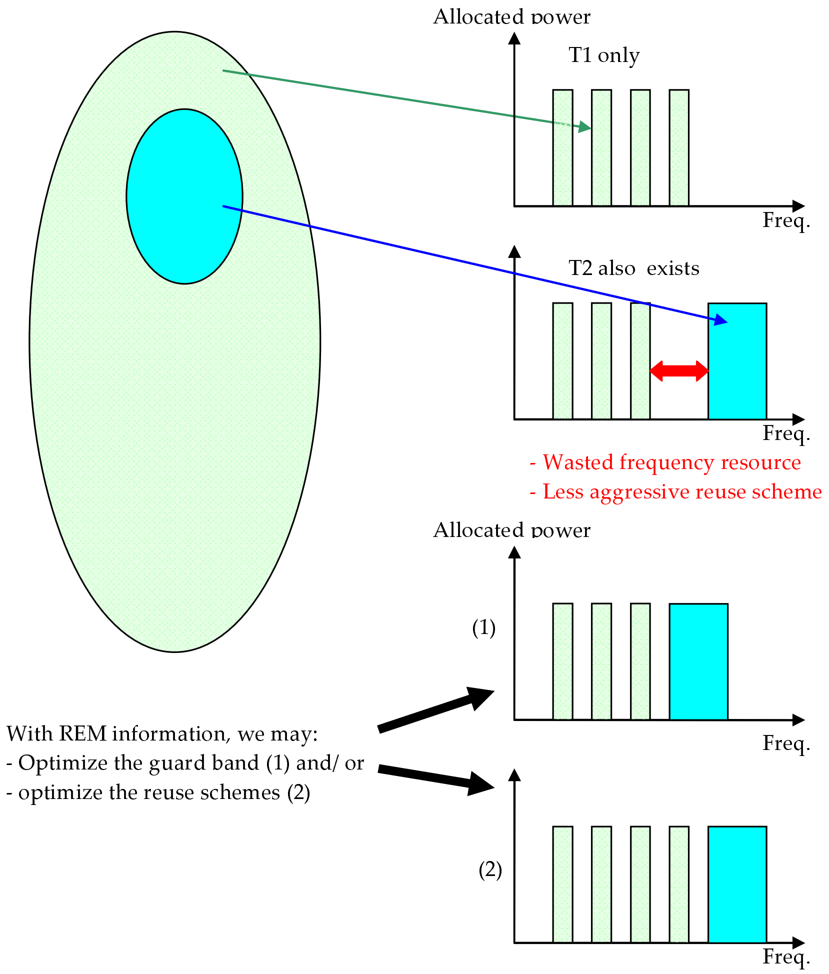

Figure 10: Introduction of a new radio access technology

5.2.4.3.1 Use of REM for interference mitigation

As introduced in the previous clause, one of the challenges of deploying a new mobile system is to extend the coverage for a new technology in an area already covered by a former radio access technology without negatively impacting the global service in terms of QoS due to potential introduction of harmful interferences. To solve the problem, a classical solution consists of having a sufficient frequency separation between both technologies at the same geographical location, which is a worst case approach and which unfortunately results in a global waste of resources.

This particular Use Case investigates the use of REM information to optimize the frequency resources when a mobile operator implements a new LTE base station in an area already covered by an existing technology with potential interfering links as shown in Figure 11.

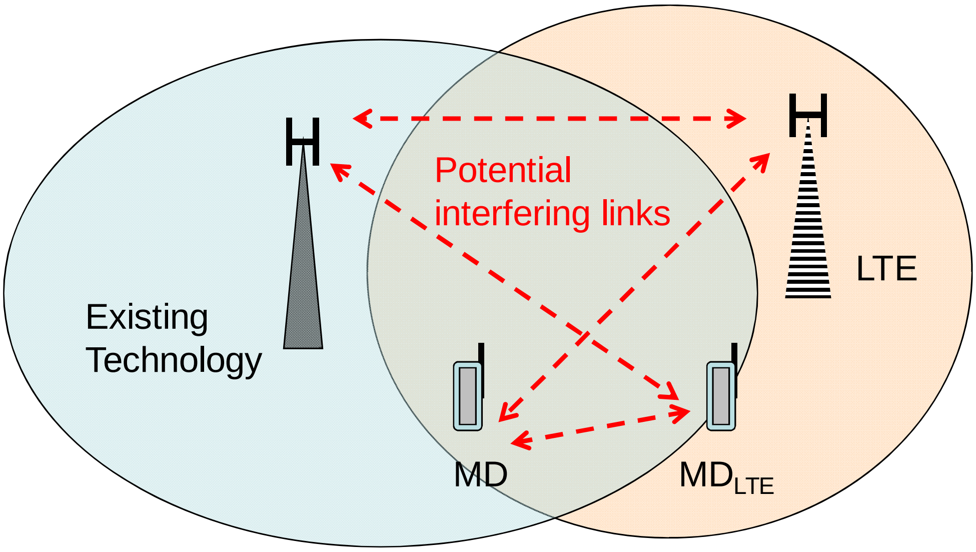

Figure 11: Potential interference links

If it is decided to optimize the resource allocation, hence reduce the frequency separation between both technologies, potential interference situations will occur and it will be necessary to:

1) identify these situations; and

2) mitigate their impact.

These 2 actions can be achieved by an appropriate use of the REM concept: Indeed, the REM database gives the geo-located coverage information in terms of power level for the wanted signals, but the REM database can also contain the geo-located interference level called interference maps.

Assuming a reliable knowledge of the interference map, it is possible to get the interference profile on each LTE sub-carrier (or group of sub-carriers) and derive the corresponding interference maps as a function of frequency.

Figure 12 shows an example where the interference maps indicate the areas where LTE receiver may operate without being interfered.

Hence, to avoid interference situations, the radio resource allocation (here in terms of LTE sub-carriers) can be managed and optimized, on the basis of:

- the geographical location of the potentially interfered LTE receiver, and
- the knowledge of the interference power level at its location.

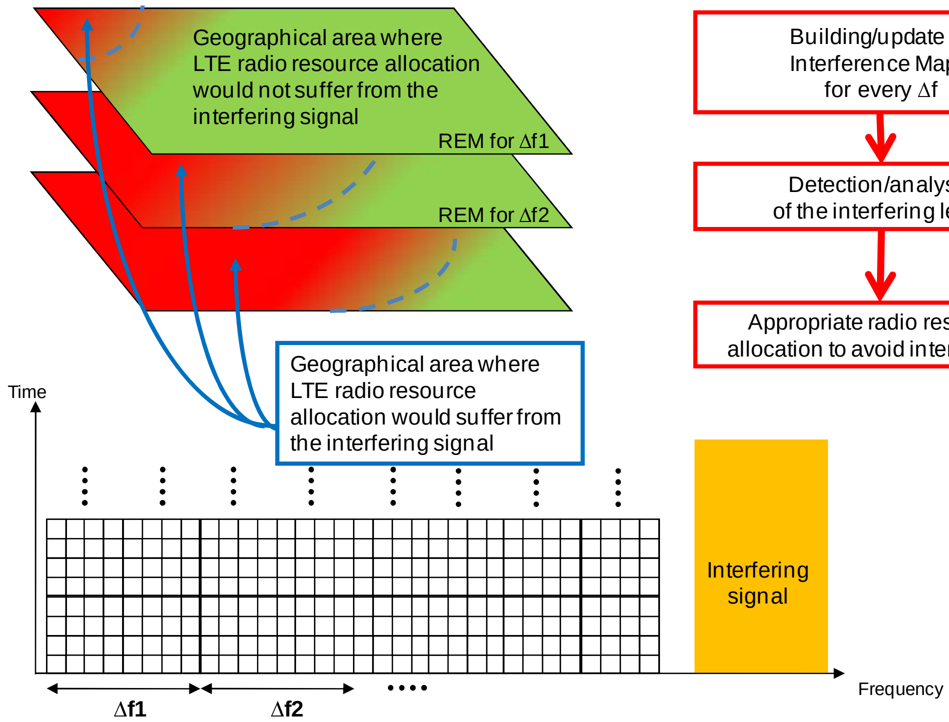

Figure 12: Example of LTE resource allocation as a function of the interference level based on REM information

As a result of the process, REM provides an adaptable mean to optimize the amount of spectrum owned by a mobile operator, improving efficient use of the spectrum.

A relatively close situation to this use case is the application to solve the problem of interference coming from radio systems that are not managed by the operator such as the systems that are operated in adjacent bands. One application example could be the coexistence in adjacent bands between FDD LTE system and radar systems where LTE Mobile Device operated in the highest part of 2 620 - 2 690 MHz band, could suffer from harmful interference due to spurious or out of band radar emissions: using the REM interference information to appropriately choose LTE resources is a way to improve the situation: the allocation of LTE sub-carriers in the area where high level of interference are detected can be carried out to avoid the subcarriers in the highest part of the FDD LTE band.

5.2.4.4 Potential System Requirements

From the Use Case scenarios presented above, the following system requirements can be drawn:

REQ_01 Mobiles Devices have the capability to perform geo-localized measurements.

REQ_07 Mobile Devices are multimode (T1 &T2).

REQ_08 Mobile Devices are capable of Vertical Hand Over (VHO) between RAN1 and RAN2.

5.2.5 Vertical Handovers Optimization

To speed and enhance the performance of Inter-Frequency/ Inter-RAT (vertical) Handovers: minimization of inter-Freq/inter-RAT measurements.

5.2.5.1 General Use Case Description

This scenario aims to enhance the performance of vertical handover (VHO) in multi-frequency and multi-technology RANs. The entity responsible for HO (RNC, MME etc.), denoted here as the "HO Manager", will use coverage information given by the REM to order a "blind" handover to the mobile. The mobile does not need to perform inter-frequency/inter-technology measurements to check the coverage on target system as this information is available via the REM. This will decrease the battery consumption and in systems with continuous transmission (UMTS/FDD), this will avoid the degradation of the transmission quality due to compressed mode.

5.2.5.2 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.

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

5.2.5.3 Scenario

In cases where the HO manager described in clause 5.2.5.1 may trigger a VHO (e.g. for reasons such as load balancing, mobility to/from pico-cell/macro-cell coverage) and when the HO manager can determine whether or not target cells provide appropriate coverage, there is no need for handover measurements: coverage information can be maintained and provided by REM and decisions on VHO can be taken by the HO manager.

The following assumptions are made:

1) The coverage information on the target frequency/technology is available via the REM.

2) The coverage information is associated to a reliability metric. The reliability metric is an attribute of the REM information that evaluates the error of the metric estimation in a given location.

3) The MD has geo-location capability or the network is able to determine the location of the MD with appropriate accuracy.

4) By combining MD location information and REM information, there is a guarantee of coverage with respect to the target cell, taking into account the reliability metrics mentioned in assumption (2) above.

The situation is depicted in Figure 13.

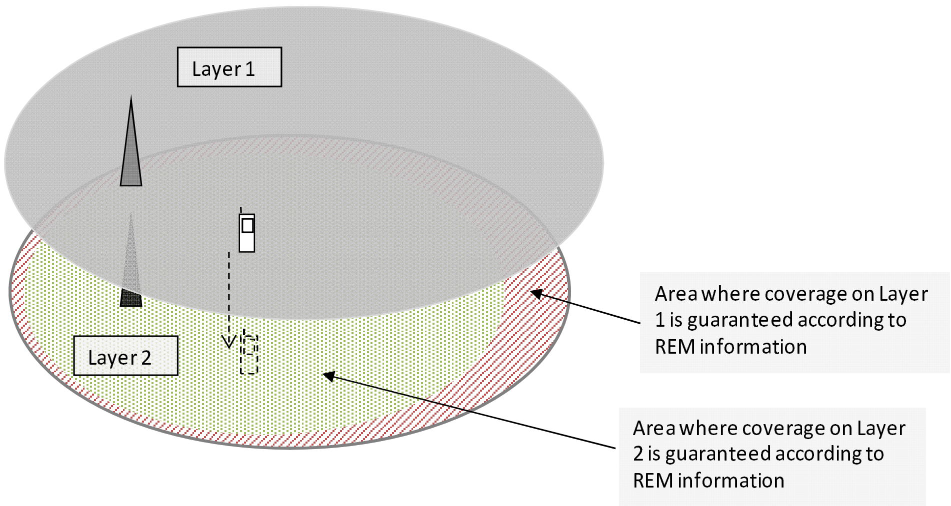

Figure 13: Scenario of vertical HO based on REM information

As the location of the MD is in the green area where the coverage is guaranteed on Layer 2, then a vertical HO can be triggered to Layer 2. The two layers can be different RATs or different frequencies of the same RAT.

Examples of situations where this scenario is applicable are shown below in Figure 14. In particular, for the case where one cell covers another cell and the MD is moving out of coverage of the smaller cell, blind handover can be done directly with the benefit of MD power saving and without the risk of handover failure.

In Figure 14, cell 1, 2, 3 and 4 are provided by different frequencies and cell 1 and cell 2 are both provided by the same multi standard base station.

- For a terminal moving from cell 2 to cell 1 in Figure 2, e.g. handover from a HSPA/LTE cell to its co-sited GSM cell.

- For a terminal moving from cell 3 to cell 2 in Figure 2, e.g. from picocell to macrocell where the picocell is inside the coverage area of macrocell.

For the more general case if the mobile can be located in some way by the network (without requiring the mobile consume battery power), the REM can assist in a handover (e.g. for a terminal moving from cell 2 to cell 4 in Figure 14) decision by combining mobile location and coverage map which is stored in the REM and the need for measurements (e.g. RSRP) for inter frequency or inter RAT HO can be therefore avoided (normally the terminal is required to determine when the target cell signal strength is above some pre-defined threshold and when current cell signal strength has fallen below some pre-defined threshold).

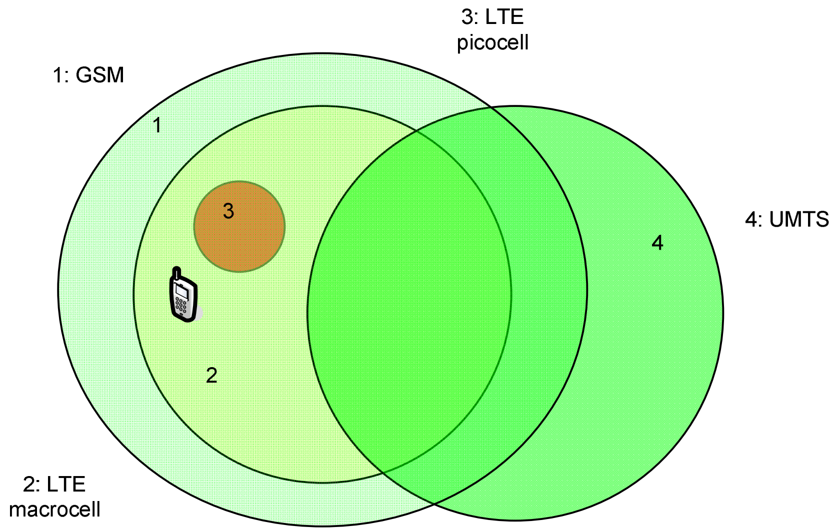

Figure 14: Scenarios for mobile's handover between different cells

5.2.5.4 Information Flow

This clause presents a high level information flow for the vertical hand over.

The new VHO procedure will consist of the following steps identified in Figure 15.

1) The HO manager decides to trigger a vertical HO for a given MD.
2) The HO manager obtains location information related to the MD:
    i) either from geo-location information provided by the MD; or
    ii) from the network-provided coverage information.
3) On the basis of this location information, the HO manager obtains from the REM coverage information and reliability metrics related to operation on the new frequency and/or RAT of target cells.
4) The HO Manager evaluates the coverage on the target system based on coverage information and reliability metrics:
    i) If the coverage is determined to be appropriate then the HO Manager executes the HO.
    ii) If the coverage is determined not to be appropriate then the HO Manager determines that VHO is not to be used and requests the MD to perform inter frequency and/or inter RAT measurements.

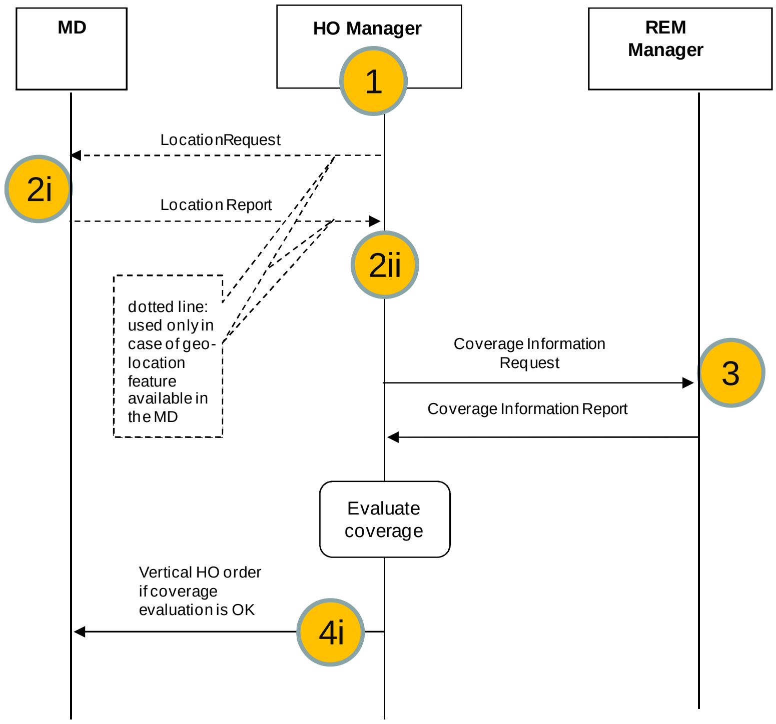

Figure 15: Vertical Handover Procedure based on REM information

5.2.5.5 Potential System Requirements

From the Use Case scenarios presented above, the following system requirements can be drawn:

REQ_01 Mobiles Devices have the capability to perform geo-localized measurements.

5.2.6 Intra-System Handovers Optimization

5.2.6.1 General Use Case Description

The knowledge of the radio environment is used so as to take optimal HO decisions.

Currently, in most cellular systems, handovers are said to be "mobile-assisted". It means that mobile terminals provide the serving BS with measurements of the field strength from neighbouring BSs. Based on these measurements, the BS decides whether to perform the HO or not. This has the following main drawbacks:

- It requires the mobile to maintain a list of valid neighbouring BSs.
- It causes the mobile to periodically monitor neighbouring signals which consumes resources.
- Due to its local point of view, the mobile is not able to cope with tunnel effects which results in a ping pong HO.
- It requires parallel RF chains (and therefore it is costly) to do sensing during transmission. Hence the current generation mobiles are not capable of doing sensing and transmission simultaneously.
- During communication, the mobile is not able to reconfigure its RF chain for sensing different frequency bands, while next generation systems are likely to be frequency-agile over several bands.

5.2.6.2 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.

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

5.2.6.3 Scenario

Figure 16 depicts two scenarios for intra-system handover optimization.

Scenario 1:

- There is no interest in performing a HO for MS1 from the outdoor BS to the indoor BS.
- There is interest in performing a HO for MS2 from the outdoor BS to the indoor BS.

A REM could avoid an unnecessary HO of MS1 to the indoor BS and allow MS2 to be handed over to the indoor BS. The MD could report its location to REM via the mobile network or, if network based positioning methods are used, then the MD location could be reported to REM by the mobile network.

In addition, the satellite and cellular technology based localization techniques, short-range device e.g. a NFC (Near-Field-Communication) device or Short-range RFID device, could be used in alternative for determining if the mobile is inside the building when the mobile terminal is equipped with the short range communications capability. Short-range devices can be sited such that only indoor mobile terminal can interact with them when the user enters or leaves the building.

For example, a short range device could be embedded into (or co-sited with) an entrance control module for a building and mobile MS2 could interact with the entrance control module/short range device within a range of several centimetres. Access related information such as indoor cell ID or building ID can be transferred to MS2 by short range device and in turn used by MS2 in handover procedure (MS2 sends indoor cell ID as target cell ID to source cell to assist handover decision). When the access related information is the building ID, REM needs to map the building ID to the indoor cell ID and communicates with the HO manager to request HO to the indoor cell. If the access related information is not provided then handover to the indoor cell would not occur, so MS1 will not be able to handover to indoor cell.

NOTE 1: The short range device could be used as one alternative method to determine whether MD is outdoor or indoor of the building. Limited access related information (e.g. indoor cell ID) is transmitted from this device to the MD to help the localization; however this device is not intended to be used as AP for data communication as the communication range between the device and the mobile is typically only several centimetres. The data communication service is still provided by indoor BS once the MD is determined as indoor. Conventionally the cell ID is broadcasted by the AP, instead the use of short range device is to transmit the cell ID only to the mobile allowed and determined to be "in the building".

NOTE 2: The short range communication device could be regarded as part of the indoor BS where there is physical/logical link between this device and indoor BS.

NOTE 3: Wi-Fi could also be used for determine if a MD is "in the building".

Scenario 2:

Mobiles are travelling together on a transportation system, e.g. bus, light-rail and train. On the same vehicle, mobiles will experience similar radio environment and handover characteristics. The REM can use mobile/network based geo-localization information or information provided by onboard short range device (e.g. the mobile's interaction with onboard NFC capable toll collection machine) to determine which mobiles are on the same vehicle and to notify a handover manager. Also the REM can provide the mobiles' location/velocity information, together with radio environment information related to the vehicle's route to the handover manager. The handover manager can take action to optimize the handover performance based on the information provided by REM.

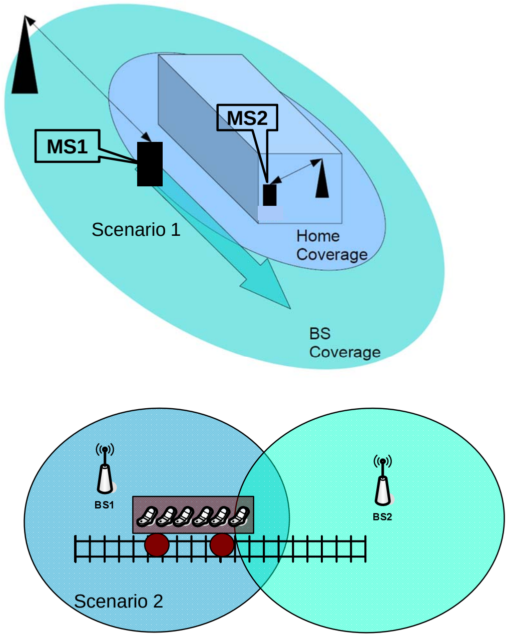

Figure 16: Intra-system handover

5.2.6.4 Information Flows

This clause presents the high level information flows for the two scenarios above described.

The information flow for scenario 1 can be described as follows (see Figure 17).

1) Mobile Device (MS2) or the network reports mobile location information to REM (As depicted in case "a" in Figure 17); short-range device can also be used to determine that MS2 is inside a building sending access related information to MS2 (As depicted in case "b" in Figure 17).

2) REM determines mobiles' location and sends notification (information such as target cell ID) to the handover manager. In the LTE system the handover manager is inside source BS and for UMTS the handover manager is in the RNC.

3) Handover procedure: two HO procedures (a) and (b) can be envisioned:

    a) handover manager can request the mobile to handover to the indoor BS via a direct handover command (without mobile assistance); or

    b) access information such as target cell identifier can be sent, via short range device, to the mobile so that the mobile can use the access information to assist handover to the indoor BS. This access information is reported to the Handover Manager to make the HO decision and send the HO command to the BS.

4) After successful handover to the indoor cell, the target BS reports the MD location update information (MD state information) to the REM.

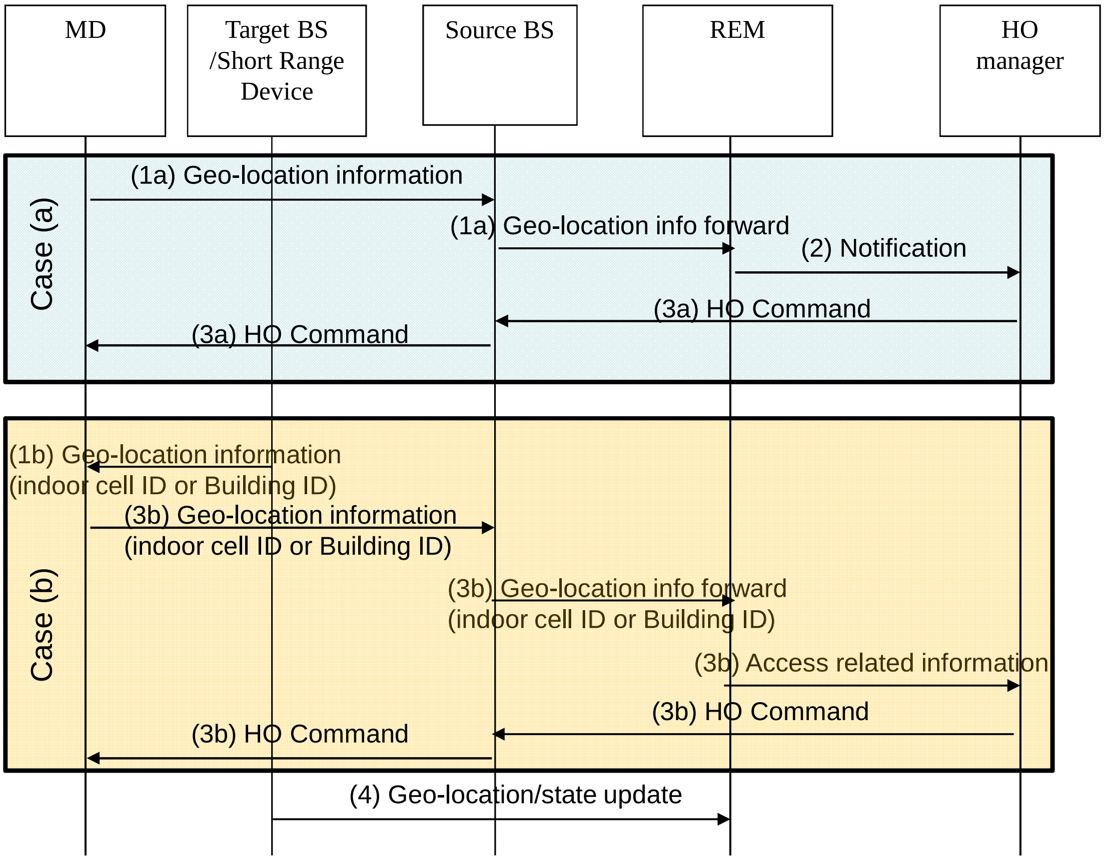

Figure 17: Information flow for scenario 1

The information flow for scenario 2 can be described as follows (see Figure 18):

1) Mobile or network reports mobile location information to REM; short-range device can also be used to determine that a mobile is onboard the vehicle, e.g. through providing vehicle ID to the mobile.

2) REM sends notification to handover manager on which mobiles are on the same vehicle, together with information as mobiles location/velocity and radio environment information along the vehicle moving route.

3) The handover manager can take actions to optimize the handover performance depending on the information provided by REM:

   a) The preparation of the target cell (in the target BS) can be done in advance for the mobiles.

   b) Handover manager can send different handover timing related parameters to mobiles so as to avoid handover signalling congestion.

4) If handover failure occurs for some of the mobiles, the handover manager can take action to improve future handover success rates(i.e. mobiles handover at the same location in future):

   a) Handover manager can control mobiles in order to perform advanced/delayed handover if previous handover failure was caused by too-late/too-early handover.

   b) Handover manager can assign different values of handover related parameters to different mobiles. The handover performance of the mobiles can be recorded and reported to REM to determine optimal values for the parameters.

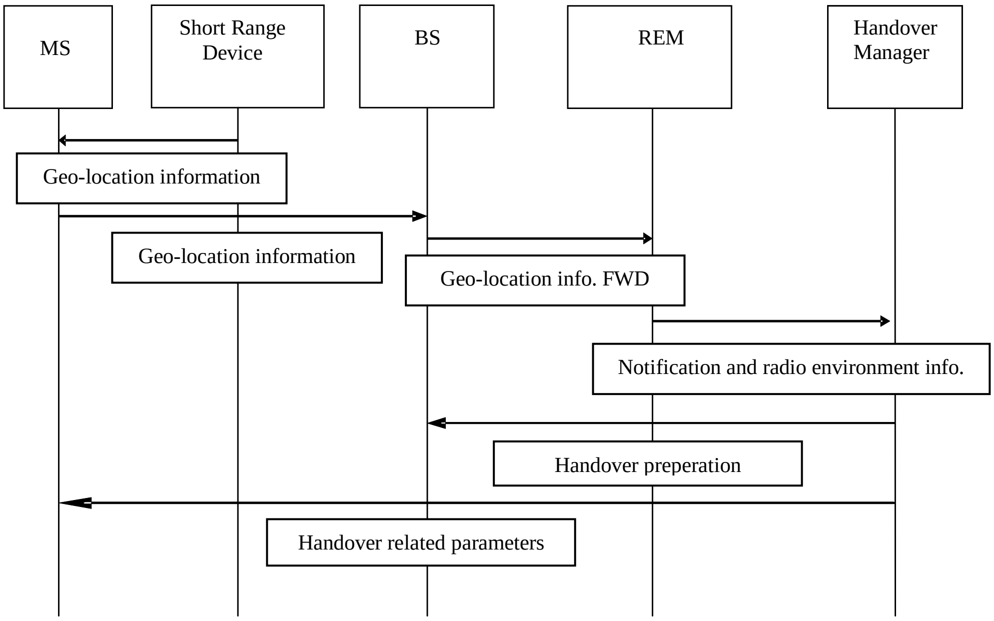

Figure 18: Information flow for scenario 2

5.2.6.5 Potential System Requirements

From the Use Case scenarios presented above, the following system requirements can be drawn:

REQ_01 Mobiles Devices have the capability to perform geo-localized measurements.

6 Technical challenges

6.1 Collection of the REM information

REM system collects the radio environment information at a given time in a given geo-location. The collection of such information is influenced by many aspects:

- Selection of the MCDs for the REM system:
  - RAN nodes (such as Base station, Relay Node)
  - Terminals
  - Sensors
- Movement of terminals
- Unbalanced terminal density between areas
- Dependency on the measurement capabilities of terminals

6.2 Processing and exploitation of the REM information

After the collection of the radio environment information, REM processes the information to assist radio resource management decisions (e.g. handovers, system optimization, etc.). The following issues need to be taken into account to perform the radio resource management decisions.

- When REM is used for real time decisions in RRM algorithms (e.g. handovers), the use of the REM information (e.g. interpolations, etc.) instead of performing real measurements, should not degrade the performance of the considered algorithm.

- Since update of the REM information depends on the movement/position of the measuring terminals, geo-location accuracy (the position can be retrieved by some network algorithms or satellite based algorithms) should always be taken into account.
- The different measurement capabilities of the terminal should always be taken into account when the measurements are processed.
- The models used in the information processing (e.g. propagation, fading, shadowing, pixel dimension, etc.) should not degrade the quality of the radio resource management decision to be taken.
- The tradeoff between the information processing results (e.g. interpolation between two points) and the related elaboration time (e.g. number of interaction to obtain the result) should be taken into account.

6.3 Measurement overhead impact to interface capacity

To collect the REM measurement information, a certain amount of measurement information should be reported to the REM system. The following items should be considered in the reporting:

- The tradeoff between the quantity of the measurement information reported and signalling overhead.
- Limited interface capacity.
- Depending on the REM implementation (centralized or distributed), impacts on interfaces in term of capacity and delays should be taken into account.

6.4 Impact on the MCD

New requirements may be essential to support the REM, and the following aspects should be taken into account. The aspects should be considered separately for different kind of MCDs, e.g. terminal, RAN nodes, sensor:

- Memory impact
- Processing capacity
- Power consumption
- Capabilities of the devices, e.g. geo-location

7 Conclusion

In the present document, Use Cases are suggested for building and exploitation of the REM in the context of the intra-operator scenarios as listed below:

- In-band Coverage/Capacity Improvement by Relays
- Self-Configuration and Self-Optimization of Femto-Cells
- System Optimization
- Introduction of New Radio Access Technologies
- Vertical Handovers Optimization
- Intra-System Handovers Optimization

From the different Use Cases, the following potential System Requirements can be identified:

- REQ_01: Mobile Devices have the capability to perform geo-localized measurements
- REQ_02: Mobile Devices can report their location information with sufficient precision

- REQ_03: BSs and relays have a connection with the REM
- REQ_04: Relays are agile enough in configuration modifications (power adjustment, beamforming capability, etc.)
- REQ_05: The femto-cells can communicate with the REM
- REQ_06: Algorithms need slowly varying measurements
- REQ_07: Mobile Devices are multimode
- REQ_08: Mobile Devices are capable of vertical Hand Over (VHO) between RANs

In general, further and more elaborated requirements will be drawn in the framework of the system requirements activities.

History

Document history		
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