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Technical Report

Reconfigurable Radio Systems (RRS); Use Cases for building and exploitation of Radio Environment Maps (REMs) for intra-operator scenarios

Reference

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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).

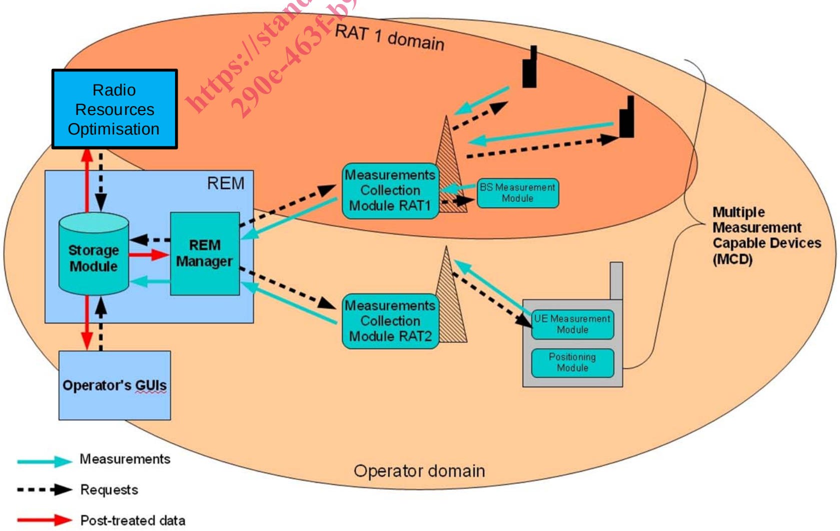

Figure 1: Generic REM description in intra-operator domain

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.

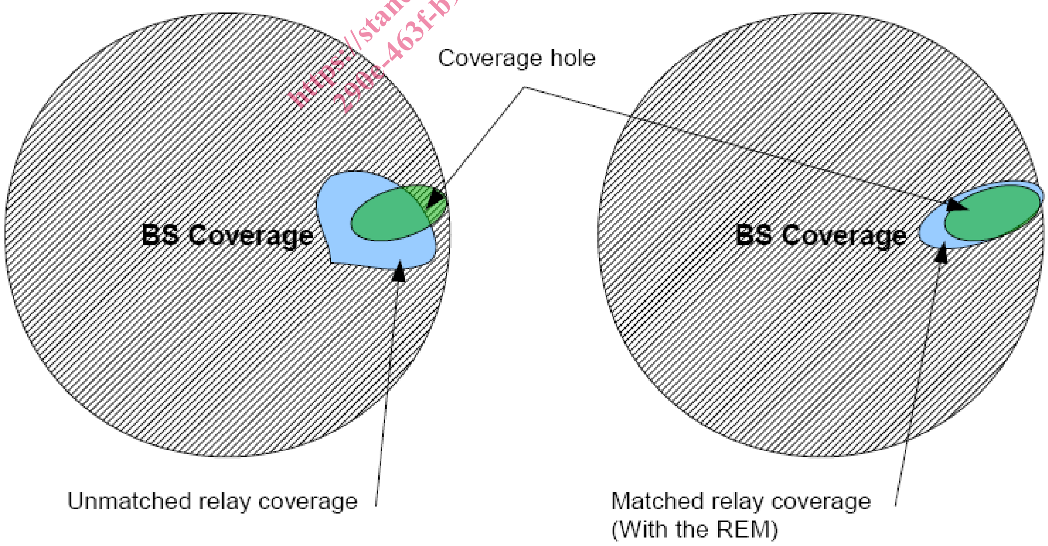

Figure 2: Relay scenario

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:

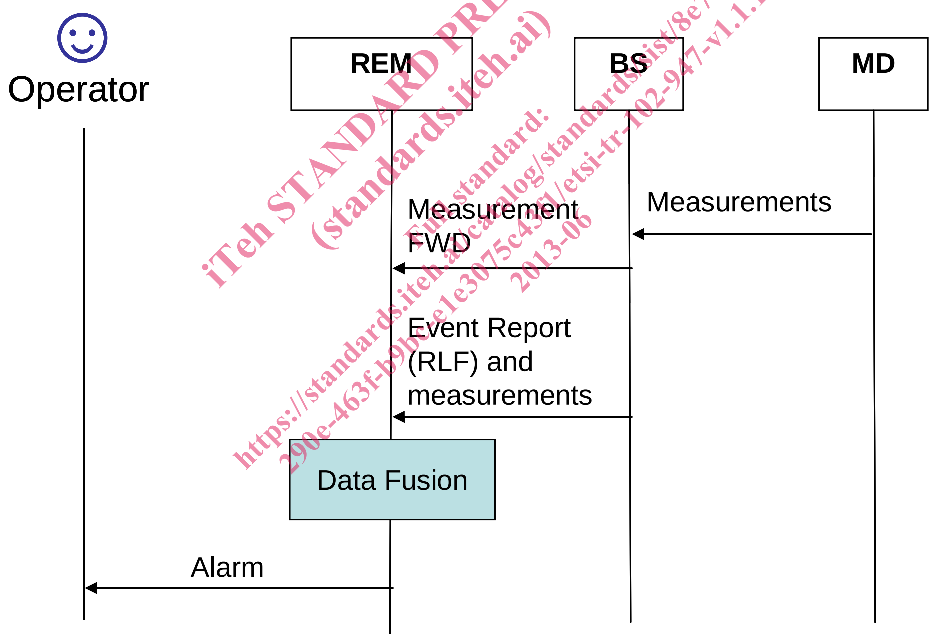

Figure 3: Phase 1 information flow

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.