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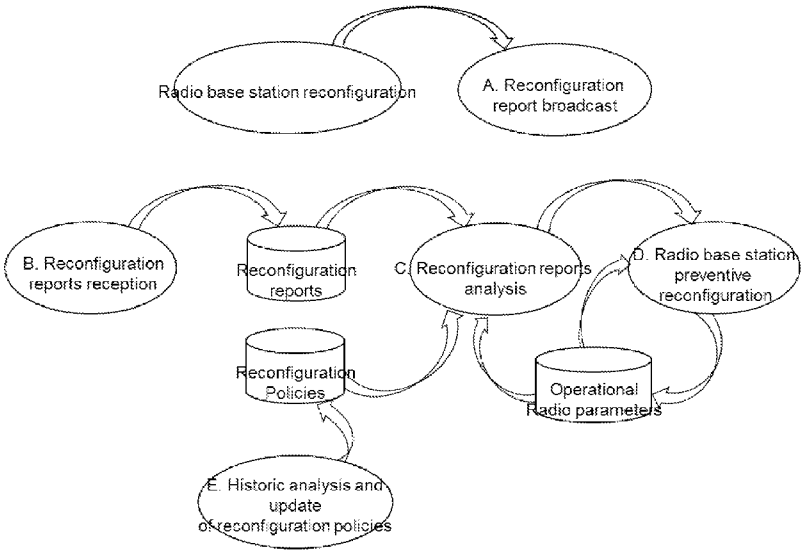
(54) Title: PREVENTIVE RECONFIGURATION OF A SECONDARY USER RADIO BASE STATION

Figure 3.



(57) Abstract: The present invention enables to preventively reconfigure, by a spectrum manager connected to a network of spectrum managers, the channels used for transmission and /or reception by a radio base station of a secondary user, so as to avoid interferences with primary users.

Preventive reconfiguration of a secondary user radio base station

ABSTRACT

The present invention enables to preventively reconfigure, by a spectrum manager connected to a network of spectrum managers, the channels used for transmission and / or reception by a radio base station of a secondary user, so as to avoid interferences with primary users.

BACKGROUND

In order to maximize usage of spectrum, new access models have been defined, that enable primary users to share spectrum with secondary users. For example, the Federal Communications Commission specified how to share the 3.5 GHz band among primary users and secondary users (in FCC 15-17 document). A subset of this band is reserved in priority for licensed usage, while the remaining part is reserved exclusively for unlicensed usage.

When a primary user is detected in a given geographical area, secondary users are required to cease using the spectrum on the frequencies used by primary users. One possible way to detect primary user's emissions is to deploy a network of RF sensors.

Figure 1 shows an architecture for detecting a primary user according to the state of the art. A multiplicity of RF sensors RFS is deployed over a geographical area. A spectrum manager (e.g., a SAS server in the case of the 3.US 5GHz band) is notified when those RF sensors detect RF signals from a primary user. The spectrum manager then reconfigures the network of secondary users (e.g., switches off radio base stations or requests radio base stations to reduce their transmission power), in order to prevent interferences with primary users.

SUMMARY

In current solutions for spectrum sharing which are based on the detection of RF signals from primary users, reconfiguration of the radio frequencies used by radio base stations of secondary users is performed at the time of the detection, upon detection of RF signals from a primary user.

In those solutions, for privacy reasons, it is not allowed to store information collected by the RF sensors related to the usage of radio frequencies by primary users.

As a result, reconfiguration of the radio frequencies used by radio base stations can only be performed in a reactive manner, leading to the following drawbacks:

- This reactive approach introduces a delay between detection of the primary user and completion of the reconfiguration of radio base stations, during which mutual interferences may impact both primary and secondary users.

- This reactive approach may result in a bad user experience for users connected to radio base stations of secondary users, since there is no time to gracefully transition those users to other frequencies for transmission or reception.

This invention provides means to overcome those limitations, by exploiting the information on channels reconfiguration, broadcasted by other radio base stations, in order to preventively initiate a reconfiguration, while protecting privacy of primary users.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows an example of architecture according to the state of the art.

Figure 2 shows an example of architecture on which this invention is applicable.

Figure 3 describes the steps to determine when to preventively reconfigure a radio base station according to the present invention.

Figure 4 shows an example of Reconfiguration Report.

Figure 5 shows an example of Reconfiguration Policies.

Figure 6 shows an example of preventive reconfiguration according to this invention.

DESCRIPTION OF THE INVENTION

Architecture of the solution

Figure 2 illustrates an example of architecture on which the present invention is applicable.

This figure shows a deployment of radio base stations, labeled ST, belonging to the same or different operators. Each radio base station is capable of communicating over a radio interface, for example with end user devices, labeled D1 to D4.

RF sensors RFS, capable of sensing radio frequencies and detecting radio frequency signals, may be deployed within the proximity of radio base stations ST, collocated with radio base stations ST, or embedded within radio base stations ST. Each RF sensor is connected to a spectrum manager SM.

Instead or in addition to RF sensors RFS, sensing data retrieved by a third party sensor network (e.g., the ESC - Environmental Sensing Capability - in the case of the US 3.5GHz band) could be provided to spectrum managers.

The means by which a spectrum manager is notified about the detection of a primary user is outside the scope of this invention.

The spectrum manager provides radio base stations ST with the allowed frequencies for transmission and reception. Spectrum managers are connected with each other and capable of exchanging information, for example through an IP network. The information exchanged among spectrum managers is used to determine which frequencies to allocate to each radio base station ST.

Figure 2 shows an example of architecture where spectrum managers are distributed. In that case, each spectrum manager is responsible for allocating frequencies to one single radio base station ST. The spectrum manager could be physically collocated with or embedded within the base station ST.

Communication between spectrum managers and RF sensors can be performed using a direct physical link, or wirelessly (e.g., using Wi-Fi or LTE). Some spectrum managers may be connected with multiple RF sensors. Conversely, some spectrum managers may be connected with no RF sensor.

Spectrum managers may communicate with radio base stations through an entity managing the network of radio base stations ST. In the case of a 3GPP network, this entity can be the Network Manager. This is illustrated in Figure 1 by SM1 communicating with ST1 through interfaces [C2] and [C3]. Alternatively, spectrum managers may communicate directly with radio base stations, for example through an IP network. This is illustrated in Figure 2 by SM2 and SM3 communicating with ST2 and ST3 via interface [C1].

Other radio base stations not managed by a spectrum manager, or whose spectrum managers are not connected to the spectrum managers of stations ST1 to ST3, labeled FST in the figure, may be deployed within the same geographical area. Devices communicating with those radio base stations, labeled FD1 to FD4 are also shown in this figure.

Detailed steps of the method to preventively reconfigure a radio base station

Figure 3 illustrates the steps performed in order to preventively reconfigure a radio base station according to the present invention.

The following 5 operations are performed at each radio site:

A. Reconfiguration Report broadcast

B. Reconfiguration Reports reception

C. Reconfiguration Reports analysis

D. Radio base station preventive reconfiguration

E. Update of Reconfiguration Policies

The following sections describe those operations in more details.

A. Reconfiguration Report broadcast

Every time a reconfiguration of the radio base station associated with a spectrum manager is performed by a spectrum manager, a Reconfiguration Report is created by this spectrum manager, except in the case of a preventive reconfiguration performed according to this invention.

This reconfiguration may be the result of the detection of a primary user in the vicinity of the radio base station associated with the spectrum manager. Alternatively, this reconfiguration may be the result of a request from the radio base station for more bandwidth for transmission or reception, or the result of a decrease in bandwidth resource needs at the radio base station.

A reconfiguration report may contain, for example:

i. The list of channels deallocated by the spectrum manager to the radio base station,

ii. The list of channel newly allocated by the spectrum manager to the radio base station,

iii. A time stamp, indicating the time of the reconfiguration report creation,

iv. The location of the radio base station reconfigured by the spectrum manager, (e.g., latitude, longitude, and height).

Figure 4 shows an example of Reconfiguration Report. In this example, following the detection of a primary user in the vicinity of the radio base station, channels 1, 3, and 4 were deallocated, and channels 6 and 7 were allocated to the radio base station.

When spectrum managers associated with radio base stations from different operators are connected to the same network of spectrum managers, some information provided in Reconfiguration Reports may be encrypted (e.g. using the public key of an operator's certificate) so that it is only accessible (e.g. using the private key of an operator's certificate) to spectrum managers associated with radio base stations of the same operator.

Once created, the Reconfiguration Report is broadcast over the network of spectrum managers and stored locally.

B. Reconfiguration Reports reception

Each spectrum manager receives all the Reconfiguration Reports that are broadcasted over the network that connects them.

C. Reconfiguration Reports analysis

This step is initiated every time a Reconfiguration Report is received.

During this step, the spectrum manager uses the information included in Reconfiguration Reports, as well as the current operational parameters of the base station stored in the spectrum manager (e.g., currently allocated channels), in order to determine whether the radio base station needs to be preventively reconfigured, according to the Reconfiguration Policies stored at the spectrum manager.

The Reconfiguration Policies provide a set of criteria that must be fulfilled in order to initiate a preventive reconfiguration.

Minimum Received Reconfiguration Reports

When a high number of Reconfiguration Reports indicate that a given channel has been deallocated, there is a high probability that this channel has been preempted by a primary user. This primary user may be mobile and therefore, potentially move within proximity of the radio base station connected to the spectrum manager that received those Reconfiguration Reports.

The parameter "Minimum Received Reconfiguration Reports" indicates the minimum of Reconfiguration Reports that must be received, indicating that a given channel has been deallocated, in order to initiate a preventive reconfiguration.

The preventive reconfiguration may consist in requesting the radio base station not to use the given channel and to allocate a new channel to the radio base station, if such channel is available.

Alternatively, the spectrum manager may simply send a notification to the radio base station indicating that the given channel may be deallocated in the near future. The radio base station may use this information, for example, to give less priority to this channel when allocating bandwidth for downlink or uplink. This enables to minimize the degradation of quality of experience in case a primary user using this channel moves within the vicinity of the radio base station. A validity period may also be provided by the spectrum manager in the notification, or pre-configured at the radio base station, indicating the duration during which the radio base station should take into account the received notification.

The farther a primary user is located from a given radio base station, the smaller is the probability that this primary user will move within the proximity of this radio base station. Therefore, the "Minimum Received Reconfiguration Reports" parameter may vary according to the distance. Alternatively, in order to take into account the impact of the environment in the estimation of the propagation range of primary user RF signals the "Minimum Received Reconfiguration Reports" may vary according to path loss.

Maximum Distance

A maximum distance between two radio base stations may be configured, beyond which two Reconfiguration Reports received from spectrum managers associated with those base stations are considered not related to the same potential primary user.

Instead of a maximum distance, a maximum path loss may be defined, enabling to take into account the impact of the environment in the estimation of the propagation range of primary user RF signals.

Density of radio base stations deployment

The "Minimum Received Reconfiguration Reports" parameter may vary according to the density of the deployment of radio base stations. When a small number radio base stations are deployed over a given area, the number of Reconfigurations Reports indicating that a given channel has been deallocated that must be received in order to initiate a preventive reconfiguration is smaller than when a high number of radio base stations is deployed over a given area.

Validity Period

A parameter defining the validity period of received Reconfiguration Reports, beyond which Reconfiguration Reports are no more used by the spectrum manager to determine whether to preventively reconfigure the radio base station associated with this spectrum manager could be configured in the Reconfiguration Policies.

Example of Reconfiguration Policies

Figure 5 shows an example of Reconfiguration Policies.

The "Minimum Received Reconfiguration Reports" indicates the minimum number of Reconfiguration Reports that must be received on a given channel to initiate a reconfiguration. This parameter depends on the distance and the density of base stations.

In this example, the first column indicates that if the density of the network deployment is 10 radio base stations per kilometer square, at least 15 Reconfiguration Reports must be received from Spectrum Managers associated with radio base stations located within less than 10 kilometers, in order to initiate a reconfiguration.

Similarly, the 5th column indicates that if the density of the network deployment is 20 radio base stations per kilometer square, at least 35 Reconfiguration Reports must be received from spectrum managers associated with radio base stations located within less than 50 kilometers, in order to initiate a reconfiguration.

The "Maximum distance between Reconfiguration Reports" parameter indicates that the distance between each radio base stations whose reconfiguration was reported must be less than 30 kilometers.

The "Validity period" parameter indicates that the Reconfiguration Reports must be received within a 10 seconds time window.

D. Radio base station preventive reconfiguration

When determining in step C that some channels should be preventively deallocated, the spectrum manager identifies whether alternative channels are available. The spectrum manager then sends a request to the radio base station indicating the channels that are deallocated and the newly allocated channels.

The spectrum manager may alternatively simply send a notification to the radio base station including the list of channels allocated to the radio base station that are more likely to be deallocated than the others channels allocated to the radio base station.

Figure 6 shows an example of reconfiguration of radio base stations according to the current invention.

In this example, SM1, SM2, and SM3 send a Reconfiguration Report indicating that channel 1 is deallocated, and SM1, SM3 and SM8 send a Reconfiguration Report indicating that channel 2 is deallocated.

SM4 receives and analyzes those reports using its Reconfiguration Policies. According to those policies, at least 3 Reconfiguration Reports need to be received, from spectrum managers associated with radio base stations located within a maximum of 3 kilometers from each other, in order to initiate a preventive reconfiguration.

SM1, SM2 and SM3 are located within 3 kilometers from each other. As a result, the criteria of the Reconfiguration Policies are fulfilled for channel 1 and SM4 initiates a preventive reconfiguration on this channel.

On the other, hand, the radio base station associated with SM8 is located at more than 3 kilometers from other radio base stations associated with spectrum managers reporting a reconfiguration on channel 2. Therefore, even though 3 Reconfiguration Reports were received for channel 2, SM4 does not initiate a preventive reconfiguration for this channel.

E. Update of reconfiguration policies

Spectrum managers may store the history of preventive reconfigurations performed according to the present invention. Using this information, spectrum managers may verify whether a given preventive reconfiguration was relevant or not, by checking whether they received a notification from a RF sensor or an entity managing a network of RF sensors about the presence of a primary user on the channel on which they requested a preventive reconfiguration, within a given period of time. This period of time may correspond to an estimation of the maximum time required for a primary user, whose presence is assumed to be nearby the location provided in received Reconfiguration Reports, to reach the radio base station.

If based on this analysis, the ratio of reconfigurations that were relevant is low, the spectrum manager may modify the parameters in the Reconfiguration Policies to limit the amount of preventive reconfigurations. For example, the "Minimum Received Reconfiguration Reports" parameter may be increased.

Conversely, if based on this analysis, the spectrum manager is often notified about the presence of a primary user within the proximity of the radio base station to which it is associated, without having anticipated a preventive reconfiguration, the spectrum manager may modify the parameters in the Reconfiguration Policies to increase the amount of preventive reconfigurations. For example, the "Minimum Received Reconfiguration Reports" parameter may be decreased.

CLAIMS

What is claimed is:

1) A collaborative method to preventively reconfigure, by a spectrum manager connected to a network of spectrum managers, the channels used for transmission and / or reception by a radio base station of a secondary user, composed of the following operations:

   i. Creating and broadcasting a reconfiguration report at said spectrum manager, upon reconfiguration of the radio base station connected to this spectrum manager, excluding when this reconfiguration is a preventive reconfiguration according to the present invention,

   ii. Receiving, at said spectrum manager, reconfiguration reports from other spectrum managers connected to the network of spectrum managers,

   iii. Analyzing, at said spectrum manager, reconfiguration reports received in step ii, in order to determine whether the radio base station connected to said spectrum manager needs to be preventively reconfigured, according to the reconfiguration policies stored at said spectrum manager,

   iv. Upon determining that the radio base station connected to said spectrum manager needs to be preventively reconfigured, sending a request by said spectrum manager to said radio base station to allocate or deallocate channels used for transmission and / or reception.

2) The method according to claim 1 wherein said reconfiguration report comprises at least one of:

   i. The list of channels that were deallocated by the spectrum manager to the radio base station connected to this spectrum manager,

   ii. The list of channels that were allocated by the spectrum manager to the radio base station connected to this spectrum manager,

   iii. A time stamp indicating the time at which said reconfiguration report was created,

   iv. The location of the radio base station connected to this spectrum manager, in 2 or 3 dimensions.

3) The method according to any one of claims 1 to 3 wherein said Reconfiguration Policies used to determine whether said spectrum manager should preventively reconfigure said radio base station comprise all or a subset of the following elements:

   i. a threshold parameter, indicating a minimum number of reconfiguration reports that must be received, indicating that a given channel has been deallocated.

   ii. a list of threshold parameters, as defined in bullet i of the present claim, each threshold parameter being associated with:

a. a density of radio base stations, indicating the minimum number of radio base stations that must be deployed, per unit of distance, in order for this threshold parameter to be applicable, and / or,

b. a value indicating the minimum distance or the minimum path loss between a radio base station connected to the spectrum manager that sends a reconfiguration report and the radio base station connected to the spectrum manager that receives the reconfiguration report, in order for this threshold parameter to be applicable.

iii. a parameter defining the validity period of received reconfiguration reports, beyond which reconfiguration reports are no more used by the spectrum manager to determine whether to preventively reconfigure said radio base station.

iv. a parameter indicating the maximum distance between radio base stations, beyond which two Reconfiguration Reports received from spectrum managers associated with those radio base stations are considered not related to the same potential primary user.

4) The method according to any one of claims 1 to 4 wherein said preventive reconfiguration consists in deallocating channels, allocating new channels, or sending a notification about channels that may be deallocated in the near future, said notification optionally including a validity period indicating the duration during which the radio base station receiving the said notification should take into account said received notification.

5) The method according to any one of claims 1 to 5 wherein said reconfiguration policies may be automatically adjusted, at a given spectrum manager, based on the ratio between the total number of past preventive reconfigurations and the number of past preventive reconfigurations that were followed, within a pre-defined period of time, by the reception, from a RF sensor or from an entity managing a network of RF sensors, of a notification about to the presence of a primary user.

6) The method according to any one of claims 1 to 5 wherein some information provided in the Reconfiguration Report may be encrypted so that this information is only accessible to spectrum managers associated with radio base stations of the same operator.

FIGURES

Figure 1.

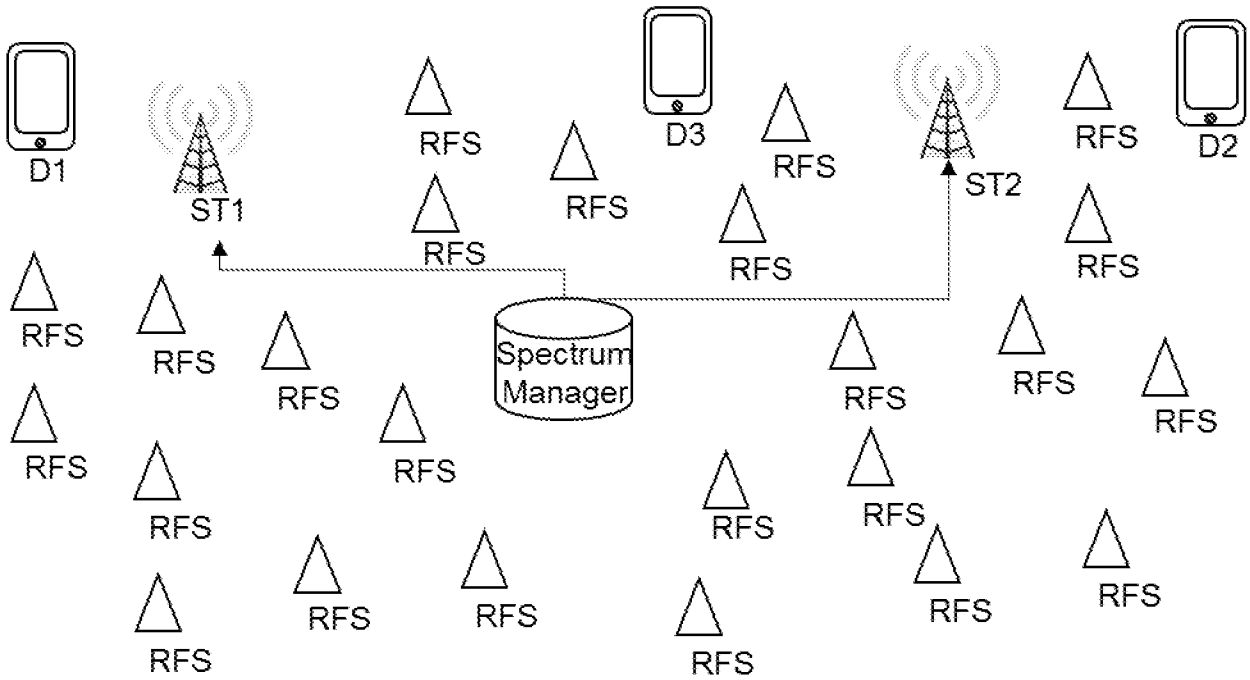


Figure 2.

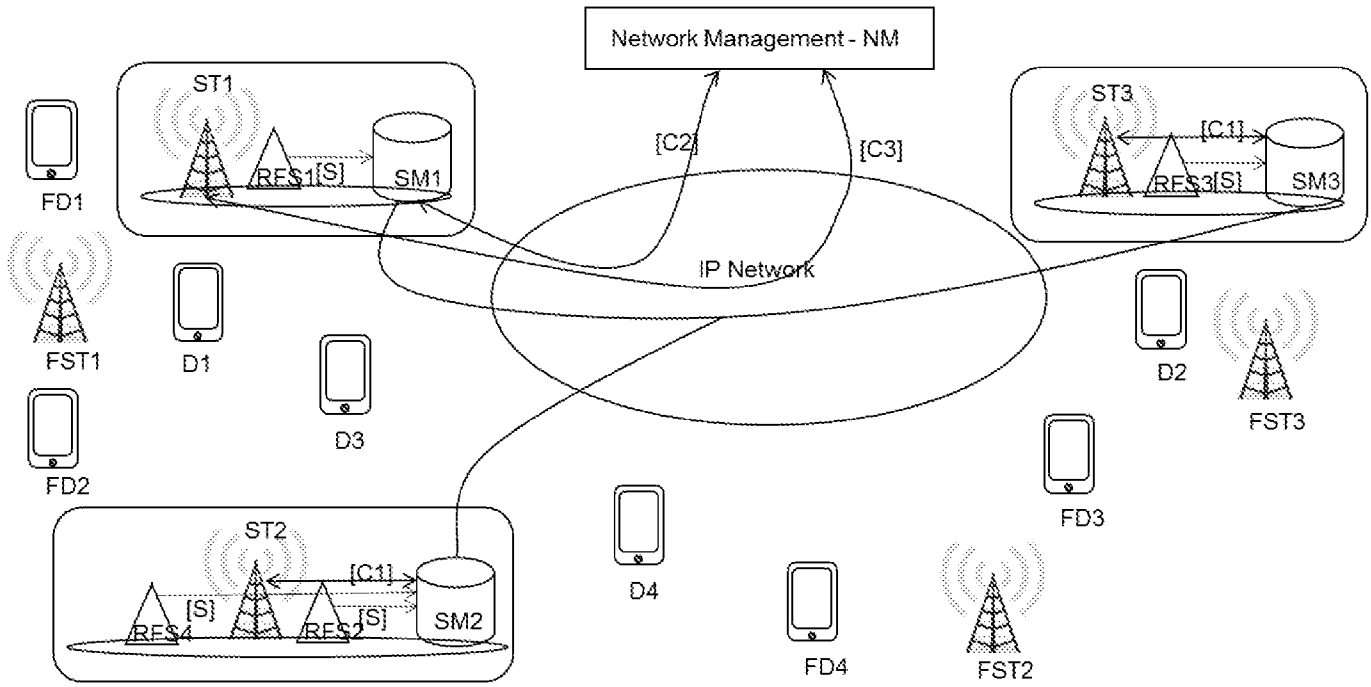

Network Management - NM
ST1
RFS1
[S]
SM1
[C2]
[C3]
ST3
[C1]
RFS3
[S]
SM3
IP Network
FD1
FST1
D1
D3
FD2
D2
FST3
FD3
ST2
[C1]
[S]
RFS4
[S]
RFS2
SM2
D4
FD4
FST2

Figure 3.

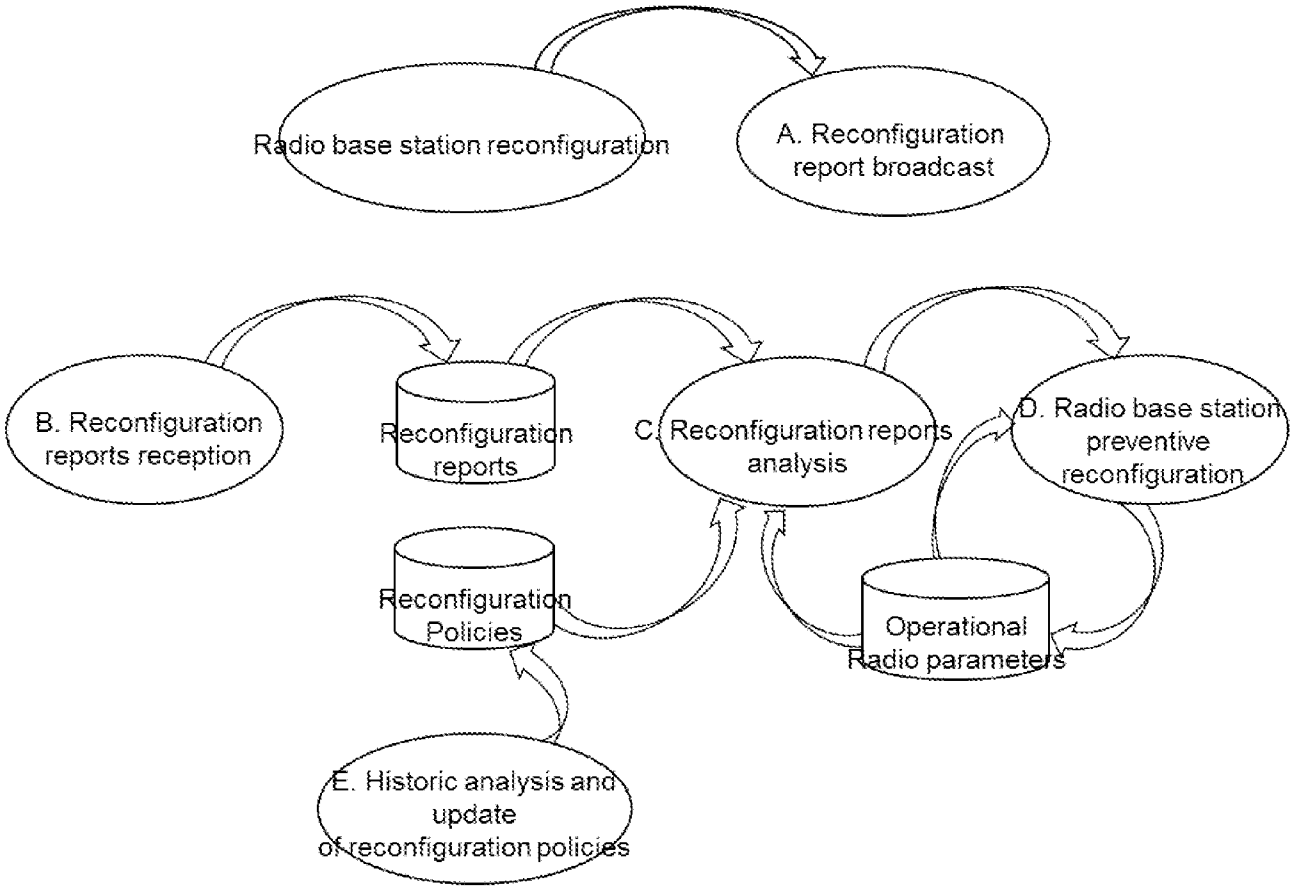

Radio base station reconfiguration
A. Reconfiguration report broadcast
B. Reconfiguration reports reception
Reconfiguration reports
C. Reconfiguration reports analysis
D. Radio base station preventive reconfiguration
Reconfiguration Policies
Operational Radio parameters
E. Historic analysis and update of reconfiguration policies

Figure 4.

Reconfiguration Report			
List of deallocated channels	1	3	4
List of newly allocated channels	6	7	-
Time stamp	8h 20m 10s		
Location	Latitude	Longitude	Height
	48.853	2.35	12

Figure 5.

Reconfiguration Policies									
Distance (kilometer)	10	10	10	50	50	50	100	100	100
Density of radio base stations (per kilometer square)	10	20	50	10	20	50	10	20	50
Minimum Received Reconfiguration Reports	15	30	75	18	35	90	20	40	100
Maximum distance between Reconfiguration Reports (kilometers)	30								
Validity period	10 seconds								

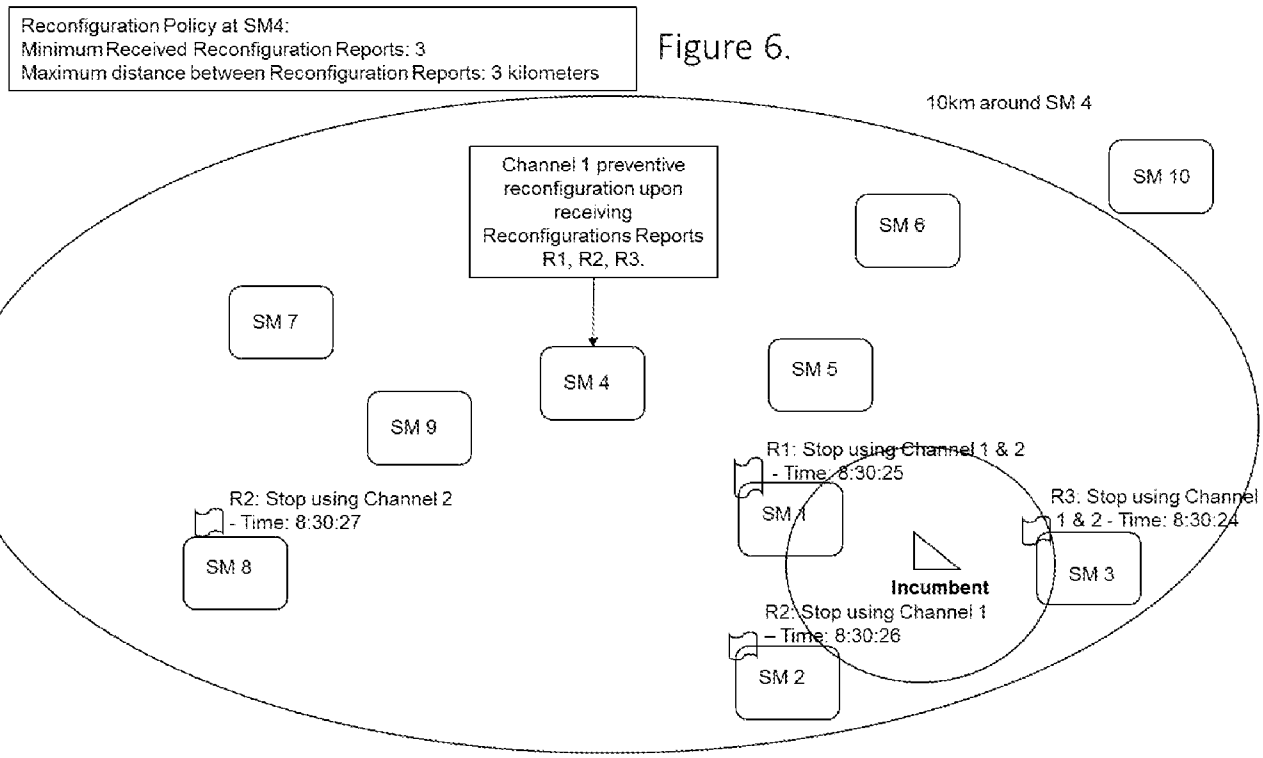

Reconfiguration Policy at SM4:
Minimum Received Reconfiguration Reports: 3
Maximum distance between Reconfiguration Reports: 3 kilometers
10km around SM 4
Channel 1 preventive reconfiguration upon receiving Reconfigurations Reports R1, R2, R3.
SM 10
SM 6
SM 7
SM 4
SM 5
SM 9
R1: Stop using Channel 1 & 2 - Time: 8:30:25
SM 1
R2: Stop using Channel 2 - Time: 8:30:27
SM 8
R3. Stop using Channel 1 & 2 - Time: 8:30:24
SM 3
Incumbent
R2: Stop using Channel 1 – Time: 8:30:26
SM 2

Figure 6.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/075061

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W16/14
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 892 266 A1 (HARRIS CORP [US]) 8 July 2015 (2015-07-08) paragraph [0001] paragraph [0004] paragraph [0007] paragraph [0014] paragraph [0019] paragraph [0022] paragraph [0026] paragraph [0032] - paragraph [0035] paragraph [0040] - paragraph [0049] paragraph [0061] - paragraph [0066] ----- -/--	1-6

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 December 2016	22/12/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	López Pérez, Mariano

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/075061

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/146257 A1 (HARMAN INT IND [US]; YANG ZENG [CN]; ZHANG QINGSHAN [CN]; ZHANG GUOXIA) 25 September 2014 (2014-09-25) paragraph [0002] - paragraph [0012] paragraph [0018] paragraph [0020] - paragraph [0021] paragraph [0031] paragraph [0034] - paragraph [0079]	1-6
A	"Reconfigurable Radio Systems (RRS); Cognitive Radio System Concept", TECHNICAL REPORT, EUROPEAN TELECOMMUNICATIONS STANDARDS INSTITUTE (ETSI), 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS ; FRANCE, vol. RRS 1, no. V1.1.1, 1 February 2010 (2010-02-01), XP014046279, paragraph [4.2.3] paragraph [5.4.6]	1-6

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2016/075061

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2892266 A1	08-07-2015	EP 2892266 A1	08-07-2015
		US 2015173085 A1	18-06-2015
WO 2014146257 A1	25-09-2014	CN 104956707 A	30-09-2015
		EP 2976906 A1	27-01-2016
		US 2016007208 A1	07-01-2016
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