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TECHNICAL SPECIFICATION

**Reconfigurable Radio Systems (RRS);
System requirements for Operation in UHF TV Band White Spaces**

Reference

DTS/RRS-01010

Keywords

control, CRS, performance, white space

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Contents

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Reconfigurable Radio Systems (RRS).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**may not**", "**need**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The scope of the present document is to define the high level system requirements for operation of Reconfigurable Radio Systems within UHF TV band White Spaces. The requirements are based on the Use Cases described in TR 102 907 [i.1]. Security requirements are not covered within the present document.

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.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

2.1 Normative references

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

Not applicable.

2.2 Informative references

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

[i.1] ETSI TR 102 907: "Reconfigurable Radio Systems (RRS); Use Cases for Operation in White Space Frequency Bands".

[i.2] Recommendation ITU-T G.1010 (2001): "Quality of service and performance".

[i.3] Recommendation ITU-T E.800 (2008): "Definitions of terms related to quality of service".

[i.4] Recommendation ITU-T G.1080 (2008): "Multimedia quality of service and performance - Generic and user-related aspects, Quality of experience requirements for IPTV services".

[i.5] Recommendation ITU-T P.10/G.100 (2006): "Vocabulary for performance and quality of service".

[i.6] ECC Report 186 (2013): "Technical and operational requirements for the operation of white space devices under geo-location approach".

3 Definitions and abbreviations

3.1 Definitions

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

geo-location database: database approved by the relevant national regulatory authority which can communicate with WSDs and provide information on TVWS channel availability

incumbent radio service: radio authorized for operation on a given frequency band with a regulatory priority

NOTE: In the frequency band 470-790 MHz, the following radio services are considered as incumbent radio services:

- Terrestrial Broadcasting Service (BS) including DVB-T in particular.
- Program Making and Special Event (PMSE) services including radio microphones in particular.
- Radio Astronomy Service (RAS) in the 608-614 MHz band.
- Aeronautical Radio Navigation Service (ARNS) in the 645-790 MHz band.

master WSD: WSD which communicates with a geo-location database and obtains operating parameters specific to its geo-location and which controls radio transmission resources of slave WSDs

Quality of Service (QoS): totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service

NOTE: This is the definition given in Recommendation ITU-T E.800 [i.3].

Quality of Experience (QoE): overall acceptability of an application or service, as perceived subjectively by the end-user

NOTE 1: Quality of Experience includes the complete end-to-end system effects (client, terminal, network, services infrastructure, etc.).

NOTE 2: Overall acceptability may be influenced by user expectations and context.

NOTE 3: This is the definition given in Recommendation ITU-T P.10/G.100 [i.5].

slave WSD: White Space Device operating under control of a master WSD

spectrum sensor: White Space Device with sensing capability or a dedicated device which measures incumbent signals and/or interference signals

system: set of physical and logical entities and related functions that take part in the operation in UHF TV band White Spaces

NOTE: The system consists of one or more TV White Space CRSs, and system functions which enable or enhance TV White Space CRS operation in UHF TV band White Spaces.

system function: clearly defined task or set of tasks that the system can implement (e.g. coexistence function providing management and/or information services)

TVWS channel: TV Channel in the range of frequencies from 470 - 790 MHz which is available for radio systems at a given time in a given geographical area on a non-interfering / non-protected basis with regard to primary services and other services with a higher priority on a national basis

NOTE: Such a channel is 8 MHz bandwidth in Europe.

TV White Space CRS: one or more WSDs operating in UHF TV White Spaces on non-interference, non-protection basis

White Space Device (WSD): wireless device controlled by a geo-location database capable of operating in UHF TV band White Spaces on a non-interference, non-protection basis

NOTE: User terminals (e.g. mobile terminals), base stations, and access points may be WSDs.

3.2 Abbreviations

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

3GPP	3rd Generation Partnership Project
ARNS	Aeronautical Radio Navigation Service
BS	Broadcasting Service
CRS	Cognitive Radio System
CSMA	Carrier Sense Multiple Access
DL	Downlink
DTT	Digital Terrestrial Television
DVB-T	Digital Video Broadcasting - Terrestrial
EIRP	Equivalent Isotropically Radiated Power
eNB	evolved Node B
EPG	Electronic Program Guide
FDD	Frequency Division Duplex
GLDB	Geo-Location DataBase
GSM	Global System for Mobile communication
IPTV	Internet Protocol based Television
LTE	Long Term Evolution
MME	Mobility Management Entity
PDB	Packet Delay Budget
PMSE	Program Making and Special Events
QoE	Quality of Experience
QoS	Quality of Service
RAS	Radio Astronomy Service
RAT	Radio Access Technology
RRS	Reconfigurable Radio Systems
TDD	Time Division Duplex
TR	Technical Report
TV	Television
TVWS	TV White Space
UHF	Ultra High Frequency
UL	Uplink
WS	White Space
WSD	White Space Device

4 Requirement Organization and Methodology

This clause describes how the requirements are organized and the related format.

4.1 Requirement Organization

As shown in Figure 1, the requirements described in the present document belong to two different categories: the functional requirements and the performance requirements. Each category, in turn, is organized into groups.

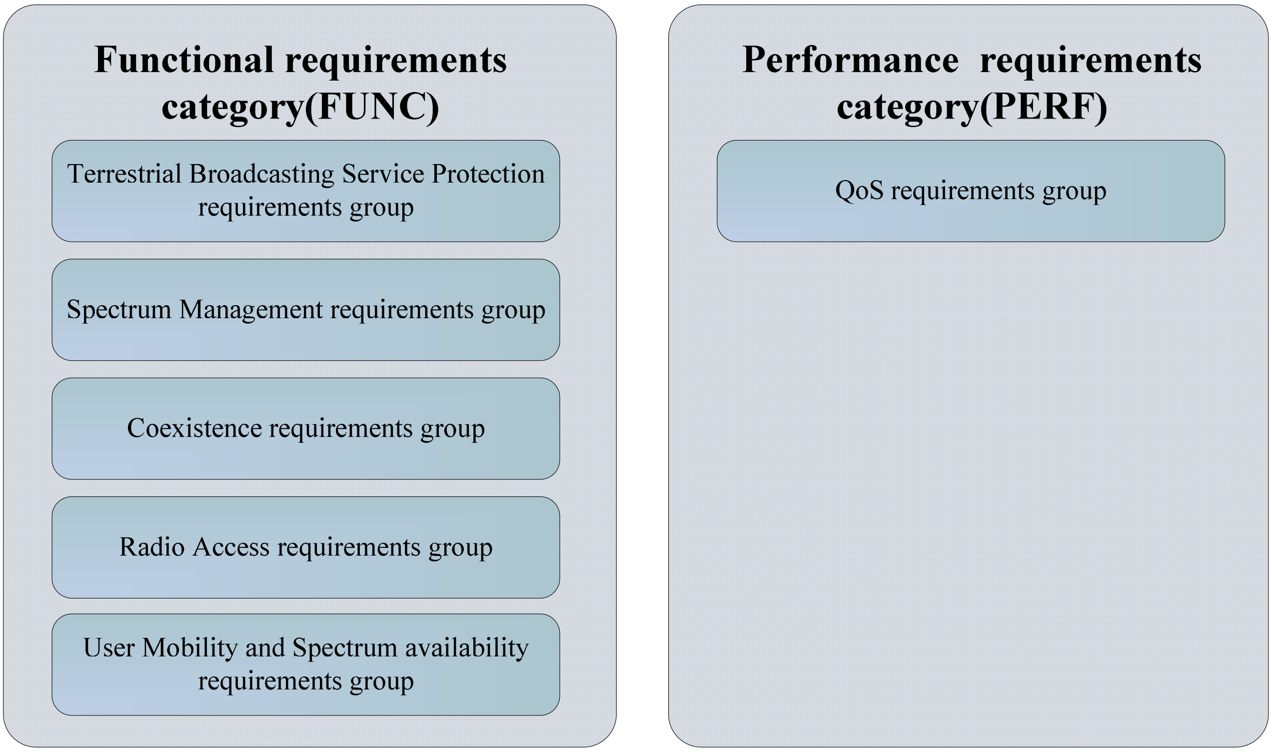

Figure 1: Overall requirements structure

4.2 Requirement Format

A letter code system is defined which makes a unique identification of each requirement R-<CAT>-<GROUP>-<XX>. It should be constructed as follows:

- R- : Standard requirement prefix
- <CAT>-

Code	Category
FUNC	Functional aspects
PERF	Performance aspects

- GROUP>: Requirement group identifier. A letter code will be used for this identifier. The three first letters will give the identifier of the group.

4.3 Requirement Formulation

A requirement is formulated in such a way that it is uniquely defined. It is built as follows:

Title: <Title Description>

- Description: the description of a requirement will be formulated using one of the following terms:
  - "shall" is used to express mandatory requirements (i.e. provisions that have to be followed);
  - "should" is used to express recommendations (provisions that an implementation is expected to follow unless there is a strong reason for not doing so);
  - "May" is used to express permissible actions (provisions that an implementation is able to follow or not follow.

5 Working assumptions

There are two approaches for use of TVWS channels by each CRS, uncoordinated approach and coordinated approach:

- Uncoordinated use of TV White Space implies that each CRS independently uses available TV White Space resources obtained with the help of geo-location database without any help from a spectrum coordination function to coordinate spectrum usage with its neighbour CRSs.
- Coordinated use of TV White Space implies that each CRS uses available TV White Space resources obtained with the help of geo-location database and with additional knowledge of spectrum usage by its neighbour CRSs and/or decision making from a spectrum coordination function.

The tag "COOR" in the requirement identifier indicates that the requirement applies only to the coordinated use and any requirement without the "COOR" tag applies either to the uncoordinated use or to the coordinated use.

6 Metrics

The present document derives the requirements from the use cases and technical challenges as defined in TR 102 907 [i.1]. It requires the availability of metrics related to the operational state of the network (or parts of it) and the user requirements. This clause describes these metrics on which the requirements are based.

6.1 Quality of Service (QoS) & Quality of Experience (QoE) Metrics

The relationship and scope of QoS and QoE is defined by Recommendation ITU-T G.1080 [i.4] and it is illustrated in Figure 2.

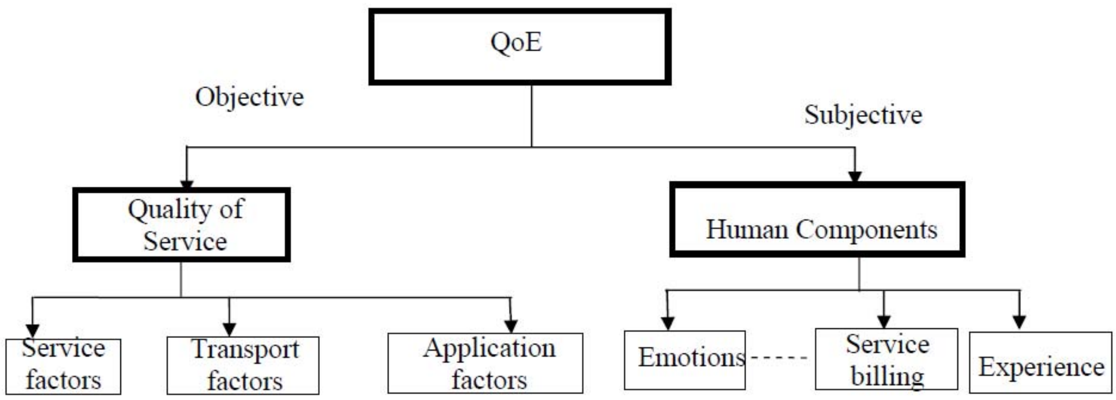

Figure 2: Quality of Experience (QoE) Dimension

The definition of suitable QoS is based on Recommendation ITU-T G.1010 [i.2] and the definitions specified in Recommendation ITU-T E.800 [i.3]. Figure 3 shows the User-centric QoS categories as defined in Recommendation ITU-T G.1010 [i.2].

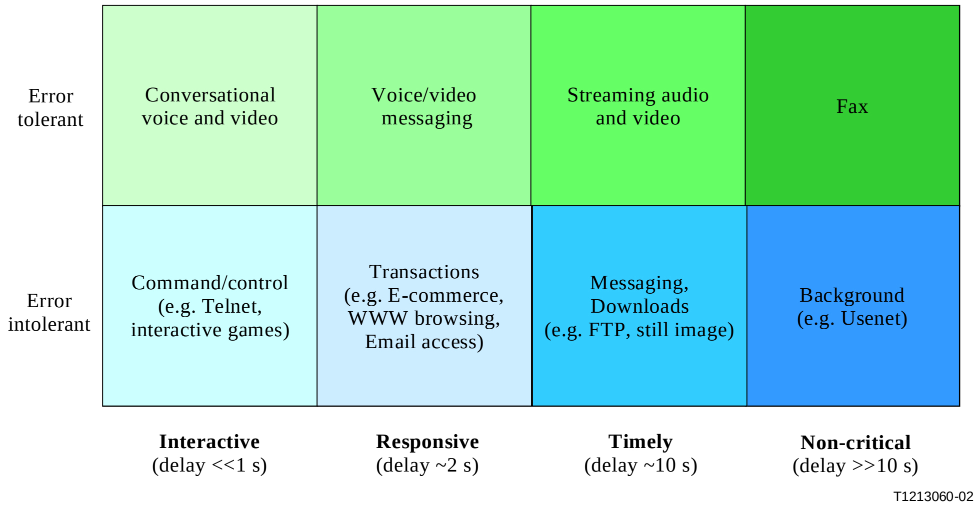

Figure 3: Model for user-centric QoS categories

Recommendation ITU-T G.1080 [i.4] defines basic indicators for QoE in the framework of IPTV, including:

- QoE requirements for metadata (e.g. subtitles, etc.);
- QoE requirements for EPG;
- QoE requirements for browser;
- QoE requirements for content navigation.

7 System Requirements

7.1 Terrestrial Broadcasting Service Protection Requirements

7.1.1 Requirements for advanced geo-location function

The system may support advanced geo-location function to facilitate management for Terrestrial Broadcasting Service protection. The function employs the calculation function of location specific WSD output power level for Terrestrial Broadcasting service receiver protection. This clause defines the requirements for the advanced geo-location function.

Explanation: There will be several possible deployment scenarios for the calculation function of location specific WSD output power level. For example, the calculation function may be a part of the geo-location database controlled by a regulatory body, or a separate function (namely advanced geo-location function) from the geo-location database managed by regulatory body. In the former case, any requirements definition on this function will be unnecessary, because it will be defined in each regulatory body itself. On the other hand, in a case where it is a separate function, a third party should take a responsibility to protect the Terrestrial Broadcasting service receivers, and the operation should be kept under surveillance by a regulatory body. In this case, requirements will be necessary in defining the interface between WSD and this calculation function.

7.1.1.1 R-FUNC-TER-01 Location specific WSD output power level calculation function

If the system supports an advanced geo-location function, the advanced geo-location function shall support calculation of location specific WSD output power level which takes into consideration the number of active master WSDs in operational TVWS channels in order to satisfy Terrestrial Broadcasting service protection requirements.

Explanation: The location specific output power level calculation for a newly entering WSD should be based on relevant parameters of both the newly entering WSD and other active master WSDs. In addition, the advanced geo-location function should re-calculate the location specific output power levels of the active master WSDs. The re-calculated maximum power levels are sent from the advanced geo-location function to the active master WSDs, and are set as their new maximum power levels.

7.1.1.2 R-FUNC-TER-02 Interference calculation function

If the system supports an advanced geo-location function, the advanced geo-location function shall be able to estimate the interference level to the incumbent receivers.

Explanation: The advanced geo-location function uses propagation estimation and/or measurements obtained from spectrum sensors to estimate interference level. The advanced geo-location function considers the interference level estimation to calculate the allowable maximum WSD output power level.

7.1.1.3 R-FUNC-TER-03 Control information of advanced geo-location function

If the system supports an advanced geo-location function, the advanced geo-location function shall support the relevant information exchange between the function itself and geo-location database, for the purpose of location specific WSD output power level control.

7.1.1.4 R-FUNC-TER-04 Control information of WSDs

If the system supports an advanced geo-location function, the advanced geo-location function shall support the relevant information exchange in controlling the connected WSDs i.e. output power level control.

7.1.1.5 R-FUNC-TER-05 Control information of spectrum sensors

If the system supports an advanced geo-location function, the advanced geo-location function may support the relevant information exchange in controlling spectrum sensors, e.g. measurement requests from the advanced geo-location function to the spectrum sensors and measurement reports from the spectrum sensors to the advanced geo-location function.

7.1.1.6 R-FUNC-TER-06 Knowledge of relevant parameters of WSDs

If the system supports an advanced geo-location function, the advanced geo-location function shall be able to obtain knowledge of relevant parameters of the master WSD and the associated slave WSDs.

Explanation: The knowledge on the relevant parameters is used to calculate location specific output power level for a newly entering WSD. In the process of this calculation, the knowledge is also used to calculate current interference level from active WSDs. The relevant parameters include at least the following ones as defined in ECC Report 186 [i.6]:

- list of available frequencies;
- associated maximum transmit power for the current WSD location;
- limits on the maximum number of contiguous DTT channels;
- total number of DTT channels the WSD can transmit;
- time of validity (of the above mentioned parameters).

The relevant parameters may be set to values which take care of measurement uncertainties and manufacturing variability of device characteristics (e.g. antenna gain).

7.1.2 Requirements for the interaction with the geo-location database

7.1.2.1 R-FUNC-TER-07 Interaction with the geo-location database

The master WSD shall be able to interact with the geo-location database access service to get information about the available TVWS spectrum.

Explanation: The master WSD needs to access the geo-location database access service following the procedures and the rules of the regulatory bodies to get the information related to the available TVWS spectrum.

7.1.2.2 R-FUNC-TER-08 Geo-location database discovery

The system shall be able to discover the geo-location database which provides the data specific to the WSD's location.

Explanation: Access to the geo-location database is essential. For example the master WSD could access a website maintained by each regulator holding a list of geo-location databases approved in that regulatory domain with the target information, e.g. information of the available spectrum at the specific location.

7.1.2.3 R-FUNC-TER-09 Registering with Geo-location database access service

The master WSD shall register to the appropriate geo-location database access service.

Explanation: The system needs to provide the relevant information to register to the geo-location database access service following specific requirements from individual regulatory domains.

7.1.3 Requirements for multiple advanced geo-location functions

This clause applies to a scenario of multiple geo-location database services in an area, each of them employing the advanced geo-location function. As an example of the multiple geo-location database services, the different database-service providers in different countries may provide the service in the area near the national border. Another example is that the multiple providers in one country may provide such services in the same area in the case that the regulator authorizes them as the providers. This clause defines the additional requirements for the advanced geo-location function in the case of multiple advanced geo-location functions deployed by service providers in the same area.

7.1.3.1 R-FUNC-TER-10 Knowledge of relevant parameters of WSDs registered to other advanced geo-location function

If multiple advanced geo-location functions are deployed, each advanced geo-location function shall be able to obtain knowledge of relevant parameters of active WSDs registered to other advanced geo-location functions in the same area.

Explanation: The knowledge is used to calculate the allowed maximum transmit power taking into account the current interference signal level from the active WSDs which are registered to other advanced geo-location functions. The location specific output power is calculated considering the aggregated interference from the active WSDs registered to different advanced geo-location functions in a given area. The knowledge may be obtained from the other advanced geo-location function directly or from the geo-location database that the advanced geo-location function is attached to.

The relevant parameters include at least the following ones as defined in ECC Report 186 [i.6]:

- list of available frequencies;
- associated maximum transmit power for the current WSD location;
- limits on the maximum number of contiguous DTT channels;
- total number of DTT channels the WSD can transmit;
- time of validity (of the above mentioned parameters).

7.1.4 Requirement for Sensing Function

The system may support a sensing function to further enhance the discovery of White Spaces. As an example information collected with the sensing function may be provided for the advanced geo-location function, which may supplement the stored incumbent information with the sensed information. Alternatively, the WSD may use the sensing function in addition to accessing the geo-location database for discovering the available spectrum, if allowed by the regulator. The sensing function may also be used to provide coexistence among WSD users (see clause 7.3.1.5).
The clauses below define the requirements for the sensing function.

7.1.4.1 R-FUNC-TER-11 Location of Sensing

If a sensing function is available, it shall support sensing performed at the Master WSD. The sensing function may or may not support sensing performed at the slave WSD.

Explanation: Sensing capability incurs additional complexity on a WSD. Although sensing at a master WSD is important, sensing at individual slave WSDs is beneficial but is not necessary and may also be impractical due to the additional complexity and the power consumption.

7.1.4.2 R-FUNC-TER-12 Exchange of Sensing Information

If a sensing function is available, it shall support the retrieval of the sensing results collected by the WSDs as well as the exchange of sensing results by WSDs involved in the sensing function.

Explanation: Sensing results are exchanged in order to allow cooperative sensing decisions.

7.1.4.3 R-FUNC-TER-13 Configuration of Sensing Parameters

The sensing function shall support the configuration of sensing duration, silent period duration and frequency/channel.

Explanation: In certain cases, the sensing function will control multiple WSDs involved in sensing and it will be able to configure each of these devices. A silent period requires all WSDs managed by the sensing function to interrupt transmission for a short period of time to allow for sensing. This may allow a more reliable detection of terrestrial broadcast service signals and potentially of other user signals.

7.2 Spectrum Management Requirements

7.2.1 Requirements for systems supporting carrier aggregation

These requirements are focused on a system supporting carrier aggregation in TVWS.

7.2.1.1 R-FUNC-SPE-01 Carrier Aggregation in TVWS

The system may support carrier aggregation of a primary component carrier with one or more secondary component carriers operating in TVWS. The primary component carrier may be in TVWS, or any other band where system operation is allowed.

7.2.2.2 R-FUNC-SPE-02 TVWS Component Carrier Management and Configuration

If carrier aggregation is supported, the system should be able to quickly adapt to variations in channel availability and quality through activation, deactivation and reconfiguration of the TVWS component carriers.

Explanation: Availability and quality of TVWS channels is not guaranteed. Decisions for TVWS component carrier management can be based on availability of TVWS channels, bandwidth offload needs of the network, and coexistence decisions.

7.2.2 Requirements for Spectrum Coordination Function

The system may support a spectrum coordination function to facilitate efficient and fair spectrum use and management. This function evaluates the actual demands of the CRSs requesting White Space spectrum and determines the spectrum assignment strategy. The clauses below define the requirements for the spectrum coordination function.

NOTE: The spectrum coordination function is operated under the condition that the incumbent system is protected and the requirements given by the geo-location database are observed.

7.2.2.1 R-FUNC- SPE-COOR-01 Spectrum resource assignment decision

The spectrum coordination function shall support decision making for spectrum resource assignment based on the actual demands of the CRSs.

Explanation: The actual demands of the CRSs will be evaluated according to the network load status, communication quality, etc. Based on these demands, the spectrum coordination function will make a decision on whether resources are allocated to CRSs, or which CRSs can get resources.

NOTE: Depending on the architecture details, this requirement could be satisfied by the coexistence function (see clause 7.3.1.3.8).

7.2.2.2 R-FUNC-SPE-COOR-02 Requirement for Spectrum Release

The spectrum coordination function shall be able to force the CRS to release the spectrum based on an evaluation of the CRS needs and priority.

Explanation: The spectrum coordination function can force one CRS to release TVWS spectrum resources in order to reallocate them to other CRSs, if other CRSs are in greater needs for the spectrum or have higher priority. For example, CRS_1 may obtain TVWS resources initially, and without any guaranteed QoS, because of its heavy network load. After some time the network load of CRS_1 decreases and CRS_2 requests TVWS resources. The spectrum coordination function can make another round evaluation of these CRSs' actual needs or priority, force the release of the TVWS resources from CRS_1 and reallocate them to CRS_2. The network load is not the only criterion for the evaluation or the reassignment decision. Geo-location of CRSs, QoS, spectrum management auction mechanisms and willingness to pay, or other policies are also possible decisions for reassignment.

7.2.2.3 R-FUNC-SPE-COOR-03 Control information exchange to support spectrum coordination function

The relevant control information exchange shall be allowed to support the resource assignment by the spectrum coordination function.

Explanation: To support spectrum coordination function decisions, control information exchange is necessary. There are two directions of information exchange: information needed for the spectrum coordination function to make decisions on spectrum assignment which is sent from the CRSs to the spectrum coordination function, and spectrum resource assignment/release decisions which is sent from the spectrum coordination function to the CRSs.

7.2.2.4 R-FUNC-SPE-COOR-04 Priority Use of Channels for TVWS Usage

The spectrum coordination function shall be able to reserve a subset of channels for TVWS usage to satisfy CRSs with guaranteed QoS requirements. The spectrum coordination function shall ensure that such priority use channels are assigned exclusively to such CRSs for a certain reservation time. The spectrum coordination function shall support appropriate negotiation mechanisms to resolve contention when multiple CRSs request a channel for priority use and the number of available channels is not sufficient.

Explanation: Certain CRSs in the system may require guaranteed QoS with exclusive access to the channel for a certain period of time. The channels for TVWS usage are a limited resource with very few channels available for CRS use especially in densely populated urban areas. The spectrum coordination function could use policies and negotiation mechanisms to resolve the assignment issues in the case of scarcity of channels when there is the need for assigning one or more priority use channels.

7.2.2.5 R-FUNC-SPE-COOR-05 Support for Spectrum Resource Reassignment

The spectrum coordination function shall be able to reassign the available spectrum resources among CRSs using the information of the current resource utilization by CRSs.

Explanation: The spectrum coordination function obtains information on the amount of available spectrum resources from the geo-location database. The amount of the available spectrum resources may have been determined based on the incumbent protection criteria instead of the actual needs of CRSs. Consequently, the maximum spectrum limit (for example, a frequency band and its associated maximum EIRP that a CRS can use while maintaining protection to incumbents) is assigned to the requesting CRS. Nevertheless, the amount of spectrum resource a CRS would need for a specific application could be smaller than the available spectrum. Also, a CRS might have completed using the spectrum and releases it before the availability time expires. The extra spectrum that has been made available can be reassigned to other CRSs if this reassignment is made without harming the incumbents. The spectrum coordination function will therefore reassign the unused portion within the available spectrum to other candidate CRSs by changing their operation parameters. Such assignment of extra resource should be based on the evaluation of the candidate CRSs' locations and their interference contribution in order to maximize the amount of the extra spectrum. For example, in an area crowded with incumbents the spectrum coordination function should consider the proximity of a candidate CRS to the CRS that has unused spectrum when reassigning the spectrum. In case of coordinated spectrum use, the frequency reassignment of the candidate CRSs should also consider the interference to the neighbouring CRSs.

7.2.2.6 R-FUNC-SPE-COOR-06 Support for CRS operational parameter configuration/reconfiguration

The spectrum coordination function shall be able to reconfigure at least the following (operational) parameters defined in ECC Report 186 [i.6]:

- list of available frequencies;
- associated maximum transmit power for the current WSD location;
- limits on the maximum number of contiguous DTT channels;
- total number of DTT channels the WSD can transmit;
- time of validity (of the above mentioned parameters).

Explanation: By adjusting the operational parameters such as the transmit power of WSDs while maintaining protection to the incumbents, more CRSs could operate on the same channel. The type of operational parameters that can be configured/reconfigured may depend on where and how the spectrum coordination function will be implemented in the system.

7.2.2.7 R-FUNC-SPE-COOR-07 Support for configuration/reconfiguration of device parameters facilitating coexistence without impact to the incumbent

The spectrum coordination function may support the configuration/reconfiguration of certain device parameters without causing additional interference to incumbents and in order to facilitate the coexistence among CRSs. Before device parameters are changed, the CRS shall re-access the GLDB with its new device parameters through the Spectrum Coordinator to obtain new operational parameters for its configuration.

Explanation: The device parameters include antenna elevation angle, antenna location, antenna direction angle, antenna height, and spectral emission mask which, if modified, may improve the coexistence among CRSs but may also alter the interference to the incumbent.

7.2.2.8 R-FUNC-SPE-COOR-08 Support for acquiring and storing spectrum usage and network information for spectrum resource assignment decision

The spectrum coordination function should be able to obtain and store spectrum usage and network information for spectrum resource assignment decision making.

Explanation: The Spectrum Coordinator is able to obtain and store spectrum usage and network information from CRS and geo-location database. As an example, the CRS could provide information of its loading changes information, communication quality changes information and channel quality information, interference information among different CRSs, etc. The information of the incumbent spectrum usage could be accessed from the geo-location database or by sensing/measuring from CRS. Through the maintenance and management of such information, the Spectrum Coordinator could form effective empirical data, such as state transition probabilities of spectrum usage, which is conducive to the spectrum resource usage strategies, or advance preparation for spectrum resources configuration/reconfiguration.

7.3 Coexistence Requirements

This clause defines the coexistence requirements for the CRS operation in UHF TV White Spaces. The requirements cover the coexistence between the TVWS CRS and incumbent spectrum users as well as the coexistence between TVWS CRS spectrum users.

7.3.1 Requirements for coexistence among TV White Space CRSs

This clause defines the requirements for the system, which facilitate the coexistence among TV White Space CRSs in UHF TV band White Spaces.

7.3.1.1 R-FUNC-COE-COOR-01 Support for heterogeneous networks

The system should ensure the coexistence with dissimilar and/or independently operated TV White Space CRSs which operate in UHF TV band White Spaces.

7.3.1.2 R-FUNC-COE-COOR-02 Support for Coordinated and non-Coordinated Coexistence

The system should allow coexistence between TV White Space CRSs using coordinated and/or non-coordinated coexistence approaches. A system may use both types of coexistence simultaneously when operating in the UHF TV band White Spaces.

Explanation: In a coordinated coexistence, the TV White Space CRSs share information about their bandwidth resources and operating parameters. A coordinated coexistence therefore assumes that decisions are made using the information received from other coexisting TV White Space CRSs. Such coordinated coexistence is provided through the use of a coexistence function to facilitate the coexistence. In non-coordinated coexistence, a TV White Space CRS uses techniques to coexist with other TV White Space CRSs when having received no information from the other TV White Space CRSs. In non-coordinated coexistence, the system may rely on lower layer mechanisms such as CSMA, for example.

7.3.1.3 R-FUNC-COE-COOR-03 Support for a coexistence function

The system may support a coexistence function to facilitate the coexistence among TV White Space CRSs. A TV White Space CRS may subscribe to the coexistence function (e.g. in the coordinated approach) in order to facilitate the efficient usage of the TV band White Space with multiple TV White Space CRSs.

The clauses below define the requirements associated to the coexistence function.

7.3.1.3.1 R-FUNC-COE-COOR-03-1 Support for different decision making topologies

The coexistence function shall enable different coexistence decision making topologies, such as distributed, centralized, and combination of distributed and centralized.

Explanation: Different coexistence decision making topologies enable flexibility in the coexistence management among the heterogeneous TV White Space CRSs. The coexistence function may dynamically change the decision making topologies according to the processing load of each decision making process.

7.3.1.3.2 R-FUNC-COE-COOR-03-2 Support for acquiring information for coexistence

The coexistence function shall be able to obtain information required for coexistence from the TV White Space CRS and from other entities, for instance from the geo-location database.

Explanation: The TV White Space CRS node provides information of its capabilities, operation parameters, and radio environment, e.g. measurement results to the coexistence function. The information of the spectrum availability from the incumbent users may be accessed from the geo-location database.

7.3.1.3.3 R-FUNC-COE-COOR-03-3 Support for both Management and Information Services

The coexistence function shall support, as a minimum:

1) a management service to choose and provide operational parameters for each TV White Space CRS based on appropriate coexistence rules; or

2) an information service to provide channel usage information to the TV White Space CRS to allow it to make its own decisions on operational parameters.

7.3.1.3.4 R-FUNC-COE-COOR-03-4 Support for both Channel Sharing and Exclusive Channel Assignment

The coexistence function shall support both channel sharing (whereby a single channel is shared by TV White Space CRSs) and exclusive channel assignment (whereby a channel is used exclusively by a single TV White Space CRS).

Explanation: Exclusive assignment of a channel may be used in situations where there are many available channels or when a certain QoS is required for a given TV White Space CRS. Channel sharing may be used in situations where exclusive channel sharing is not possible due to limited availability of channels.

7.3.1.3.5 R-FUNC-COE-COOR-03-5 Support for WSD interferer discovery

The coexistence function shall be able to discover potential conflicts between the TV White Space CRSs which subscribe to the coexistence function.

Explanation: The TV White Space CRSs which use the coexistence function provide information related to their geo-location and spectrum needs. Thus, the coexistence function is able to facilitate the interference relation discovery of the TV White Space CRSs, i.e. whether the TV White Space CRSs may cause uni-or bi-directional interference to each other. In addition, it is able to facilitate the estimation of the aggregated interference from multiple TV White Space CRSs.

7.3.1.3.6 R-FUNC-COE-COOR-03-6 Support for Spectrum Resource Classification

The coexistence function may use information acquired from different TV White Spaces CRSs to facilitate the classification of the available (i.e. not used by incumbent) spectrum resources, for TV White Spaces CRSs at the specific geo-locations.

Explanation: The coexistence function collects the information (for example, location, RAT, capabilities, operating parameters, sensing) from different TV White Spaces CRSs that it serves. From the collected information it may estimate spectrum resources for the TV White Spaces CRSs that it serves. In this estimation the coexistence function for example considers the geo-location and maximum tolerable interference of the TV White Spaces CRS and its nearby TV White Spaces CRSs. The results of estimation enable classifying the resources by co-existence function or by TV White Spaces CRS management functions. For example at the geo-location database of the TV White Spaces CRS, a channel may be classified to be "used by CSMA", "used by non-CSMA", "unidentified interference", "no interference". This facilitates organizing the TV White Spaces CRSs to use the spectrum resources in a way that interference between them is mitigated.

7.3.1.3.7 R-FUNC-COE-COOR-03-7 Support for Submission of Expected Service QoS before Spectrum Usage

A TV Whitespace CRS that subscribes to the coexistence function may submit its expected service QoS, determined according to its application purposes, to the coexistence function prior to any transmission on the TV White Spaces.

Explanation: The coexistence system may use the expected QoS for a system in order to further restrict the subset of channels (deemed usable by the geo-location database) on which a CRS may operate. For example, a channel or subset of channels may be reserved for use by a CRS which requires some guaranteed QoS, while other channels may be reserved for systems which choose not to submit its required QoS. The number of channels usable by such systems may then be decreased as the number of systems requiring guaranteed QoS increases. The expected QoS may also be used to predict the amount of bandwidth resources required by each CRS. The QoS of a CRS is different for different services, such as audio transmission, video transmission, downloading, etc., the system provides. The expected QoS can be the minimum service QoS, the average service QoS, etc. based on implementation.

7.3.1.3.8 R-FUNC-COE-COOR-03-8 Support for Spectrum Resource Assignment based on CRS Service QoS

The coexistence function may consider the QoS of new TV White Space CRSs when assigning spectrum in TVWS.

Explanation: A master WSD obtains its available spectrum resource from the geo-location database. Using the WSD interferer discovery function (see clause 7.3.1.3.5), the coexistence function may estimate the usable spectrum resources of the new TV White Space CRS within the available spectrum obtained from the geo-location database, under the condition that the QoS of existing TV White Space CRSs will not be degraded to an unacceptable level (e.g. due to mutual interference). The coexistence function may limit the new TV White Space CRS to use only the estimated required spectrum resources based on its QoS. If the amount of available resources is not sufficient to satisfy the required QoS, the TV White Space CRSs may be notified accordingly by the coexistence system. In this case, the CRS may not use the TV White Spaces, or may use it for a service that does not require a guaranteed QoS.

7.3.1.3.9 R-FUNC-COE-COOR-03-9 Providing a Ranked Channel List to a CRS

The coexistence function shall be able to provide information on available channels to a CRS in the form of a ranked list, or other arrangement, in order to indicate the most recommended channels.

Explanation: The quality of each channel can be assessed by the coexistence function based on measurements (such as sensing information provided by the sensing function) sent by each CRS. These measurement reports can be sent along with the geo-location information of the CRS when making/sending the measurements. The coexistence function may then process these measurements from all CRSs in a neighbourhood and assess the channel quality as seen by a specific CRS due to the presence of other CRSs in its neighbourhood. In addition, channel availability time may be used as criteria in the ranking.

7.3.1.3.10 R-FUNC-COE-COOR-03-10 Support for determining the number of operating CRSs per available frequency channel

The coexistence function shall be able to determine the number of operating CRSs per available frequency channel and use this information to facilitate the coexistence among TV White Space CRSs.

Explanation: A multiplicity of CRSs operating at the same time can cause mutual interference. The coexistence function may need to limit the number of possible operating CRSs in order to reduce the possibility of mutual interference. For example, too many CRSs operating in the same frequency channel can cause harmful interference among the CRSs. To protect the CRSs from such interference, including co-channel and adjacent channels, the number of operating CRSs should be less than the number that creates an unacceptable interference level. The coexistence function may calculate and restrict the number of possible operating CRSs in the frequency channels in order to facilitate the coexistence among TV White Space CRSs. This operation may be based on knowledge of the configuration (e.g. the number of WSDs and their relation) of the coexisting CRSs.

7.4 Radio Access Requirements

The use of TVWS is assumed to be unlicensed and therefore:

- there is no designation of UL or DL TVWS channels. Also we assume that operating of UL and DL within the same TVWS channel is only possible via some Time division scheme;
- there is a need to adapt to changes in TVWS channel availability (in time and space) and to interference (e.g. from other WSD usage).

7.4.1 General Requirements

7.4.1.1 R-FUNC-RAD-01 Reliability of Control and Data Transmission

The system shall ensure reliability of the control information and data transmission while operating in TVWS within the power limits set for the system.

Explanation: The system may need to operate in the TVWS with high levels of interference from other WSD users or from incumbent radio services operating at high power in an adjacent channel. The interference from primary users in the adjacent bands may be significant when operating close to a DTT broadcast station, for example. This may require the control and data to be sent robustly when it is transmitted in the TVWS. It may alternatively require the coexistence system to ensure this reliability.

7.4.1.2 R-FUNC-RAD-02 Radio Reconfiguration Management

The system shall support radio reconfiguration via reconfiguration commands delivered to one WSD, several or all WSDs simultaneously.

Explanation: Radio reconfiguration commands can be sent to one WSD when the radio reconfiguration is related to this WSD only, or radio reconfiguration commands can be sent to several or all WSDs simultaneously e.g. based on radio device capabilities, geographic location, etc. For instance, a reconfiguration command related to a WSD's handover decision could be delivered to one WSD only while, whenever the system decides to reconfigure several or all of the WSDs to new TVWS channels to alleviate the current load pressure or to protect the incumbent system, the reconfiguration command will be sent simultaneously to several or all the WSDs with the same reconfiguration decision.

7.4.2 Requirements on usage of LTE in TVWS

The requirements herein described are focused on an LTE system operating in TVWS band.

7.4.2.1 R-FUNC-RAD-03 LTE Modes of Operation

It should be possible to operate LTE-TDD in TVWS as a stand-alone system or to provide a Secondary Carrier in TVWS in the context of LTE carrier aggregation with the primary carrier provided via non TVWS frequencies.

It should be possible to operate LTE-FDD DL or LTE-FDD UL in TVWS in the context of LTE carrier aggregation with the primary carrier provided via non TVWS frequencies.

Explanation: The decision of which mode (TDD/FDD-DL/FDD-UL) an LTE system will be deployed in TVWS will depend on multiple factors, including preference by the operator, bandwidth needs of the system, and/or coexistence issues.

7.4.2.2 R-FUNC-RAD-04 LTE Core Network capacity limitation

The Available Core Network capacity should be considered when initiating the connection establishment in the UHF TV band White Space.

Explanation: The reconfiguration of CRS is not only based on RAN radio access capacity but also the remaining capacity of the appropriate Core Networks node (e.g. MME in LTE).

7.4.2.3 R-FUNC-RAD-COOR-05 LTE Assignment of Parameters

The coexistence function may provide means to agree on use of different sets of frequencies to be used by each LTE system in an area. The co-existence function may also provide a means to agree on a common cell bandwidths, operation modes, and different sets of physical Cell Ids for an LTE cell, e.g. if it is not possible to assign different sets of frequencies to each LTE system in an area.

7.4.2.4 R-FUNC-RAD-COOR-06 Interference Reduction between LTE TV White Space CRSs

The system shall allow co-ordination between multiple LTE TV White Space CRSs to either avoid that they use the same frequency in a given area, or by agreeing on a common cell bandwidth (e.g. 5 MHz), same mode of operation (TDD, FDD-UL, FDD-DL), and use of different sets of physical cell Ids to reduce interference.

Explanation: LTE systems normally operate in licensed spectrum and different LTE systems operate in different frequencies. Thus, different LTE systems which operate in licensed spectrum do not cause significant interference to each other. When operating as TV White Space CRSs, co-ordination between multiple LTE systems will be required.

7.5 Requirements for User Mobility and Spectrum availability

7.5.1 R-FUNC-USE-01 Support for Changing the Operating Channel

The system shall be able to change its operating channel(s).

Explanation: Two examples when a system would need to change channel(s) are the following:

- a primary service indicates that it will use the channel(s) at a given time;
- the interference on the channel(s) becomes too high for the system to operate reliably.

7.5.2 R-FUNC-USE-02 Support for continuous service

In order to ensure service continuity when a master WSD changes its channel:

- The master WSD should provide to slave WSDs all the information necessary for service continuity before changing to the new TVWS channel.
- The slave WSDs should measure the received channel qualities of the target TVWS channels and should report them to the master WSD.

- The slave WSDs should indicate to the master WSD that the change has completed.

Explanation: In TVWS transmission resources are provided on one or more TVWS channels. The TVWS channels may vary in time and from one location to another due to incumbent use (e.g. TV Channels 21 and 23 may be available at one time and TV Channels 26, 27 and 29 may be available at another time. TV Channels 26, 27 and 29 may be available at location A but only Channels 26 and 29 may be available at location B). It may also be necessary to change the TVWS channel configurations due to detection of high interference levels (e.g. presence of other WSD usage) or reduction in signal strength (e.g. terminal movement towards edge of coverage) in order to meet desired quality of service. Services are not impacted by the change of TVWS channel if the slave WSDs can start to operate on the old TVWS channel until the new one is taken in use. To ensure this and to protect incumbent users, the master WSDs should inform slave WSDs of the new channel configuration in advance, before changing the TVWS channel or removing TVWS channels from use.

7.5.3 R-FUNC-USE-COOR-03 Support for coordination between handover and reconfiguration

The system, when operating exclusively in TVWS, should ensure that the master WSD from which a handover is performed obtains the availability time of TVWS frequency resources used by the master WSDs to which the handover is performed.

Explanation: Compared with traditional systems, there might be additional handover performance degradation in CRSs operating exclusively on TVWS frequency resources. For example, some of the master WSDs that serve as the target of a handover operation may need to reconfigure their TVWS frequency resources due to short availability time of these resources. Handover to these master WSDs could therefore lead to handover failure or subsequent handover to other master WSDs.

To avoid such an issue, time availability of TVWS frequency resources of WSDs should be obtained and considered when making handover decisions. Considering LTE as an example, handover to a target LTE eNB whose TVWS spectrum resources require reconfiguration will lead to handover failure or subsequent handover to other LTE eNBs. The time availability of the spectrum resources at neighbour master WSDs could be obtained by accessing a database or directly contacting neighbouring master WSDs.

NOTE: The above requirement applies when the time availability of the spectrum can be known a priori. The performance of handover may not be guaranteed if the time availability of spectrum cannot be known in advance.

7.6 QoS Requirements

7.6.1 R-PERF-QOS -01 Delay of the service

The system should meet the delay budget defined for the service (e.g. PDB) when operating in TV White Spaces.

History

Document history		
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