CBRS Coexistence Technical Specification

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1 Introduction and Scope

This document is a Technical Specification (TS) of procedures for coexistence of multiple LTE networks that are composed of CBSDs which are certified by CBRS Alliance. This version of the specification focuses on GAA coexistence requirements for CBSDs including cell phase synchronization and TDD configuration for LTE-TDD CBSDs, GAA channelization and SAS-CBSD protocol extensions. Treatment of deployments that rely on Frame Structure 3 (FS3) are left for future revisions of the document.

2 References

[1] J. Sanz Subirana et al, "Time References in GNSS", at European Space Agency, 2011.

[2] 3GPP TS 36.133, "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management (Release 14)."

[3] 3GPP TS 36.401, "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Architecture description (Release 14)"

[4] 3GPP TS 36.211, "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation (Release 14)"

[5] 3GPP TS 36.104, "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (Release 14)."

[6] Signaling Protocols and Procedures for Citizens Broadband Radio Service (CBRS): Spectrum Access System (SAS) – Citizens Broadband Radio Service Device (CBSD) Interface Technical Specification, WINNF-TS-0016, Version V1.1.0, 18 July 2017.

[7] Electronic Code of Federal Regulations, Title 47, Chapter I, Subchapter D, Part 96, **http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=0076fe7586178336d9db4c5146da8797&mc=true&n=pt47.5.96&r=PART&ty=HTML.**

[8] West, D. B. (1996), Introduction to Graph Theory, Prentice-Hall.

3 Definitions and Abbreviations

3GPP: 3rd Generation Partnership Project

BS: Base Station

CA: Carrier Aggregation

CBRS: Citizens Broadband Radio Service

CBRS-A: CBRS Alliance

CBSD: Citizens Broadband Radio Service Devices

CCG (Common Channel Group): A group of CBSDs, that are part of the same ICG, requesting a common primary channel assignment.

Connected Set: A set of CBSDs represented by the largest set of vertices of a graph created at the SAS or CxM, in which any two vertices of the set are connected to each other through at least one path in the graph.

CP: Cyclic Prefix

CxG (Coexistence Group): A group of CBSDs that abide by a common interference management policy which is used to coordinate their interference within the group.

CxM (Coexistence Manager): A logical entity responsible for managing coexistence between GAA users within a CxG in coordination with SAS.

DL: Downlink

DP: Domain Proxy

FFS: For Further Study

FS2: Frame Structure 2 corresponding to LTE-TDD operation in 3GPP Band 48.

FS3: Frame Structure 3 corresponding to LTE-LBT operation.

FSS: Fixed Satellite Service

GAA: General Authorized Access.

GNSS: Global Navigation Satellite System

GPS: Global Positioning System

GWBL: Grandfathered Wireless Broadband Licensee

ICG (Interference Coordination Group): A group of CBSDs belonging to the same CxG indicating that they can manage their own interference within the group, and do not need channel orthogonalization even if they have overlapping coverage.

ID: IDentification

LTE: Long Term Evolution

LTE-LBT: LTE-Listen Before Talk

LTE-TDD: LTE-Time Division Duplex. In the CBRS Band, LTE-TDD corresponds to Band 48 as defined by 3GPP.

NL: Network Listen

OOBE: Out Of Band Emission

OTA: Over the Air

PAL: Priority Access License

PTP: Precision Time Protocol

RAN: Radio Access Network

RF: Radio Frequency

SAS: Spectrum Access System

SFN: System Frame Number

SSF: Special Subframe

TAI: Temps Atomique International

TDD: Time Division Duplex

TDD Configuration: A TDD configuration for a LTE-TDD deployment is defined as a combination of a UL/DL configuration and an associated SSF configuration

TR: Technical Report

TS: Technical Specifications

UE: User Equipment

UL: Uplink

UTC: Coordinated Universal Time

4 GAA Coexistence Requirements for CBSDs

4.1 Cell Phase Synchronization and LTE-TDD Configuration

Cell phase synchronization and well-defined alignment of downlink and uplink resources have been identified as necessary requirements for coexistence between two LTE-TDD networks.

4.1.1 Cell Phase Synchronization

When several operators deploying LTE-TDD networks have to share a CBRS channel or operate in adjacent CBRS channels, coordination of timing and TDD configuration is important. Several methods are available to achieve phase synchronization of TDD networks, e.g. GPS or GNSS assistance [1], PTP, and NL. It is possible to achieve multi-operator frame synchronization based on existing parameters in 3GPP specifications in a manner that is independent of the actual source of timing information.

The definition of cell phase synchronization accuracy appears in 3GPP TS 36.133, Section 7.4 [2]:

> *Cell phase synchronization accuracy is defined as the maximum absolute deviation in frame start timing between any pair of cells on the same frequency that have overlapping coverage areas.*

The specification further establishes a requirement for accuracy at ≤ 3 μs for a wide area BS that has a cell radius ≤ 3 km and at ≤ 10 μs for a wide area BS that has a larger cell radius when measured against a common reference. In addition, accuracy requirement for Home BS small cells at a propagation distance smaller than or equal to 500 m is ≤ 3 μs, while a large cell Home BS covering more than 500 m distance and operating in Network Listening mode will have to maintain Cell Phase Synchronization accuracy at a level ≤ 1.33 μs more than the time of propagation from the network synchronization source; the requirement for Home Base Stations without network listening is equal to the small cell requirement. The 3GPP TS 36.133 is the definite reference for all requirements pertaining to cell phase synchronization [2].

The parameters that establish synchronization are further detailed in 3GPP TS 36.401, Section 9.1 [3].

An LTE-TDD CBSD that belongs to CBRS Alliance CxG shall derive frame timing with the following agreements:

1. **Time reference:** A time reference traceable to a common time reference. This time reference shall not be leap second adjusted according to [3]. Temps Atomique International (TAI) shall be used.

2. **SFN init time:** Initialization time for the SFN timing formula according to Section 9.1 of [3], expressed in the time reference above.

   A suitable SFN initialization time is the GPS epoch 1980-01-06 at midnight UTC, which equals 00:00:19 expressed in TAI [4]. It is not intended that two CBSDs match the SFN exactly, although they may choose to do so. However, the use of a common SFN initialization time serves to align the frame boundaries, and indeed the subframe boundaries, within the required timing accuracy.

All carriers in a CA scenario shall further maintain a common frame reference for all bands and band combinations as per 3GPP specifications [5].

When a LTE-TDD CBSD belonging to a CBRS Alliance CxG determines or predicts it is operating outside the allowable limits required for cell phase synchronization, the CBSD shall stop radio transmission. Once the CBSD determines or predicts it is able to operate within the allowable limits required for cell phase synchronization, the CBSD can start radio transmission assuming that it has authorization from the SAS.

4.1.2 TDD Configurations

The goal of the CBRS Alliance is to allow flexible use of CBRS band if coexistence of multiple deployments is preserved. It is well understood in the industry that multiple overlapping LTE-TDD deployments in the same band can coexist if they align their frame boundaries and use the same TDD configuration. Asynchronous operation in the same area can lead to detrimental interference conditions, and coexistence solutions without alignment of cell phases and TDD configurations may not be practical and/or efficient.

Table 1 lists the mandatory E-UTRA TDD Configurations for the CBRS Alliance CxG. The SSF configuration for these options is fixed to be SSF Configuration 7.

Table 1: Mandatory E-UTRA TDD Configurations for the CBRS Alliance Coexistence Group.

Note: The SSF configuration for these options is fixed to be SSF Configuration 7.

Uplink-Downlink Configuration	UL:DL ratio	Subframe Number									
		0	1	2	3	4	5	6	7	8	9
1	4:4	D	S	U	U	D	D	S	U	U	D
2	2:6	D	S	U	D	D	D	S	U	D	D

CBRS Alliance requires all LTE-TDD CBSDs that are part of the same connected set use the same TDD configuration. LTE-TDD CBSDs may attempt to agree on a common TDD configuration within the connected set in cases of conflict.

If all the LTE-TDD CBSDs in a connected set agree to use the same TDD configuration, any 3GPP TDD Configuration and SSF Configuration as defined within [4] may be used.

If LTE-TDD CBSDs belonging to the same connected set cannot agree on a common TDD configuration, the CBRS Alliance CxM shall designate the use of one mandatory TDD configuration from those listed in Table 1, which also requires the use of SSF Configuration 7. The choice of a particular mandatory TDD configuration in the corresponding connected set is FFS.

All LTE-TDD CBSDs that are part of the CBRS-A CxG shall support the mandatory TDD configurations described in Table 1.

4.2 SAS-CBSD Protocol Extensions

To facilitate management of the CBRS Alliance CxG by the CBRS Alliance CxM, all CBSDs that declare themselves to be part of the CBRS Alliance CxG need to exchange information with the CBRS Alliance CxM. This is accomplished by including this information on various messages of the SAS-CBSD protocol [6]. In particular, in the direction of CBSD to CxM, the information is contained in the *groupInfo* object of the *GroupParam* data object. In the direction of CxM to CBSD, the information is contained in the *GroupConfig* data object. The details are in the following subsections.

4.2.1 Information Transfer from CBSD/DP to CxM

A CBSD can send grouping information to a CxM by including the *groupingParam* parameter in the *RegistrationRequest,* the *SpectrumInquiryRequest, or* the *GrantRequest* object [6]. The *groupingParam* parameter and its content are defined in Table 2 and Table 3.

Table 2: *groupingParam* in request messages

Parameter	R/O/C	Parameter Information
NAME: *groupingParam* DATA TYPE: array of object: *GroupParam*	Conditional	An array of data objects that include information on CBSD grouping. This parameter shall be included in the *RegistrationRequest* object and the *GrantRequest* object. This parameter may be included in the *SpectrumInquiryRequest* object.

Table 3: *GroupParam* Object Definition

Parameter	R/O/C	Parameter Information
NAME: *groupType* DATA TYPE: string	Required	Enumeration field describing the type of group this group ID describes.
NAME: *groupId* DATA TYPE: string	Required	This field specifies the identifier for this group of CBSDs.
NAME: *groupInfo* DATA Type: object: *GroupInfo*	Required	This field specifies group information for CBSDs.

A CBSD shall indicate membership in the CBRS Alliance CxG by use of a single instance of the *GroupParam* object. In particular, it shall set *groupType* to "COEXISTENCE_GROUP" and *groupId* to "CBRS_ALLIANCE" in the *GroupParam* object.

GroupInfo is a data object that specifies group information in addition to *groupType* and *groupID* as specified in Table 4 to Table 7.

Table 4: *GroupInfo* Object Definition

Parameter	R/O/C	Parameter Information
NAME: *cbrsAllianceInfo* DATA TYPE: object: *CbrsAllianceInfo*	Required	This parameter includes additional group information of the CBRS Alliance CxG.

Table 5: *CbrsAllianceInfo* Object Definition

Parameter	R/O/C	Parameter Information
NAME: cbrsaVersion DATA TYPE: string	Required	This parameter indicates the version of the CBRS Alliance CBSD/DP – CxM protocol implemented by the CBSD/DP. In this version of this specification, this parameter shall be set to the value "v1.0".
NAME: *frameStructure* DATA TYPE: *array of string*	Required	The type of radio access technology used by the CBSD. Permitted enumerations are "FS2" and "FS3".
NAME: *desiredTddConfig* DATA TYPE: object: *EutraTddConfig*	Optional	If *frameStructure* is "FS2", this parameter indicates the desired E-UTRA TDD configuration.

Parameter	R/O/C	Parameter Information
NAME: *usedTddConfig* DATA TYPE: object: *EutraTddConfig*	Conditional	If *frameStructure* is "FS2", this parameter shall be included in the *GrantRequest* object, indicating the E-UTRA TDD configuration to be used for the grant.
NAME: *cbrsaGroupingParam* DATA TYPE: array of object: *CbrsaGroupParam*	Optional	The CBSD can optionally indicate its membership of group types defined by the CBRS Alliance.

Table 6: *EutraTddConfig* Object Definition

Parameter	R/O/C	Parameter Information
NAME: *ulDLConfig* DATA TYPE: number	Required	E-UTRA TDD UL/DL configuration. Permitted values are 0, 1, 2, 3, 4, 5, and 6.
NAME: *ssfConfig* DATA TYPE: number	Required	E-UTRA TDD special subframe configuration. Permitted values are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10.

Table 7: *CbrsaGroupParam* Definition

Parameter	R/O/C	Parameter Information
NAME: *cbrsaGroupType* DATA TYPE: string	Required	Allowed values are "CBRSA_ICG" or "CBRSA_CCG". If *cbrsaGroupType* is set to "CBRSA_ICG", the CBSD belongs to an Interference Coordination Group (ICG) defined by the CBRS Alliance. If *cbrsaGroupType* is set to "CBRSA_CCG", the CBSD belongs to a Common Channel Group (CCG). In this version of the specification, a CBSD shall belong to no more than one CCG. Definitions of ICG and CCG are in Appendix A: Intra-CxG Coexistence.

Parameter	R/O/C	Parameter Information
NAME: *cbrsaGroupId* DATA TYPE: string	Required	This field specifies the identifier for this group of CBSDs. *cbrsaGroupId* shall be the concatenation of CBSD *userId* (as defined in [6]) and a string chosen by the user to uniquely identify the group among CBSDs with the same *userId*.

4.2.2 Information Transfer from CxM to CBSD/DP

Based on the CBRS Alliance coexistence policies (described in Section 4.1.2), a CxM can suggest a new E-UTRA TDD configuration for a CBSD by assigning an E-UTRA TDD parameter value in the *groupingConfig* parameter that the SAS can include in the *RegistrationResponse,* the *SpectrumInquiryResponse,* the *GrantResponse,* or the *HeartbeatResponse* object [6]. The *groupingConfig* parameter and its content are defined in Table 8 to Table 10.

Table 8: *groupingConfig in response messages*

Parameter	R/O/C	Parameter Information
NAME: *groupingConfig* DATA TYPE: object: *GroupConfig*	Optional	A data object that contains group configuration information for the CBSD.

Table 9: *GroupConfig* Object Definition

Parameter	R/O/C	Parameter Information
NAME: *cbrsAllianceConfig* DATA TYPE: object: *CbrsAllianceConfig*	Optional	This parameter is included if the CxM intends to configure the CBSD with specified coexistence parameter values.

Table 10: *CbrsAllianceConfig* Object Definition

Parameter	R/O/C	Parameter Information
NAME: cbrsaVersion DATA TYPE: string	Required	This parameter indicates the version of the CBRS Alliance CBSD/DP – CxM protocol implemented by the CxM. In this version of this specification, this parameter shall be set to the value "v1.0". If the CxM implements multiple versions of this specification that include the version supported by the CBSD/DP, the CxM shall set this parameter to the value sent by the CBSD/DP in the most recent *cbrsAllianceInfo* object and shall operate according to that version of the protocol.
NAME: *eutraTddConfig* DATA TYPE: object: *EutraTddConfig*	Required	If included, this parameter specifies the EUTRA TDD configuration that the CBSD shall use for all its "FS2" grants.

Inclusion of a parameter to indicate primary or expansion channels is for further study.

4.3 GAA channelization

For CBSDs that are members of the CBRS Alliance CxG, only combinations of 5 MHz channel units can be used for spectrum inquiry and grant request for GAA. Thirty channel units of 5 MHz width are defined with the following frequency ranges (in MHz)

$$[3550 + (k-1) * 5, 3550 + k * 5], k = 1, 2, \dots, 30.$$

CBSDs shall request a spectrum grant in multiples of these 5 MHz channel units. CxM will follow the above GAA channelization for any guard band allocation in multiples of 5MHz.

Appendices (Informative)

Appendix A: Intra-CxG Coexistence

This section describes intra-CxG primary channel assignment of GAA grants for the CBRS Alliance CxG assuming LTE-TDD (FS2) as the underlying technology. Future versions of this specification aim to add support for LTE-LBT (FS3). Incumbent and PAL protection is handled by the SAS per Part-96 requirements [7] and the CxM procedures are subordinate to any decisions imposed by the SAS for this purpose.

The CBRS Alliance CxM is responsible for allocating a pool of spectrum designated by the SAS for the CBRS Alliance CxG among all CBSDs claiming membership in the CxG. The allocation of spectrum will account for fair division and/or sharing of spectrum between CBSDs that fall under different classifications e.g., LTE-TDD or LTE-LBT. Intra-CXG coexistence procedures may also require insertion of guard bands between classes of CBSDs that would otherwise interfere with one another due to insufficient adjacent channel protection, e.g., between LTE-TDD and LTE-LBT.

The assumption in the following is that all the LTE-TDD CBSDs use the same TDD configuration and are time synchronous (per the specifications defined in Section 4) to eliminate CBSD to CBSD or UE to UE interference between different LTE-TDD systems.

The objective of the intra-CxG channel assignment is to balance fairness and spectrum allocation efficiency. CBSDs that have secured CBRS Alliance certification can indicate an optional membership in an ICG to the CxM. Membership in an ICG in turn indicates to the CxM managing the declared CxG that the corresponding CBSDs are capable of managing interference among themselves, and that the CxM need not require orthogonalization of spectrum allocation between individual radios that may be in close proximity to one another. Any subset of CBSDs in an ICG can further declare membership in a CCG. Membership in a CCG declares that corresponding CBSDs are requesting a common primary channel allocation, e.g., for improved mobility performance or advanced antenna techniques. Membership in an ICG should classify a CBSD as being LTE-TDD or LTE-LBT. The ability of a CBSD to belong to different CCGs, e.g., each CCG corresponding to a different spectrum grant, is for further study. The following figure illustrates the relationship between CBSDs in the CBRS Alliance CxG, ICGs, and CCGs.

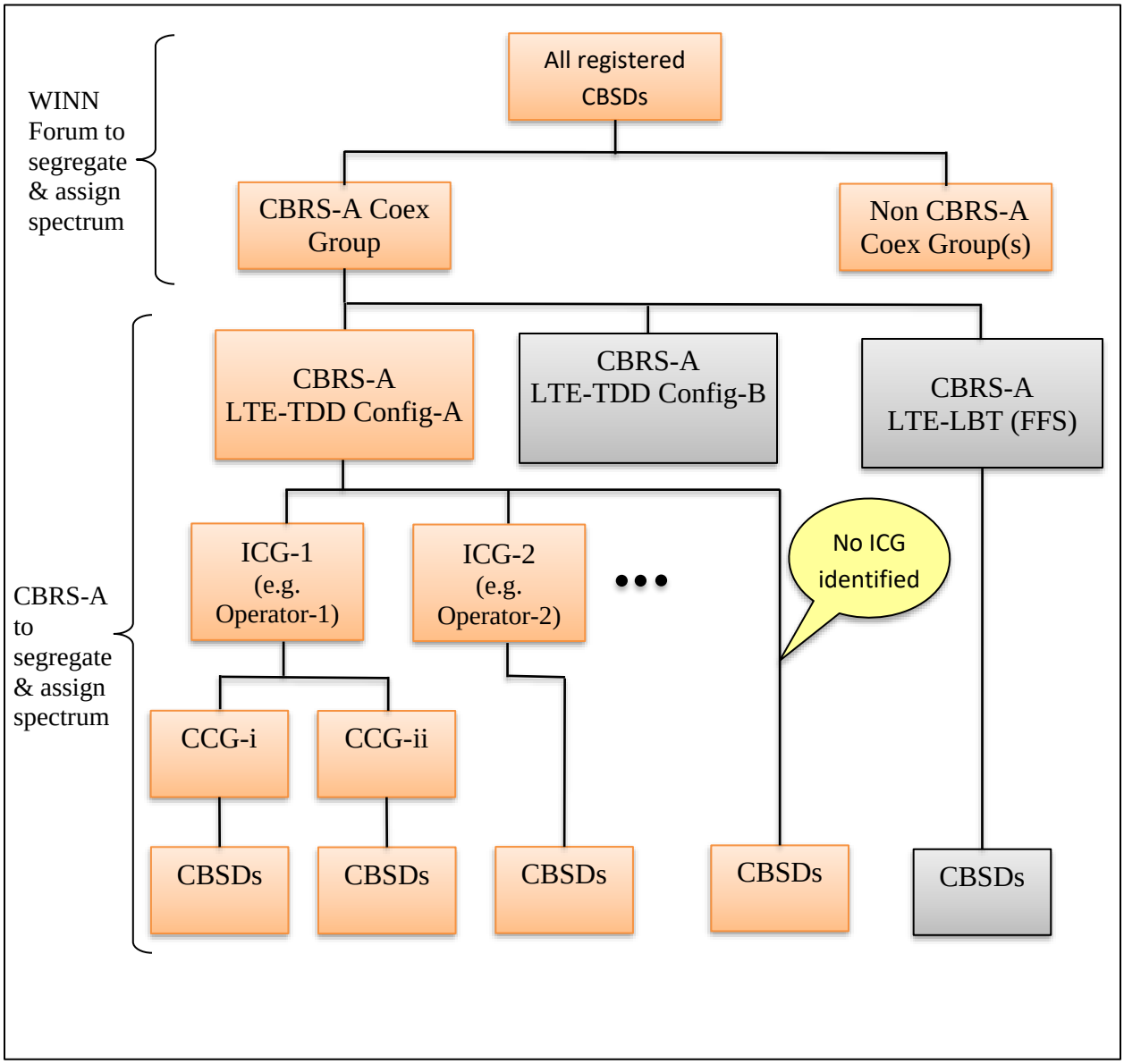

Figure 1: Relationship between CBSDs in the CBRS Alliance CxG, ICGs, and CCGs.

Note: Config-A and Config-B represent different TDD configuration choices in CBRS Alliance CxG.

In this section, "coverage" refers to the CBSD downlink coverage. Considerations for coverage adjustment based on uplink performance are for further study.

Primary Channel Assignment

The SAS is responsible for providing the CxG with a spectrum allocation that is meant to be distributed among CBSDs within that CxG. The SAS decides the spectrum availability on the basis of a process that involves the construction of graphs made up of SAS connected sets, one or more of which belong to a particular CxG. Each graph is composed of CBSDs at the vertices with edges connecting them if CBSDs on either side of an edge exhibit a coverage overlap and are potentially mutual interferers. The method of allocating spectrum to a CxG is a matter for the SAS and is under study in WInnForum. The CBRS Alliance CxG is managed by a CxM that is initialized with the SAS provided list of CBSDs in the associated SAS connected sets and a pool of spectrum for distribution to the CBSDs. The SAS also makes available to the CxM any declarations of membership in an ICG or a CCG as provided by the CBSD during registration. The SAS may optionally share with the CxM the entire graph of each connected set.

The CxM proceeds by constructing new graphs with the SAS-provided list of CBSDs in the original connected sets. The resulting graphs will be based on internal modeling of the propagation environment as well as RF measurements available at the CxM that may initially remove edges from the original graph constructed by the SAS due to more realistic modeling assumptions. Further removal of edges is also carried out following a principle of separation to be further developed below: the connected set can be partitioned on the basis of incompatibility of the air-interface of any sort, e.g., different TDD configurations, the corresponding spectrum pool is partitioned for the purposes of primary channel allocation. The allocation of spectrum for LTE-LBT use is left for further study.

The CxM considers each SAS connected set and its associated pool of spectrum separately. To ensure proper coexistence between LTE-TDD CBSDs within the LTE-TDD spectrum, the CxM considers LTE-TDD CBSDs and the coverage overlap between different CCGs by creating a "LTE-TDD overlap graph". The ICG and CCG memberships of CBSDs in a particular SAS connected set are recorded. Each SAS connected set is processed independently as follows:

- Each vertex of the graph is a CCG partition.
    - The CxM may separate each CCG into two or more CCG partitions, each representing a separate vertex in the graph, if the CBSDs from a given CCG partition do not have coverage overlap with any CBSD of any other CCG partitions. It is noteworthy that no new edges are created in the process. Since channels will be assigned to vertices of the graph, this will ensure common primary channel assignment only when it is necessary. The coverage contour threshold for this purpose is FFS. Also, the impact of incumbent protection constraints on CCGs is FFS.
    - If a CBSD does not indicate any CCG, the CxM treats the CBSD as a CCG by itself and creates a vertex for the CBSD in the graph.
- There is an edge between two vertices of the graph if the corresponding CBSDs have coverage overlap. The definition of coverage overlap is based on coverage contours around a group of CBSDs represented by a vertex and determining if another group of CBSDs represented by another vertex creates undesirable aggregated interference on the boundary or inside the coverage contour. The coverage contour and interference threshold for this purpose is FFS.

- If all CBSDs corresponding to two vertices belong to the same ICG, there should be no edge between the two vertices.

After the CxM creates the LTE-TDD overlap graph, it finds different connected components of the graph, and each connected component becomes a "LTE-TDD connected set". At this point, the CxM considers each LTE-TDD connected set separately and performs the primary channel assignment independently for each LTE-TDD connected set:

- The CxM attempts to color each vertex of a LTE-TDD connected set with minimum number of colors in the entire graph such that any two vertices with an edge between them have different colors. This minimum number is called the chromatic number [8].
- The LTE-TDD spectrum available to the LTE-TDD connected set is divided into orthogonal and equal primary channels, and each vertex is assigned one of these channels corresponding to the color of the vertex in the graph.

The CxM should ensure stability of primary channel assignments as much as possible except in cases where the SAS is constrained by incumbent protection requirements. After the primary channel assignment, different CBSDs will still have to individually request grants for the assigned channels, since SAS has to enforce incumbent and PAL protection and modify parameters for individual grants as requested by the CBSDs.

Primary Channel Protection and Bandwidth Expansion

The CxM can allow bandwidth expansion outside the primary channel allocation. Primary channel protection is a fundamental factor behind allowing any CBSD to be permitted bandwidth expansion. That is, expansion outside the primary channel is possible only if such expansion does not cause unacceptable interference to another CBSD's primary channel allocation. Interference analysis will account for cochannel and adjacent channel protection in this regard.

In addition, any bandwidth expansion needs to comply with incumbent and PAL protection that is enforced by SAS.

The bandwidth expansion can be dynamic (e.g., based on load and RF conditions) and is left for further study. Multiple bandwidth expansion requests for the same spectrum may result in unacceptable interference to those CBSDs. The resolution of such conflicts is FFS.

Appendix B: Revision History

Table B-1: Change History

Version	Date	Description
V1.0.0	2018-02-01	Release 1 of this Specification