Signaling Protocols and Procedures for Citizens Broadband Radio Service (CBRS):

Spectrum Access System (SAS) - Citizens Broadband Radio Service Device (CBSD) Interface Technical Specification

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Spectrum Access System (SAS) - Citizens Broadband Radio Service Device (CBSD) Interface Technical Specification

1   Introduction

2   Scope

This document is the Technical Specification of the signaling protocol and procedures for the SAS-CBSD interface.

The key words "required", "shall", "shall not", "should", "should not", "recommended", "may", and "optional" in this document are to be interpreted as described in RFC-2119 [n.2]. In addition, the key word "conditional" shall be interpreted to mean that the definition is an absolute requirement of this specification only if the stated condition is met.

3   References

3.1   Normative references

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

[n.1]   WINNF-TS-0065 Version V1.0.0, "CBRS Communications Security Technical Specification".

[n.2]   RFC-2119, "Key words for use in RFCs to Indicate Requirement Levels", March 1997.

[n.3]   RFC-5246, "The Transport Layer Security (TLS) Protocol Version 1.2", Dierks and Rescorla, August 2008.

[n.4]   RFC-2818, "HTTP Over TLS", Rescorla, May 2000.

[n.5]   RFC-5280, "Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Profile", Cooper, Santesson, Farrell, Boeyen, Housley & Polk, May 2008.

[n.6]   RFC-2616, "Hypertext Transfer Protocol -- HTTP/1.1", Fielding, Gettys, Mogul, Frystyk, Masinter, Leach and Berners-Lee, June 1999.

[n.7]   RFC-3339, "Date and Time on the Internet: Timestamps", Klyne, Newman, July 2002.

[n.8]   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.

[n.9]   RFC-3986, "Uniform Resource Identifier (URI): Generic Syntax", Berners-Lee, Fielding, Masinter, January 2005.

[n.10] RFC-7159, "The JavaScript Object Notation (JSON) Data Interchange Format", March 2014.

[n.11] NGA.STND.0036_1.0.0_WGS84 (Version 1.0.0 - July 8, 2014): Department of Defense (DoD) World Geodetic System (WGS) 1984.

[n.12] WINNF-TS-0112 Version 1.3.0, "Requirements for Commercial Operation in the U.S. 3550-3700 MHz Citizens Broadband Radio Service Band".

[n.13] 47 CFR §2.302 (see http://www.ecfr.gov/cgi-bin/text-idx?node=se47.1.2_1302).

[n.14] RFC-1035, "Domain Names - Implementation and Specification", Mockapetris, November 1987.

[n.15] RFC-7231, "Hypertext Transfer Protocol (HTTP/1.1): Semantics and Content", Fielding, Reschke, June 2014.

[n.16] VOID

[n.17] VOID

[n.18] RFC-7542, "The Network Access Identifier", DeKok, May 2015.

[n.19] RFC-7515, JSON Web Signature (JWS), Jones, Bradley and Sakimura, May 2015.

[n.20] RFC-4648, The Base16, Base32, and Base64 Data Encodings, Josefsson, October 2006.

[n.21] WINNF-17-SSC-0002, "Signaling Protocols and Procedures for Citizens Broadband Radio Service (CBRS): WInnForum Recognized CBRS Air Interfaces and Measurements" V2.0.2.

3.2   Informative references

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

[i.1] WINNF-15-P-0047-V1.0.0, "SAS Functional Architecture", Wireless Innovation Forum Spectrum Sharing Committee, 7 September 2015.

[i.2] VOID

[i.3] VOID

[i.4] Report and Order and Second Further Notice of Proposed Rulemaking, Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, GN Docket No. 12-354, Federal Communications Commission, 21 April 2015.

[i.5] Order on Reconsideration and Second Report and Order, Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, GN Docket No. 12-354, Federal Communications Commission, 2 May 2016.

4   Definitions and abbreviations

4.1   Abbreviations

CBSD   Citizens Broadband Radio Service Device

CBRS	Citizens Broadband Radio Service.
CFR	Code of Federal Regulation.
CPI	Certified Professional Installer.
DP	Domain Proxy
EIRP	Effective Isotropic Radiated Power
FFS	For Further Study
GAA	General Authorized Access.
HAAT	Height Above Average Terrain
HTTP	Hypertext Transfer Protocol.
HTTPS	HTTP over TLS.
ICG	Interference Coordination Group
JSON	JavaScript Object Notation.
PAL	Priority Access License
PPA	PAL Protection Area
SAS	Spectrum Access System
TLS	Transport Layer Security.
UR-ID	User Registration Identity (see [n.12]).

4.2   Definitions

Blacklist: A list of *CBSDs* that are to be denied service.

CBRS band: The 3550-3700 MHz Citizens Broadband Radio Service band.

CBSD Antenna: The radiating element(s) of the CBSD. Each CBSD has one CBSD Antenna. Note that the CBSD's antenna may be instantiated with multiple physical antennas (e.g., an antenna array for MIMO operation), but those antennas must be transmitting one aggregate waveform collectively from a single geolocation, and with a total transmit power that conforms to all the CBSD's registration parameters and authorized transmit power levels provided by the SAS in its active Grants (e.g., maximum allowable EIRP).

CBSD Registration: The procedure by which a CBSD indicates to a SAS its intention to operate. Successful registration implies a validation by the SAS that the CBSD has been FCC certified and confers on the CBSD the right to be authorized by the SAS to operate in accordance with a Grant. During the registration process, each CBSD provides a fixed location, unique identifiers (e.g., owner information, device information), *Group* membership, and radio-related capabilities. A successful registration procedure concludes with the SAS providing a unique identifier for that CBSD.

CBSD User: The registered entity that has operational responsibility for the CBSD.

Channel: the contiguous frequency range between lower and upper frequency limits.

Citizens Broadband Radio Service Device (CBSD): Fixed Stations, or networks of such stations, that operate on a Priority Access or General Authorized Access basis in the Citizens Broadband Radio Service consistent with Title 47 CFR Part 96 [n.8]. For CBSDs which comprise multiple nodes or networks of nodes, CBSD requirements apply to each node even if network management and communication with the SAS is accomplished via a single network interface.

Domain Proxy (DP): An entity engaging in communications with the SAS on behalf of multiple individual CBSDs or networks of CBSDs. The Domain Proxy can also provide a translational capability to interface legacy radio equipment in the 3650-3700 MHz band with a SAS to ensure compliance with Part 96 rules [n.8].

Grant: The authorization provided by a SAS to a CBSD, subject to a Heartbeat exchange, to transmit using specified operating parameters. Grants are identified by a unique Grant identifier. Once issued, a Grant's operating parameters are never changed; if new or modified operating parameters are required, then a new Grant must be obtained. The Grant's operating parameters are maximum EIRP and Channel. A Grant can be in different states as defined in section 7.

Group: A collection of *CBSDs* which are provided a special, common form of management by the SAS. The nature of the special management is dependent on Group type.

Interference Coordination Group: A group of CBSDs that does not require intra-group, inter-CBSD interference coordination from the SAS.

PAL reserved channel: A 10 MHz channel in the range of 3550-3650 that a SAS may establish for exclusive use of a set of one or more CBSDs that are registered as belonging to a PPA based upon acquired PAL rights.

PAL Protection Area (PPA): An area within a PAL established by a PAL owner for protecting exclusive use of channels based upon the acquisition of PAL rights. The area is based upon the coverage area of the set of CBSDs that are members of the PPA. The SAS maintains a list of CBSDs that are members of the PPA.

REG-Conditional: A parameter in the *RegistrationRequest* object that may be provided by the CBSD or may be provided through other means. See section 10.1.

Spectrum Access System (SAS): A system that authorizes and manages use of spectrum for the Citizens Broadband Radio Service in accordance with subpart F in [n.8].

5 Architecture of SAS-CBSD Interfaces

This informative section provides the interfaces related to the protocols that are defined in this specification. The figure below is a subset of the architecture described in [i.1].
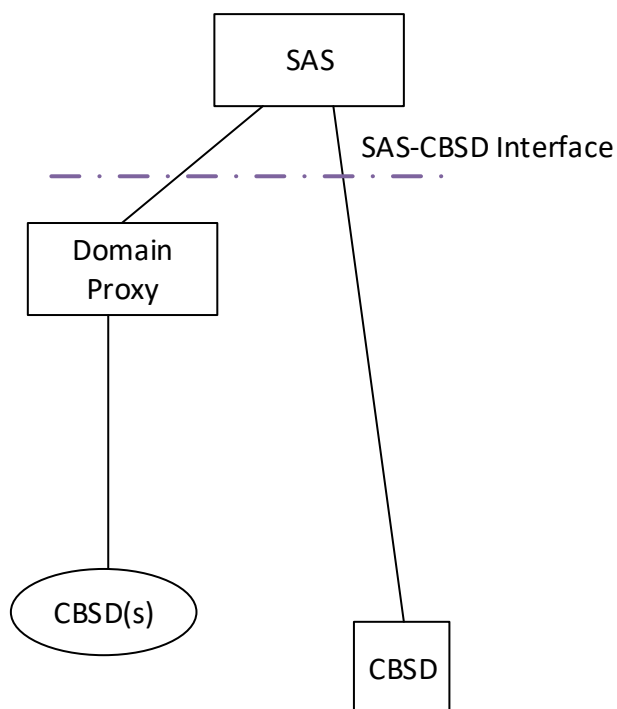
Figure 1: SAS-CBSD Protocol Interfaces

CBSD: The CBSD is a radio device that communicates in the CBRS band. It obtains Grants from the SAS via the SAS-CBSD interface.

Domain Proxy (DP): The DP is a logical entity that can represent one or more CBSD(s) to the SAS. The DP presents a consistent and secure interface to the SAS that can convey all messages pertaining to the SAS-CBSD interface for client CBSDs.

SAS: A system that authorizes and manages use of spectrum for the Citizens Broadband Radio Service in accordance with subpart F [n.8].

For further information please see:

- The first and second Report and Order documents from the FCC [i.4] and [i.5].

- Part 96 rules [n.8].

- Wireless Innovation Forum Spectrum Sharing Committee CBRS requirements [n.12].

6 Void

7 CBSD States and State Transitions

The operation of a CBSD can be informatively described using two state machines. The registration state machine is responsible for identifying the presence of a CBSD at the SAS and determines whether the CBSD is *Unregistered* or *Registered* at the SAS. Each CBSD has one registration state machine. The Grant state machine represents the states of a CBSD Grant, i.e., *Idle*, *Granted*, and *Authorized*. A CBSD can have multiple Grants and each Grant corresponds to a separate Grant state machine.

Figures 2 and 3 illustrate the CBSD registration state diagram and the CBSD Grant state diagram respectively, where rectangle boxes indicate different states and arrows show possible state transitions.
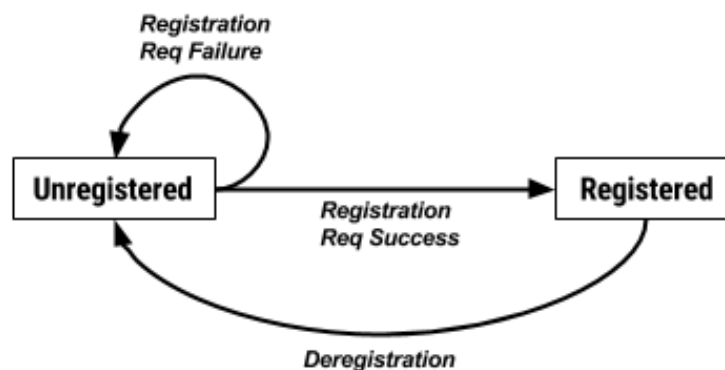
Figure 2: CBSD Registration State Diagram

In Figure 2, a CBSD starts off in the *Unregistered* state. An *Unregistered* CBSD can send a *RegistrationRequest* object to the SAS and if the SAS approves the registration in a *RegistrationResponse* object, the CBSD transitions to the *Registered* state. If the SAS rejects the registration in a *RegistrationResponse* object, the CBSD remains in the *Unregistered* state. A CBSD in the *Registered* state can also send a *DeregistrationRequest* object to deregister the CBSD. Once a SAS receives a *DeregistrationRequest* object, the SAS responds to the CBSD with a *DeregistrationResponse* object and declares the CBSD to be in the *Unregistered* state. The CBSD transitions to the *Unregistered* state and all existing Grants associated with the CBSD are terminated.

Notes regarding SAS implementation:

- Incomplete CBSD registration information can be known by the SAS for an *Unregistered* CBSD.

- Any *RegistrationRequest* object received by the SAS can be rejected (the CBSD remains in the *Unregistered* state) with the *responseCode* parameter set to 200 (REG_PENDING) due to incomplete registration information.

- CBSD registration information can be supplied from a variety of sources, including information conveyed by a Certified Professional Installer (CPI), e.g., by entry into a web-interface provided by the SAS administrator or via entry into the CBSD, by a set of data provided by the CBSD manufacturer, by the CBSD using the protocol specified in this document, or by other means outside of the scope of this document.
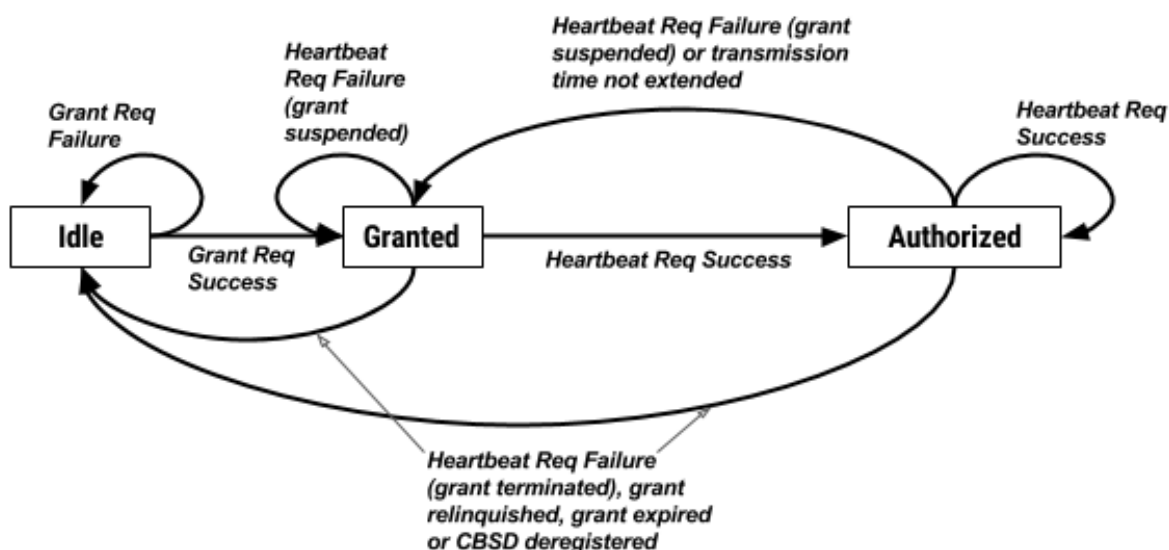
Figure 3: CBSD Grant State Diagram

Figure 3 shows the state transitions of a CBSD Grant. A CBSD in the *Registered* state can request one or multiple Grants from the SAS. A Grant state machine is in the *Idle* state if a Grant has not been approved by the SAS. A CBSD can send the SAS a *GrantRequest* object. If a Grant request is approved, a new Grant is created with operational parameters and a channel allocation. The reception of a successful *GrantResponse* object causes transition to the *Granted* state. A CBSD with a Grant that is ready to commence RF transmission commences heartbeat requests associated with the Grant. If a CBSD receives multiple Grants, individual heartbeat requests are sent for each Grant, possibly aggregated in a single transmission to the SAS. If the SAS approves a heartbeat request, the Grant transitions to the *Authorized* state. In the *Authorized* state, the CBSD is permitted to commence RF transmission and operate in the CBRS band using the operational parameters specific to that Grant. The Grant transitions from the *Authorized* state back to the *Granted* state if the Grant is suspended by the SAS or the transmission right, as defined by the *transmitExpireTime* parameter in the *HeartbeatResponse* object, has expired. The Grant state transitions to *Idle* if a Grant is terminated by the SAS, relinquished by the CBSD, or expired as defined in the *grantExpireTime* parameter, or the SAS to CBSD connectivity is lost (see Section 8.6).

8 SAS-CBSD Procedures

This section contains detailed procedures describing the transactions over the SAS-CBSD interface (see Figure 1). These procedures describe how the messages specified in section 10 are used and how they are combined to perform activities.

The SAS-CBSD protocol is based on the HTTPS (HTTP over TLS, ref. [n.4]) protocol as specified in section 9.2. The HTTPS protocol provides transport level assurance that a message has been received by the intended recipient. In this version of this specification, the procedures of section 8 will use the mechanisms provided by the HTTPS protocol to manage SAS-CBSD message delivery.

8.1   SAS Discovery Procedure

All SAS administrators shall provide a URL formatted in accordance with [n.9] to CBSD Users. One or more SAS URLs are provisioned to CBSDs and Domain Proxies using a mechanism which is outside the scope of this specification.

All SAS administrators shall ensure that for URLs corresponding to their service, all required DNS resource records (e.g., A record, see section 3.4.1 in RFC-1035 [n.14]) are provisioned and up-to-date.

All SAS administrators shall provide their services using IPv4 and optionally using IPv6.

8.2   Authentication Procedure

TLS mutual authentication shall be performed per [n.1] whenever a CBSD or Domain Proxy communicates with a SAS. TLS-v1.2 as specified in [n.3] shall be used to perform authentication. Previous versions of TLS (e.g., TLS-v1.1 per RFC-4346, TLS-v1.0 per RFC-2246 or SSL-v3.0) shall not be used. During the TLS exchange, mutual authentication shall be performed. The CBSD/Domain Proxy initiating the TLS connection shall authenticate the SAS, and the SAS shall authenticate the CBSD/Domain Proxy.

During the TLS message exchange, the CBSD/Domain Proxy shall authenticate a SAS according to the procedures defined in [n.4]. Server certificate validation shall be performed according to the procedures in [n.5]. A CBSD or Domain Proxy which is unable to successfully authenticate a SAS shall abort the TLS connection establishment procedure. It is implementation specific when the CBSD should re-attempt the TLS connection establishment procedure.

During the TLS message exchange, the CBSD/Domain Proxy provides its client certificate to the SAS. The SAS shall perform client certificate validation according to the procedures in [n.5]. A SAS which is unable to successfully authenticate a CBSD or Domain Proxy shall abort the TLS connection establishment procedure.

8.2.1   TLS Encryption

Subsequent to successful authentication, the CBSD/Domain Proxy and SAS shall negotiate a ciphersuite to use for encrypting all communications between the two entities. The ciphersuite shall be selected from the following list (ref. [n.1]):

- TLS_RSA_WITH_AES_128_GCM_SHA256
- TLS_RSA_WITH_AES_256_GCM_SHA384
- TLS_ECDHE_ECDSA_WITH_AES_128_GCM_SHA256

- TLS_ECDHE_ECDSA_WITH_AES_256_GCM_SHA384
- TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256

A CBSD or Domain Proxy which is unable to successfully setup such an encrypted connection with a SAS shall abort the TLS connection establishment procedure. It is implementation specific when the CBSD/Domain Proxy should re-attempt the TLS connection establishment procedure.

8.2.2 *Successful Authentication Prerequisite for All SAS-CBSD Procedures*

All message exchanges involving communication between a CBSD or Domain Proxy and the SAS shall be performed in a TLS connection context established as described in sections 8.2 and 8.2.1. If such a TLS connection is already open, the procedures may be performed within that context. If a new connection is required, it shall be established using the same mechanisms and exception handling described in sections 8.2 and 8.2.1.

8.3 CBSD Registration Procedure

This procedure describes how a CBSD registers with a SAS as shown in Figure 4.

Informative Note: The CBSD Registration message exchange is initiated when the CBSD is in the *Unregistered* state (see section 7).
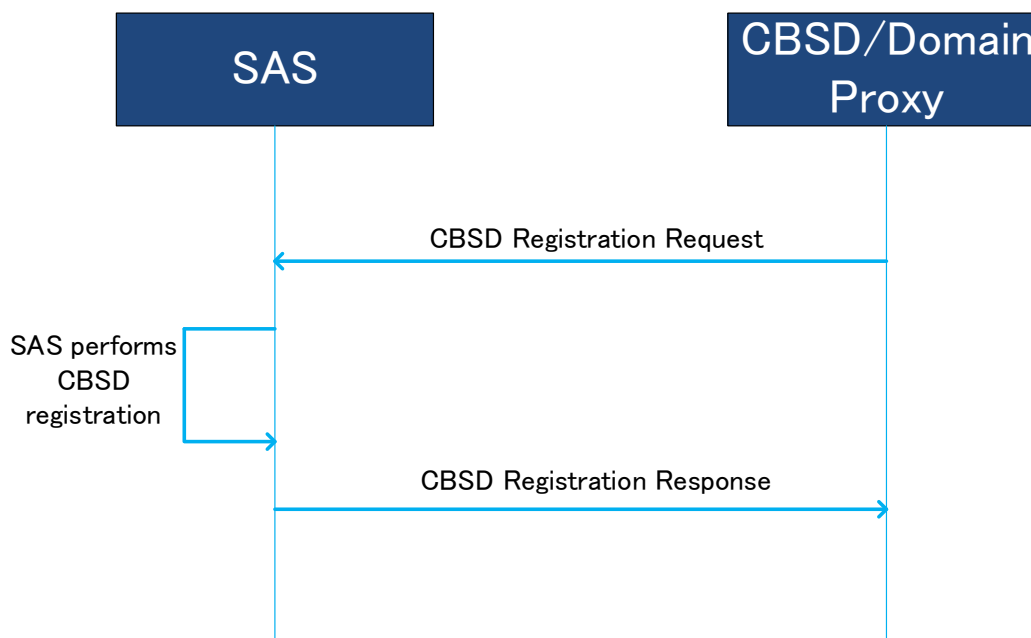
Figure 4: CBSD Registration Procedure.

8.3.1 *Successful operation*

This procedure is initiated after the CBSD has successfully discovered the SAS and performed Authentication per sections 8.2 and 8.2.1. The details of the authentication procedure are found in reference [n.1].

In the absence of the domain proxy, the CBSD first creates a secure association per section 8.2. The CBSD then initiates the Registration procedure by sending a *RegistrationRequest* object(*userId*, *fccId*, *cbsdSerialNumber*, *callSign*, *cbsdCategory*, *cbsdInfo*, *airInterface*, *installationParam*, *measCapability*, *groupingParam*) to the SAS. The *fccId*, *callSign*, *cbsdSerialNumber*, and *userId* parameters identify the CBSD to the SAS. The *cbsdCategory*, *cbsdInfo*, *airInterface*, and *installationParam* parameters provide specific information on the CBSD equipment capabilities. The *measCapability* parameter identifies the measurement reporting capabilities of the CBSD. The optional *GroupingParam* object requests the SAS to enroll the CBSD as a member of one or more Groups.

The SAS responds to the CBSD with a *RegistrationResponse* object (*cbsdId*, *measReportConfig*, *response*). The *response* parameter indicates whether the registration succeeded or failed. If the registration succeeded, the *RegistrationResponse* object contains a *cbsdId* parameter. The CBSD uses the *cbsdId* parameter value for all subsequent procedures with the SAS. If the *cbsdId* parameter value is missing or invalid in subsequent procedures, the SAS should use *responseCode* parameter value 103 (INVALID_VALUE) and include "cbsdId" in the *responseData* parameter. If the *measReportConfig* parameter is included in the *RegistrationResponse* object, the CBSD shall send the requested measurement report to the SAS (as indicated by the value of the *measReportConfig* parameter) per the defined semantics of the measurement capabilities in [n.21]. The measurement report requested by the SAS shall be consistent with the CBSD measurement capabilities indicated in the registration request. If the *measCapability* parameter contains only the empty string (""), the SAS assumes that the CBSD is not capable of reporting any measurements.

If the CBSD has any existing Grants prior to sending the *RegistrationRequest* object, all Grants shall be deleted. If the SAS had any existing Grants assigned to the CBSD, upon receiving the *RegistrationRequest* object from the CBSD, all such Grants shall be deleted.

If there is a Domain Proxy and the Domain Proxy is performing bulk CBSD registration, the Domain Proxy aggregates registration information for multiple CBSDs. The Domain Proxy sends an array of *RegistrationRequest* objects to the SAS which represents the aggregated CBSD registration information. Each *RegistrationRequest* object contains one instance of a registration request for a CBSD that the Domain Proxy is registering. Upon reception of the array of *RegistrationRequest* objects, the SAS initiates registration for each CBSD. The SAS responds with an array of *RegistrationResponse* objects, each containing a registration response to a CBSD (*cbsdId*, *measReportConfig*, *response*). The *response* parameter indicates whether the registration succeeded or failed. A Domain Proxy correlates the response objects with request objects as described in section 9.1. For requests that succeed, the Domain Proxy shall use the registered *cbsdId* parameter for all subsequent procedures with the SAS relative to each *Registered* CBSD.

If the *RegistrationRequest* object contains a *groupingParam* parameter containing a *GroupParam* object having the *groupType* parameter set to "INTERFERENCE_COORDINATION", the CBSD is requesting the SAS to not provide any intra-group, inter-CBSD interference coordination between CBSDs sharing the value of the *groupId* parameter provided in the request (Ref [n.8] 96.35(e), 96.41(d)(1)).

Notes:

- The procedure by which CBSDs determine a common value of *groupId*, and therefore Interference Coordination Group membership, is outside the scope of this specification.

- The CBSD's use of an Interference Coordination Group declares to the SAS that all members of the particular Group are using methods defined outside the scope of this specification to manage radio interference among themselves.

8.3.2 *Unsuccessful Operation*

If the registration is not successful, the SAS sends a *RegistrationResponse* object that does not contain a *cbsdId* parameter, and contains a *response* parameter indicating failure.

If the SAS determines the registration is incomplete, the SAS returns a *REG_PENDING* value in the *response* parameter. The CBSD should periodically repeat sending the *RegistrationRequest* object until receiving a successful *RegistrationResponse* object from the SAS.

> Note: For example, the REG_PENDING *responseCode* value can be used when the CPI needs to enter some additional part of the CBSD information.

If the SAS determines the CBSD operating privileges have been revoked, the SAS returns a *BLACKLISTED* value in the *response* parameter. When the CBSD operating privileges are restored, the CBSD may initiate a *RegistrationRequest* object. The method by which operating privileges are restored to the CBSD is outside the scope of this specification. The method used to trigger the CBSD registration is implementation specific.

If the SAS determines that there is an error with the format of the HTTP payload, it may return HTTP 400.

If the SAS determines an error with one of the parameters in the *RegistrationRequest* object, the SAS returns an *INVALID_VALUE* value in the *response* parameter along with the faulty parameter(s), see Table 40. The handling of a failure is out of scope of this specification.

If there is a Domain Proxy, the Domain Proxy can receive an aggregated list of *RegistrationResponse* objects, each containing a registration response to a CBSD. For each CBSD registration that fails, there will be one *RegistrationResponse* object per CBSD containing a *response* parameter having a non-zero value. For each CBSD registration that fails, the corresponding *RegistrationResponse* object does not contain a *cbsdId* parameter. The Domain Proxy matches the individual responses to the individual requests as defined in section 9.1 and takes the appropriate action, possibly involving the CBSD(s).

8.4   CBSD Spectrum Inquiry Procedure

This procedure describes how a CBSD performs the Spectrum Inquiry procedure with the SAS. Spectrum Inquiry allows *Registered* CBSDs to request information on available channels. With the SAS providing available channel information, the CBSD can decide operational parameters for a Grant request. The CBSD may initiate this procedure after it has received a *cbsdId* value (see section *8.3.1*).
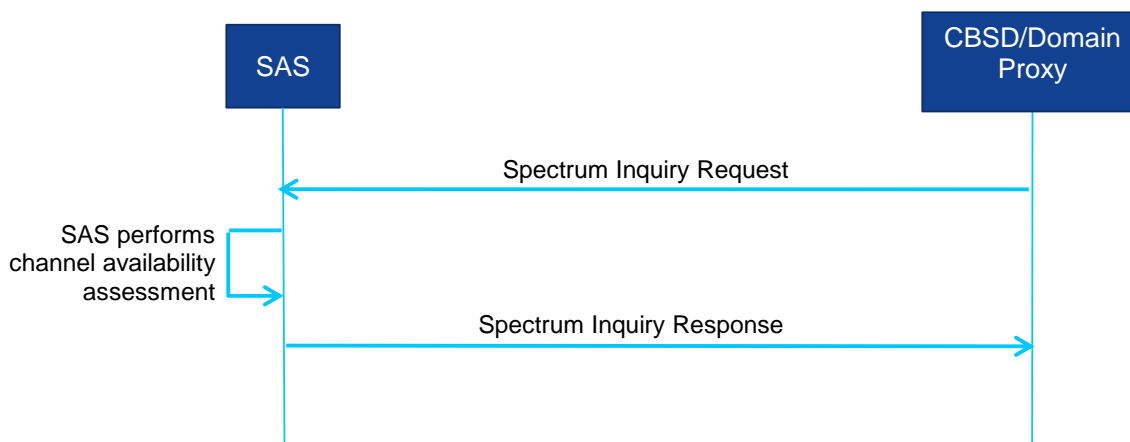
Figure 5: CBSD Spectrum Inquiry Procedure.

8.4.1   Successful operation

The Spectrum Inquiry procedure may be initiated if the CBSD wants the SAS to indicate specific information on channels available for the CBSD.

If there is no Domain Proxy, the CBSD initiates the Spectrum Inquiry procedure by sending a *SpectrumInquiryRequest* object (*cbsdId*, *inquiredSpectrum*, *measReport*) to the SAS. The *cbsdId* parameter identifies the CBSD to the SAS. The *inquiredSpectrum* parameter is an array of *FrequencyRange* objects indicating the frequency range(s) for which the CBSD seeks information. The CBSD may request information for one or more frequency ranges as described in section 10.3. The *measReport* parameter provides a means for the CBSD to report measurement results.

The SAS returns a *SpectrumInquiryResponse* object (*cbsdId*, *availableChannel*, *response*) to the CBSD with the results of the potential channel availability for the inquired spectrum. If a particular channel is not available, the corresponding response returned is the NULL string and a nominal regulatory rule designation of "Part 96". Available channels have a response code with the channel type ("PAL" or "GAA") and the regulatory rule that the SAS used to determine availability.

The SAS shall respond to the *SpectrumInquiryRequest* object. The CBSD should consider the information in the *availableChannel* parameter as an indication of the channels available to the CBSD.

> Note: The SAS is not required to reserve any channel allocations as part of Spectrum Inquiry procedure, nor is the SAS required to guarantee that the information in the AvailableChannel object is still valid when the CBSD initiates a Grant Request procedure.

If there is a Domain Proxy and the Domain Proxy is sending bulk *SpectrumInquiryRequest* objects, the Domain Proxy aggregates information related to each applicable CBSD into an array of *SpectrumInquiryRequest* objects as described in section 10. When the Domain Proxy receives the array of *SpectrumInquiryResponse* objects from the SAS, the Domain Proxy matches the individual responses to the individual requests as described in section 9.1 and takes the appropriate action, possibly involving the CBSD(s).

8.4.2 *Unsuccessful Operation*

If the SAS determines an error with one of the parameters in the *SpectrumInquiryRequest* object, the SAS returns a *SpectrumInquiryResponse* object with a *response* parameter including the faulty parameter(s); see Table 40. The handling of a failure is out of scope of this specification. If the *cbsdId* parameter is not present, a 102 (MISSING_PARAM) error shall be generated by the SAS. If the *cbsdId* parameter is invalid, a 103 (INVALID_VALUE) error shall be generated by the SAS. If the SAS finds the *inquiredSpectrum* parameter indicates a frequency range that is partially or completely outside of the CBRS band, a 300 (UNSUPPORTED_SPECTRUM) error shall be generated by the SAS.

If there is a Domain Proxy, the Domain Proxy can receive an aggregated list of *SpectrumInquiryResponse* objects. For each failed request, there is a failure reason in the *response* parameter. The Domain Proxy matches the response with the originating request as described in section 9.1 and takes the appropriate action, possibly involving the CBSD(s).

8.5 CBSD Grant Procedure

This procedure describes how a CBSD requests spectrum from the SAS. This procedure shall not be initiated until after the CBSD has successfully registered with the SAS. A CBSD is considered to be *Registered* when it has obtained a *cbsdId* value; the *cbsdId* value is revoked (i.e., invalidated) when the CBSD is deregistered. *SpectrumInquiryRequest* objects may be sent prior to sending the *GrantRequest* object if the CBSD wants the SAS to indicate specific information on channels available for the CBSD. A successful *HeartbeatResponse* object shall be received by the CBSD prior to activating its transmitter on any channel assigned during the Grant procedure.

Figure 6: CBSD Grant Procedure.

8.5.1 *Successful operation*

Prior to initiating a Grant request, the CBSD determines the operational parameters used in the Grant request. These operational parameters include the frequency range and maximum EIRP the
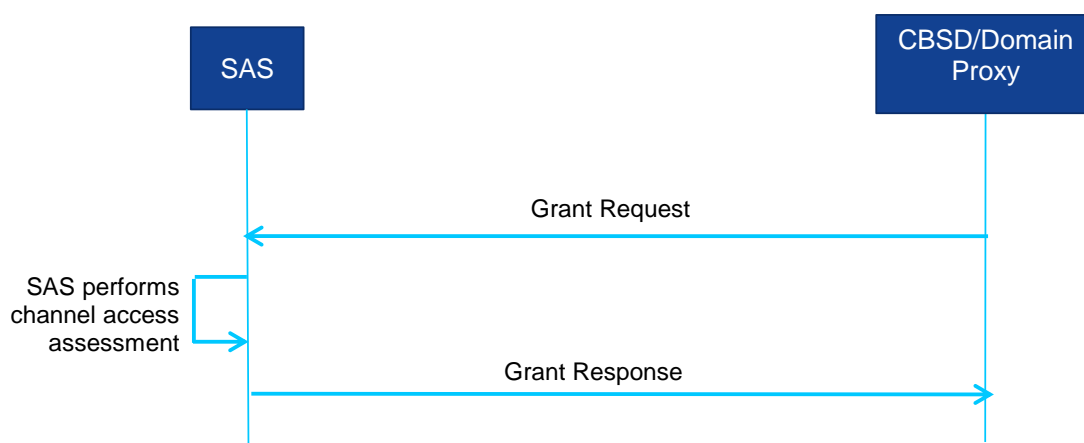
CBSD wants to use for operation. The determination of the specific operational parameters used in the Grant request depends on CBSD capabilities, current operation and configuration.

The CBSD initiates a Grant request by sending a *GrantRequest* object (*cbsdId*, *operationParam*, *measReport*) to the SAS. The *cbsdId* parameter identifies the CBSD to the SAS. The *operationParam* parameter contains the details of the Grant request including the CBSD maximum EIRP and the desired frequency range for use as described in section 10.5. The SAS may determine the eligibility of the CBSD to use PAL reserved channels by ascertaining if the CBSD (*cbsdId*) is a member of the set of CBSDs defining the PPA and the requested channel(s) corresponds to the PAL reserved channel(s) for that area. The SAS maintains a list of all the CBSDs that are registered members of the PPA. If the CBSD is a member of the list of CBSDs associated with a PPA, and if the requested frequency range is within that PPA's PAL reserved portion of the band, the Grant request is considered to be a PAL Grant request. If the requested frequency range is outside the PAL reserved portion of the band, or if the requesting CBSD is not a member of the appropriate PPA, then the Grant request is not considered to be a PAL Grant request, but is considered to be a GAA Grant request. The CBSD maximum EIRP indicates the maximum transmission EIRP the CBSD is requesting. The desired frequency range is a contiguous frequency range specified by low and high frequency values. The *measReport* parameter provides a means for the CBSD to report measurement results.

The SAS responds to the CBSD with a *GrantResponse* object (*cbsdId*, *grantId*, *grantExpireTime*, *heartbeatInterval*, *measReportConfig*, *operationParam*, *channelType, response*). The *response* parameter indicates whether the request succeeded or failed. If the Grant request succeeded, the SAS includes the *grantId* parameter, the *grantExpireTime* parameter, and the *heartbeatInterval* parameter. The CBSD uses the value of the *grantExpireTime* parameter to determine when the associated Grant expires. If the *heartbeatInterval* parameter is included, the CBSD uses the value as the maximum time interval between two consecutive *HeartbeatRequest* objects. Since the CBSD cannot transition to the *Authorized* state until the successful completion of the Heartbeat procedure, the CBSD should execute the first Heartbeat procedure following the *GrantResponse* object as soon as possible after the *GrantResponse* object is received. The *channelType* parameter is included if and only if the *response* parameter indicates SUCCESS. If the *measReportConfig* parameter is included, the CBSD shall send the requested measurement report to the SAS, as indicated by the value of the *measReportConfig* parameter, according to [n.21]. The measurement report requested by the SAS shall be consistent with the CBSD measurement capabilities indicated in the registration request. If the *GrantResponse* object includes an *operationParam* parameter, the CBSD may elect to issue a new *GrantRequest* object using the operational parameters included from that *operationParam* parameter.

If the SAS approves the Grant request, the SAS allocates spectrum according to the parameters in the *operationParam* parameter in the *GrantRequest* object. The SAS allocates the spectrum in a frequency range indicated by the *lowFrequency* and *highFrequency* parameters in the *operationParam* parameter. The CBSD shall not use that spectrum (i.e., activate its radio transmitter) until successfully completing the Heartbeat procedure.

If there is a Domain Proxy and the Domain Proxy is performing bulk Grant requests, the Domain Proxy aggregates information related to each applicable CBSD into an array of *GrantRequest* objects, each containing a Grant request of a CBSD as described in section 10. When the Domain Proxy receives the array of *GrantResponse* objects from the SAS, the Domain Proxy matches the

individual responses to the individual requests as described in section 9.1. If the response to a specific Grant request indicates that the Grant request succeeded, the CBSD/Domain Proxy takes the appropriate action.

8.5.2 *Unsuccessful Operation*

If the SAS determines an error with one of the parameters in the *GrantRequest* object, the SAS returns a *GrantResponse* object with a *response* parameter including the faulty parameter(s), see Table 40. The handling of a failure is out of scope of this specification. If the *cbsdId* parameter is not present, a 102 (MISSING_PARAM) error shall be generated by the SAS. If the *cbsdId* parameter is invalid, a 103 (INVALID_VALUE) error shall be generated by the SAS.

The SAS shall reject a Grant request which results in a Grant that includes both PAL and GAA channels. If the Grant request failed, the *GrantResponse* object:

- indicates the error in the *response* parameter,
- does not include a *grantId* parameter, and
- may optionally include an *operationParam* parameter.

If there is a Domain Proxy, the Domain Proxy can receive an aggregated list of *GrantResponse* objects. For each failed request, there will be a failure reason in the *response* parameter. The Domain Proxy matches the response with the originating request as described in section 9.1 and takes the appropriate action, possibly involving the CBSD(s).

8.6   CBSD Heartbeat Procedure

This procedure describes how a CBSD performs the Heartbeat procedure with the SAS. The *HeartbeatRequest* object informs the SAS that the CBSD needs access to the allocated spectrum. It also allows the SAS to suspend or terminate the Grant. If the transmit expiration timer expires prior to reception of a *HeartbeatResponse* object, the CBSD shall discontinue transmission for the Grant within 60 seconds after the value of the *transmitExpireTime* parameter expires, in accordance with part 96.39(c)(2) (ref. [n.8]). If the Grant is suspended or terminated, the SAS has the option, within the *HeartbeatResponse* object, of suggesting that the CBSD request alternative spectrum based on the *operationParam* parameter in the *HeartbeatResponse* object. The CBSD Heartbeat procedure may be executed concurrently for each active Grant. An active Grant has a *grantId* and is not terminated, expired or relinquished. Additionally, the SAS to CBSD connectivity is not considered to be lost. When a Grant is terminated, expires or is relinquished, or the SAS to CBSD connectivity is considered to be lost, its *grantId* is revoked (i.e., is no longer usable).

SAS to CBSD connectivity is considered to be lost when during a seven-day period there is no successful Heartbeat procedure between the SAS and the CBSD.

> Informative Note: This procedure is used by a CBSD when it has one or more Grants in the *Granted* or *Authorized* states (see section 7).
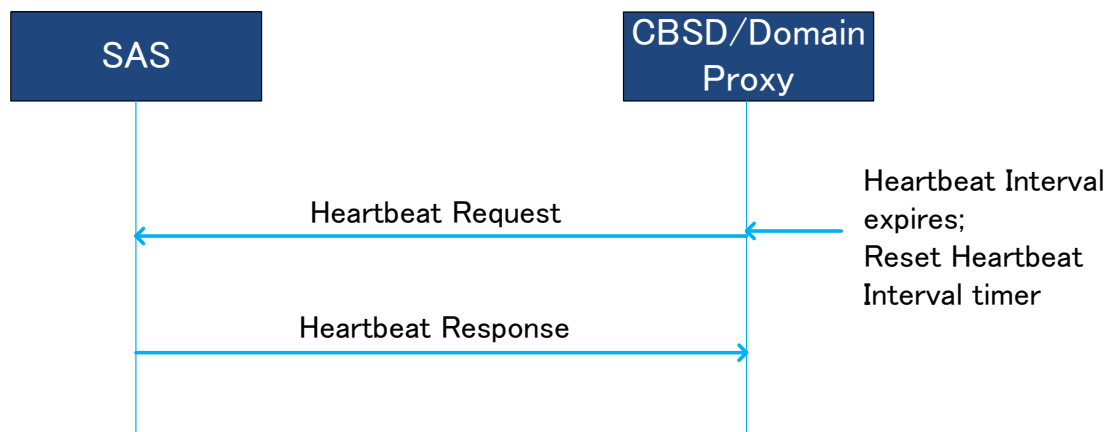
Figure 7: CBSD Heartbeat Procedure.

8.6.1 Successful operation

The CBSD initiates this procedure any time prior to the expiration of the Heartbeat Interval timer. The Heartbeat interval is defined as the time interval between the transmission of the two messages that include consecutive *HeartbeatRequest* objects associated with the same Grant. The timer is reset when the *HeartbeatRequest* object is sent to the SAS. The *heartbeatInterval* parameter may be included in the *HeartbeatResponse* object. The CBSD should send the *HeartbeatRequest* object as soon as a Grant is approved by the SAS.

If there is no Domain Proxy, the CBSD initiates the Heartbeat procedure by sending a *HeartbeatRequest* object (*cbsdId*, *grantId*, *grantRenew*, *operationState*, *measReport*) to the SAS. The *cbsdId* parameter identifies the CBSD to the SAS. The *grantId* parameter identifies the intended Grant for the heartbeat. The *grantRenew* parameter is an optional parameter. The CBSD includes this parameter and sets its value to TRUE when the CBSD wants to renew the Grant associated with the *grantID*. The *operationState* parameter is required. The *measReport* parameter provides a means for the CBSD to report the measurement results requested in a *GrantResponse* object or a *HeartbeatResponse* object from the SAS.

The CBSD obtains the heartbeat interval value in the *GrantResponse* object or in a previous *HeartbeatResponse* object. The SAS responds to the CBSD with a *HeartbeatResponse* object (*cbsdId*, *grantId*, *transmitExpireTime*, *grantExpireTime*, *heartbeatInterval*, *operationParam*, *measReportConfig*, *response*). The *response* parameter indicates whether the request succeeded or failed.

If the request succeeded, the SAS includes the *transmitExpireTime* parameter. The CBSD uses the value of the *transmitExpireTime* parameter to determine when the CBSD stops transmitting on the assigned spectrum. The CBSD shall treat expiry of the *transmitExpireTime* parameter value as the time at which the CBSD is directed by the SAS to turn off its transmitter and shall cease

transmission using the SAS authorized radio resource within 60 seconds after the value of the *transmitExpireTime* parameter expires, in accordance with part 96.39(c)(2) (ref. [n.8]).

If the request succeeded and the CBSD included the *grantRenew* parameter with a value set to TRUE in the *HeartbeatRequest* object, the SAS includes the *grantExpireTime* parameter. If included, the CBSD uses the value of the *grantExpireTime* parameter as the new time when the Grant expires.

If the *heartbeatInterval* parameter is included, the CBSD uses the value as the time interval before the next *HeartbeatRequest* object is sent; the CBSD continues to use this value of heartbeat interval until a new value is provided by the SAS.

If the *HeartbeatRequest* object succeeds, the *operationParam* parameter is optional in the *HeartbeatResponse* object. If the request fails, the SAS may include the *operationParam* parameter. The CBSD may ignore the *operationParam* parameter if it is included in the response. If the *operationParam* parameter is included, the CBSD interprets it as a recommendation on spectrum availability from the SAS.

In the successful *HeartbeatResponse* object (i.e., the *response* parameter indicates SUCCESS), if this is the response for the first *HeartbeatRequest* object following the *GrantResponse* object for this Grant, or the first *HeartbeatRequest* object following a *HeartbeatResponse* object with the *response* parameter set to SUSPENDED_GRANT, the CBSD is authorized to transmit and may initiate radio transmission any time after receiving this *HeartbeatResponse* object. Moreover, the CBSD shall update the *heartbeatInterval* and *grantExpireTime* based on the contents of the *HeartbeatResponse* object. If the *HeartbeatResponse* object contains the *measReportConfig* parameter, the CBSD shall send the requested measurement report to the SAS, as indicated by the value of the *measReportConfig* parameter, according to [n.21]. The measurement report requested by the SAS shall be consistent with the CBSD measurement capabilities indicated in the registration request. If the *operationParam* parameter is included in *HeartbeatResponse* object, the CBSD:

- should consider it as a recommendation from the SAS to obtain a new Grant using the included operational parameter values,
- may request a new Grant by sending a *GrantRequest* object including the recommended operational parameters, and
- may relinquish the existing Grant by sending a *RelinquishmentRequest* object to the SAS.

If the *response* parameter value indicates SUSPENDED_GRANT, the SAS shall include the *transmitExpireTime* parameter in the *HeartbeatResponse* object. The CBSD shall terminate radio operation by turning off its radio transmission associated with this Grant within 60 seconds after the value of the *transmitExpireTime* parameter expires, in accordance with part 96.39(c)(2) (ref. [n.8]). The CBSD shall update the Grant parameters (i.e., *heartbeatInterval*, *grantExpireTime*, *transmitExpireTime*) based on the contents of the *HeartbeatResponse* object. The CBSD may request relinquishment of the Grant at any time. If not relinquished, the CBSD shall continue sending *HeartbeatRequest* objects at or before the expiration of the most recently updated value of the *heartbeatInterval* parameter. However, the CBSD is not authorized to transmit until it receives a successful *HeartbeatResponse* object (i.e., the *response* parameter of the *HeartbeatResponse* object indicates SUCCESS).

If the *operationParam* parameter is included in the *HeartbeatResponse* object, the CBSD:

- should consider it as a recommendation from the SAS to obtain a new Grant using the included operational parameter values,
- may request a new Grant by sending a *GrantRequest* object including the recommended operational parameters, and
- may relinquish the existing Grant by sending a *RelinquishmentRequest* object to the SAS.

If the *response* parameter indicates TERMINATED_GRANT, the CBSD shall terminate radio operation associated with this Grant by turning off its radio transmission within 60 seconds after the time specified in the *transmitExpireTime* parameter according to Part 96.39.(c).(2) (ref. [n.8]). The Grant is considered terminated by the SAS. If the *operationParam* parameter is included in the *HeartbeatResponse* object, the CBSD:

- should consider it as a recommendation from the SAS to obtain a new Grant using the included operational parameter values,
- may choose to send a *RelinquishmentRequest* object to relinquish the Grant, and
- may request a new Grant by sending a *GrantRequest* object including the recommended operational parameters.

If the *response* parameter indicates UNSYNC_OP_PARAM, the CBSD shall interpret it as an indication that the CBSD is out of sync with the SAS on operational parameters or Grant state. The CBSD shall immediately terminate radio operation by turning off its radio transmission according to Part 96.39.(c).(2) (ref. [n.8]), and shall relinquish the Grant by sending a *RelinquishmentRequest* object. The CBSD may subsequently request a new Grant.

If the *measReportConfig* parameter is included, the CBSD should send the requested measurement report in the subsequent *HeartbeatRequest* object. The measurement report requested by the SAS shall be consistent with the CBSD measurement capabilities indicated in the registration request.

If there is a Domain Proxy and the Domain Proxy is performing bulk *HeartbeatRequest* objects, the Domain Proxy aggregates information related to each applicable CBSD into an array of *HeartbeatRequest* objects, each containing a heartbeat request of a CBSD as described in section 10. When the Domain Proxy receives the set of *HeartbeatResponse* objects from the SAS in an array of *HeartbeatResponse* objects, the Domain Proxy matches the individual responses to the individual requests as described in section 9.1. If the response indicates the *HeartbeatRequest* object succeeded, the Domain Proxy performs the previously described CBSD behavior on behalf of the successful CBSD(s). If this is the initial *HeartbeatRequest* object after a successful *GrantResponse* object, the Domain Proxy takes the appropriate action to initiate radio transmission.

8.6.2   *Unsuccessful Operation*

If the SAS determines an error with one of the parameters in the *HeartbeatRequest* object, the SAS returns a *HeartbeatResponse* object with a *response* parameter including the faulty parameter(s), see Table 40. The handling of a failure is out of scope of this specification. If the *cbsdId* parameter is not present, a 102 (MISSING_PARAM) error shall be generated by the SAS. If the *cbsdId* parameter is invalid, a 103 (INVALID_VALUE) error shall be generated by the SAS.

If there is a Domain Proxy, the Domain Proxy can receive an array of *HeartbeatResponse* objects. For each failed request, there will be a failure reason in the *response* parameter. The Domain Proxy

matches the response with the originating request as described in section 9.1 and takes the appropriate action, possibly involving the CBSD(s).

8.7   CBSD Grant Relinquishment Procedure

This procedure describes how a CBSD can inform the SAS if a Grant is no longer needed by the CBSD. This procedure can be executed at any time by a CBSD for a non-expired Grant.

Informative Note: This procedure is used by a CBSD on a Grant in the *Granted* or *Authorized* state (see section 7).
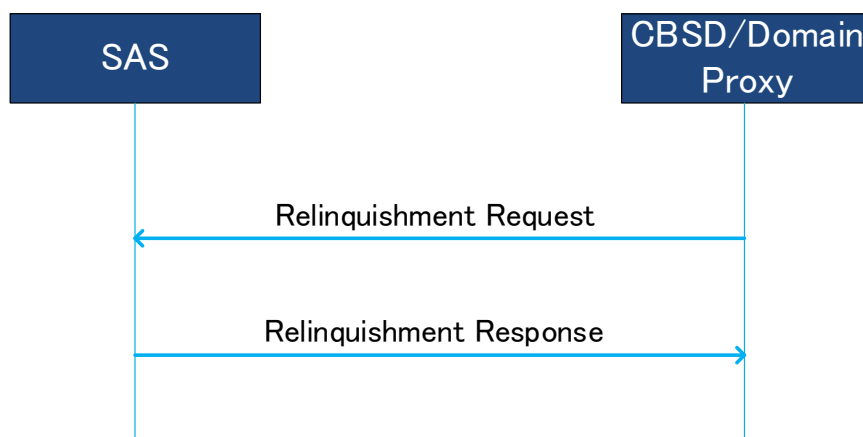
Figure 8: CBSD Grant Relinquishment Procedure.

8.7.1   Successful operation

The CBSD may initiate this procedure for an existing Grant. The CBSD shall terminate radio operation associated with this Grant before initiating this procedure.

If there is no Domain Proxy, the CBSD initiates the Grant Relinquishment Procedure by sending a *RelinquishmentRequest* object (*cbsdId*, *grantId*) to the SAS. The *cbsdId* parameter identifies the CBSD to the SAS. The *grantId* parameter identifies the Grant the CBSD wants to relinquish. Upon reception of the *RelinquishmentRequest* object, the SAS relinquishes the spectrum assigned to the CBSD. The SAS responds to the CBSD with a *RelinquishmentResponse* object (*cbsdId*, *grantId*, *response*). If the request succeeded, the CBSD no longer has authorization to use the spectrum associated with the Grant.

If there is a Domain Proxy and the Domain Proxy is sending bulk *RelinquishmentRequest* objects, the Domain Proxy aggregates relinquishment information for multiple CBSDs. The Domain Proxy aggregates this information into an array of *RelinquishmentRequest* objects and sends the resulting JSON *relinquishmentRequest* array to the SAS. Each *RelinquishmentRequest* object contains one instance of a relinquishment request for a CBSD requesting Grant relinquishment. Upon reception of the *RelinquishmentRequest* object, the SAS initiates the relinquishment process for each Grant. The SAS responds to the Domain Proxy with an array of one or more *RelinquishmentResponse* objects. If an individual request succeeded, the associated CBSD no longer has authorization to use the spectrum associated with the Grant. The Domain Proxy matches the individual responses

to the individual requests as described in section 9.1 and takes the appropriate action, with the CBSD(s).

8.7.2   Unsuccessful Operation

Regardless of the reason for failure of *RelinquishmentRequest* object, the CBSD no longer has authorization to use the spectrum associated with the Grant.

If the SAS determines an error with one of the parameters in the *RelinquishmentRequest* object, the SAS returns a *RelinquishmentResponse* object containing a *responseCode* parameter indicating the error. If the *responseCode* parameter is set to 103 (INVALID_VALUE), the *responseData* parameter shall be set by the SAS to the name(s) of the parameter(s) that contained an invalid value. The handling of a failure is out of scope of this specification. If the *cbsdId* parameter is not present, a 102 (MISSING_PARAM) error shall be generated by the SAS. If the *cbsdId* parameter is invalid, a 103 (INVALID_VALUE) error shall be generated by the SAS. The CBSD shall cease use of the spectrum associated with the Grant. If the *responseCode* parameter indicates 103 (INVALID_VALUE) and the *responseData* parameter contains "cbsdId", the CBSD shall immediately terminate all transmissions and consider itself to be *Unregistered*.

If there is a Domain Proxy, the Domain Proxy can receive an array of *RelinquishmentResponse* objects. If an individual request failed and the *RelinquishmentResponse* object contains a *responseCode* parameter indicating 103 (INVALID_VALUE), the *responseData* parameter shall be set by the SAS to the name(s) of the parameter(s) that contained an invalid value. The associated CBSD shall cease use of the spectrum associated with the Grant. If the *responseCode* parameter indicates 103 (INVALID_VALUE) and the *responseData* parameter contains "cbsdId", the CBSD shall immediately terminate all transmissions and consider itself to be *Unregistered*. The Domain Proxy matches the response with the originating relinquishment request as described in section 9.1 and takes the appropriate action, possibly involving the CBSD(s).

8.8   CBSD Deregistration Procedure

This procedure describes how a CBSD deregisters from the SAS. The CBSD deregistration procedure is shown in the figure below.

Informative Note: This procedure is used by a CBSD in the *Registered* state.
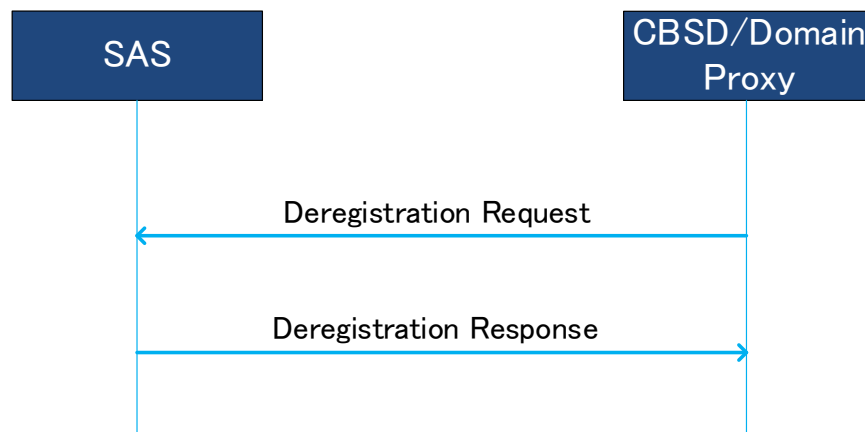
Figure 9: CBSD Deregistration Procedure.

8.8.1   Successful operation

When the CBSD determines that it should deregister from the SAS, it shall cease transmission associated with any Grants and then shall send a *DeregistrationRequest* object (*cbsdId*) to the SAS. The CBSD then cancels any Grants that it still believes are allocated to it.

The SAS marks the CBSD as *Unregistered*, removes any existing Grants, and responds with a *DeregistrationResponse* object (*cbsdId*, *response*).

The CBSD should send a *RelinquishmentRequest* object for each Grant prior to sending the *DeregistrationRequest* object.

Upon receiving a *DeregistrationResponse* object from the SAS with a *response* parameter indicating SUCCESS, the CBSD concludes any remaining local aspects of deregistration and considers itself as *Unregistered*.

8.8.2   Unsuccessful operation

If the *DeregistrationResponse* object has a *response* parameter value other than SUCCESS, the CBSD shall consider itself *Unregistered*.

9   Message Encoding and Transport

9.1   Message Encoding

SAS-CBSD messages shall be encoded using JSON (JavaScript Object Notation) as defined in RFC-7159 [n.10]. Note that this means that Unicode characters are used and have a default encoding of UTF-8.

When a Domain Proxy sends a SAS-CBSD message to the SAS, multiple requests of the same type can be aggregated together in the form of a JSON array and sent in one HTTP request. Similarly, the SAS can include multiple responses in a JSON array and send it to a Domain Proxy. Therefore, a JSON-encoded SAS-CBSD message is in an array format that can accommodate one or multiple requests or responses of the same type. Different types of requests or responses shall not be included in one JSON-encoded SAS-CBSD message.

Per [n.10], JSON arrays are ordered sequences; as such, a multiple request message or multiple response message contains an ordered sequence of objects. Domain Proxies, SASs and CBSDs shall preserve array ordering. SASs receiving a message having an array of request objects shall respond with an array of response objects in which the order of the response objects is exactly matched to the order of the request objects. For example, if a SAS receives a message containing an array of three request objects, the SAS prepares the response message in which the first object in the array is the response to the first object in the request array, the second object in the array is the response to the second object in the request array and so on. When employing aggregated requests, Domain Proxies rely on this ordering to match responses with requests.

The following example shows the format of a JSON-encoded SAS-CBSD message (Registration Request Message). As shown in the example, the SAS-CBSD message contains two objects in a JSON array, whose name is *registrationRequest*. Each object denotes a registration request for a CBSD.

```
{
  "registrationRequest": [
    {
      "fccId": "abc123",
      "cbsdCategory": "A",
      "callSign": "CB987",
      "userId": "John Doe",
      "airInterface": {
        "radioTechnology": "E_UTRA"
      },
      "cbsdSerialNumber": "abcd1234",
      "measCapability": [
        "RECEIVED_POWER_WITHOUT_GRANT"
      ],
      "installationParam": {
        "latitude": 37.419735,
        "longitude": -122.072205,
        "height": 6,
        "heightType": "AGL",
        "indoorDeployment": true
      },
      "groupingParam": [
        { "groupId": "example-group-1",
          "groupType": "INTERFERENCE_COORDINATION" },
        { "groupId": "example-group-2",
          "groupType": "INTERFERENCE_COORDINATION" }
      ]

    },
    {
      "fccId": "321cba",
      "cbsdCategory": "B",
      "callSign": "WSD987",
      "userId": "John Doe",
      "airInterface": {
        "radioTechnology": "E_UTRA"
      },
      "cbsdSerialNumber": "4321dcba",
      "measCapability": [
```

```
      "RECEIVED_POWER_WITHOUT_GRANT"
    ],
    "installationParam": {
      "latitude": 37.425056,
      "longitude": -122.084113,
      "height": 9.3,
      "heightType": "AGL",
      "indoorDeployment": false,
      "antennaAzimuth": 271,
      "antennaDowntilt": 3,
      "antennaGain": 16,
      "antennaBeamwidth": 30
    },
    "groupingParam": [
      { "groupId": "example-group-3",
        "groupType": "INTERFERENCE_COORDINATION" },
    ]
    }
  ]
}
```

The name of the outermost array in a JSON-encoded SAS-CBSD message maps to a SAS-CBSD message defined in section 10. Mapping of SAS-CBSD messages and the corresponding JSON array names can be found in the following table.

Table 1: Mapping of SAS-CBSD Messages to JSON Array Names

SAS-CBSD Message Name	Reference	JSON Array Name
Registration Request Message	Section 10.1	*registrationRequest*
Registration Response Message	Section 10.2	*registrationResponse*
Spectrum Inquiry Request Message	Section 10.3	*spectrumInquiryRequest*
Spectrum Inquiry Response Message	Section 10.4	*spectrumInquiryResponse*
Grant Request Message	Section 10.5	*grantRequest*
Grant Response Message	Section 10.6	*grantResponse*
Heartbeat Request Message	Section 10.7	*heartbeatRequest*
Heartbeat Response Message	Section 10.8	*heartbeatResponse*
Relinquishment Request Message	Section 10.9	*relinquishmentRequest*
Relinquishment Response Message	Section 10.10	*relinquishmentResponse*
Deregistration Request Message	Section 10.11	*deregistrationRequest*
Deregistration Response Message	Section 10.12	*deregistrationResponse*

9.2   Message Transport

HTTPS shall be used as the transport protocols for SAS-CBSD message exchanges. The TLS protocol as specified in [n.1] and HTTP version 1.1 as specified in [n.6] shall be used. The SAS

shall include its system time, upon which all SAS-CBSD protocol timers are based, in the Date HTTP header field in all SAS-CBSD messages (ref. [n.15]).

An example HTTP request message header follows:

```
POST /v1.2/registration HTTP/1.1
Host: www.sasadministratorapi.com
Content-type: application/json
Date: Mon, 03 Oct 2016 11:07:33 GMT
```

The HTTP POST method shall be used for all requests from the CBSD/DP to the SAS. The POST is sent to the SAS URL path (ref. [n.9]) which ends with the string "/{sas_version_number}/{sas_method_name}"[1] to indicate the SAS-CBSD protocol version and the SAS method name for the message. Each SAS administrator chooses the base URL of its SAS service. The SAS-CBSD protocol version number shall be in the form of vx.y, where v is the string value "v", x is the CBRS release number and y is the version number. The sas_version_number of the SAS-CBSD protocol defined in this version of this technical specification shall be set to "v1.2". A SAS method corresponds to a pair of request and response messages defined in Section 10. SAS method names are listed below in Table 2.

Table 2: SAS Methods

sas_method_name	JSON Array Name of Request Message	JSON Array Name of Response Message
registration	*registrationRequest*	*registrationResponse*
spectrumInquiry	*spectrumInquiryRequest*	*spectrumInquiryResponse*
grant	*grantRequest*	*grantResponse*
heartbeat	*heartbeatRequest*	*heartbeatResponse*
relinquishment	*relinquishmentRequest*	*relinquishmentResponse*
deregistration	*deregistrationRequest*	*deregistrationResponse*

9.3   Inclusion of CPI information in CBSD Registration

In the event that a CPI inserts registration parameter data directly into the CBSD, a digital signature is applied to the data inserted by the CPI. See sections 10.1.3, 10.1.8, 10.1.6, and 10.1.7 for the protocol details.

The following is an example of a *CpiSignedData* object included in a *RegistrationRequest* object.

---

[1] The curly braces indicate that the CBSD should substitute the appropriate string value for the enclosed parameter.

```
{ "fccId": "abc123",
 "cbsdSerialNumber": "abcd1234",
 "installationParam": {
   "latitude": 37.425056,
   "longitude": -122.084113,
   "height": 9.3,
   "heightType": "AGL",
   "indoorDeployment": true},
 "professionalInstallerData": {
   "cpiId": "10987654321AA",
   "cpiName": "John Doe",
   "installCertificationTime": "2017-10-11T20:30:00Z"}
}
```

10 Parameters of SAS-CBSD Messages

In this section parameters of SAS-CBSD message are described in more detail. A parameter value can be one of the primitive JSON data types, i.e., string, number, boolean, array, or object. If a parameter is an object, a name for the object is given and a separate table describes parameters in the object.

Each parameter is indicated as "Required", "Optional" or "Conditional". The definitions of these indicators are as follows:

> **"Required":**   The parameter shall always be included in the message.
>
> **"Optional":**   The parameter may be included in the message.
>
> **"Conditional":**   The parameter shall be included in the message, if and only if the specified conditions are satisfied.

The tables of parameters in this section have a column marked R/O/C that indicates whether the particular parameter is required, optional, or conditional.

10.1   Registration Request Message

The following criteria (called "REG-Conditional Registration Request Parameters" in this document) applies to all "REG-Conditional" parameters in the Registration Request Message in Section 10.1 and its Sub-sections, and defines the criteria by which the parameter is required to be included in the Message:

REG-Conditional Registration Request Parameters: This parameter is required by the SAS to complete the CBSD registration process, but may be omitted in the *RegistrationRequest* object. If not included in the *RegistrationRequest* object, the parameter, to the extent that it is needed by the SAS to satisfy the Part 96 Rules, shall be provided to the SAS by other means outside the protocol specified in this document, e.g., it may be provided by a CPI as required by Part 96 Rules for category B CBSDs or CBSDs without automatic location determination, or for operational reasons. Other means based on CBSD device characteristics that are beyond the scope of this specification, are not precluded from use.

Table 3: Registration Request Message

Parameter	R/O/C	Description
NAME: *registrationRequest* DATA TYPE: array of object: *RegistrationRequest*	Required	Array of *RegistrationRequest* data objects. Each *RegistrationRequest* data object represents a registration request of a CBSD.

10.1.1 *RegistrationRequest object*

Table 4: *RegistrationRequest* Object Definition

Parameter	R/O/C	Description
NAME: *userId* DATA TYPE: string	Required	The UR-ID per [n.12] R2-SRR-02 conformant per section 2.2 of [n.18].
NAME: *fccId* DATA TYPE: string	Required	The FCC certification identifier of the CBSD. It is a string of up to 19 characters as described in [n.13] and [n.15].
NAME: *cbsdSerialNumber* DATA TYPE: string	Required	A serial number assigned to the CBSD by the CBSD device manufacturer having a maximum length of 64 octets. This serial number shall be unique for every CBSD instance sharing the same value of *fccId*. Each CBSD has a single CBSD Antenna (Ref. definition in section 4) and has a single *cbsdSerialNumber*.
NAME: *callSign* DATA TYPE: string	Optional	A device identifier provided by the FCC per [i.5]. NOTE: This parameter is for further study.
NAME: *cbsdCategory* DATA TYPE: string	REG-Conditional	Device Category of the CBSD. Allowed values are "A" or "B" as defined in Part 96. See "REG-Conditional Registration Request Parameters" above.
NAME: *cbsdInfo* DATA TYPE: object: *CbsdInfo*	Optional	Information about this CBSD model.

Parameter	R/O/C	Description
NAME: *airInterface* DATA TYPE: object: *AirInterface*	REG-Conditional	A data object that includes information on the air interface technology of the CBSD. See "REG-Conditional Registration Request Parameters" above.
NAME: *installationParam* DATA TYPE: object: *InstallationParam*	REG-Conditional	A data object that includes information on CBSD installation. See "REG-Conditional Registration Request Parameters" above.
NAME: *measCapability* DATA TYPE: array of string	REG-Conditional	The array of string lists measurement reporting capabilities of the CBSD. The permitted enumerations are specified in [n.21]. See "REG-Conditional Registration Request Parameters" above.
NAME: *groupingParam* DATA TYPE: array of object: *GroupParam*	Optional	An array of data objects that includes information on CBSD grouping.
NAME: *cpiSignatureData* DATA TYPE: object: *CpiSignatureData*	Optional	The CPI is vouching for the parameters included in this object. In addition, the digital signature for these parameters is included.

10.1.2 *AirInterface object*

Table 5: *AirInterface* Object Definition

Parameter	R/O/C	Description
NAME: *radioTechnology* DATA TYPE: string	REG-Conditional	This parameter specifies the radio access technology that the CBSD uses for operation in the CBRS band. The permitted values are specified in [n.21]. See "REG-Conditional Registration Request Parameters" above.

10.1.3 InstallationParam object

Table 6: *InstallationParam* Object Definition

Parameter	R/O/C	Description
NAME: *latitude* DATA TYPE: number	REG-Conditional	Latitude of the CBSD antenna location in degrees relative to the WGS 84 datum [n.11]. The allowed range is from -90.000000 to +90.000000. Positive values represent latitudes north of the equator; negative values south of the equator. Values are specified using 6 digits to the right of the decimal point. Note: Use of WGS84 will also satisfy the NAD83 positioning requirements for CBSDs with the accuracy specified by Part 96 [n.8]. For reporting the CBSD location to the FCC, the SAS is responsible for converting coordinates from the WGS84 datum to the NAD83 datum. See "REG-Conditional Registration Request Parameters" above.
NAME: *longitude* DATA TYPE: number	REG-Conditional	Longitude of the CBSD antenna location in degrees relative to the WGS84 datum [n.11]. The allowed range is from -180.000000 to +180.000000. Positive values represent longitudes east of the prime meridian; negative values west of the prime meridian. Values are specified using 6 digits to the right of the decimal point. Note: Use of WGS84 will also satisfy the NAD83 positioning requirements for CBSDs with the accuracy specified by Part 96 [n.8]. For reporting the CBSD location to the FCC, the SAS is responsible for converting coordinates from the WGS84 datum to the NAD83 datum. See "REG-Conditional Registration Request Parameters" above.

Parameter	R/O/C	Description
NAME: *height* DATA TYPE: number	REG-Conditional	The CBSD antenna height in meters. When the *heightType* parameter value is "AGL", the antenna height should be given relative to ground level. When the *heightType* parameter value is "AMSL", it is given with respect to WGS84 datum. For reporting the CBSD location to the FCC, the SAS is responsible for converting coordinates from the WGS84 datum to the NAD83 datum. See "REG-Conditional Registration Request Parameters" above.
NAME: *heightType* DATA TYPE: string	REG-Conditional	The value should be "AGL" or "AMSL". AGL height is measured relative to the ground level. AMSL height is measured relative to the mean sea level. See "REG-Conditional Registration Request Parameters" above.
NAME: *horizontalAccuracy* DATA TYPE: number	Optional	A positive number in meters to indicate accuracy of the CBSD antenna horizontal location. This optional parameter should only be present if its value is less than the FCC requirement of 50 meters.
NAME: *verticalAccuracy* DATA TYPE: number	Optional	A positive number in meters to indicate accuracy of the CBSD antenna vertical location. This optional parameter should only be present if its value is less than the FCC requirement of 3 meters.
NAME: *indoorDeployment* DATA TYPE: boolean	REG-Conditional	Whether the CBSD antenna is indoor or not. True: indoor. False: outdoor. See "REG-Conditional Registration Request Parameters" above.

Parameter	R/O/C	Description
NAME: *antennaAzimuth* DATA TYPE: number	REG-Conditional	Boresight direction of the horizontal plane of the antenna in degrees with respect to true north. The value of this parameter is an integer with a value between 0 and 359 inclusive. A value of 0 degrees means true north; a value of 90 degrees means east. This parameter is optional for Category A CBSDs and REG-conditional for Category B CBSDs. See "REG-Conditional Registration Request Parameters" above.
NAME: *antennaDowntilt* DATA TYPE: number	REG-Conditional	Antenna down tilt in degrees and is an integer with a value between -90 and +90 inclusive; a negative value means the antenna is tilted up (above horizontal). This parameter is optional for Category A CBSDs and REG-conditional for Category B CBSDs. See "REG-Conditional Registration Request Parameters" above.
NAME: *antennaGain* DATA TYPE: number	REG-Conditional	Peak antenna gain in dBi. This parameter is an integer with a value between -127 and +128 (dBi) inclusive. See "REG-Conditional Registration Request Parameters" above.
NAME: *eirpCapability* DATA TYPE: number	Optional	This parameter is the maximum CBSD EIRP in units of dBm/10MHz and is an integer with a value between -127 and +47 (dBm/10MHz) inclusive. If not included, SAS interprets it as maximum allowable EIRP in units of dBm/10MHz for CBSD category.

Parameter	R/O/C	Description
NAME: *antennaBeamwidth* DATA TYPE: number	REG-Conditional	3-dB antenna beamwidth of the antenna in the horizontal-plane in degrees. This parameter is an unsigned integer having a value between 0 and 360 (degrees) inclusive; it is optional for Category A CBSDs and REG-conditional for category B CBSDs. Note: A value of 360 (degrees) means the antenna has an omnidirectional radiation pattern in the horizontal plane. See "REG-Conditional Registration Request Parameters" above.
NAME: *antennaModel* DATA TYPE: string	Optional	If an external antenna is used, the antenna model is optionally provided in this field. The string has a maximum length of 128 octets.

10.1.4 GroupParam object

Table 7: *GroupParam* Object Definition

Parameter	R/O/C	Description
NAME: *groupType* DATA TYPE: string	Required	Enumeration field describing the type of group this group ID describes. The following are permitted enumerations: "INTERFERENCE_COORDINATION". Note: Additional group types are expected to be defined in future revisions of this specification.
NAME: *groupId* DATA TYPE: string	Required	This field specifies the identifier for this group of CBSDs. When the *groupType* is set to "INTERFERENCE_COORDINATION", the namespace for *groupId* is *userId*.

10.1.5 CbsdInfo object

Table 8: *CbsdInfo* Object Definition

Parameter	R/O/C	Description
NAME: *vendor* DATA TYPE: string	Optional	The name of the CBSD vendor. The maximum length of this string is 64 octets.
NAME: *model* DATA TYPE: string	Optional	The name of the CBSD model. The maximum length of this string is 64 octets.
NAME: *softwareVersion* DATA TYPE: string	Optional	Software version of this CBSD. The maximum length of this string is 64 octets.
NAME: *hardwareVersion* DATA TYPE: string	Optional	Hardware version of this CBSD. The maximum length of this string is 64 octets.
NAME: *firmwareVersion* DATA TYPE: string	Optional	Firmware version of this CBSD. The maximum length of this string is 64 octets.

The CbsdInfo object can be extended with other vendor information in additional key-value pairs.

10.1.6 CpiSignatureData object

Table 9: *CpiSignatureData* Object Definition

Parameter	R/O/C	Description

NAME: *protectedHeader*
DATA TYPE: string
	Required	The value of this parameter is the BASE64-encoded JOSE protected header. This is a JSON object equivalent to the JWT RS256 method or the ES256 method described in RFC 7515 [n.19] Section 3. BASE64 encoding is per RFC 4648 (see [n.20]).
		Valid values are equivalent to the JSON:
		`{ "typ": "JWT", "alg": "RS256" } or`
		`{ "typ": "JWT", "alg": "ES256" }`

Parameter	R/O/C	Description
NAME: *encodedCpiSignedData* DATA TYPE: string	Required	The value of this parameter is the encoded JOSE payload data to be signed by the CPI's private key. This parameter is calculated by taking the BASE64 encoding of a *CpiSignedData* object (see Table 10) according to the procedures in RFC 7515 [n.19], Section 3.
NAME: *digitalSignature* DATA TYPE: string	Required	The value of this parameter is the CPI digital signature applied to the *encodedCpiSignedData* field. This signature is the BASE64URL encoding of the digital signature, prepared according to the procedures in RFC 7515 [n.19] Section 3, using the algorithm as declared in the *protectedHeader* field.

Note: The JOSE JSON Web Signature per RFC-7515 (see [n.19]) is used to ensure data integrity and CPI non-repudiation of the signed parameters. The JOSE compact serialization is formed by concatenating the *protectedHeader*, *encodedCpiSignedData*, and *digitalSignature* fields with "." characters, as described in section 3 of RFC 7515 [n.19].

10.1.7 CpiSignedData object

Table 10: *CpiSignedData* Object Definition

Parameter Name	R/O/C	Description
NAME: *fccId* DATA TYPE: string	Required	The value of this parameter is the FCC ID of the CBSD. Shall be equal to the *fccId* parameter value in the enclosing registration request.
NAME: *cbsdSerialNumber* DATA TYPE: string	Required	The value of this parameter is the CBSD serial number. Shall be equal to the *cbsdSerialNumber* of the enclosing registration request.
NAME: *installationParam* DATA TYPE: object: *InstallationParam*	Required	The value of this parameter is the *InstallationParam* object containing the parameters being certified by the CPI, and only those.

Parameter Name	R/O/C	Description
NAME: *professionalInstallerData* TYPE: object: *ProfessionalInstallerData*	Required	The value of this parameter is the data identifying the CPI vouching for the installation parameters included in the *installationParam* value contained in this object.

10.1.8 *ProfessionalInstallerData object*

Table 11: *ProfessionalInstallerData* Object Definition

Parameter	R/O/C	Description
NAME: *cpiId* DATA TYPE: string	Required	The value of this parameter is the ID of the CPI providing information to the SAS. This string has a maximum length of 256 octets.
NAME: *cpiName* DATA TYPE: string	Required	The value of this parameter is the human-readable name of the CPI providing information to the SAS. This string has a maximum length of 256 octets.
NAME: *installCertificationTime* DATA TYPE: string	Required	The value of this parameter is the UTC date and time at which the CPI identified in this object certified the CBSD's installed parameters. It is expressed using the format, YYYY-MM-DDThh:mm:ssZ, as defined by [n.7].

10.2   Registration Response Message

Table 12: Registration Response Message

Parameter	R/O/C	Description
NAME: *registrationResponse* DATA TYPE: array of object: *RegistrationResponse*	Required	This parameter is an array of *RegistrationResponse* data objects. Each *RegistrationResponse* data object represents a registration response to a registration request from a CBSD.

10.2.1 RegistrationResponse object

Table 13: *RegistrationResponse* Object Definition

Parameter	R/O/C	Description
NAME: *cbsdId* DATA TYPE: string	Conditional	This is a CBRS-wide unique identifier for this CBSD. This parameter shall be included if and only if the *responseCode* indicates SUCCESS. The CBSD shall set its CBSD identity to the value received in this parameter. The string has a maximum length of 256 octets.
NAME: *measReportConfig* DATA TYPE: array of string	Optional	SAS uses this parameter to configure CBSD measurement reporting. The measurement report requested by SAS shall be consistent with the CBSD measurement capabilities reported during the registration request. The CBSD shall report the measurement listed in this array. The permitted enumerations are specified in [n.21].
NAME: *response* DATA TYPE: object: *Response*	Required	This parameter includes information on whether the corresponding CBSD request is approved or disapproved for a reason. See Table 14: *Response* Object Definition.

10.2.2 Response object

Table 14: *Response* Object Definition

Parameter	R/O/C	Description
NAME: *responseCode* DATA TYPE: number	Required	An integer to indicate the type of result. The value 0 means the corresponding CBSD request is successful. This shall be one of the values in Table 39.
NAME: *responseMessage* DATA TYPE: string	Optional	A short description of the result.

Parameter	R/O/C	Description
NAME: *responseData* DATA TYPE: Dependent on *responseCode*– see Table 40: *responseData* Definitions.	Optional	Additional data can be included to help the CBSD resolve failures.

10.3   Spectrum Inquiry Request Message

Table 15: Spectrum Inquiry Request Message

Parameter	R/O/C	Description
NAME: *spectrumInquiryRequest* DATA TYPE: array of object: *SpectrumInquiryRequest*	Required	Array of *SpectrumInquiryRequest* objects. Each *SpectrumInquiryRequest* object represents a spectrum inquiry request of a CBSD.

10.3.1 SpectrumInquiryRequest object

Table 16: *SpectrumInquiryRequest* Object Definition

Parameter	R/O/C	Description
NAME: *cbsdId* DATA TYPE: string	Required	The CBSD shall set this parameter to the value of its CBSD identity.
NAME: *inquiredSpectrum* DATA TYPE: array of object: *FrequencyRange*	Required	This field describes the spectrum for which the CBSD seeks information on spectrum availability.
NAME: *measReport* DATA TYPE: object: *MeasReport*	Conditional	The CBSD uses this parameter to report measurements to the SAS. The format of the *MeasReport* object is provided in [n.21]. Refer to section 8 and the measurement capabilities in [n.21] for inclusion rules.

10.3.2 FrequencyRange object

<p align="center">**Table 17: *FrequencyRange* Object Definition**</p>

Parameter	R/O/C	Description
NAME: *lowFrequency* DATA TYPE: number	Required	The lowest frequency of the frequency range in Hz.
NAME: *highFrequency* DATA TYPE: number	Required	The highest frequency of the frequency range in Hz.

10.3.3 MeasReport object

<p align="center">**Table 18: *MeasReport* Object Definition**</p>

Parameter	R/O/C	Description
The parameters of this object are defined in [n.21].		

10.4 Spectrum Inquiry Response Message

<p align="center">**Table 19: Spectrum Inquiry Response Message**</p>

Parameter	R/O/C	Description
NAME: *spectrumInquiryResponse* DATA TYPE: array of object: *SpectrumInquiryResponse*	Required	Array of *SpectrumInquiryResponse* objects. Each *SpectrumInquiryResponse* object represents a spectrum inquiry response to a spectrum inquiry request of a CBSD.

10.4.1 SpectrumInquiryResponse object

<p align="center">**Table 20: *SpectrumInquiryResponse* Object Definition**</p>

Parameter	R/O/C	Description
NAME: *cbsdId* DATA TYPE: string	Conditional	This parameter is included if and only if the *cbsdId* parameter in the *SpectrumInquiryRequest* object contains a valid CBSD identity. If included, the SAS shall set this parameter to the value of the *cbsdId* parameter in the corresponding *SpectrumInquiryRequest* object.

Parameter	R/O/C	Description
NAME: *availableChannel* DATA TYPE: array of object: *AvailableChannel*	Conditional	This parameter is an array of zero or more data objects, *AvailableChannel*, which describes a channel that is available for the CBSD, see Table 21. Included: If and only if the Spectrum Inquiry is successful.
NAME: *response* DATA TYPE: object: *Response*	Required	This parameter includes information on whether the corresponding CBSD request is approved or disapproved for a reason. See Table 14: *Response* Object Definition.

10.4.2 AvailableChannel object

Table 21: *AvailableChannel* Object Definition

Parameter	R/O/C	Description
NAME: *frequencyRange* DATA TYPE: object: *FrequencyRange*	Required	This parameter is the frequency range of the available channel, see Table 17.
NAME: *channelType* DATA TYPE: string	Required	"PAL": the frequency range is a PAL channel. "GAA": the frequency range is for GAA use.
NAME: *ruleApplied* DATA TYPE: string	Required	The regulatory rule used to generate this response, e.g., "FCC_PART_96".
NAME: *maxEirp* DATA TYPE: number	Optional	Maximum EIRP likely to be permitted for a Grant on this *frequencyRange,* given the CBSD registration parameters, including location, antenna orientation and antenna pattern. The maximum EIRP is in the units of dBm/MHz and is an integer with a value between -137 and +37 (dBm/MHz) inclusive.

10.5   Grant Request Message

Table 22: Grant Request Message

Parameter	R/O/C	Description
NAME: *grantRequest* DATA TYPE: array of object: *GrantRequest*	Required	Array of *GrantRequest* objects. Each *GrantRequest* object represents a Grant request of a CBSD.

10.5.1 GrantRequest object

A *GrantRequest* object contains operating parameters that the CBSD plans to operate with. Operation parameters include a continuous segment of spectrum and the maximum EIRP.

Table 23: *GrantRequest* Object Definition

Parameter	R/O/C	Description
NAME: *cbsdId* DATA TYPE: string	Required	The CBSD shall set this parameter to the value of its CBSD identity.
NAME: *operationParam* DATA TYPE: object: *OperationParam*	Required	This data object includes operation parameters of the requested Grant.
NAME: *measReport* DATA TYPE: object: *MeasReport*	Conditional	The CBSD uses this parameter to report measurements to the SAS. The format of the *MeasReport* object is provided in [n.21]. Refer to section 8 and [n.21] for inclusion rules.

10.5.2 OperationParam object

Table 24: *OperationParam* Object Definition

Parameter	R/O/C	Description
NAME: *maxEirp* DATA TYPE: number	Required	Maximum EIRP permitted by the Grant. The maximum EIRP is in the units of dBm/MHz and is an integer with a value between -137 and +37 (dBm/MHz) inclusive. The value of *maxEirp* represents the average (RMS) EIRP that would be measured per the procedure defined in FCC §96.41(e)(3).

Parameter	R/O/C	Description
NAME: *operationFrequencyRange* DATA TYPE: object: *FrequencyRange*	Required	This parameter is frequency range of a contiguous segment.

10.6 Grant Response Message

<p align="center">**Table 25: Grant Response Message**</p>

Parameter	R/O/C	Description
NAME: *grantResponse* DATA TYPE: array of object: *GrantResponse*	Required	Array of *GrantResponse* objects. Each *GrantResponse* object represents a Grant response to a Grant request of a CBSD.

10.6.1 GrantResponse object

<p align="center">**Table 26: *GrantResponse* Object Definition**</p>

Parameter	R/O/C	Description
NAME: *cbsdId* DATA TYPE: string	Conditional	This parameter is included if and only if the *cbsdId* parameter in the *GrantRequest* object contains a valid CBSD identity. If included, the SAS shall set this parameter to the value of the *cbsdId* parameter in the corresponding *GrantRequest* object.
NAME: *grantId* DATA TYPE: string	Conditional	An ID provided by the SAS for this Grant. Included: If and only if the Grant request is approved by the SAS. The CBSD shall set the Grant identity for this Grant to the value received in this parameter.

Parameter	R/O/C	Description
NAME: *grantExpireTime* DATA TYPE: string	Conditional	The *grantExpireTime* indicates the time when the Grant associated with the *grantId* in this Heartbeat Response expires. This parameter is UTC time expressed in the format, YYYY-MM-DDThh:mm:ssZ as defined by [n.7]. This parameter shall be included if the *responseCode* parameter indicates SUCCESS or SUSPENDED_GRANT and the *grantRenew* parameter was included and set to True in the corresponding *HeartbeatRequest* object. This parameter may be included at other times by SAS choice.
NAME: *heartbeatInterval* DATA TYPE: number	Conditional	This parameter is a positive integer and indicates the maximum time interval in units of seconds between two consecutive heartbeat requests. This parameter is included when the SAS wants to change the heartbeat interval.
NAME: *measReportConfig* DATA TYPE: array of string	Optional	The SAS uses this parameter to configure CBSD measurement reporting. The measurement report requested by the SAS shall be consistent with the CBSD measurement capabilities reported during the registration request. The CBSD shall report the measurements listed in this array. The permitted enumerations are specified in [n.21].
NAME: *operationParam* DATA TYPE: object: *OperationParam*	Optional	If the Grant request is disapproved, using this object the SAS can optionally provide a new set of operation parameters to the CBSD for use in a new Grant request.
NAME: *channelType* DATA TYPE: string	Conditional	This parameter is included if and only if the *responseCode* parameter indicates SUCCESS, i.e., the Grant request was successful. "PAL": the frequency range is a PAL channel. "GAA": the frequency range is for GAA use.

Parameter	R/O/C	Description
NAME: *response* DATA TYPE: object: *Response*	Required	This parameter includes information on whether the corresponding CBSD request is approved or disapproved for a reason. See Table 14.

10.7   Heartbeat Request Message

Table 27: Heartbeat Request Message

Parameter	R/O/C	Description
NAME: *heartbeatRequest* DATA TYPE: array of object: *HeartbeatRequest*	Required	Array of *HeartbeatRequest* objects. Each *HeartbeatRequest* object represents a heartbeat request of a CBSD.

10.7.1 HeartbeatRequest object

Table 28: *HeartbeatRequest* Object Definition

Parameter	R/O/C	Description
NAME: *cbsdId* DATA TYPE: string	Required	The CBSD shall set this parameter to the value of its CBSD identity.
NAME: *grantId* DATA TYPE: string	Required	The CBSD shall set this parameter to the value of the Grant identity of this Grant.
NAME: *grantRenew* DATA TYPE: boolean	Optional	If set to True, the CBSD asks for renewal of the current Grant. SAS shall include a *grantExpireTime* parameter in the following *HeartbeatResponse* object.
NAME: *operationState* DATA TYPE: string	Required	This parameter contains the CBSD operation state (*"AUTHORIZED"* or *"GRANTED"*).
NAME: *measReport* DATA TYPE: object: *MeasReport*	Conditional	The CBSD uses this parameter to report measurements to the SAS. The format of the *MeasReport* object is provided in [n.21]. Refer to section 8 and [n.21] for inclusion rules.

10.8 Heartbeat Response Message

Table 29: Heartbeat Response Message

Parameter	R/O/C	Description
NAME: *heartbeatResponse* DATA TYPE: array of object: *HeartbeatResponse*	Required	Array of *HeartbeatResponse* objects. Each *HeartbeatResponse* object represents a heartbeat response of a CBSD.

10.8.1 HeartbeatResponse object

Table 30: *HeartbeatResponse* Object Definition

Parameter	R/O/C	Description
NAME: *cbsdId* DATA TYPE: string	Conditional	This parameter is included if and only if the *cbsdId* parameter in the *HeartbeatRequest* object contains a valid CBSD identity. If included, the SAS shall set this parameter to the value of the *cbsdId* parameter in the corresponding *HeartbeatRequest* object.
NAME: *grantId* DATA TYPE: string	Conditional	This parameter is included if and only if the *grantId* parameter in the *HeartbeatRequest* object contains a valid Grant identity. If included, the SAS shall set this parameter to the value of the *grantId* parameter in the corresponding *HeartbeatRequest* object.
NAME: *transmitExpireTime* DATA TYPE: string	Required	The CBSD shall cease transmission using the SAS authorized radio resource within 60 seconds after the value of the *transmitExpireTime* parameter expires, in accordance with part 96.39(c)(2) (ref. [n.8]). The *transmitExpireTime* is UTC time expressed in the format, YYYY-MM-DDThh:mm:ssZ as defined by [n.7]. The *transmitExpireTime* value shall be no later than the *grantExpireTime*.

Parameter	R/O/C	Description
NAME: *grantExpireTime* DATA TYPE: string	Conditional	Required if the *responseCode* parameter indicates SUCCESS or SUSPENDED_GRANT and the *grantRenew* parameter was included and set to True in the corresponding *HeartbeatRequest* object. This parameter may be included at other times by SAS choice.
NAME: *heartbeatInterval* DATA TYPE: number	Optional	This parameter is a positive integer and indicates the maximum time interval in units of seconds between two consecutive heartbeat requests. This parameter is included when the SAS wants to change the heartbeat interval.
NAME: *operationParam* DATA TYPE: object: *OperationParam*	Optional	If heartbeat request is disapproved or the SAS intends to change the CBSD operation parameters, the SAS can provide a new set of operation parameters to the CBSD using this object.
NAME: *measReportConfig* DATA TYPE: array of string	Optional	The SAS uses this parameter to configure CBSD measurement reporting. The measurement report requested by the SAS shall be consistent with the CBSD measurement capabilities reported during the registration request. The CBSD shall report the measurement listed in this array. The permitted enumerations are specified in [n.21].
NAME: *response* DATA TYPE: object: *Response*	Required	This parameter includes information on whether the corresponding CBSD request is approved or disapproved for a reason. See Table 14.

10.9 Relinquishment Request Message

Table 31: Relinquishment Request Message

Parameter	R/O/C	Description
NAME: *relinquishmentRequest*	Required	Array of *RelinquishmentRequest* objects. Each *RelinquishmentRequest* object

Parameter	R/O/C	Description
DATA TYPE: array of object: *RelinquishmentRequest*		Represents a relinquishment request of a CBSD.

10.9.1 RelinquishmentRequest object

Table 32: *RelinquishmentRequest* Object Definition

Parameter	R/O/C	Description
NAME: *cbsdId* DATA TYPE: string	Required	The CBSD shall set this parameter to the value of its CBSD identity.
NAME: *grantId* DATA TYPE: string	Required	The CBSD shall set this parameter to the value of the Grant identity of this Grant.

10.10   Relinquishment Response Message

Table 33: Relinquishment Response Message

Parameter	R/O/C	Description
NAME: *relinquishmentResponse* DATA TYPE: array of object: *RelinquishmentResponse*	Required	Array of *RelinquishmentResponse* objects. Each *RelinquishmentResponse* object represents a relinquishment response to a relinquishment request of a CBSD.

10.10.1RelinquishmentResponse object

Table 34: *RelinquishmentResponse* Object Definition

Parameter	R/O/C	Description
NAME: *cbsdId* DATA TYPE: string	Conditional	This parameter is included if and only if the *cbsdId* parameter in the *RelinquishmentRequest* object contains a valid CBSD identity. If included, the SAS shall set this parameter to the value of the *cbsdId* parameter in the corresponding *RelinquishmentRequest* object.

Parameter	R/O/C	Description
NAME: *grantId* DATA TYPE: string	Conditional	This parameter is included if and only if the *grantId* parameter in the *RelinquishmentRequest* object contains a valid Grant identity. If included, the SAS shall set this parameter to the value of the *grantId* parameter in the corresponding *RelinquishmentRequest* object.
NAME: *response* DATA TYPE: object: *Response*	Required	This parameter includes information on whether the corresponding CBSD request is approved or disapproved for a reason. See Table 14: *Response* Object Definition.

10.11   Deregistration Request Message

Table 35: Deregistration Request Message

Parameter	R/O/C	Description
NAME: *deregistrationRequest* DATA TYPE: array of object: *DeregistrationRequest*	Required	Array of *DeregistrationRequest* data objects. Each *DeregistrationRequest* data object represents a deregistration request of a CBSD.

10.11.1DeregistrationRequest object

Table 36: *DeregistrationRequest* Object Definition

Parameter	R/O/C	Description
NAME: *cbsdId* DATA TYPE: string	Required	The CBSD shall set this parameter to the value of its CBSD identity.

10.12   Deregistration Response Message

Table 37: Deregistration Response Message

Parameter	R/O/C	Description
NAME: *deregistrationResponse* DATA TYPE: array of object: *DeregistrationResponse*	Required	Array of *DeregistrationResponse* data objects. Each *DeregistrationResponse* data object represents a deregistration response to a deregistration request of a CBSD.

10.12.1DeregistrationResponse object

Table 38: *DeregistrationResponse* Object Definition

Parameter	R/O/C	Description
NAME: *cbsdId* DATA TYPE: string	Conditional	This parameter is included if and only if the *cbsdId* parameter in the *DeregistrationRequest* object contains a valid CBSD identity. If included, the SAS shall set this parameter to the value of the *cbsdId* parameter in the corresponding *DeregistrationRequest* object.
NAME: *response* DATA TYPE: object: *Response*	Required	This parameter includes information on whether the corresponding CBSD request is approved or disapproved for a reason. See Table 14: *Response* Object Definition.

10.13   Response Codes and Data

In the *Response* object of a SAS-CBSD response message, the SAS shall include a *responseCode* parameter to inform the CBSD of the status of the corresponding request. The response codes are grouped into the following categories and defined in the following table. The name associated with each *responseCode* parameter is not included in the *Response* object, but can be attached to a *responseCode* parameter by the CBSD or other network entity for logging or human-involved troubleshooting.

0: success

100 – 199: general errors related to the SAS-CBSD protocol

200 – 299: error events related to the CBSD Registration procedure

300 – 399: error events related to the Spectrum Inquiry procedure

400 – 499: error events related to the Grant procedure

500 – 599: error events related to the Heartbeat procedure

Table 39: Response Code Definitions

responseCode Value	Name	Description
0	SUCCESS	CBSD request is approved by SAS
100	VERSION	SAS protocol version used by CBSD is not supported by SAS
101	BLACKLISTED	CBSD is blacklisted. This responseCode is returned if the CBSD is under a SAS or FCC enforcement action and is barred from CBRS operation. In general, the CBSD should not try to re-register until actions external to this specification are taken. Note: Blacklisting behavior by the SAS and CBSD is FFS.
102	MISSING_PARAM	Required parameters missing
103	INVALID_VALUE	One or more parameters have invalid value
104	CERT_ERROR	There is an error in the certificate used to make the request (e.g. the credential is of the wrong role). Note: Most certificate errors, such as expired or syntactically invalid certificates, will cause errors at the TLS connection.
105	DEREGISTER	A CBSD receiving this responseCode is automatically deregistered by the SAS. The CBSD shall cease all transmissions, terminate all Grants, and consider itself *Unregistered*. The SAS may include this *responseCode* parameter in any message. The *responseMessage* parameter may contain a string describing the reason for deregistration. See NOTE 1 below.

responseCode Value	Name	Description
200	REG_PENDING	Incomplete registration information. The registration process is pending. One or more REG-Conditional parameters have not yet been supplied to the SAS. The CBSD is likely to accomplish a successful registration when the missing registration information is made available to the SAS.
201	GROUP_ERROR	An error has been identified in the grouping parameters of the CBSD.
300	UNSUPPORTED_SPECTRUM	The frequency range indicated in the spectrum inquiry request or grant request is at least partially outside of the CBRS band.
400	INTERFERENCE	Requested operation parameters cause too much interference. This *responseCode* value indicates that the Grant request is unlikely to be successful if retried by the CBSD.
401	GRANT_CONFLICT	Conflict with an existing Grant of the same CBSD. The CBSD should be able to remediate this using the data returned in the *responseData* structure, by synchronizing its Grant state with the SAS and relinquishing any out-of-sync Grants.
500	TERMINATED_GRANT	The Grant is terminated. This condition occurs if, for example, incumbent status has changed permanently causing the current Grant to terminate. The CBSD shall terminate radio operation by turning off its radio transmission associated with this Grant within 60 seconds after the value of the *transmitExpireTime* parameter expires, in accordance with part 96.39(c)(2) (ref. [n.8]). The Grant is considered terminated by the SAS, but the CBSD may relinquish the Grant. If the *operationParam* parameter is included in the *HeartbeatResponse* object, the CBSD should consider it as a recommendation by the SAS to obtain a new Grant using the included operational parameter values, and may request a new Grant using those operational parameters.

responseCode Value	Name	Description
501	SUSPENDED_GRANT	The Grant is suspended. This condition occurs if incumbent status has changed temporarily. The CBSD shall terminate radio operation by turning off its radio transmission associated with this Grant within 60 seconds after the value of the *transmitExpireTime* parameter expires, in accordance with part 96.39(c)(2) (ref. [n.8]). In such a case the CBSD may continue to send *HeartbeatRequest* objects and waiting until the Grant is re-enabled, or may relinquish the Grant and request another. If the *operationParam* parameter is included in the *HeartbeatResponse* object, the CBSD should consider it as a recommendation by the SAS to obtain a new Grant using the included operational parameter values, and may request a new Grant using those parameters.
502	UNSYNC_OP_PARAM	Operation parameters or Grant state(s) is/are out of sync between the CBSD and the SAS. In this case, the CBSD shall immediately turn off all radio transmission and shall relinquish the Grant.

NOTE 1 (Informative): This is an assistive *responseCode* parameter value to reset the CBSD out of a situation where it is out of sync with the SAS and there is no easier solution than to reset the registration. Examples are: The CBSD has been deregistered by the owner or deregistration is required by authorities, and presumably the CBSD needs to refresh its local configuration management.

In the *Response* object, the SAS can optionally include supplemental data (e.g., using the *responseData* parameter) to help the CBSD with further investigation of the error. The following table describes supplemental data to be included with some *responseCode* values.

Table 40: *responseData* Definitions

responseCode Value	Name	*responseData* Data Type	Description of error data
0	SUCCESS	*Not present*	
100	VERSION	array of string	Protocol versions supported by the SAS administrator
101	BLACKLISTED	*Not present*	
102	MISSING_PARAM	array of string	A list of missing parameters

responseCode Value	Name	*responseData* Data Type	Description of error data
103	INVALID_VALUE	array of string	A list of parameters names with invalid values
104	CERT_ERROR	*Not present*	
105	DEREGISTER	*Not present*	
200	REG_PENDING	array of string	A list of missing registration parameters
201	GROUP_ERROR	*Not present*	
300	UNSUPPORTED_SPECTRUM	*Not present*	
400	INTERFERENCE	*Not present*	
401	GRANT_CONFLICT	array of string	The Grant ID of an existing Grant that causes the conflict.
500	TERMINATED_GRANT	*Not present*	
501	SUSPENDED_GRANT	*Not present*	
502	UNSYNC_OP_PARAM	*Not present*	

11 Document History

<table>
<tr><th colspan="3">Document history</th></tr>
<tr><td>V1.0.0</td><td>29 November 2016</td><td>Version 1 released by Forum Chair</td></tr>
<tr><td>V2.0.0</td><td>14 Jun 2017</td><td>Version 2 released by Forum Chair</td></tr>
<tr><td>V1.1.0</td><td>14 July 2017</td><td>Renaming from V2.0.0 to V1.1.0</td></tr>
<tr><td>V1.2.0</td><td>13 December 2017</td><td>Technical revision to Version 1.1</td></tr>
</table>