

SAS to CBSD Protocol Technical Report-B

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Preface

This Technical Report (TR) describes details on information flows and functional description relating to SAS and CBSD operation. The main goal of this TR is to enable initial testing and trials of CBRS systems. WG3 will use this document, Interim SAS to CBSD Protocol Technical Report-A and any other relevant TRs to develop SAS to CBSD Protocol Technical Specification (TS). The TS will be developed in phases and published according to the work progress.

Note: There are a number of Working Group 1 Task Groups (Registration, Domain Proxy, ESC, Measurements) whose requirements outputs will be processed during the 1st or 2nd iterations of the Technical Specification.

SAS to CBSD Protocol Technical Report

1 Introduction

2 Scope

This document is a Technical Report on the signaling protocol for the SAS-CBSD (SAS-CBSD) interface.

3 References

3.1 Normative references

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

[n.1] “Interim SAS to CBSD Protocol Technical Report-A”, Document WINNF-15-P-0023, Version V1.0.0, 2 November 2015 (<http://groups.winnforum.org/d/do/8699>)

[n.2] “CBRS Communications Security Technical Report”, Working Document WINNF-15-P-0065, Version V0.3.3, 4 December 2015

3.2 Informative references

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

[i.1] Amendment of the Commission’s Rules with Regard to Commercial Operations in the 3550-3650MHz Band, GN Docket No. 12-354, “Report and Order and Second Further Notice of Proposed Rulemaking”, adopted April 17, 2015, FCC 15-47.

4 Definitions and abbreviations

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 this rule part. 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. End User Devices are not considered CBSDs.[i.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 [i.1].

5 Information Flows

This section contains detailed information flows describing the transactions over SAS-U. These information flows are intended to show an example of how the messages specified in reference [n.1] are used and how they combined to perform activities.

5.1 SAS Discovery

This procedure discusses how a CBSD discovers a SAS entity the CBSD can use for registration requests. A Domain Proxy can also discover a SAS on behalf of all CBSDs that it serves.

5.1.1 Successful operation

The CBSD or Domain Proxy shall initiate this procedure whenever needed to identify the SAS, e.g. prior to initiating the registration procedure.

The CBSD or Domain Proxy may use static methods for SAS discovery. For static methods, SAS connection information is provisioned into the CBSD or Domain Proxy. The CBSD or Domain Proxy then uses this provisioned information to establish a secure session with SAS. Once a secure session is successfully established, CBSD Registration may be initiated.

If supported by the network hosting the CBSD/Domain Proxy, dynamic provisioning may be used and leverage existing protocols like Domain Name System (DNS)/ Dynamic Host Control Protocol (DHCP) to determine the SAS connection information. The CBSD or Domain Proxy then uses this information to establish a secure session with SAS. [n.2]

One or more SAS addresses may be provisioned for SAS discovery. The method used to provision the SAS discovery information is outside the scope of this document.

5.1.2 Unsuccessful Operation

SAS discovery may fail due to e.g. SAS URL configuration errors or DNS configuration errors. The CBSD or Domain Proxy sends the failure cause to the appropriate entity for resolution, possibly involving a separate element management system.

5.2 CBSD Registration

This procedure describes how a CBSD registers with a SAS.

5.2.1 Successful operation

This procedure is initiated after the CBSD has successfully discovered the SAS. The CBSD initiates the procedure by performing SAS Authentication. The details of the authentication procedure are found in reference [n.2].

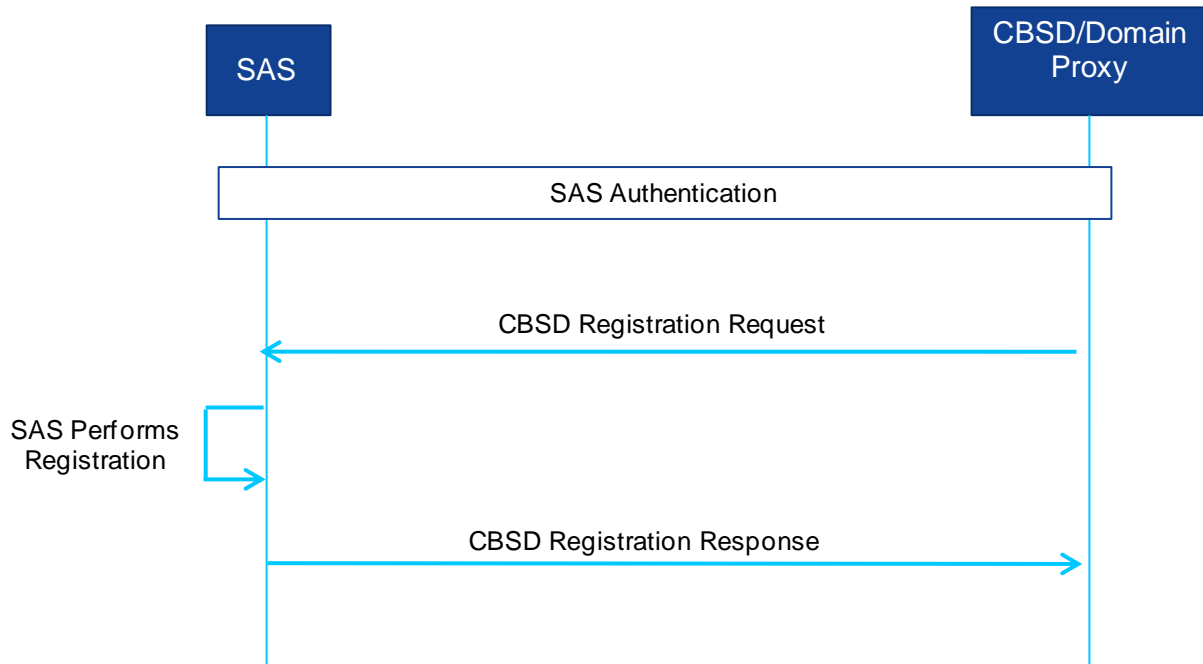


Figure 1: CBSD Registration procedure. Successful operation.

Item for further study: It is to be determined whether authentication details are included in this document or a reference to a WG2 document.

After successful authentication, if there is no Domain Proxy, the CBSD initiates registration by sending a CBSD [registrationRequest](#) (fccId, cbsdCategory, callSign, userId, [airInterface](#), cbsdManufacturer, cbsdSerialNumber, maximumGrants, sensingCapability, [installationParam](#)) message to SAS. The fccId, callSign, cbsdSerialNumber, and userId identify the CBSD to SAS. The cbsdCategory, airInterface, cbsdManufacturer, sensingCapability and installationParam provide specific information on the CBSD equipment capabilities. The maximumGrants parameter informs the SAS on the maximum number of grants the CBSD can use simultaneously (CBSD capability). Upon reception of the CBSD registrationRequest, SAS initiates the registration of the CBSD. SAS responds to the CBSD with a CBSD [registrationResponse](#) containing a *CBSD ID* Information Element (IE) along with an indication whether the registration succeeded or failed. The CBSD uses the *CBSD ID* parameter for all subsequent procedures with SAS. If registration fails, there will be a registrationResponse containing an [error code](#).

If there is a Domain Proxy and the Domain Proxy is performing bulk CBSD registration, the Domain Proxy will aggregate registration information for multiple CBSDs. The Domain Proxy sends a CBSD registrationRequest message to the SAS containing a list of registrationRequest objects which represents the aggregated CBSD registration information. The CBSD registrationRequest contains one instance of CBSD registration parameters per CBSD that the Domain Proxy is registering. Upon reception of the CBSD registrationRequest, SAS initiates the registration for each CBSD. SAS responds with a CBSD registrationResponse containing a

CBSD ID IE along with an indication whether the registration succeeded or failed for each registrationRequest and sends the aggregated response list to the Domain Proxy. The Domain Proxy and/or CBSD shall use the registered *CBSD ID* parameter for all subsequent procedures with SAS relative to each registered CBSD. The details of the interaction between the Domain Proxy, the CBSDs, and a possible CBSD element management system are outside the scope of this specification.

Item for further study: The current working assumption is the fccId+cbsdSerialNumber can be used for matching requests and responses in a Domain Proxy list.

5.2.2 Unsuccessful Operation

If SAS determines the registration is incomplete, the SAS returns a *REG_PENDING* error code. The CBSD periodically repeats the registrationRequest until receiving a successful registrationResponse from the SAS.

Item for further study: It is to be determined whether the CBSD implements a retry timer to initiate the Registration Request or receives a notification from the SAS. If a retry timer is implemented, its implementation including retry timer duration is internal to the CBSD.

If SAS determines the CBSD operating privileges have been revoked, SAS returns a *BLACKLISTED* error code. When the CBSD operating privileges are restored, the CBSD may initiate a registrationRequest. How operating privileges are restored to the CBSD is outside the scope of this document. The method used to trigger the CBSD registration is implementation specific.

If SAS determines an error with one of the parameters in the registrationRequest, SAS returns a *Registration Failed* error code along with the [faulty parameter\(s\)](#). The CBSD passes the failure cause to the upper layers for resolution.

If there is a Domain Proxy, the Domain Proxy receives an aggregated list of registrationResponse objects. For each registration that fails, there will be one registrationResponse object per CBSD containing an error code. The Domain Proxy matches the individual responses to the individual requests and takes the appropriate action, possibly involving the CBSD(s) and/or a separate CBSD element management system.

5.3 CBSD Spectrum Inquiry

This procedure describes how a CBSD performs the Spectrum Inquiry procedure with SAS. Spectrum Inquiry allows registered CBSDs to request information on available channels. With SAS providing available channel information, the CBSD can decide operational parameters for a grant request.

5.3.1 Successful operation

The CBSD initiates this procedure anytime after successfully registering with SAS. Spectrum Inquiry messages may be sent prior to the Grant Request if the CBSD wants SAS to indicate specific information on channels available for the CBSD.

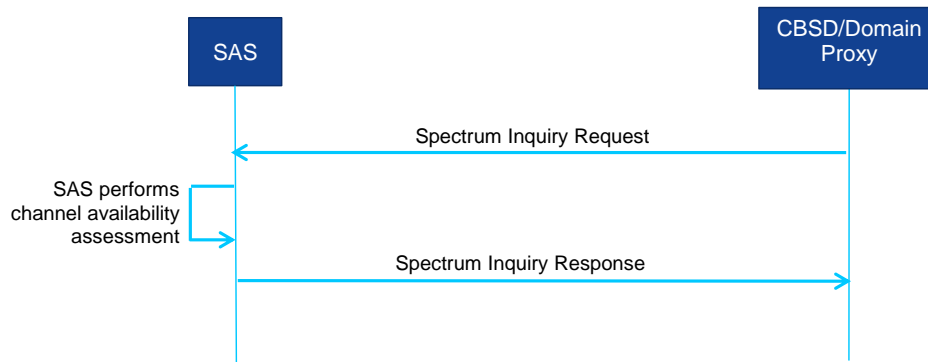


Figure 2: CBSD Spectrum Inquiry. Successful operation.

If there is no Domain Proxy, the CBSD initiates spectrum inquiry by sending a [spectrumInquiryRequest](#) (cbsdId, palCredential, inquiredSpectrum) message to SAS. The cbsdId identifies the CBSD to SAS. The palCredential is an optional parameter and is included in spectrumInquiryRequest as described in section 7.3. The inquiredSpectrum is an array of [FrequencyRange](#) data objects indicating the frequency range(s) which the CBSD seeks information. The CBSD may request information for one or more frequency ranges as described in section 7.3.

SAS performs an assessment of channel availability for the frequency ranges indicated in the spectrumInquiryRequest. If the request succeeds, SAS sends a [spectrumInquiryResponse](#) (cbsdId, availableChannel, error) message to the CBSD with the results of its channel assessment in the [availableChannel object](#). The availableChannel object contains a list of frequency ranges available for the CBSD for grant requests. For each frequency range contained in the availableChannel object, SAS also indicates the channel access type (PAL/GAA) and the regulatory rule SAS used to determine availability. If the parameter cbsdId used in the spectrumInquiryRequest message does not match with the palCredential (e.g. the CBSD location does not match), the SAS fails the request and responds with an error message

SAS does not reserve any channel allocations as part of Spectrum Inquiry nor does SAS guarantee the information in the availableChannel object is still valid when the CBSD initiates a grant request. The CBSD should consider the information in the availableChannel object as an indication of the channels available to the CBSD.

If there is a Domain Proxy and the Domain Proxy is performing bulk Spectrum Inquiry Requests, the Domain Proxy aggregates information related to each applicable CBSD into an array of

spectrumInquiryRequest objects as described in section 7. When the Domain Proxy receives the the array of spectrumInquiryResponse objects from SAS, the Domain Proxy matches the individual responses to the individual requests and takes the appropriate action, possibly involving the CBSD(s) and/or a separate CBSD element management system. The details of the interaction between the Domain Proxy, the CBSDs, and a possible CBSD element management system are outside the scope of this specification.

5.3.2 Unsuccessful Operation

If SAS determines an error with one of the parameters in the spectrumInquiryRequest message, SAS returns a spectrumInquiryResponse message with an error code along with the [faulty parameter\(s\)](#). The CBSD passes the failure cause to the upper layers for resolution.

If there is a Domain Proxy, the Domain Proxy receives an aggregated list of spectrumInquiryResponse objects. For each failed request, there will be a failure reason in the *error* object. The Domain Proxy matches the response with the originating request and takes the appropriate action, possibly involving the CBSD(s) and/or a separate CBSD element management system.

5.4 CBSD Grant Request

This procedure describes how a CBSD requests spectrum from SAS. This procedure can only be performed by CBSD after it has successfully registered with the SAS and has obtained its CBSD ID.

5.4.1 Successful operation

This procedure is initiated after the CBSD has successfully registered with the SAS. This procedure moves the CBSD from the Registered state to the Granted state and must be successfully completed prior to the CBSD moving to the Transmission state. Spectrum Inquiry messages may be sent prior to the Grant Request if the CBSD wants SAS to indicate specific information on channels available for the CBSD. Heartbeat is required prior to activating any channels assigned during the grant request.

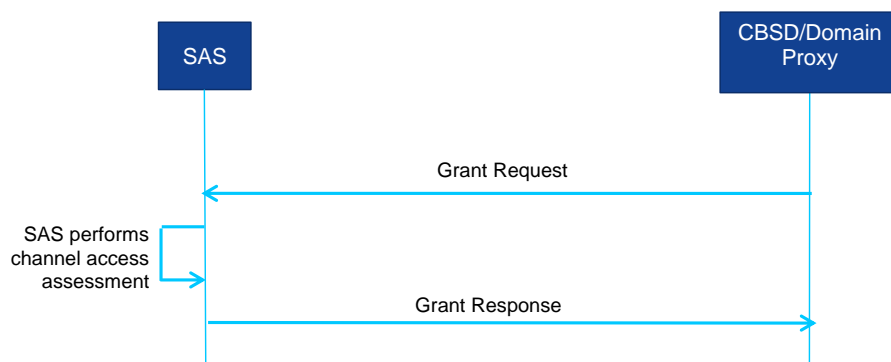


Figure 3: CBSD Grant Request. Successful operation.

Prior to initiating a grant request, the CBSD has to determine the operational parameters used in the grant request. These operational parameters include the frequency range and peak power the CBSD wants to use for operation and whether the CBSD wants to operate this frequency range with PAL access or GAA access. 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](#) (cbsdId, operationParam) message to SAS. The cbsdId identifies the CBSD to SAS. The [operationParam object](#) contains the details of the grant request and contains the PAL credentials, CBSD peak power and the desired frequency range for use as described in section 7.5. The PAL credentials is an optional parameter and must be included if the CBSD is requesting PAL access for the desired frequency range. The CBSD peak power indicates the peak transmission power the CBSD will use during the grant time. The desired frequency range is a contiguous frequency range specified by low and high frequency values.

SAS responds to the CBSD with a [grantResponse](#) (cbsdId, grantId, grantExpireTime, heartbeatDuration, [measReportConfig](#), operationParam, error) message. The error parameter indicates whether the request succeeded or failed. If the grantRequest succeeded, SAS shall include the grantExpireTime parameter and the heartbeatDuration parameter. The CBSD uses the value of the grantExpireTime parameter to determine when the CBSD stops transmitting on the assigned spectrum. If the heartbeatDuration parameter is included, the CBSD uses the value as the time interval between two consecutive Heartbeat requests. Since the CBSD can not transition to the Transmission state until completion of the Heartbeat procedure, the CBSD should execute the first Heartbeat procedure as soon as possible after the grantResponse. If the grantRequest failed, the CBSD may issue a new grantRequest and may use the operational parameters included in the operationParam object. In this case, the optional parameter grantId should not be included in the response. The measReportConfig parameter is an optional parameter containing the CBSD measurement report configuration. If the parameter cbsdId used in the grantRequest message does not match with the palCredential (e.g. the CBSD location doesn't match), the SAS fails the request and responds with an error message.

Note: SAS may include operationParam if SAS wants to recommend a frequency range for the CBSD to use in the new grantRequest. It is optional whether SAS includes this object in a failed grantResponse. Whether the CBSD chooses to use the operationParam object in the new grantRequest is left to CBSD implementation.

If SAS accepts the grantRequest, SAS allocates spectrum according to the parameters in the operationParam object in grantRequest. SAS allocates the spectrum in a frequency range indicated by the lowFrequency and highFrequency parameters in the operationalParam object. The CBSD cannot use that spectrum (e.g. activate its radio) 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 as described in section 7. When the Domain Proxy receives the array of

grantResponse objects from SAS, the Domain Proxy matches the individual responses to the individual requests. If the response indicates the Grant Request succeeded, the Domain Proxy takes the appropriate action, either directly with the CBSD(s) or optionally via a separate CBSD element management system. The details of the interaction between the Domain Proxy, the CBSDs, and a possible CBSD element management system are outside the scope of this specification.

5.4.2 *Unsuccessful Operation*

If SAS determines an error with one of the parameters in the grantRequest message, SAS returns a grantResponse message with an error code along with the [faulty parameter\(s\)](#). The CBSD passes the failure cause to the upper layers for resolution.

If there is a Domain Proxy, the Domain Proxy receives an aggregated list of grantResponse objects. For each failed request, there will be a failure reason in the *error* object. The Domain Proxy matches the response with the originating request and takes the appropriate action, possibly involving the CBSD(s) and/or a separate CBSD element management system.

5.5 **CBSD Heartbeat Request**

This procedure describes how a CBSD performs the Heartbeat procedure with SAS. The Heartbeat Request informs SAS that the CBSD is still using the allocated spectrum. It also allows SAS to suspend or terminate the grant. If the grant is suspended or terminated, SAS has the option of reassigning the CBSD to alternative spectrum.

5.5.1 *Successful operation*

The CBSD initiates this procedure anytime prior to the expiration of the Heartbeat Duration timer. Heartbeat duration is defined as the time interval between two consecutive heartbeats. The timer is reset when the [heartbeatRequest](#) is sent to SAS. The Heartbeat Duration timer is included in the grantResponse message and in the [heartbeatResponse](#) message. The CBSD should also send the heartbeatRequest as soon as a grant is approved by SAS.

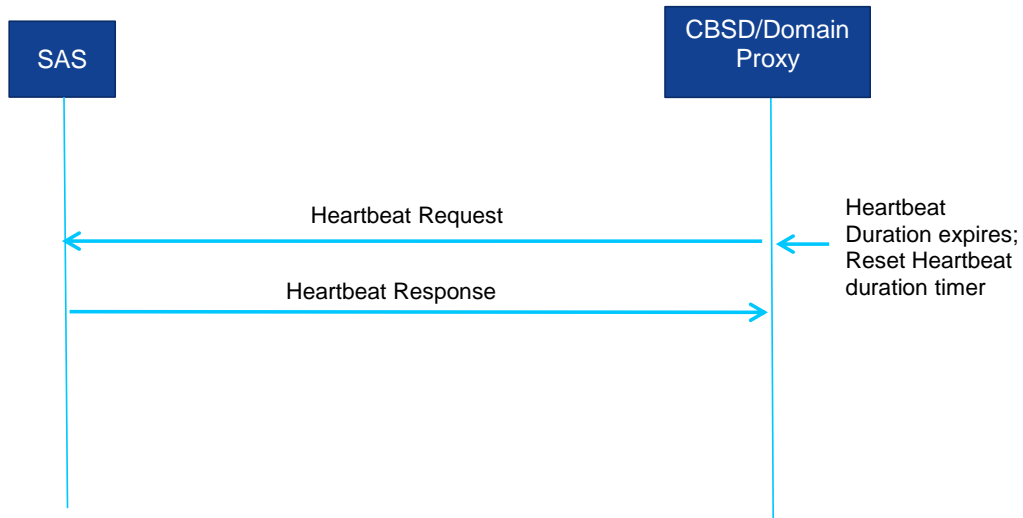


Figure 4: CBSD Heartbeat Request. Successful operation.

If there is no Domain Proxy, the CBSD initiates heartbeat by sending a heartbeatRequest (cbsdId, grantId, operationState, operationParam, measReport) message to SAS. The cbsdId identifies the CBSD to SAS. The grantId provides specific information on the spectrum grant intended for the heartbeat. The operationState and operationParam are optional parameters and are included in Heartbeat Request as described in section 7.7. The measReport parameter is an optional parameter containing the CBSD measurement report.

The CBSD obtains the heartbeat duration value in the grantResponse message or in a previous heartbeatResponse message. SAS responds to the CBSD with a heartbeatResponse (cbsdId, grantId, operationStatusReq, transmitExpireTime, heartbeatDuration, operationParam, measReportConfig, error) message. The error parameter indicates whether the request succeeded or failed. If the request succeeded, SAS includes the transmitExpireTime parameter and may include the heartbeatDuration parameter. The CBSD uses the value of the transmitExpireTime parameter to determine when the CBSD stops transmitting on the assigned spectrum. If the heartbeatDuration parameter is included, the CBSD uses the value as the time interval before the next heartbeatRequest is sent. If the request fails, SAS may include the operationParam parameter. If the operationParam parameter is included, the CBSD interprets the values as a spectrum reassignment. The following text summarizes the CBSD behavior based on errorCode in the error parameter.

IF errorCode = SUCCESS

- Initiate radio transmission if initial heartbeatRequest
- Update parameters based on heartbeatResponse

- Continue operation (or resume operation if grant was suspended)

ELSE IF errorCode = SUSPENDED_GRANT

- Turn off radio transmission (suspend radio operations)


```

Update parameters based on heartbeatResponse
Reset heartbeat timer if there are no new operational parameters
    Resend heartbeatRequest after timer expires
Issue relinquishmentRequest if new operational parameters
Issue grantRequest with new operational parameters
ELSE IF errorCode = TERMINATED_GRANT
    Turn off radio transmission (terminate radio operations)
    Issue relinquishmentRequest if new operational parameters
    Issue grantRequest
END

```

The operationStatusReq parameter is an optional parameter informing the CBSD whether operational parameters and operational state are to be included in the next heartbeatRequest. If the operationStatusReq parameter is true, the operationState and operationParam associated with the grantId are included in the next heartbeatRequest. If the operationStatusReq parameter is false, these parameters are not included in the next heartbeatRequest. The measReportConfig parameter is an optional parameter containing the CBSD measurement report configuration.

Item for further study: The specification and inclusion of the measurement report parameter needs further discussion and agreement.

If there is a Domain Proxy and the Domain Proxy is performing bulk heartbeatRequests, the Domain Proxy aggregates information related to each applicable CBSD into a heartbeatRequest message as described in section 7. When the Domain Proxy receives the heartbeatResponse message from SAS, the Domain Proxy matches the individual responses to the individual requests. If the response indicates the heartbeatRequest succeeded, the Domain Proxy performs the previously described CBSD behavior on behalf of the successful CBSD(s). If this is the initial heartbeatRequest message after a grantResponse message, the Domain Proxy takes the appropriate action to initiate radio transmission, either directly with the CBSD(s) or optionally via a separate CBSD element management system. The details of the interaction between the Domain Proxy, the CBSDs, and a possible CBSD element management system are outside the scope of this specification.

5.5.2 Unsuccessful Operation

If SAS determines an error with one of the parameters in the heartbeatRequest message, SAS returns a heartbeatResponse message with an error code along with the [faulty parameter\(s\)](#). The CBSD passes the failure cause to the upper layers for resolution.

If there is a Domain Proxy, the Domain Proxy receives an aggregated list of heartbeatResponse objects. For each failed request, there will be a failure reason in the *error* object. The Domain Proxy matches the response with the originating request and takes the appropriate action, possibly involving the CBSD(s) and/or a separate CBSD element management system..

5.6 CBSD Spectrum Relinquishment

This procedure describes how a CBSD informs SAS if a grant is no longer used by the CBSD.

5.6.1 Successful operation

The CBSD initiates this procedure anytime after the CBSD has successfully completed the Grant Request procedure.

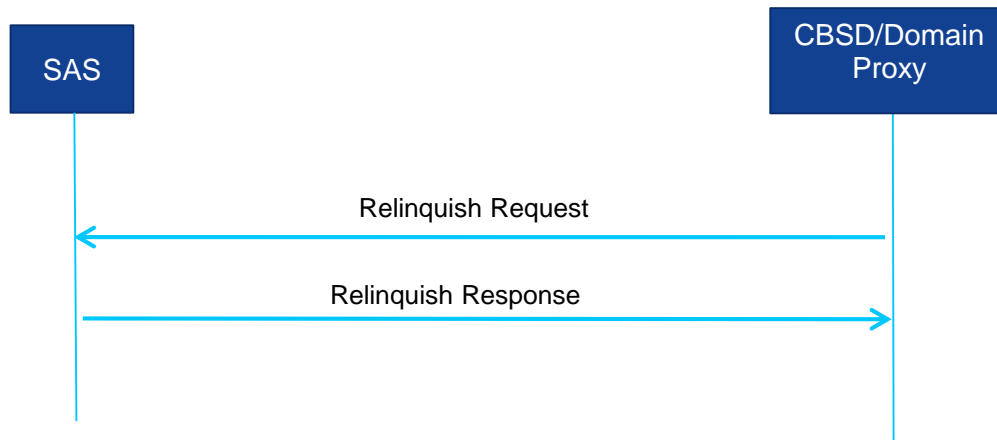


Figure 5: CBSD Spectrum Relinquishment. Successful operation.

If there is no Domain Proxy, the CBSD initiates spectrum relinquishment by sending a [relinquishmentRequest](#) (cbsdId, grantId) message to SAS. The cbsdId identifies the CBSD to SAS. The grantId provides specific information on the spectrum grant the CBSD wants to relinquish. The relinquishmentRequest message may be sent while the grant associated with the grantId is valid. Upon reception of the relinquishmentRequest message, SAS relinquishes the spectrum assigned to the CBSD and associated with the grantId. SAS responds to the CBSD with a [relinquishmentResponse](#) message containing the cbsdId and grantId Information Elements (IEs) along with an indication whether the request succeeded or failed. If the request succeeded, the CBSD no longer has authorization to use the spectrum associated with the grant and must repeat the CBSD Grant Request procedure. If the request fails, the relinquishmentResponse message will contain an error code.

If there is a Domain Proxy and the Domain Proxy is performing bulk Relinquishment Requests, the Domain Proxy will aggregate relinquishment information for multiple CBSDs. The Domain Proxy aggregates this information into a list of relinquishmentRequest objects and sends a relinquishmentRequest message to SAS. The relinquishmentRequest message contains one instance of the Relinquishment Request parameters per CBSD requesting spectrum relinquishment. Upon reception of the relinquishmentRequest message, SAS initiates the relinquishment process for each CBSD. SAS responds to the CBSD with a relinquishmentResponse message containing the associated cbsdId and grantId along with an

indication whether the relinquishment succeeded or failed for each relinquishment request and sends the aggregated response list to the Domain Proxy. The Domain Proxy matches the individual responses to the individual requests and takes the appropriate action, possibly involving the CBSD(s) and/or a separate CBSD element management system. The details of the interaction between the Domain Proxy, the CBSDs, and a possible CBSD element management system are outside the scope of this specification.

5.6.2 Unsuccessful Operation

If SAS determines an error with one of the parameters in the relinquishmentRequest message, SAS returns a relinquishmentResponse message with a failure reason along with the [faulty parameter\(s\)](#). The CBSD passes the failure cause to the upper layers for resolution.

If there is a Domain Proxy, the Domain Proxy receives an aggregated list of relinquishmentResponse objects. For each failed relinquishment request, there will be a failure reason in the *error* object of the relinquishmentResponse for the CBSD(s). The Domain Proxy matches the response with the originating relinquishment request and takes the appropriate action, possibly involving the CBSD(s) and/or a separate CBSD element management system.

6 Message Encoding and Transport

6.1 Message Encoding

SAS-CBSD messages are encoded using JSON, or JavaScript Object Notation. JSON encoded messages are in the form of single or multiple of name/value pairs, where a name, represented as a string, and its value is separated by a colon. A value can be one of four primitive types (strings, numbers, booleans, and null) and two structured types (objects and arrays).

- **String:** a string begins and ends with quotation marks. All Unicode characters can be placed within the quotation marks except quotation mark, reverse solidus and control characters.
- **Number:** a signed integer or a floating number belongs to this category. A floating number can contain a fractional part or be represented in exponential form.
- **Boolean:** a Boolean value can be true or false
- **Object:** An object is a data structure represented as a pair of curly brackets surrounding zero or more name/value pairs. A SAS-CBSD message is represented as a JSON object. To better organize data in a message, an object can also be created to include a group of name/value pairs that belong to a certain category.
- **Array:** represented as square brackets surrounding zero or more values, separated by commas. There is no requirement that values in an array are of the same type.

When a domain proxy sends requests to SAS, multiple JSON encoded requests of the same type can be aggregated together in the form of a JSON array and sent in one HTTP request. Similarly

SAS can include multiple response messages in a JSON array and send it to a domain proxy. Therefore a JSON encoded 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 should not be included in one JSON-encoded message.

The following example shows the format of a JSON-encoded SAS message. As shown in the example, the message contains two objects in a JSON array, whose name is registrationRequest. Each object denotes a registrationRequest for a CBSD.

```
{
  "registrationRequest": [
    {
      "fcclId": "abc123",
      "cbsdCategory": "B",
      "callSign": "KQQQ",
      "userId": "John Doe",
      "airInterface": {
        "radioTechnology": "E-UTRA",
        "supportedSpec": "LTE-Rel10"
      },
      "cbsdManufacturer": "Equipment Maker B",
      "cbsdSerialNumber": "abcd1234",
      "maxNumberOfGrant": 2,
      "sensingCapability": [
        "signalStrength",
        "interferenceStrength"
      ],
      "installationParam": {
        "latitude": 37.419735,
        "longitude": -122.072205,
        "height": 6,
        "indoorDeployment": true
      }
    },
    {
      "fcclId": "321cba",
      "cbsdCategory": "A",
      "callSign": "KPPP",
      "userId": "John Doe",
      "airInterface": {
        "radioTechnology": "E-UTRA",
        "supportedSpec": "LTE-Rel10"
      },
      "cbsdManufacturer": "Equipment Maker C",
      "cbsdSerialNumber": "4321dcba",
      "maxNumberOfGrant": 2,
    }
  ]
}
```

```

    "sensingCapability": [
      "signalStrength",
      "interferenceStrength"
    ],
    "installationParam": {
      "latitude": 37.425056,
      "longitude": -122.084113,
      "height": 9.3,
      "indoorDeployment": false,
      "antennaAzimuth": 270.5,
      "antennaDowntiltMech": 3,
      "antennaGain": 16,
      "antennaBeamwidth": 30
    }
  }
}

```

The name of the outermost array in a JSON-encoded SAS message maps to a SAS-CBSD message defined in Section 7. Mapping of SAS-CBSD messages and the corresponding JSON array names can be found in the following table.

JSON Array Name	Reference	SAS-CBSD Message
registrationRequest	Section 7.1	Registration Request Message
registrationResponse	Section 7.2	Registration Response Message
spectrumInquiryRequest	Section 7.3	Spectrum Inquiry Request Message
spectrumInquiryResponse	Section 7.4	Spectrum Inquiry Response Message
grantRequest	Section 7.5	Grant Request Message
grantResponse	Section 7.6	Grant Response Message
heartbeatRequest	Section 7.7	Heartbeat Request Message
heartbeatResponse	Section 7.8	Heartbeat Response Message
relinquishmentRequest	Section 7.9	Relinquishment Request Message
relinquishmentResponse	Section 7.10	Relinquishment Response Message
deregistrationRequest	Section 7.11	Deregistration Request Message

deregistrationResponse	Section 7.12	Deregistration Response Message
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6.2 Message Transport

HTTPS (HTTP plus TLS) is used as the transport mechanism for the SAS-CBSD protocol. A HTTP request message sent to SAS has a header like the following.

```
POST /v1.0/registration HTTP/1.1
Host: www.sasproviderapi.com
Content-type: application/json
```

The first line is the request line. POST is a standard HTTP request method that is used for all requests from CBSD to SAS. The string after POST is the URL that the message is sent to. The URL should end with /sas_version_number/sas_method_name to indicate the SAS protocol version and the SAS method included in the message. Each SAS administrator can choose the URL of its SAS service, as long as the end of the URL is in the format defined in this specification. The SAS version number is in the form of vx.y where x is the major release number and y is the minor release number. A SAS method corresponds to a pair of request and response messages defined in Section 7. Valid SAS methods are listed in the table below. HTTP/1.1 indicates that HTTP protocol version 1.1 is used. The second line shows the hostname of the SAS server. The third line indicates JSON as the encoding method for the content in the HTTP message.

SAS Method Name	Request	Response
registration	registrationRequest	registrationResponse
spectrumInquiry	spectrumInquiryRequest	spectrumInquiryResponse
grant	grantRequest	grantResponse
heartbeat	heartbeatRequest	heartbeatResponse
relinquishment	relinquishmentRequest	relinquishmentResponse
deregistration	deregistrationRequest	deregistrationResponse

7 Parameters of SAS-CBSD Messages

In this section parameters of SAS-CBSD message are described in more details. 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.

A parameter marked as “Required” should always be included when its associated message or object is used, while an “Optional” parameter may not be present. In the registrationRequest, some parameters are marked as “Conditional”. These parameters are required by SAS to complete the CBSD registration process but may not be included in a registrationRequest message. For example, some required CBSD registration information could be provided to SAS through the device type registration process or the CBSD installation process.

7.1 Registration Request Message: registrationRequest

Parameter Name	Data Type	Required/ Optional	Description
userId	string	Required	The identifier of a CBSD user.
fccId	string	Required	The FCC certification identifier of the CBSD. It is a string of 19 characters as described in FCC Administration Topics Review.
cbsdSerialNumber	string	Required	A serial number assigned to CBSD by the CBSD device manufacturer.
cbsdManufacturer	string	Conditional	A unique name for the CBSD manufacturer.
callSign	string	Conditional	A device identifier provided by FCC.
cbsdCategory	string	Conditional	Device Category of the CBSD. Allowed values are “A” or “B” as defined in Part 96.
maximumGrants	number	Conditional	The maximum number of grants that the CBSD can use simultaneously.
airInterface	object: AirInterface	Conditional	A data object that includes information on the air interface technology of the CBSD.

installationParam	object: InstallationParam	Conditional	A data object that includes information on CBSD installation. Installation information may be provided to SAS through a separate interface between SAS and installers.
sensingCapability	array of string	Conditional	The array describes all sensing capabilities of CBSD relevant to SAS operation. Examples of sensing capability include “esc”, “receivedInterferencePower”.

7.1.1 *AirInterface data object:*

Parameter Name	Data Type	Required/ Optional	Description
radioTechnology	string	Conditional	This field specifies the radio access technology that is going to be used for the CBSD, e.g., “lte”, “hspa”, “wimax”, “wifi”, etc
supportedSpec	string	Optional	This field specifies the latest release supported by CBSD. Examples include “lte-rel10”, “ieee802.11ac”, etc.

7.1.2 *InstallationParam data object:*

Parameter Name	Data Type	Required/ Optional	Description
latitude	number	Conditional	Latitude of the CBSD antenna location. The allowed range is from -90.000000 to +90.000000
longitude	number	Conditional	Longitude of the CBSD antenna location. The allowed range is from -180.000000 to +180.000000.
height	number	Conditional	CBSD antenna height in meters.
heightType	string	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.
horizontalAccuracy	number	Optional	A positive number in meters to indicate accuracy of CBSD antenna horizontal location if it's smaller than the FCC requirement (50 meters)
verticalAccuracy	number	Optional	A positive number in meters to indicate accuracy of CBSD antenna vertical location if it's smaller than the FCC requirement (3 meters)
indoorDeployment	boolean	Conditional	Whether the CBSD antenna is indoor or not. True: indoor. False: outdoor.
antennaAzimuth	number	Optional / Conditional	Antenna azimuth in degrees. It is optional for Category A CBSD and required for category B CBSD.
antennaDowntiltMech	number	Optional / Conditional	Mechanical antenna downtilt in degrees. It is optional for Category A CBSD and required for category B CBSD.
antennaDowntiltElec	number	Optional / Conditional	Electrical antenna downtilt in degrees. It is only required for category B CBSD capable of electrical antenna downtilt.
antennaGain	number	Optional / Conditional	Peak antenna gain in dBi. It is optional for Category A CBSD and required for category B CBSD.
antennaBeamwidth	number	Optional / Conditional	3 dB antenna beamwidth in degrees. It is optional for Category A CBSD and required for category B CBSD.
antennaModel	string	Optional	If an external antenna is used, the antenna model is optionally provided in this field.

7.2 Registration Response message: registrationResponse

Parameter Name	Data Type	Required/ Optional	Description
cbsdId	string	Required	This is a globally unique identifier for each CBSD registered to SAS. Definition of this ID is FFS.
error	object: Error	Required	This parameter includes information on whether the corresponding CBSD request is approved or disapproved for a reason.

7.2.1 Error data object:

Parameter Name	Data Type	Required/ Optional	Description
errorCode	number	Required	An integer to indicate the type of error. 0 means the corresponding CBSD request is approved.
errorMessage	string	Optional	A short description of the error.
errorData	errorCode dependent	Optional	Additional data can be included to help CBSD resolve error. The data type depends on the value of the error code.

Definitions of errorCode and errorData are specified in [Section 7.13](#).

7.3 Spectrum Inquiry Request Message: spectrumInquiryRequest

Parameter Name	Data Type	Required/ Optional	Description
cbsdId	string	Required	This is a globally unique identifier for each CBSD registered to SAS.
palCredential	array of string	Optional	If the CBSD owner has PAL right, the PAL credential(s) should be included here. Credentials are formatted as an

			array of strings. This field is not included if the CBSD has no PAL right.
inquiredSpectrum	array of FrequencyRange	Required	This field describes the spectrum in which CBSD seeks information. The parameter is an array of the FrequencyRange data object.

7.3.1 FrequencyRange data object:

Parameter Name	Data Type	Required/Optional	Description
lowFrequency	Number	Required	The lowest frequency of the frequency range in Hz.
highFrequency	Number	Required	The highest frequency of the frequency range in Hz.

7.4 Spectrum Inquiry Response Message: spectrumInquiryResponse

Parameter Name	Data Type	Required/Optional	Description
cbsdId	string	Required	This is a globally unique identifier for each CBSD registered to SAS.
availableChannel	array of AvailableChannel	Required	This parameter is an array of a data object, AvailableChannel, which describes a channel that is available for the CBSD.
error	object: Error	Required	This parameter includes information on whether the corresponding CBSD request is approved or disapproved for a reason.

7.4.1 AvailableChannel data object:

Parameter Name	Data Type	Required/ Optional	Description
frequencyRange	FrequencyRange	Required	This parameter is frequency range of the available channel.
channelType	string	Required	“PAL”: the channel is a PAL channel based on the credentials provided in the spectrum inquiry request. “GAA”: the frequency range is for GAA use.
ruleApplied	string	Required	The regulatory rule used to generate this response, e.g., “FCC Part 96”.

7.5 Grant Request Message: grantRequest

A grant request contains operating parameters that CBSD plans to operate with. Operation parameters include a continuous segment of spectrum and the peak transmission power. A CBSD shall present its PAL credentials in the grant request if it requires PAL protection for the grant.

Parameter Name	Data Type	Required/ Optional	Description
cbsdId	string	Required	This is a globally unique identifier for each CBSD registered to SAS.
operationParam	object: OperationParam	Required	This data object includes operation parameters of the requested grant.

7.5.1 OperationParam data object:

Parameter Name	Data Type	Required/ Optional	Description
palCredential	array of string	Optional	PAL credential(s) shall be provided here if the grant requires

			PAL protection. This field is not included if the CBSD does not demand PAL protection for the grant.
peakPower	Number	Required	Peak transmission power to be used in the grant. The peak power is in the unit of dBm/MHz.
operationFrequencyRange	FrequencyRange	Required	This parameter is frequency range of a contiguous segment.

7.6 Grant Response Message: grantResponse

Parameter Name	Data Type	Required/ Optional	Description
cbsdId	string	Required	This is a globally unique identifier for each CBSD registered to SAS.
grantId	string	Optional	An ID provided by SAS for each approved grant. If the request is rejected, this field must not be included.
grantExpireTime	string	Optional	If the request is approved, SAS shall include this field to indicate the UTC time when the grant expires. It is expressed using the format, YYYY-MM-DDThh:mm:ssZ, as defined by "Date and Time on the Internet: Timestamps" [RFC3339].
heartbeatDuration	number	Optional	If the request is approved, SAS shall include this field to indicate the time interval in seconds between two consecutive heartbeat requests.
measReportConfig	object: MeasReportConfig	Optional	Configuration for CBSD to perform various measurements (interference, incumbent, etc) and report to SAS.
operationParam	object:	Optional	If grant request is disapproved, SAS

	OperationParam		can optionally provide a new set of operation parameters for the CBSD.
error	object: Error	Required	This parameter includes information on whether the corresponding CBSD request is approved or disapproved for a reason.

7.7 Heartbeat Request Message: heartbeatRequest

Parameter Name	Data Type	Required/Optional	Description
cbsdId	string	Required	This is a globally unique identifier for each CBSD registered to SAS.
grantId	string	Required	An ID provided by SAS for each approved grant.
grantRenew	boolean	Optional	If set to True, CBSD asks for renewal of the current grant. SAS should include a grantExpireTime in the following heartbeatResponse.
operationState	string	Optional	If operationStatusReq is True in the previous heartbeat response, CBSD operation state (Transmission or Granted) should be included.
operationParam	object: OperationParam	Optional	If operationStatusReq is True in the previous heartbeat response, operationParam should be included.
measReport	object: MeasReport	Optional	If CBSD is configured to report measurements, this field includes the measurement reports.

7.8 Heartbeat Response Message: heartbeatResponse

Parameter Name	Data Type	Required/ Optional	Description
cbsdId	string	Required	This is a globally unique identifier for each CBSD registered to SAS.
grantId	string	Required	An ID provided by SAS for each approved grant.
operationStatusReq	boolean	Optional	If True, CBSD should include operation parameters and operation state in the next heartbeat request.
transmitExpireTime	string	Required	If the request is approved, this field indicates the time CBSD can transmit until. It is UTC time expressed in the format, YYYY-MM-DDThh:mm:ssZ
grantExpireTime	string	Optional	If grantRenew is set to True in a heartbeatRequest, SAS should include this field in heartbeatResponse.
heartbeatDuration	number	Optional	SAS can change the future heartbeat duration with this field.
operationParam	OperationParam	Optional	If heartbeat request is disapproved or SAS intends to change CBSD operation parameters, SAS can provide a new set of operation parameters to the CBSD.
measReportConfig	object: MeasReportConfig	Optional	Configuration for CBSD to perform various measurements (interference, incumbent, etc) and report to SAS.
error	object: Error	Required	This parameter includes information on whether the corresponding CBSD request is approved or disapproved for a reason.

7.9 Relinquishment Request Message: `relinquishmentRequest`

Parameter Name	Data Type	Required/ Optional	Description
<code>cbsdId</code>	string	Required	This is a globally unique identifier for each CBSD registered to SAS.
<code>grantId</code>	string	Required	An ID provided by SAS for each approved grant.

7.10 Relinquishment Response Message: `relinquishmentResponse`

Parameter Name	Data Type	Required/ Optional	Description
<code>cbsdId</code>	string	Required	This is a globally unique identifier for each CBSD registered to SAS.
<code>grantId</code>	string	Required	An ID provided by SAS for each approved grant.
<code>error</code>	object: Error	Required	This parameter includes information on whether the corresponding CBSD request is approved or disapproved for a reason.

7.11 Deregistration Request Message: `deregistrationRequest`

Parameter Name	Data Type	Required/ Optional	Description
<code>cbsdId</code>	string	Required	This is a globally unique identifier for each CBSD registered to SAS.

7.12 Deregistration Response Message: deregistrationResponse

Parameter Name	Data Type	Required/ Optional	Description
cbsdId	string	Required	This is a globally unique identifier for each CBSD registered to SAS.
error	object: Error	Required	This parameter includes information on whether the corresponding CBSD request is approved or disapproved for a reason.

7.13 Error Codes and Data

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

0: success

100 – 199: general errors regarding CBSD and protocol

200 – 299: error events related to CBSD registration

300 – 399: error events related to spectrum inquiry

400 – 499: error events related to grant

500 – 599: error events related to heartbeat

errorCode	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

102	MISSING_PARAM	Required parameters missing
103	INVALID_VALUE	One or more parameters have invalid value
104	PAL_CRED_MISMATCH	The CBSD parameters do not match with the PAL attributes announced through palCredential field.
200	REG_PENDING	Incomplete registration information. The registration process is pending.
201	DUPLICATED_REG	Duplicated registration. Deregister first and re-register.
300	UNSUPPORTED_SPECTRUM	SAS doesn't support the spectrum in the spectrum inquiry request
400	INTERFERENCE	Requested operation parameters cause too much interference to other users
401	GRANT_CONFLICT	Conflict with an existing grant of the same CBSD
402	TOO_MANY_GRANTS	The grant request exceeds the maximum number of grants of a CBSD
500	TERMINATED_GRANT	The grant is terminated
501	SUSPENDED_GRANT	The grant is suspended
502	UNSYNC_OP_PARAM	Operation parameters are out of sync between CBSD and SAS

In the error data object, SAS can optionally include supplemental data (errorData) to help CBSD with further investigation of the error. The following table describes supplemental data to be included with some error codes.

errorCode	Name	errorData Data Type	Description of error data
0	SUCCESS		
100	VERSION	array of string	Protocol versions supported by the SAS administrator

101	BLACKLISTED		
102	MISSING_PARAM	array of string	A list of missing parameters
103	INVALID_VALUE	array of string	A list of parameters names with invalid values
104	PAL_CRED_MISMATCH		The CBSD parameters do not match with the PAL attributes announced through palCredential field.
200	REG_PENDING	array of string	A list of missing registration parameters
201	DUPLICATED_REG	string	CBSD ID of the existing registration
300	UNSUPPORTED_SPECTRUM		
400	INTERFERENCE	array of AvailableChannel	A list of available channels CBSD can use
401	GRANT_CONFLICT	string	Grant ID of an existing grant that causes the conflict
402	TOO_MANY_GRANTS	array of string	A list of approved grant IDs
500	TERMINATED_GRANT		
501	SUSPENDED_GRANT		
502	UNSYNC_OP_PARAM		