PAWS   V. Chen, Ed.
Internet-Draft   Google
Intended status: Standards Track   S. Das
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                                                         November 9, 2012

Protocol to Access Spectrum Database
draft-ietf-paws-protocol-00

Abstract

   Portions of the radio spectrum that are allocated to licensees are
   available for non-interfering use. This available spectrum is called
   "White Space." Allowing secondary users access to available spectrum
   "unlocks" existing spectrum to maximize its utilization and to
   provide opportunities for innovation, resulting in greater overall
   spectrum utilization.

   One approach to manage spectrum sharing uses databases to report
   spectrum availability to devices. To achieve interoperability among
   multiple devices and databases, a standardized protocol must be
   defined and implemented. This document defines such a protocol, the
   "Protocol to Access White Space database" (PAWS).

Status of this Memo

   This Internet-Draft is submitted in full conformance with the
   provisions of BCP 78 and BCP 79.

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   Task Force (IETF). Note that other groups may also distribute
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   Drafts is at http://datatracker.ietf.org/drafts/current/.

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   time. It is inappropriate to use Internet-Drafts as reference
   material or to cite them other than as "work in progress."

   This Internet-Draft will expire on May 13, 2013.

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1. Introduction

This section provides some high level introductory material. Readers
are strongly encouraged to read
[I-D.ietf-paws-problem-stmt-usecases-rqmts] for use cases,
requirements, and additional background.

A geospatial database can track available spectrum (in accordance
with the rules of one or more regulatory domains) and make this
information available to devices. This approach shifts the
complexity of spectrum-policy conformance out of the device and into
the Database. This approach also simplifies adoption of policy
changes, limiting updates to a handful of databases, rather than
numerous devices. It opens the door for innovations in spectrum
management that can incorporate a variety of parameters, including
user location and time. In the future, it can include other
parameters, such as user priority, time, signal type and power,
spectrum supply and demand, payment or micro-auction bidding, and
more.

In providing this service, a database records and updates information
necessary to protect primary users -- for example, this information
may include parameters such as a fixed transmitter's call sign, its
geo-location, antenna height, power, and periods of operation. The
rules that the Database must follow, including its schedule for
obtaining and updating protection information, protection rules, and
information reported to devices, vary according to regulatory domain.
Such variations, however, should be handled by each database, and
exposure to the variations by devices should be minimized.

This specification defines an extensible protocol to obtain available
spectrum from a geospatial database by a device with geo-location
capability. It enables a device to operate in any regulatory domain
that implements the same protocol and in which the device is
authorized to operate. The document describes the use of HTTP/TLS as
transport for the protocol.

2. Conventions and Terminology

2.1. Conventions Used in This Document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
"SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this
document are to be interpreted as described in [RFC2119].

2.2. Terminology

   Database or Spectrum Database: A database that provides spectrum
      availability information to devices.
   Master Device: A device with geo-location capability that queries a
      database to find available spectrum.
   Slave Device: A device without geo-location capability that uses the
      spectrum made available by a Master Device. It does not query the
      Database directly.
   RAT: Radio Access Technology

3. Protocol Overview

   A Master Device uses the PAWS protocol to obtain a schedule of
   available spectrum at its location. The security necessary to ensure
   the accuracy, privacy, and confidentiality of the Device's location
   is described in the Security Considerations (Section 10). This
   document assumes that the Master Device and the Database are
   connected to the Internet.

   A typical sequence of PAWS operations is outlined as follows. See
   Protocol Functionalities (Section 4) and Protocol Parameters
   (Section 5) for details:

   1.   The Master Device locates or discovers the regulatory domain for
        its location and the URI for the Database to send subsequent
        PAWS messages. [Editor's Note: It is an open item whether
        database discovery should be a separate document.]
   2.   The Master Device establishes an HTTPS session with database.
   3.   The Master Device optionally sends an initialization message to
        the Database to exchange capabilities.
   4.   If the Database receives an initialization message, it responds
        with a message in the body of the HTTP response.
   5.   If required by regulatory domain, the Database registers the
        Master Device.
   6.   The Master Device sends an available-spectrum request message to
        the Database.
   7.   If the Master Device is obtaining the schedule on behalf of a
        Slave Device, if required by the regulatory domain, the Database
        validates the Slave Device.
   8.   The database responds with an available-spectrum response
        message in the body of the HTTP response.
   9.   Depending on regulatory domain requirements and database
        implementation, the Master Device sends a spectrum-usage
        notification message to the Database.

10. If the Database receives a spectrum-usage notification message,
     it responds by sending the Master Device a spectrum-usage
     acknowledgement message.

4. Protocol Functionalities

The PAWS protocol consists of several components:

o Database Discovery (Section 4.2) MUST be supported by Master
   Device
o Initialization (Section 4.3) MAY be used by the Master Device and
   MUST be implemented by the Database.
o Device Registration (Section 4.4) MAY be used by the Master Device
   and MAY be implemented by the Database.
o Available Spectrum Query (Section 4.5) MUST be supported by Master
   Device and the Database.
o Device Validation (Section 4.6) MAY be used by the Master Device
   and MUST be implemented by the Database if the regulatory domain
   requires device validation.

This section describes the protocol components and their messages.
Section 5 contains a more thorough discussion of the parameters that
comprise the PAWS request and response messages. Section 6 provides
details of the message encodings. Section 7 describes the use of
HTTPS [RFC2818] for transporting PAWS messages and optional device
authentication.

4.1. Indicating Errors

Each PAWS response messages contains a "responseInfo" parameter (see
Section 5.2). When the Database encounters an error, it MUST report
the error code using the "responseInfo" parameter and SHOULD include
an optional error message. The message MAY be in any language. When
the Database reports an error, it MAY omit otherwise required
portions of the response message.

Note that all PAWS-level errors are reported within a successful
transport-level response, e.g., 200 OK HTTPS response. Valid error
codes are listed in Section 5.15.

4.2. Database Discovery

A device MUST determine the URI for the Database and applicable
regulatory domain before it can send PAWS messages. The URI for the
Database SHOULD be obtained from an authorized and authenticated
entity, but it MAY be statically configured into the device.
[Editor's Note: It is an open item whether database discovery should

be a separate document.]

4.3. Initialization

A Master Device SHOULD use the initialization procedure to exchange
capability information with the Database whenever the Master Device
powers up or initiates communication with the Database. The
initialization response informs the Master Device of specific
regulatory-dependent parameterized-rule values, such as threshold
distances and time periods beyond which the device must update its
available-spectrum data (see Section 5.8). The Master Device MAY
manually configure these parameterized-rule values. The
initialization messages also represents extension points for database
implementations or regulatory domains that require the extra
handshake.

The Initialization request procedure is depicted in Figure 1.
o   INIT_REQ (Section 4.3.1) is the initialization request message
o   INIT_RESP (Section 4.3.2) is the initialization response message

```
    +---------------+    +-------------------+
    | Master Device |    | Spectrum Database |
    +---------------+    +-------------------+
            |                    |
            |       INIT_REQ     |
            |------------------->|
            |                    |
            |       INIT_RESP    |
            |<-------------------|
            |                    |
```
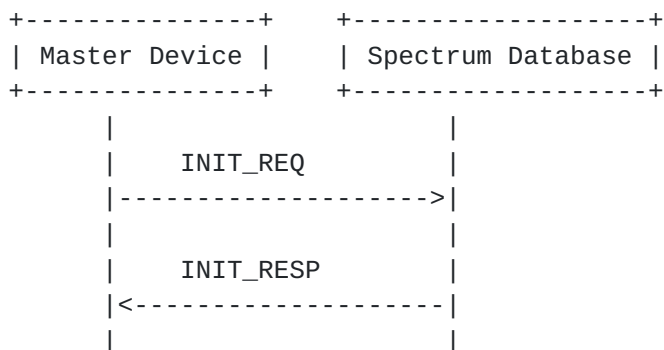
                          Figure 1

4.3.1. INIT_REQ

The initialization request message allows a device to initiate
exchange of capabilities with a database.
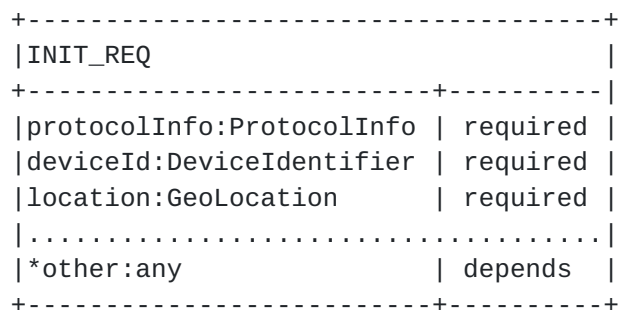
```
    +-------------------------------------+
    |INIT_REQ                             |
    +--------------------------+----------|
    |protocolInfo:ProtocolInfo | required |
    |deviceId:DeviceIdentifier | required |
    |location:GeoLocation      | required |
    |.....................................|
    |*other:any                | depends  |
    +--------------------------+----------+
```

   Parameters:

   protocolInfo: The protocol info (Section 5.1) for this message is
      REQUIRED. The "messageType" parameter MUST be "INIT_REQ".
   deviceId: The device identifier (Section 5.4) for the device is
      REQUIRED. If the Database does not support the regulatory domain
      specified by the "authority" parameter, it MUST return an error
      code (TBD value) in the response.
   location: The geo-location (Section 5.3) for the device is REQUIRED.
   other: Depending on the regulatory domain or database
      implementation, the Master Device MAY specify additional handshake
      parameters in the INIT_REQ message. A database MUST ignore all
      parameters it does not understand.

4.3.2. INIT_RESP

   The initialization response message communicates database parameters
   to the requesting device.

```
   +--------------------------------------+
   |INIT_RESP                             |
   +--------------------------+----------+
   |protocolInfo:ProtocolInfo | required |
   |responseInfo:ResponseInfo | required |
   |rulesetInfo:RulesetInfo   | required*|
   |......................................|
   |*other:any                | depends  |
   +--------------------------+----------+
```

   Parameters:

   protocolInfo: The protocol info (Section 5.1) for this message is
      REQUIRED. The messageType parameter MUST be "INIT_RESP".
   responseInfo: The response info (Section 5.2) is REQUIRED and
      contains the response code, timestamp, etc.
   rulesetInfo: This ruleset info (Section 5.8) parameter MUST be
      included in the response if "responseInfo" does not contain an
      error code. If there is an error, "rulesetInfo" MUST NOT be
      included in the response message. This parameter specifies the
      regulatory domain and parameters applicable for that domain. The
      database MUST specify the same "authority" as that specified in
      the "deviceId" parameter of the INIT_REQ message.
   other: Depending on the regulatory domain or database
      implementation, the Database MAY include additional handshake
      parameters in the INIT_RESP message. The Master Device MUST
      ignore all parameters it does not understand.

4.4. Device Registration

   When a regulatory domain requires registration of a Master Device,
   the device MUST send its registration information to the Database to
   establish certain operational parameters. FCC rules, for example,
   require that a 'Fixed Device' MUST register its owner and operator
   contact information, its device identifier, its location, and its
   antenna height.

   The database MAY support device registration as a separate Device
   Registration component, or as part of the Spectrum Availability
   component. If a database does not support a separate Device
   Registration request, it MUST return an error in the registration
   response message.

   The Device Registration request procedure is depicted in Figure 2.
   o REGISTRATION_REQ (Section 4.4.1) is the device-registration
      request message
   o REGISTRATION_RESP (Section 4.4.2) is the device-registration
      response message

```
     +---------------+          +------------------+
     | Master Device |          | Spectrum Database |
     +---------------+          +------------------+
             |                       |
             |     REGISTRATION_REQ    |
             |------------------------>|
             |                       |
             |     REGISTRATION_RESP   |
             |<------------------------|
             |                       |
```
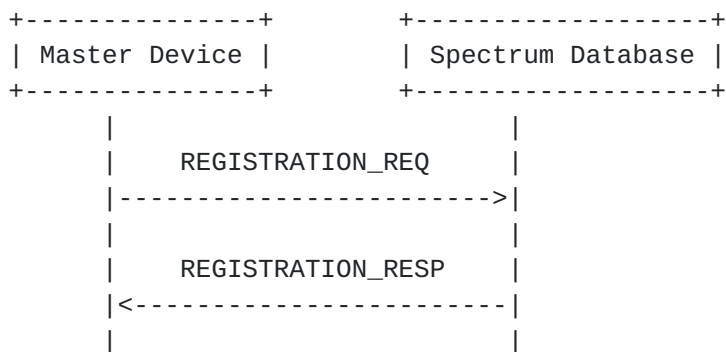
                              Figure 2

4.4.1. REGISTRATION_REQ

   The registration request message contains the required registration
   parameters.

```
     +--------------------------------------+
     |REGISTRATION_REQ                      |
     +--------------------------+----------+
     |protocolInfo:ProtocolInfo | required |
     |deviceId:DeviceIdentifier | required |
     |location:GeoLocation      | required |
     |deviceOwner:DeviceOwner   | required |
     |......................................|
     |*other:any                | depends  |
```

```
   +--------------------------+----------+
```

   Parameters:

   protocolInfo: The protocol info (Section 5.1) for this message is
      REQUIRED. The "messageType" parameter MUST be "REGISTRATION_REQ".
   deviceId: The device identifier (Section 5.4) for the device is
      REQUIRED.
   location: The geo-location (Section 5.3) for the device is REQUIRED.
   deviceOwner: The device-owner (Section 5.7) information is REQUIRED.
   other: Regulatory domains MAY require additional registration
      parameters. To simplify its registration logic, a device MAY send
      a union of the registration information required by all supported
      regulatory domains. A database MUST ignore all parameters it does
      not understand.

4.4.2. REGISTRATION_RESP

   The registration response message simply acknowledges receipt of the
   request.

```
   +-------------------------------------+
   |REGISTRATION_RESP                    |
   +--------------------------+----------+
   |protocolInfo:ProtocolInfo | required |
   |responseInfo:ResponseInfo | required |
   +--------------------------+----------+
```

   Parameters:

   protocolInfo: The protocol info (Section 5.1) for this message is
      REQUIRED. The "messageType" parameter MUST be
      "REGISTRATION_RESP".
   responseInfo: The response info (Section 5.2) is REQUIRED and
      contains the response code, timestamp, etc.

4.5. Available Spectrum Query

   To obtain the available spectrum from a database, a Master Device
   sends a request that contains its geo-location and any parameters
   required by the regulatory rules (such as device identifier,
   capabilities, and characteristics). The database returns a response
   that describes what frequencies are available, at what permissible
   operating power levels, and a schedule of when they are available.

   The Available Spectrum Query procedure is depicted in Figure 3.

o AVAIL_SPECTRUM_REQ (Section 4.5.1) is the available-spectrum
   request message
o AVAIL_SPECTRUM_RESP (Section 4.5.2) is the available-spectrum
   response message
o AVAIL_SPECTRUM_BATCH_REQ (Section 4.5.3) is an OPTIONAL batch
   version of the available-spectrum request message that allows
   multiple locations to be specified in the request
o AVAIL_SPECTRUM_BATCH_RESP (Section 4.5.4) is the response message
   for the batch version of the available-spectrum request that
   contains available spectrum for each location
o SPECTRUM_USE_NOTIFY (Section 4.5.5) is the spectrum-usage
   notification message
o SPECTRUM_USE_RESP (Section 4.5.6) is the spectrum-usage
   acknowledgment message

```
   +---------------+          +-------------------+
   | Master Device |          | Spectrum Database |
   +---------------+          +-------------------+
           |                           |
           |      AVAIL_SPECTRUM_REQ   |
           |  (AVAIL_SPECTRUM_BATCH_REQ) |
           |-------------------------->|
           |                           |
           |      AVAIL_SPECTRUM_RESP  |
           | (AVAIL_SPECTRUM_BATCH_RESP)|
           |<--------------------------|
           |                           |
           |    (SPECTRUM_USE_NOTIFY)  |
           |-------------------------->|
           |                           |
           |     (SPECTRUM_USE_RESP)   |
           |<--------------------------|
           |                           |
```
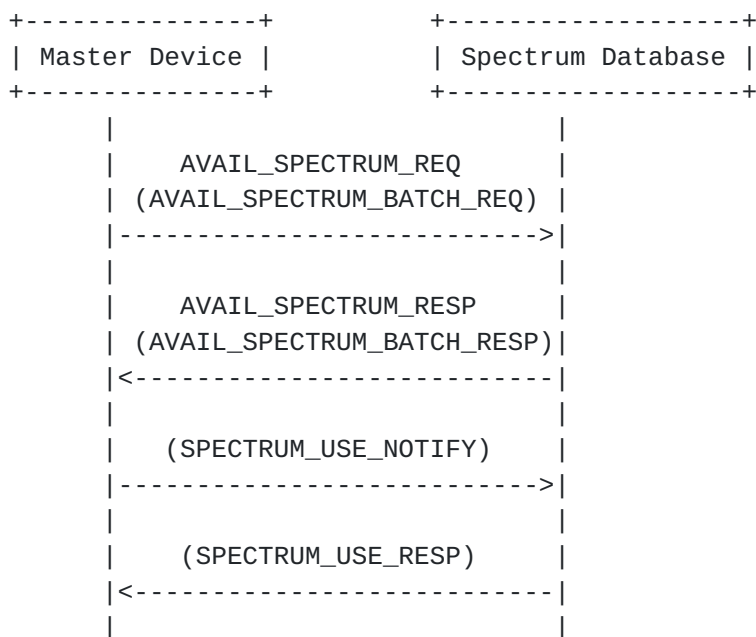
                           Figure 3

   1. First, the Master Device sends an available-spectrum request
       message to a database.
   2. The database it MUST respond with an error message (error code
       TBD) if:
       * registration information is required, and
       * the request does not include registration information, and
       * the device has not previously registered
   3. If the location specified in the request is outside the
       regulatory domain, the Database MUST respond with an error
       message (error code TBD).

4. The database MAY perform other validation of the request, (e.g.,
    checking for missing required parameters, authorizations). It
    MUST return an error message with appropriate error code, if
    validation fails.

5. If the request is valid, the Database responds with an available-
    spectrum response message. If the regulatory domain requires
    that devices must report anticipated spectrum usage, the Database
    MUST indicate so in the response message.

6. If the available-spectrum response indicates that the Master
    Device must send a spectrum-usage notification message, the
    Master Device MUST send the notification message to the Database
    .

7. If the Database receives a spectrum-usage notification message,
    it MUST send a spectrum-usage acknowledgment message to the
    Master Device.

The procedure for asking for available spectrum on behalf of a slave
device is similar, except that the process is initiated by the slave
device. Also, the device identifier, capabilities, and
characteristics communicated in the AVAIL_SPECTRUM_REQ message SHALL
be those of the slave device. Although the communication and
protocol between the slave device and Master Device is outside the
scope of this document, the expected message sequence is shown in
Figure 4.

```
+------------+     +---------------+      +-------------------+
|Slave Device|     | Master Device |      | Spectrum Database |
+------------+     +---------------+      +-------------------+
     |                   |                         |
     | AVAIL_SPEC_REQ    |                         |
     |................>|                           |
     |                   |                         |
     |                   |    AVAIL_SPECTRUM_REQ   |
     |                   |------------------------->|
     |                   |                         |
     |                   |    AVAIL_SPECTRUM_RESP  |
     |                   |<-------------------------|
     |                   |                         |
     | AVAIL_SPEC_RESP |    (SPECTRUM_USE_NOTIFY)  |
     |<...............|------------------------->|
     |                   |                         |
     |                   |    (SPECTRUM_USE_RESP)  |
     |                   |<-------------------------|
     |                   |                         |
```
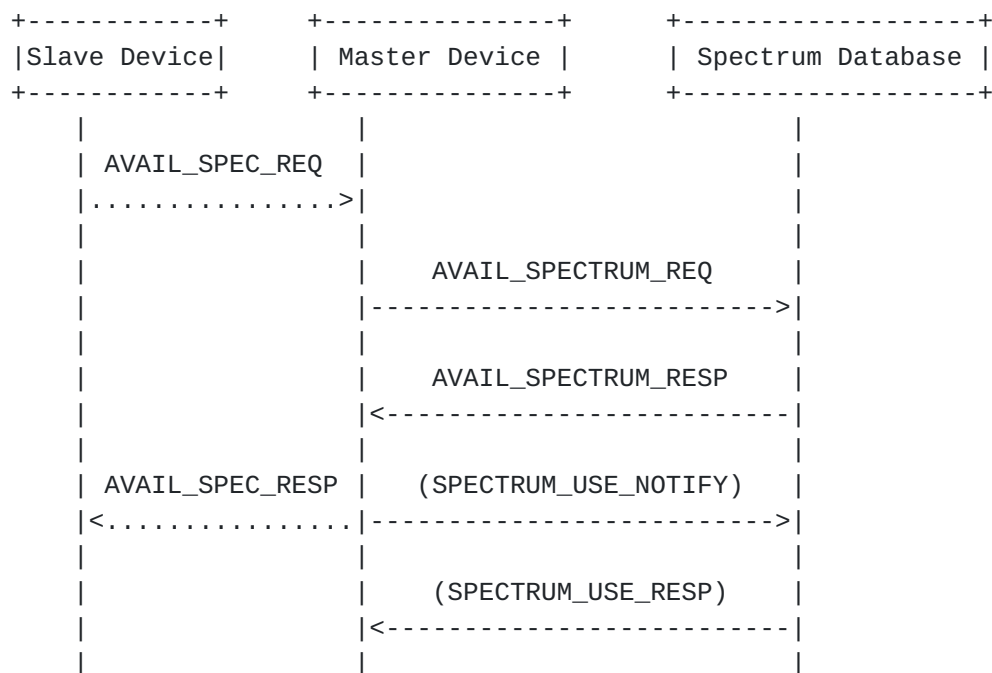
Figure 4

4.5.1. AVAIL_SPECTRUM_REQ

The request message for the Available Spectrum Query protocol MUST
include the device's geo-location.

```
+--------------------------------------------------------------+
|AVAIL_SPECTRUM_REQ                                            |
+------------------------------+-------------------------------+
|protocolInfo:ProtocolInfo     | required                      |
|deviceId:DeviceIdentifier     | required                      |
|location:GeoLocation          | required                      |
|antenna:AntennaCharacteristics| depends on regulatory domain  |
|owner:DeviceOwner             | depends on regulatory domain  |
|capabilities:DeviceCapabilities| optional                     |
+------------------------------+-------------------------------+
```

Parameters:

protocolInfo: The protocol info (Section 5.1) for this message is
   REQUIRED. The "messageType" parameter MUST be
   "AVAIL_SPECTRUM_REQ".
deviceId: The device identifier (Section 5.4) for the device is
   REQUIRED.
location: The geo-location (Section 5.3) for the device is REQUIRED.
   The location SHOULD be the current location of the device.
   Depending on the regulatory domain, the location MAY be an
   anticipated position of the device.
antenna: Depending on the device type and regulatory domain, the
   antenna characteristics (Section 5.5) MAY be required.
owner: Depending on the device type and regulatory domain, the
   device owner (Section 5.7) information MAY be included to register
   the device with the Database. This enables a device to register
   and get spectrum-availability information in a single request.
capabilities: The Master Device MAY include its device capabilities
   (Section 5.6) to limit the available-spectrum response to the
   spectrum that is compatible with its capabilities. The database
   SHOULD NOT return spectrum that is not compatible with the
   specified capabilities.

4.5.1.1. Regulatory Specifics

For the US / FCC TV-Band devices:

o The "antenna" parameter is REQUIRED for FIXED device types. It
   MUST specify the antenna height the and height type.
o The "owner" parameter is REQUIRED for FIXED device types and if
   the device has not been registered yet with the Database or if the
   Database does not implement a separate device registration

request.

4.5.2. AVAIL_SPECTRUM_RESP

The response message for the Available Spectrum Query contains a
schedule of available spectrum for the device.

```
+-------------------------------------+
|AVAIL_SPECTRUM_RESP              |
+--------------------------+----------+
|protocolInfo:ProtocolInfo | required |
|responseInfo:ResponseInfo | required |
|deviceId:DeviceIdentifier | required |
|spectrumSchedule:list     | required |-------+
|needsSpectrumReport:bool  | optional |       |
|..........................|..........|       |
|location:GeoLocation      | optional |       |
+--------------------------+----------+       | 1..*
                                              V
                                  +------------------------------+
                                  |SpectrumSchedule             |
                                  +------------------+----------+
                                  |time:EventTime    | required |
                                  |spectrum:Spectrum | required |
                                  +------------------+----------+
```

Parameters:

protocolInfo: The protocol info (Section 5.1) for this message is
   REQUIRED. The "messageType" parameter MUST be
   "AVAIL_SPECTRUM_RESP"
responseInfo: The response info (Section 5.2) is REQUIRED and
   contains the response code, timestamp, etc.
deviceId: The database MUST include the device identifier
   (Section 5.4) specified in the AVAIL_SPECTRUM_REQ message
spectrumSchedule: The schedule (Section 5.12) of available spectrum.
   The Database MAY return more than one schedule to represent future
   changes to the available spectrum. How far in advance a schedule
   may be provided depends on the regulatory domain.
needsSpectrumReport: For regulatory domains that require a spectrum-
   usage report from devices, the Database MUST return true for this
   parameter. The default value is false.
location: The database MAY copy other elements from the request,
   such as the geo-location (Section 5.3) of the device. The device
   MUST ignore any parameters it does not understand.

When the stop time specified in the schedule has been reached, a
device:

o MUST obtain a new spectrum-availability schedule, either by using
   the next one in the list (if provided) or making another Available
   Spectrum Query (Section 4.5)
o If the new schedule indicates the in-use spectrum is no longer
   available, the device MUST stop operation immediately.
o If the device is unable to contact the Database to obtain a new
   schedule, depending on the regulatory domain, the device MAY
   continue to operate for a period of time, as indicated by
   parameters returned in the INIT_RESP (Section 4.3.2) message.

When the device moves beyond a threshold distance (established by
regulatory rules) away from the actual location and all anticipated
location(s) it reported in previous AVAIL_SPECTRUM_REQ or
AVAIL_SPECTRUM_BATCH_REQ requests (see "maxLocationChange" in
Section 5.8), it:
o MUST obtain a new spectrum-availability schedule by making another
   Available Spectrum Query (Section 4.5).
o If the new response indicates the in-use spectrum is no longer
   available, the device MUST stop operation immediately.
o If the device is unable to contact the Database to obtain a new
   schedule, depending on the regulatory domain, the device MUST stop
   operation immediately.

4.5.3. AVAIL_SPECTRUM_BATCH_REQ

The Database MAY support the batch request that allows multiple
locations to be specified. This allows a portable Master Device to
get available spectrum for a sequence of anticipated locations using
a single request. Each location is treated independently such that a
single batch request is equivalent to multiple AVAIL_SPECTRUM_REQ
(Section 4.5.1) requests. The request message for the batch
Available Spectrum Query protocol MUST include at least one geo-
location. If the Database does not support batch requests, it MUST
return a NOT_SUPPORTED error.

```
+--------------------------------------------------------------+
|AVAIL_SPECTRUM_BATCH_REQ                                       |
+------------------------------+-------------------------------+
|protocolInfo:ProtocolInfo     | required                      |
|deviceId:DeviceIdentifier     | required                      |
|locations:list                | required                      |--+
|antenna:AntennaCharacteristics | depends on regulatory domain |  |
|owner:DeviceOwner             | depends on regulatory domain |  |
|capabilities:DeviceCapabilities| optional                    |  | 1..*
+------------------------------+-------------------------------+  V
                                              +-------------+
                                              | GeoLocation |
                                              +-------------+
```

Parameters:

protocolInfo: The protocol info (Section 5.1) for this message is
   REQUIRED. The "messageType" parameter MUST be
   "AVAIL_SPECTRUM_BATCH_REQ".
deviceId: The device identifier (Section 5.4) for the device is
   REQUIRED.
locations: The list of geo-locations (Section 5.3) for the device is
   REQUIRED. This allows a device to specify its actual location
   plus additional anticipated locations, when allowed by the
   regulatory domain. At least one location MUST be included. This
   specification places no upper limit on the number of locations,
   but the Database MAY restrict the number of locations it supports
   by returning a response with fewer locations than specified in the
   request.
antenna: Depending on the device type and regulatory domain, the
   antenna characteristics (Section 5.5) MAY be required.
owner: Depending on the device type and regulatory domain, the
   device owner (Section 5.7) information MAY be included to register
   the device with the Database. This enables a device to register
   and get spectrum-availability information in a single request.
capabilities: The Master Device MAY include its device capabilities
   (Section 5.6) to limit the available-spectrum response to the
   spectrum that is compatible with its capabilities. The database
   SHOULD NOT return spectrum that is not compatible with the
   specified capabilities.

4.5.3.1. Regulatory Specifics

For the US / FCC TV-Band devices:

o The "antenna" parameter is REQUIRED for FIXED device types. It
   MUST specify the antenna height the and height type.
o The "owner" parameter is REQUIRED for FIXED device types and if
   the device has not been registered yet with the Database or if the
   Database does not implement a separate device registration
   request.

4.5.4. AVAIL_SPECTRUM_BATCH_RESP

The response message for the batch Available Spectrum Query contains
a schedule of available spectrum for the device at multiple
locations.

```
  +------------------------------------+
  |AVAIL_SPECTRUM_BATCH_RESP           |
  +--------------------------+---------+
  |protocolInfo:ProtocolInfo | required |
  |responseInfo:ResponseInfo | required |
  |deviceId:DeviceIdentifier | required |
  |geoSpectrumSchedules:list | required |-------+
  |needsSpectrumReport:bool  | optional |       |
  +--------------------------+---------+       | 1..*
                                                V
                            +--------------------------------+
                            |GeoSpectrumSchedule             |
                            +----------------------+---------+
                            |location:GeoLocation  | required |
                            |spectrumSchedule:list | required |
                            +----------------------+---------+
```

   Parameters:

   protocolInfo: The protocol info (Section 5.1) for this message is
      REQUIRED. The "messageType" parameter MUST be
      "AVAIL_SPECTRUM_BATCH_RESP"
   responseInfo: The response info (Section 5.2) is REQUIRED and
      contains the response code, timestamp, etc.
   deviceId: The database MUST include the device identifier
      (Section 5.4) specified in the AVAIL_SPECTRUM_REQ message
   geoSpectrumSchedules: The list of spectrum-availability schedules
      for a location (Section 5.13) is REQUIRED. For each location, the
      Database MAY return more than one schedule to represent future
      changes to the available spectrum. How far in advance a schedule
      may be provided depends on the regulatory domain. The Database
      MAY return available spectrum for fewer locations than requested.
      The Device MUST NOT make any assumptions on the order of the
      entries in the list and MUST use the location value in each
      GeoSpectrumSchedule entry to match available spectrum to a
      location.
   needsSpectrumReport: For regulatory domains that require a spectrum-
      usage report from devices, the Database MUST return true for this
      parameter. The default value is false.

   When the stop time specified in the schedule has been reached, a
   device:

   o MUST obtain a new spectrum-availability schedule, either by using
      the next one in the list (if provided) or making another Available
      Spectrum Query (Section 4.5)

   o If the new schedule indicates the in-use spectrum is no longer
      available, the device MUST stop operation immediately.
   o If the device is unable to contact the Database to obtain a new
      schedule, depending on the regulatory domain, the device MAY
      continue to operate for a period of time, as indicated by
      parameters returned in the INIT_RESP (Section 4.3.2) message.

   When the device moves beyond a threshold distance (established by
   regulatory rules) away from all actual or anticipated location(s) it
   reported in the AVAIL_SPECTRUM_BATCH_REQ message (see
   "maxLocationChange" in Section 5.8), it:
   o MUST obtain a new spectrum-availability schedule by making another
      Available Spectrum Query (Section 4.5).
   o If the new schedule indicates the in-use spectrum is no longer
      available, the device MUST stop operation immediately.
   o If the device is unable to contact the Database to obtain a new
      schedule, depending on the regulatory domain, the device MUST stop
      operation immediately.

4.5.5. SPECTRUM_USE_NOTIFY

   The spectrum-use notification message MUST contain the geo-location
   of the device and parameters required by the regulatory domain.

```
   +------------------------------------+
   |SPECTRUM_USE_NOTIFY                 |
   +--------------------------+---------+
   |protocolInfo:ProtocolInfo | required |
   |deviceId:DeviceIdentifier | required |
   |location:GeoLocation      | required |
   |spectrum:list             | required |-------+
   |..................................|         |
   |*other:any                | depends  |         |
   +--------------------------+---------+       | 0..*
                                                V
                              +--------------------------------+
                              |Spectrum                        |
                              +--------------------+---------+
                              |bandwidth:float       | required |
                              |frequencyRanges:list | required |
                              +--------------------+---------+
```

   Parameters:

protocolInfo: The protocol info (Section 5.1) for this message is
   REQUIRED. The "messageType" parameter MUST be
   "SPECTRUM_USE_NOTIFY".
deviceId: The device identifier (Section 5.4) for the device is
   REQUIRED.
location: The geo-location (Section 5.3) for the device is REQUIRED.
spectrum: The spectrum (Section 5.9) is REQUIRED and specifies the
   spectrum anticipated to be used by the device, which includes
   frequency ranges and maximum power levels. For consistency, the
   "bandwidth" value SHOULD match that from one of the Spectrum
   elements in the corresponding AVAIL_SPECTRUM_RESP message, and the
   maximum power levels in the Spectrum element MUST be expressed as
   total power (EIRP) computed over the specified "bandwidth" value.
   The actual bandwidth to be used (as computed from the start and
   stop frequencies) MAY be different from the "bandwidth" value. As
   an example, when regulatory rules express maximum power spectral
   density in terms of maximum power over any 100 kHz band, then the
   "bandwidth" value should be set to 100 kHz, even though the actual
   bandwidth used is 20 kHz.
other: Depending on the regulatory domain, other parameters MAY be
   required. To simplify its logic, the device MAY include the union
   of all parameters required by all supported regulatory domains.
   The database MUST ignore all parameters it does not understand.

4.5.6. SPECTRUM_USE_RESP

The spectrum-use response message simply acknowledges receipt of the
notification.

```
+------------------------------------+
|SPECTRUM_USE_RESP                   |
+--------------------------+---------+
|protocolInfo:ProtocolInfo | required |
|responseInfo:ResponseInfo | required |
+--------------------------+---------+
```

Parameters:

protocolInfo: The protocol info (Section 5.1) for this message is
   REQUIRED. The "messageType" parameter MUST be "SPECTRUM_USE_RESP"
responseInfo: The response info (Section 5.2) is REQUIRED and
   contains the response code, timestamp, etc.

4.6. Device Validation

Typically, a slave device needs a Master Device to ask the Database
on its behalf for available spectrum. Depending on the regulatory
domain, the Master Device also must validate with the Database that

the slave device is permitted to operate. When regulatory rules
allow a Master Device to "cache" the available spectrum for a period
of time, the Master Device MAY use the simpler Device Validation
component, instead of the full Available Spectrum Query component, to
validate a slave device.

When validating one or more slave devices, the Master Device sends
the Database a request that includes the device identifier -- and any
other parameters required by the regulatory rules -- for each slave
device. The database returns a response that indicates whether each
device is permitted to use the spectrum.

A typical sequence for using the Device Validation request is
illustrated in Figure 5, where the Master Device already has a valid
set of available spectrum for slave devices. Note that the
communication and protocol between the slave device and Master Device
is outside the scope of this document.

o DEV_VALID_REQ (Section 4.6.1) is the device-validation request
   message
o DEV_VALID_RESP (Section 4.6.2) is the device-validation response
   message

```
+------------+    +---------------+     +-------------------+
|Slave Device|    | Master Device |     | Spectrum Database |
+------------+    +---------------+     +-------------------+
     |                   |                        |
     | AVAIL_SPEC_REQ    |                        |
     |................>|                          |
     |                   |                        |
     |                   |      DEV_VALID_REQ     |
     |                   |------------------------->|
     |                   |                        |
     |                   |      DEV_VALID_RESP     |
     |                   |<-------------------------|
     | AVAIL_SPEC_RESP   |                        |
     |<................|                          |
     |                   |
```
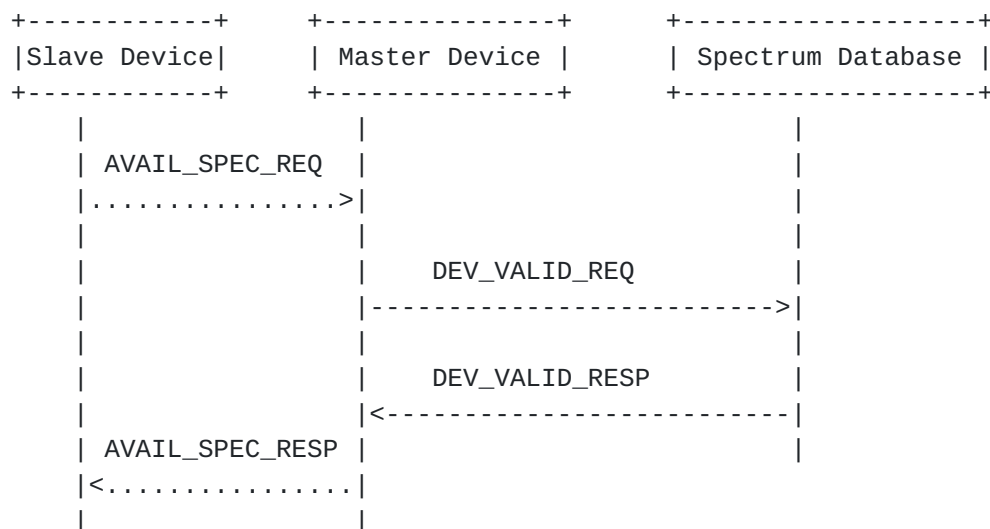
                         Figure 5

4.6.1. DEV_VALID_REQ

```
+--------------------------------------+
|DEV_VALID_REQ                         |
+--------------------------+----------+
|protocolInfo:ProtocolInfo | required |
|deviceIds:list            | required |----
+--------------------------+----------+   |
                                   V 1..*
                          +----------------------+
                          |DeviceIdentifier      |
                          +----------------------+
```

   Parameters:

   protocolInfo: The protocol info (Section 5.1) for this message is
      REQUIRED. The "messageType" parameter MUST be "DEV_VALID_REQ".
   deviceIds: A list of device identifiers Section 5.4 is REQUIRED to
      specify the list of slave devices that must be validated.

4.6.2. DEV_VALID_RESP

```
+--------------------------------------+
|DEV_VALID_RESP                        |
+--------------------------+----------+
|protocolInfo:ProtocolInfo | required |
|deviceValidity:list       | required |----
+--------------------------+----------+   |
                                   V 1..*
                      +--------------------------------------+
                      |DeviceValidity                        |
                      +--------------------------+----------+
                      |deviceId:DeviceIdentifier | required |
                      |isValid:boolean           | required |
                      +--------------------------+----------+
```

   Parameters:
   protocolInfo: The protocol info (Section 5.1) for this message is
      REQUIRED. The "messageType" parameter MUST be "DEV_VALID_RESP".
   deviceValidity: A list of device validity elements Section 5.14 is
      REQUIRED to report the list of slave devices and corresponding
      code of whether the device is valid. The number of entries MUST
      match the number of device IDs specified in the DEV_VALID_REQ
      message.

5. **Protocol Parameters**

   This section presents the more details of parameters that make up the
   PAWS request and response messages. It also includes a sub-section
   defining response codes.

5.1. **ProtocolInfo**

   All PAWS request and response messages MUST include the ProtocolInfo
   parameter:

   ```
   +------------------------------+
   |ProtocolInfo                  |
   +-------------------+----------+
   |version:string     | required |
   |messageType:string | required |
   +-------------------+----------+
   ```

   Parameters:

   version: Version of the PAWS protocol is REQUIRED. It MUST be the
      string, "1.0". If the data receives a request message containing
      a version it does not support, it MUST respond with an error
      message.
   messageType: Name of the message type is REQUIRED. It specifies the
      name of its containing message.

5.2. **ResponseInfo**

   All PAWS response messages MUST include the ResponseInfo parameter:

   ```
   +------------------------------+
   |ResponseInfo                  |
   +------------------+----------+
   |code:string       | required |
   |message:string    | optional |
   |timestamp:string  | optional |
   |responseId:string | optional |
   |..............................|
   |*other:any        | optional |
   +------------------+----------+
   ```

   Parameters:

code: The result code is REQUIRED. If the Database needs to respond
   with an error, it MUST set this to a defined error code. Valid
   values for result and error codes are TBD.
message: The message is OPTIONAL. When the result code is an error
   code, the Database SHOULD include a message that provides more
   details. The message MAY be in any language.
timestamp: The database MAY include the timestamp of the response.
   When provided, it MUST be in the form, YYYY-MM-DDThh:mm:ssZ, as
   defined by [RFC3339]. It MUST be expressed in UTC.
responseId: The database MAY include a unique ID for the response.
other: The database MAY include additional error details. The
   device MUST ignore any parameters it does not understand.

NOTE: When there is an error, the Database MUST include ResponseInfo
in the response message, but MAY omit otherwise required portions of
the response message.

5.3. GeoLocation

This parameter is used to specify the geo-location of the device.

```
+-----------------------------------------------------+
|GeoLocation                                          |
+--------------------+--------------------------------+
|latitude:float      | required                       |
|longitude:float     | required                       |
|uncertainty:float   | depends on regulatory domain   |
|confidence:int      | depends on regulatory domain   |
+--------------------+--------------------------------+
```

Parameters:

latitude, longitude: Floating-point numbers that express the
   latitude and longitude in degrees using the WGS84 datum.
   REQUIRED.
uncertainty: The uncertainty of the location in meters MAY be
   required, depending on the regulatory domain. When this parameter
   is optional, its default value is 0.
confidence: The location confidence level as an integer percentage
   MAY be required, depending on the regulatory domain. When the
   parameter is optional, its default value is 100.

5.3.1. Regulatory Specifics

For UK / Ofcom UHF TV-band devices:
o The "uncertainty" parameter is REQUIRED if the uncertainty is
   greater than 50 meters.

5.4. DeviceIdentifier

The device identifier contains parameters that identify the specific
device, such as its manufacturer serial number, and regulatory-
specific ID (e.g., FCC ID), and any other regulatory-specific
information, such as device-type classification.

```
+-----------------------------------------------------+
|DeviceIdentifier                                     |
+--------------------+--------------------------------+
|authority:string    | required                       |
|serialNumber:string | required                       |
|identity:string     | required                       |
|....................|................................|
|*deviceType:string  | depends on regulatory domain   |
|*RAT:string         | depends on regulatory domain   |
|*other:any          |                                |
+--------------------+--------------------------------+
```

Parameters:

authority: A string that indicates the regulatory domain to which
   the device identifier applies is REQUIRED. It MUST use the
   2-letter country codes defined by [ISO3166-1].
serialNumber: The manufacturer's device serial number is REQUIRED.
identity: The device's regulatory domain ID is REQUIRED.

Additional parameters in the DeviceIdentifer depend on each
regulatory domain, and must be defined on a per-domain basis.

5.4.1. Regulatory Specifics

For the US / FCC TV-Band devices:
o The authority value MUST be "US"
o The identity value is the device's FCC ID
o The "deviceType" parameter is REQUIRED to indicate the device
   type. Valid values are FIXED, MODE_1, MODE_2

For UK / Ofcom TV-Band devices:
o The authority value MUST be "UK"
o The "RAT" parameter is required to specify the Radio Access
   Technology. Valid values are TBD.
o A "deviceClass" parameter is required to identify, among other
   things, the emission mask of the device. Valid values are TBD.

5.5. AntennaCharacteristics

   Antenna characteristics provide additional information, such as the
   antenna height, antenna type, etc. Whether antenna characteristics
   must be provided in a request depends on the device type and
   regulatory domain.

```
+----------------------------------------------------------+
|AntennaCharacteristics                                    |
+-------------------------+--------------------------------+
|height:float             | depends on regulatory domain  |
|heightType:enum          | optional                      |
|heightUncertainty:float  | depends on regulatory domain  |
|.........................|...............................|
|*characteristics:        | depends on regulatory domain  |
|    various              |                               |
+-------------------------+--------------------------------+
```

   Parameters:

   height: The antenna height in meters. Whether the antenna height is
      required depends on the device type and the regulatory domain.
   heightType: If the height is required, then heightType is also
      REQUIRED. Valid values are:
      AGL Above ground level (default)
      AMSL Above mean sea level
   heightUncertainty: The height uncertainty in meters. Whether this
      is required depends on the regulatory domain.

   Depending on the regulatory authority, additional antenna
   characteristics may be required, such as:
   o antenna direction
   o antenna radiation pattern
   o antenna gain
   o antenna polarization

5.5.1. Regulatory Specifics

   For the US / FCC TV-Band devices:
   o The height and heightType parameters are REQUIRED for FIXED device
      types.

5.6. DeviceCapabilities

   Device capabilities provide additional information that MAY be used
   by the device provide additional information to the Database they may
   help it to determine available spectrum. If a database does not
   support device capabilities it MUST ignore the parameter altogether.

```
+-----------------------------------------------------+
|DeviceCapabilities                                   |
+---------------------+-------------------------------+
|frequencyRange:list  | optional                      |
+---------------------+-------------------------------+
```

   Parameters:

   frequencyRange: Optional list of frequency ranges (Section 5.10)---
      start and stop frequencies --- in which the device can operate.
      When specified, the Database SHOULD NOT return available spectrum
      that falls outside these ranges.

5.7. DeviceOwner

   This parameter contains device-owner information required as part of
   device registration. Regulatory domains MAY require additional
   parameters. The minimum set of parameters are described below.

```
+-----------------------------+
|DeviceOwner                  |
+------------------+----------+
|owner:string      | required |
|operator:string   | required |
|address:string    | required |
|email:string      | required |
|phone:string      | required |
+------------------+----------+
```

   Parameters:

   owner: Name of the individual or business that owns the device is
      REQUIRED.
   operator: Name of the device operator is REQUIRED.
   address: Civic address of the device owner or operator of the device
      is REQUIRED.
   email: Email address of the device owner or operator of the device
      is REQUIRED.
   phone: Phone number of the device owner or operator of the device is
      REQUIRED.

   NOTE: Whether the contact information must be that of the device
   owner or operator depends on the regulatory domain. Depending on the
   regulatory domain, the Database MAY be required to validate the
   device-owner information. In these cases, the Database MUST respond
   with an error message if validation fails.

5.8. RulesetInfo

This contains parameters for the rule set of a regulatory domain that
is communicated using the Initialization component (Section 4.3).

```
+---------------------------------+
|RulesetInfo                      |
+---------------------------------+
|authority:string        | required |
|maxLocationChange:float | required |
|maxPollingSecs:int      | required |
|maxValiditySecs:int     | required |
|.................................|
|*other:any              | depends  |
+------------------------+----------+
```

Parameters:
authority: A string that indicates the regulatory domain to which
   the ruleset applies is REQUIRED. It MUST use the 2-letter country
   codes defined by [ISO3166-1].
maxLocationChange: The maximum location change in meters is
   REQUIRED. When a device changes location by more than this
   specified distance, it MUST contact the Database to get the
   available spectrum for the new location. If the device is using
   spectrum that is no longer available, it MUST stop operation in
   those frequencies immediately.
maxPollingSecs: The maximum duration, in seconds, between requests
   for available spectrum is REQUIRED. The device MUST contact the
   Database to get available spectrum no less frequently than this
   duration. If the new spectrum information indicates that the
   device is using spectrum that is no longer available, it MUST stop
   operation in those frequencies immediately.
maxValiditySecs: The maximum duration that the available-spectrum
   information may be considered valid is REQUIRED. When a device is
   unable to contact the Database, it MAY continue to use the latest
   available- spectrum information at its location until its validity
   expires. The expiration is determined by adding maxValiditySecs
   to the timestamp of the AVAIL_SPECTRUM_RESP that provided the
   latest available-spectrum information.
other: This message is intended to be extensible with other
   regulatory-specific parameters. Devices MUST ignore all
   parameters in the message it does not understand.

5.8.1. RegulatorySpecifics

For the US / FCC TV-band rules:

    o "authority" MUST be the string, "US"
    o "maxLocationChange" MUST be 50 meters
    o "maxPollingSecs" MUST be 86400 seconds, corresponding to 24 hours
    o "maxValiditySecs" MUST be 172800 seconds, corresponding to 48
       hours

5.9. Spectrum

   Available spectrum can logically be characterized by a list of
   frequency ranges and permissible power levels for each range.

```
   +------------------------------+
   |Spectrum                      |
   +---------------------+--------+
   |bandwidth:float      |required |      +----------------------------+
   |frequencyRanges:list |required |------>|FrequencyRange             |
   +---------------------+--------+  1..* +-----------------+---------+
                                           |startHz:float    |required |
                                           |stopHz:float     |required |
                                           |maxPowerDBm:float|optional |
                                           |channelId:string |optional |
                                           +-----------------+---------+
```

   Parameters:

   bandwidth: This parameter is REQUIRED to define the operating
      bandwidth for which permissible power levels is to be specified.
      For example, FCC regulation would require only one spectrum
      specification at 6MHz bandwidth, but Ofcom regulation would
      require 2 specifications, at 0.1MHz and 8MHz.
   frequencyRanges: A list of FrequencyRange (Section 5.10) objects is
      REQUIRED to specify frequency ranges and permissible power levels.

5.10. FrequencyRange

   The FrequencyRange parameter specifies the maximum permissible power
   levels within a frequency range.
   startHz: The inclusive start of the frequency range is REQUIRED
   stopHz: The exclusive end of the frequency range is REQUIRED
   maxPowerDBm: The maximum total power level (EIRP) -- computed over
      the corresponding operating bandwidth -- that is permitted within
      the frequency range. Depending on the context in which the
      FrequencyRange element appears, maxPowerDBm may be REQUIRED. For
      example, it is REQUIRED in the AVAIL_SPECTRUM_RESP (Section 4.5.2)
      and SPECTRUM_USE_NOTIFY (Section 4.5.5) messages, but it would not
      be used to describe Device Capabilities (Section 5.6).

   channelId: The server MAY include a channel identifier, when
      applicable. When it is included, the Master Device SHOULD treat
      it as informative.

   NOTE: (maxPowerDBm / bandwidth) defines the maximum permitted EIRP
   spectral density.

5.11. EventTime

   The EventTime element specifies the start and stop times of an
   "event". This is used to indicate the time period for which a
   Spectrum (Section 5.9) is valid.

```
+---------------------------+
|EventTime                  |
+-----------------+---------+
|startTime:string |required |
|stopTime:string  |required |
+-----------------+---------+
```

   Parameters:

   startTime: The inclusive start of the event is REQUIRED.
   stopTime: The exclusive end of the event is REQUIRED.

   Both times are expressed using the format, YYYY-MM-DDThh:mm:ssZ, as
   defined by [[RFC3339]]. The times MUST be expressed using UTC.

5.12. SpectrumSchedule

   The SpectrumSchedule element combines EventTime with Spectrum to
   define a time period in which the spectrum is valid.

```
+-------------------------------+
|SpectrumSchedule               |
+--------------------+----------+
|eventTime:EventTime | required |        +-------------------+
|spectrum:list       | required |------->|Spectrum           |
+--------------------+----------+   1..* +-------------------+
                                         |bandwidth:float    |
                                         |frequencyRange:list|
                                         +-------------------+
```

   Parameters:

eventTime: The time period (Section 5.11) is REQUIRED to express
   "when" this specification is valid.
spectrum: List of Spectrum (Section 5.9) elements is REQUIRED to
   specify the available spectrum and permissible power levels, one
   per bandwidth.

5.13. GeoSpectrumSchedule

The GeoSpectrumSchedule element encapsulates the schedule of
available spectrum at a location.

```
+---------------------------------+
|GeoSpectrumSchedule              |
+-----------------------+---------+
|location:GeoLocation   | required |
|spectrumSchedule:list  | required |----------+
+-----------------------+---------+           |
                                              | 1..*
                                              V
                        +-----------------------------+
                        |SpectrumSchedule             |
                        +-----------------+---------+
                        |time:EventTime   | required |
                        |spectrum:Spectrum | required |
                        +-----------------+---------+
```

Parameters:

location: The location (Section 5.3) is REQUIRED to identify the
   location at which the spectrum schedule applies
location: The list of spectrum schedules (Section 5.12) is REQUIRED.
   At least one schedule MUST be included. More than one schedule
   MAY be included to represent future changes to the available
   spectrum.

5.14. DeviceValidity

The DeviceValidity element is used to indicate whether a device is
valid. See Section 4.6.2.

```
+------------------------------------+
|DeviceValidity                      |
+--------------------------+---------+
|deviceId:DeviceIdentifier | required |
|isValid:boolean           | required |
|reason:string             | optional |
+--------------------------+---------+
```

Parameters:

   deviceId: The device identifier (Section 5.4) that was used to check
      for validity. This is REQUIRED.
   isValid: A REQUIRED boolean value that indicates whether the device
      is valid.
   reason: If the device identifier is not valid, the Database MAY
      include a reason. The reason MAY be in any language.

5.15. Response Codes

   TBD

6. Message Encoding

   TBD

7. HTTPS Binding

   This section describes the use of HTTP over TLS (HTTPS) [RFC2818] as
   the transport mechanism for the PAWS protocol. TLS provides message
   integrity and confidentiality between the Master Device and the
   Database. The Master Device MUST implement server authentication, as
   described in Section 3.1 of [RFC2818]. The device uses the URI
   determined (either statically configured or dynamically discovered)
   to authenticate the server. The device SHOULD fail a request if
   server authentication fails.

   Depending on prior relationship between a database and device, the
   server MAY require client authentication, as described in The TLS
   Protocol [RFC5246], to authenticate the device.

   To enable databases to handle large numbers of requests from large
   numbers of devices, the Database MAY support and devices SHOULD
   support Stateless TLS Session Resumption [RFC5077].

   A PAWS request message is carried in the body of an HTTP POST
   request. A PAWS response message is carried in the body of an HTTP
   response. A PAWS response SHOULD include a Content-Length header.

   The POST method is the only method REQUIRED for PAWS. If a database
   chooses to support GET, it MUST be an escaped URL, but the encoding
   of the URL is outside the scope of this document. The database MAY
   refuse to support the GET request by returning an HTTP error code,
   such as 404 (not found).

   The Database MAY redirect a PAWS request. The Master Device MUST
   handle redirects by using the Location header provided by the server

in a 3xx response. When redirecting, the Master Device MUST observe
the delay indicated by the Retry-After header. The Master Device
MUST authenticate the Database that returns the redirect response
before following the redirect. The Master Device MUST authenticate
the Database indicated in the redirect.

8. Example Messages

TBD

9. IANA Considerations

TBD

10. Security Considerations

PAWS is a protocol whereby a Master Device requests a schedule of
available spectrum at its location (or location of its slave devices)
before it (they) can operate using those frequencies. Whereas the
information provided by the Database must be accurate and conform to
applicable regulatory rules, the Database cannot enforce, through the
protocol, that a client device uses only the spectrum it provided.
Specific requirements and security considerations for the PAWS
protocol are described in
[I-D.ietf-paws-problem-stmt-usecases-rqmts].

By using the PAWS protocol, the Master Device and the Database expose
themselves to the following risks:
o Accuracy: The Master Device receives incorrect spectrum-
   availability information.
o Privacy: An unauthorized entity intercepts identifying data for
   the Master Device, such as serial number and location.

Protection from these risks depends on the success of the following
steps:

1. The Master Device must determine a proper database.
2. The Master Device must connect to the proper database.
3. The database must determine or compute accurate spectrum-
    availability information.
4. PAWS messages must be transmitted unmodified between the Database
    and the Master Device.
5. PAWS messages must be encrypted to between the Database and the
    Master Device to prevent exposing private information.

   6. For a slave device, the spectrum-availability information also
       must be transmitted unmodified and secure between the Master
       Device and the slave device, but that is outside the scope of the
       PAWS protocol.
   Of these, only steps 2, 4, and 5 are within the scope of this
   document. [Editor's note: It is still open whether Step 1 is within
   the scope of this document]. Step 3 dependent on specific database
   implementations and regulatory rules and is outside the scope of this
   document. Step 6 requires a protocol between master and slave
   devices and is thus outside the scope of this document.

10.1. Assurance of Proper Database

   This document assumes that the Database is contacted using a domain
   name or an IP address. Using HTTP over TLS [RFC2818], the Database
   authenticates its identity, either as a domain name or IP address, to
   the Master Device by presenting a certificate containing that
   identifier as a "subjectAltName" (i.e., as a dNSName or IP address).
   If the Master Device has external information as to the expected
   identity or credentials of the proper database (e.g., a certificate
   fingerprint), these checks MAY be omitted. Note that in order for
   the presented certificate to be valid at the client, the client must
   be able to validate the certificate. In particular, the validation
   path of the certificate must end in one of the client's trust
   anchors, even if that trust anchor is the Database certificate
   itself. [Editor's note: certificates can change certificate
   authorities (CAs) over time. Should there be a recommendation about
   not relying on a single, statically configured CA certificate in the
   Master Device?]

10.2. Protection Against Modification

   To prevent a PAWS response message from being modified en route,
   messages must be transmitted over an integrity-protected channel.
   Using HTTP over TLS, the channel will be protected by appropriate
   cyphersuites.

10.3. Protection Against Eavesdropping

   Using HTTP over TLS, messages protected by appropriate cyphersuites
   are also protected from eavesdropping or otherwise access by
   unauthorized parties en route

10.4. Client Authentication Considerations

   Although the Database can inform a device of available spectrum it
   can use, the Database cannot enforce that the device uses any/only
   those frequencies. Indeed, a malicious device can operate without

ever contacting a database. Consequently, client authentication is
not required for the PAWS protocol. Depending on prior relationship
between a database and device, the Database may require client
authentication. TLS provides client authentication, but there are
some considerations:

o As indicated in [Section 3.2 of [RFC2818]](), the TLS client
   authentication procedure only determines that the device has a
   certificate chain rooted in an appropriate CA. The database would
   not know what the client identity ought to be, unless it has some
   external source of information. Distribution and management of
   such information, including revocation lists, are outside the
   scope of this document.
o Authentication schemes are secure only to the extent that secrets
   or certificates are kept secure. When there are a vast number of
   devices in the world using PAWS, the possibility that device keys
   will not leak becomes small. Implementations should consider how
   to manage the system in the eventuality that there is a leak.

11. Contributors

This document draws heavily from the following Internet Draft
documents, [I-D.das-paws-protocol] and [I-D.wei-paws-framework]. The
editor would like to specifically call out and thank the contributing
authors of these two documents.

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12. Acknowledgments

The authors gratefully acknowledge the contributions of: Gabor Bajko,
Teco Boot, Nancy Bravin, Rex Buddenberg, Gerald Chouinard, Stephen
Farrell, Michael Fitch, Joel M. Halpern, Donald Joslyn, Jussi
Kahtava, Warren Kumari, Paul Lambert, Andy Lee, Anthony Mancuso,

Peter McCann, Basavaraj Patil, Scott Probasco, Brian Rosen, Andy
Sago, Peter Stanforth, John Stine, and Juan Carlos Zuniga.

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Appendix A. Changes / Author Notes.

Notes:

   o For date-time format this is referencing [RFC3339](), instead of
      ISO8601 as discussed on the list, since it is more precise in its
      definition and is a real RFC. Is that acceptable?
   o Change needed: maxValidityTime in RulesetInfo doesn't work for US/
      FCC, since the rule indicates 11:59 of following day (no timezone
      specified), which cannot be expressed as a duration

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