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Protocol to Access White Space database: PS, use cases and rqmts
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Abstract

Portions of the radio spectrum that are allocated to a licensed, primary user but are unused or unoccupied at specific locations and times are defined as "white space". The concept of allowing secondary transmissions (licensed or unlicensed) in white space is a technique to "unlock" existing spectrum for new use. An obvious requirement is that these secondary transmissions do not interfere with the primary use of the spectrum. One approach to using the white space spectrum at a given time and location is to verify with a database available channels.

This document describes the concept of TV White Spaces. It also describes the problems that need to be addressed for enabling the use of the primary user owned white space spectrum for secondary users, without causing interference, by querying a database which knows the channel availability at any given location and time. A number of possible use cases of this spectrum and derived requirements are also described.

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1. Introduction

Wireless spectrum is a commodity that is regulated by governments. The spectrum is used for various purposes, which include entertainment (e.g. radio and television), communication (telephony and Internet access), military (radars etc.) and, navigation (satellite communication, GPS). Portions of the radio spectrum that are allocated to a licensed, primary user but are unused or unoccupied at specific locations and times are defined as "white space". The concept of allowing secondary transmissions (licensed or unlicensed) in white space is a technique to "unlock" existing spectrum for new use. An obvious requirement is that these secondary transmissions do not interfere with the primary use of the spectrum. One interesting observation is that often, in a given physical location, the primary user(s) may not be using the entire band allocated to them. The available spectrum for a secondary use would then depend on the location of the secondary user. The fundamental issue is how to determine for a specific location and specific time, if any of the primary spectrum is available for secondary use. Academia and Industry have studied multiple cognitive radio mechanisms for use in such a scenario. One simple mechanism is to use a geospatial database that records the primary users occupation, and require the secondary users to check the database prior to selecting what part of the spectrum they use. Such databases could be available on the Internet for query by secondary users.

Spectrum useable for data communications, especially wireless Internet communications, is scarce. One area which has received much attention globally is the TV white space: portions of the TV band that are not used by broadcasters in a given area. In 2008 the United States regulator (the FCC) took initial steps when they published their first ruling on the use of TV white space, and then followed it up with a final ruling in 2010[FCC Ruling]. Finland passed an Act in 2009 enabling testing of cognitive radio systems in the TV white space. The ECC has completed Report 159 [ECC Report 159] containing requirements for operation of cognitive radio systems in the TV white space. Ofcom published in 2004 their Spectrum Framework Review [Spectrum Framework Review] and their Digital Dividend Review [DDR] in 2005, and have followed up with a proposal to access TV white space. More countries are expected to provide access to their TV spectrum in similar ways. Any entity holding spectrum that is not densely used may be asked to give it up in one way or another for more intensive use. Providing a mechanism by which secondary users share the spectrum with the primary user is attractive in many bands in many countries.

Television transmission until now has primarily been analog. The switch to digital transmission has begun. As a result the spectrum

allocated for television transmission can now be more effectively used. Unused channels and bands between channels can be used as long as they do not interfere with the primary service for which that channel is allocated. While urban areas tend to have dense usage of spectrum and a number of TV channels, the same is not true in rural and semi- urban areas. There can be a number of unused TV channels in such areas that can be used for other services. The figure below shows TV white space within the lower UHF band:

```
     Avg  |
     usage|                             |-------------- White Space
          |                    |    |   |   |  |
       0.6|                   ||    ||  V   V  ||
          |                   ||   |||    |    ||
       0.4|                   ||   ||||   |    ||
          |                   ||   ||||   |    ||<----TV transmission
       0.2|                   ||   ||||   |    ||
          |-----------------------------------------
          400     500       600      700       800
                   Frequency in MHz ->
```

Figure 1: High level view of TV White Space

The fundamental issue is how to determine for a specific location and specific time if any of the spectrum is available for secondary use. There are two dimensions of use that may be interesting: space (the area in which a secondary user would not interfere with a primary user, and time: when the secondary use would not interfere with the primary use. In this discussion, we consider the time element to be relatively long term (hours in a day) rather than short term (fractions of a second). Location in this discussion is geolocation: where the transmitters (and sometimes receivers) are located relative to one another. In operation, the database records the existing user's transmitter (and some times receiver) locations along with basic transmission characteristics such as antenna height, and sometimes power. Using rules established by the regulator, the database calculates an exclusion zone for each authorized primary user, and attaches a time schedule to that use. The secondary user queries the database with it location. The database intersects the exclusion zones with the queried location, and returns the portion of the spectrum not in any exclusion zone. Such methods of geospatial database query to avoid interference have been shown to achieve favorable results, and are thus the basis for rulings by the FCC and reports from ECC and Ofcom. In any country, the rules for which primary entities are entitled to protection, how the exclusion zones

are calculated, and what the limits of use by secondary entities are may vary. However, the fundamental notion of recording primary users, calculating exclusion zones, querying by location and returning available spectrum (and the schedule for that spectrum) are common

This document includes the problem statement, use cases and requirements associated with the use of white space spectrum by secondary users via a database query 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 RFC 2119 [RFC2119].

2.2. Terminology

Database

In the context of white space and cognitive radio technologies, the database is an entity which contains current information about available spectrum at any given location and other types of information.

Location Based Service

An application or device which provides data, information or service to a user based on their location.

Master Device

A device which queries the WS Database to find out the available operating channels.

Protected Entity

A primary user of white space spectrum which is afforded protection against interference by secondary users (white space devices) for its use in a given area and time.

Protected Contour

The exclusion area for a Protected Entity, held in the database and expressed as a polygon with geospatial points as the vertices.

Slave Device

A device which uses the spectrum made available by a master device.

TV White Space

TV white space refers specifically to radio spectrum which has been allocated for TV broadcast, but is not occupied by a TV broadcast, or other licensed user (such as a wireless microphone), at a specific location and time.

White Space

Radio spectrum which has been allocated for some primary use, but is not fully occupied by that primary use at a specific location and time.

White Space Device

A device which is a secondary user of some part of white space spectrum. A white space device can be an access point, base station, a portable device or similar. In this context, a white space device is required to query a database with its location to obtain information about available spectrum.

3. Prior Work

3.1. The concept of Cognitive Radio

A cognitive radio uses knowledge of the local radio environment to dynamically adapt its own configuration and function properly in a changing radio environment. Knowledge of the local radio environment can come from various technology mechanisms including sensing (attempting to ascertain primary users by listening for them within the spectrum), location determination and internet connectivity to a database to learn the details of the local radio environment. TV White Space is one implementation of cognitive radio. Because a cognitive radio adapts itself to the available spectrum in a manner that prevents the creation of harmful interference, the spectrum can be shared among different radio users.

3.2. Background information on white space in US

Television transmission in the United States has moved to the use of digital signals as of June 12, 2009. Since June 13, 2009, all full-power U.S. television stations have broadcast over-the-air signals in

digital only. An important benefit of the switch to all-digital broadcasting is that it freed up parts of the valuable broadcast spectrum. More information about the switch to digital transmission is at : [DTV].

With the switch to digital transmission for TV, the guard bands that existed to protect the signals between stations can now be used for other purposes. The FCC has made this spectrum available for unlicensed use and this is generally referred to as white space. Please see the details of the FCC ruling and regulations in [FCC Ruling]. The spectrum can be used to provide wireless broadband as an example. The term "Super-Wifi" is also used to describe this spectrum and potential for providing wifi type of service.

3.3. Air Interfaces

Efforts are ongoing to specify air-interfaces for use in white space spectrum. IEEEs 802.11af task group is currently working on one such specification. IEEE 802.22 is another example. Other air interfaces could be specified in the future such as LTE.

4. Problem Statement

The use of white space spectrum is enabled via the capability of a device to query a database and obtain information about the availability of spectrum for use at a given location. The databases are reachable via the Internet and the devices querying these databases are expected to have some form of Internet connectivity, directly or indirectly. The databases may be country specific since the available spectrum and regulations may vary, but the fundamental operation of the protocol should be country independent.

An example high-level architecture of the devices and white space databases is shown in the figure below:

```
           -----------
           |WS Device|                              ------------
           |Lat: X   |\           .---.    /--------|Database X|
           |Long: Y  | \         (     )  /         ------------
           -----------  \-------/       \/              o
                              ( Internet )              o
           -----------  /------(        )\              o
           |WS Device| /         (_____)  \         ------------
           |Lat: X   |/                    \--------|Database Y|
           |Long: Y  |                              ------------
           -----------
```

Figure 2: High level view of the White space database architecture

In the figure above, note that there could be multiple databases serving white space devices. The databases are country specific since the regulations and available spectrum may vary. In some countries, for example, the U.S., the regulator has determined that multiple, competing databases may provide service to White Space Devices.

A messaging interface between the white space devices and the database is required for operating a network using the white space spectrum. The following sections discuss various aspects of such an interface and the need for a standard. Other aspects of a solution including provisioning the database, and calculating protected contours are considered out of scope of the initial effort, as there are significant differences between countries and spectrum bands.

4.1. Global applicability

The use of TV white space spectrum is currently approved by the FCC in the United States. However regulatory bodies in other countries are also considering similar use of available spectrum. The principles of cognitive radio usage for such spectrum is generally the same. Some of the regulatory details may vary on a country specific basis. However the need for devices that intend to use the spectrum to communicate with a database remains a common feature. The database provides a known, specifiable Protection Contour for the primary user, not dependent on the characteristics of the White Space Device or it's ability to sense the primary use. It also provides a way to specify a schedule of use, because some primary users (for example, wireless microphones) only operate in limited time slots.

Devices need to be able to query a database, directly or indirectly over the public Internet and/or private IP networks prior to operating in available spectrum. Information about available

spectrum, schedule, power, etc. are provided by the database as a response to the query from a device. The messaging interface needs to be:

1. Radio/air interface agnostic - The radio/air interface technology used by the white space device in available spectrum can be 802.11af, 802.16, 802.22, LTE etc. However the messaging interface between the white space device and the database should be agnostic to the air interface while being cognizant of the characteristics of various air-interface technologies and the need to include relevant attributes in the query to the database.

2. Spectrum agnostic - the spectrum used by primary and secondary users varies by country. Some spectrum has an explicit notion of a "channel" a defined swath of spectrum within a band that has some assigned identifier. Other spectrum bands may be subject to white space sharing, but only have actual frequency low/high parameters to define protected entity use. The protocol should be able to be used in any spectrum band where white space sharing is permitted.

3. Globally applicable - A common messaging interface between white space devices and databases will enable the use of such spectrum for various purposes on a global basis. Devices can operate in any country where such spectrum is available and a common interface ensures uniformity in implementations and deployment. Since the White Space device must know it's geospatial location to do a query, it is possible to determine which database, and which rules, are applicable, even though they are country specific.

4. Address regulatory requirements - Each country will likely have regulations that are unique to that country. The messaging interface needs to be flexible to accommodate the specific needs of a regulatory body in the country where the white space device is operating and connecting to the relevant database.

4.2. Database discovery

Another aspect of the problem space is the need to discover the database. A white space device needs to find the relevant database to query based on its current location or for another location. Since the spectrum and databases are country specific, the device will need to discover the relevant database. The device needs to obtain the IP address of the specific database to which it can send queries in addition to registering itself for operation and using the available spectrum.

4.3. Protocol

A protocol that enables a white space device to query a database to obtain information about available channels is needed. A device may be required to register with the database with some credentials prior to being allowed to query. The requirements for such a protocol are specified in this document.

4.4. Data model definition

The contents of the queries and response need to be specified. A data model is required which enables the white space device to query the database while including all the relevant information such as geolocation, radio technology, power characteristics, etc. which may be country and spectrum and regulatory dependent. All databases are able to interpret the data model and respond to the queries using the same data model that is understood by all devices.

Use of XML for specifying a data model is an attractive option. The intent is to evaluate the best option that meets the need for use between white space devices and databases.

5. Use cases

There are many potential use cases that could be considered for the TV white space spectrum. Providing broadband internet access in hotspots, rural and underserved areas are examples. Available channels may also be used to provide internet 'backhaul' for traditional Wi-Fi hotspots, or by towns and cities to monitor/control traffic lights or read utility meters. Still other use cases include the ability to offload data traffic from another internet access network (e.g. 3G cellular network) or to deliver location based services. Some of these use cases are described in the following sections.

5.1. TVWS database discovery

This use case is preliminary to creating a radio network using TV white space; it is a prerequisite to other use cases. The radio network is created by a master device which can be an access point that establishes Hotspot coverage, a base station that establish cellular coverage, or a device that establishes a peer-to-peer or ad-hoc network. Before the master device can transmit in TV white space spectrum, it must contact a trusted database where the device can learn if any channels are available for it to use.

In the simplest case the radio device is pre-programmed with the

internet address of at least one trusted database. The device can establish contact with a trusted database using one of the pre-programmed internet addresses and establish a TV white space network (as described in one of the following use cases).

If the radio device (master) does not have a pre-programmed address for a trusted white space database, or if the trusted database at the pre-programmed address is not responsive, or perhaps the trusted database does not provide service for the radio device's current location, or at the user's choice, the device may attempt to "discover" a trusted database which provides service at the current location.

1. The master is connected to the internet by any means other than using the TV white space radio.

2. The master constructs and broadcasts a query message over the internet and waits for responses.

3. If no acceptable response is received within a pre-configured time limit, the device concludes that no trusted database is available. If one or more response is received, the device evaluates the response to determine if a trusted database can be identified where the device is able to register and receive service from the database.

5.2. Hotspot: urban internet connectivity service

In this use case internet connectivity service is provided in a "hotspot" to local users. Typical deployment scenarios include urban areas where internet connectivity is provided to local businesses and residents, and campus environments where internet connectivity is provided to local buildings and relatively small outdoor areas. This deployment scenario is typically characterized by multiple masters (APs or hotspots) in close proximity, with low antenna height, cells with relatively small radius (a few kilometers or less), and limited numbers of available radio channels. Many of the masters/APs are assumed to be individually deployed and operated, i.e. there is no coordination between many of the masters/APs. The masters/APs in this scenario use a TDD radio technology and transmit at or below a relatively low transmit power threshold. Each master/AP has a connection to the internet and provides internet connectivity to multiple end user or slave devices.

The figure below shows an example deployment of this scenario.

```
    -------
    |Slave|\                  \|/                           ----------
    |Dev 1| (TDD AirIF)        |                            |Database|
    -------            \       |                     .---.   /---------
       o                \    |-|---------|          (     ) /
       o                     |  Master   |         /       \
       o                 /   |           |========( Internet )
       o                /    |-----------|         \        /
    -------  (TDD AirIF)                            (      )
    |Slave| /                                        (----)
    |Dev n|
    -------
```

Figure 3: Hotspot service using TV white space spectrum

Once a master/AP has been correctly installed and configured, a simplified power up and operation scenario utilizing TV White Space to provide Internet connectivity service consists of the following steps:

1. The master/AP powers up; however its WS radio and all other WS capable devices will power up in idle/listen only mode (no active transmissions on the WS frequency band).

2. The master/AP has Internet connectivity and establishes a connection to a trusted white space database (see use case "TVWS database discovery" above).

3. The master/AP registers its geolocation, address, contact information, etc. associated with the owner/operator of the master/AP with the trusted database administrator (if not currently registered). Depending upon local regulator policy, the DB administrator may be required to store and forward the registration information to the regulatory authority.

4. Following the registration process, the master/AP will send a query to the trusted database requesting a list of available WS channels based upon its geolocation.

5. If the master/AP has been previously authenticated, the database responds with a list of available white space channels that the master may use, and optionally a duration of time for their use.

6. Once the master/AP authenticates the WS channel list response message from the database, the AP selects an available WS channel(s) from the list.

7. The master/AP acknowledges to the database which of the available WS channels it has selected for its operation. The database is updated with the information provided by the master/AP.

8. The slave or user device scans the TV bands to locate a master/AP transmission, and associates with the AP. The slave/user device queries the master for a channel list, based on the slaves' geolocation.

9. The master provides the list of channels locally available to the slave/user device. If the channel that the user terminal is currently using is not included in the list of locally available channels, the slave/user device ceases all operation on its current channel. The slave/user device may scan for another AP transmission on a different channel.

5.3. Wide-Area or Rural internet broadband access

In this use case internet broadband access is provided as a Wide-Area Network (WAN) or Wireless Regional Area Network (WRAN). A typical deployment scenario is a wide area or rural area, where internet broadband access is provided to local businesses and residents from a master (i.e. BS) connected to the internet. This deployment scenario is typically characterized by one or more fixed master(s)/ BS(s), cells with relatively large radius (tens kilometers up to 100 km), and many available radio channels. Many of the masters/BSs are assumed to be deployed and operated by a single entity, i.e. there is coordination between many of the masters/BSs. The BS in this scenario use a TDD radio technology and transmit at or below a transmit power threshold established by the local regulator. Each base station has a connection to the internet and provides internet connectivity to multiple slave/end-user devices. End user terminals or devices may be fixed or portable.

The figure below shows an example deployment of this scenario.

```
      -------
      |Slave|\                \|/                             ----------
      |Dev 1| (TDD AirIF)      |                              |Database|
      -------          \       |                     .---.   /----------
         o              \    |-|---------|          (     ) /
         o                   |   Master  |         /       \
         o               /   |   (BS)    |========( Internet )
         o              /    |-----------|         \        /
      -------  (TDD AirIF)                          (      )
      |Slave| /                                      (----)
      |Dev n|
      -------
```

Figure 4: Rural internet broadband access using TV white space spectrum

Once the master/BS has been professionally installed and configured, a simplified power up and operation scenario utilizing TV White Space to provide rural internet broadband access consists of the following steps:

1. The master/BS powers up; however its WS radio and all other WS capable devices will power up in idle/listen only mode (No active transmissions on the WS frequency band)

2. The master/BS has internet connectivity and establishes a connection to a trusted white space database (see use case "TVWS database discovery" above).

3. The master/BS registers its geolocation, address, contact information, etc. associated with the owner/operator of the master/BS with the trusted database service (if not currently registered). Meanwhile the DB administrator may be required to store and forward the registration information to the regulatory authority. If a trusted white space database administrator is not discovered, further operation of the WRAN may be allowed according to local regulator policy (in this case operation of the WRAN is outside the scope of the PAWS protocol).

4. Following the registration process, the master/BS will send a query to the trusted database requesting a list of available WS channels based upon its geolocation.

5. If the master/BS has been previously authenticated, the database responds with a list of available white space channels that may be used and optionally a maximum transmit power (EIRP) for each channel and a duration of time the channel may be used.

6. Once the master/BS authenticates the WS channel list response message from the database, the master/BS selects an available WS channel(s) from the list. The operator may disallow some channels from the list to suit local needs if required.

7. The master/BS acknowledges to the database which of the available WS channels the BS has selected for its operation. The database is updated with the information provided by the BS.

8. The slave or user device scans the TV bands to locate a WRAN transmission, and associates with the master/BS. The slave/user device queries the master for a channel list, based on the slaves' geolocation.

9. The master provides the list of channels locally available to the slave/user device. If the channel that the user terminal is currently using is not included in the list of locally available channels, the slave/user device ceases all operation on its current channel. The slave/user device may scan for another WRAN transmission on a different channel.

5.4. Offloading: moving traffic to a white space network

In this use case internet connectivity service is provided over TV white space as a supplemental or alternative datapath to a 3G or other internet connection. In a typical deployment scenario an end user has a primary internet connection such as a 3G cellular packet data subscription. The user wants to use a widget or application to stream video from an online service (e.g. youtube) to their device. Before the widget starts the streaming connection it checks connectivity options available at the current time and location. Both 3G cellular data is available as well as TVWS connectivity (the user is within coverage of a TVWS master -- hotspot, WAN, WRAN or similar). The user may decide for many and various reasons such as cost, RF coverage, data caps, etc. to prefer the TVWS connection over the 3G cellular data connection. Either by user selection, preconfigured preferences, or other algorithm, the streaming session is started over the TVWS internet connection instead of the 3G cellular connection. This deployment scenario is typically characterized by a TVWS master/AP providing local coverage in the same geographical area as a 3G cellular system. The master/AP is assumed to be individually deployed and operated, i.e. the master/AP is deployed and operated by the user at his home or perhaps by a small business such as a coffee shop. The master/AP has a connection to the internet and provides internet connectivity to the slave/ end-user's device.

The figure below shows an example deployment of this scenario.

```
                              \|/
                               |
                               |
                             |-|---------|
                             | Master/AP |\
                            /| Router    | \
                  Streaming/ |-----------|  \
       --------  /                           \               -----------
       |Slave/| /                             \      (----)  | Database |
       |WS Dev|                                \    (      ) /----------
        ------- \                               \  /        \
                 \                               X( Internet )
                  \                             /  \        /
                   Signaling  \|/              /    (      )\
                          \    |              /      (----)  \----------
                           \   |             /                | YouTube |
                            \|-|---------|  /                 ----------
                             | Master /  | /
                             | 3G BTS    |/
                             |-----------|
```

Figure 5: Offloading: moving traffic to a white space network

Once a dual or multi mode device (3G + TVWS) is connected to a 3G network, a simplified operation scenario of offloading selected content such as video stream from the 3G connection to the TWVS connection consists of the following steps:

1. The dual mode (or multi mode) device (3G + TVWS) is connected to a 3G network. The device has contacted a trusted database to discover the list of available TV channels at is current location. The device has located a TVWS master/AP operating on an available channel and has associated or connected with the TVWS master/AP.

2. The user activates a widget or application that streams video from YouTube. The widget connects to YouTube over 3G cellular data. The user browses content and searches for video selections.

3. The user selects a video for streaming using the widget's controls. Before the widget initiates a streaming session, the widget checks the available connections in the dual mode device and finds a TVWS master/AP is connected.

4. Using either input from the user or pre-defined profile preferences, the widget selects the TVWS master/AP as the

connection to stream the video.

5.5. TVWS for backhaul

In this use case internet connectivity service is provided to users over a traditional wireless protocol, one common example is Wi-Fi. The TV white space network provides the "backhaul" or connection from the Wi-Fi to the internet. In a typical deployment scenario an end user has a device with a radio such as Wi-Fi. A service provider or shop owner wants to provide Wi-Fi internet service for their customers. The location where the service provider wants to provide Wi-Fi is within range of a TVWS master (e.g. Hotspot or Wide-Area/ Rural network). The service provider installs a TVWS slave device and connect this slave to a Wi-Fi access point. This deployment scenario is typically characterized by a TVWS master/AP/BS providing local coverage. The master/AP has a connection to the internet and provides internet connectivity to the slave device. The slave device is then 'bridged' to a Wi-Fi network

The figure below shows an example deployment of this scenario.

```
                   \|/     white    \|/    \|/   WiFi  \|/
                    |      space     |      |           |
                    |                |      |         |-|----|
   |--------|      |-|---------|    |-|------|-|       | WiFi |
   |        |      | Master    |    |  Slave   |       | Dev  |
   |internet|------| (AP/BS)   |    |  Bridge  |       |------|
   |        |      |           |    | to WiFi  |
   |--------|      |-----------|    |----------|        \|/
                                                         |
                                                       |-|----|
                                                       | WiFi |
                                                       | Dev  |
                                                       |------|
```

Figure 6: TVWS for backhaul

Once the bridged device (TVWS+WiFi) is connected to a master and TVWS network, a simplified operation scenario of backhaul for WiFi consists of the following steps:

1. A bridged device (TVWS+WiFi) is connected to a master device operating in the TVWS. The bridged device operates as a slave device in either Hotspot or Wide-Area/Rural internet use cases described above.

2. Once the slave device is connected to the master, the Wi-Fi access point configures its internet settings automatically based on the backhaul connection (i.e. it uses DHCP).

3. End users connect their WiFi device to the bridged device and receive internet connectivity.

5.6. Location based service usage scenario

The owner of a shopping mall wants to provide internet access to customers when they are at the shopping mall. His internet service provider (ISP) recommends using master/AP devices in the TV white space frequency band since these radios will have good propagation characteristics, and thus will require fewer devices, and also because the frequency band used by traditional Wi-Fi is crowded with users such as individual stores operating their own Wi-Fi network and also Bluetooth devices. The ISP installs APs in each large store in the mall, and several other APs throughout the mall building. For each AP, the professional installer programs the location (latitude and longitude) of the device. Special tools are required to determine the location, since typical GPS receivers do not function indoors. When each AP is powered on, the radio does not transmit initially. The AP contacts a white space database, using its wired internet connection, via a URL and provides its programmed location coordinates plus other information required by the database. A reply is received by the AP from the database containing a list of available channels where the AP can operate its transmitter. The AP selects a channel for operation and notifies the database, which records information about the AP including the identity of the AP and its location coordinates. The AP activates its radio and begins to function as a typical wireless AP, providing internet access to connected devices.

A user has a slave device that is capable of operating in the TV white spaces frequency band. A typical device would be a smartphone with multiple radios, including a cellular radio, a Wi-Fi radio, and TV white space radio. The user arrives at the shopping mall and enters the building. The white space radio in the smartphone is on, and is scanning for a master/AP. As the user gets near the entrance to the shopping mall, the smartphone locates one of the APs in the building and connects to it. The smartphone begins to use this TVWS radio for internet access. This internet access does not count against the users cellular data cap (the mall owner is providing the internet access) and also the data rates are better than cellular data. As the user walks throughout the mall the smartphone moves between coverage of different APs, and the smartphone connects to a new AP when the user and smartphone move near it.

In order to encourage customers to come to the shopping mall, the mall owner has a loyalty program where members register, build points, and receive coupons and other notices from the shops in the mall. Before installing the internet service in the mall, all loyalty program information was mailed to the user, at an address which was provided by the user when joining the loyalty program.

The ISP provider describes to the mall owner how the loyalty program can be improved using the internet service provided by the APs in the TV white space. A new app is developed for this loyalty program, and promoted to users, asking them to install the app on their smartphone. The app is provisioned with the user's loyalty program information. When the user comes to the shopping mall, the smartphone locates the master/AP providing internet service and connects to the AP. The app in the smartphone sees that a radio connection to an AP in the TV white space frequency band is now active. The app registers the identity of the AP and forwards this to the home server for the loyalty program, using the internet connection provided by the AP in the TV white space band. The loyalty program server registers the identity of the user from the loyalty program credentials and also the identity of the AP. Next the loyalty program server contacts the TV white space database and requests the location of the master/AP having the identity forwarded by the app and smartphone. When the TV white space database replies with the location coordinates of the AP, the loyalty program server knows the approximate location of the user and smartphone. With this location information, the loyalty program server can now forward loyalty program information to the user. As the user moves through the mall, the smartphone connects to different APs. The process is repeated, allowing the loyalty program to delivery current location based information to the user.

1. The master create a TVWS network as described in use case "Hotspot: urban internet connectivity service."

2. An application running on the user's slave device (e.g. smartphone) determines that a network connection exists in the TVWS band. The identify of the master/AP is recorded by the application and forwarded to a server in the internet cloud.

3. The server queries the trusted white space database with the master identity provided by the application in the user's smartphone.

4. The trusted white space database replies to the server with the location of the master device.

5. The server uses the location of the master/AP to determine the approximate location of the user's smartphone. The server provides location-specific service to the user via the application running in the smartphone.

6. Requirements

This section is the placeholder for the requirements derived from the use cases.

7. IANA Considerations

This document has no requests to IANA.

8. Security Considerations

The messaging interface between the white space device and the database needs to be secured. Both the queries and the responses need to be delivered securely. The device must be certain it is talking to a bona fide database authoritative for the location and spectrum band the device operates on. The database may need to restrict interactions to devices that it has some prior relationship with, or may be restricted from providing service to devices that are not authorized in some manner.

As the device will query with it's location, the location must be protected against eavesdropping. Some regulations include personally identifiable information as required elements of registration and/or query and must similarly be protected.

All communications between the device and the database will require integrity protection.

Man-in-the-middle attacks could modify the content of a response which can cause problems for other networks or devices operating at a given location. Interference as well as total loss of service could result from malicious information being delivered to a white space device.

9. Summary and Conclusion

Wireless spectrum is a scarce resource. As the demand for spectrum grows, there is a need to more efficiently utilize the available and allocated spectrum. Cognitive radio technologies enable the

efficient usage of spectrum via means such as sensing or by querying a database to determine available spectrum at a given location for secondary use. White space is the general term used to refer to the bands within the spectrum which is available for secondary use at a given location. In order to use this spectrum a device needs to query a database which maintains information about the available channels within a band. A protocol is necessary for communication between the devices and databases which would be globally applicable.

The document describes some examples of the role of the white space database in the operation of a radio network and also shows an examples of a services provided to the user of a TVWS device. From these use cases requirements are determined. These requirements are to be used as input to the definition of a Protocol to Access White Space database (PAWS).

10. References

10.1. Normative References

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