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Protocol to Access White Space database: Problem statement
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Abstract

Governments around the world continue to search for new bands of radio
spectrum which can be used by the expanding wireless communications
industry to provide more services in the usable spectrum. The concept
of allowing secondary transmissions (licensed or unlicensed) in
frequencies occupied by a primary user 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. This document discusses the
problems that need to be addressed for enabling the use of white space
spectrum by obtaining information from such a database.

Status of this Memo

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1. Introduction

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.

The concept of allowing secondary transmissions in frequencies occupied by a primary user 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. 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 querier 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.

In a typical implementation of geolocation and database to access TV
white space, a radio is configured with its location in latitude and
longitude. There are multiple ways to configure this location
information, e.g. programmed at installation (e.g. for a fixed device)
or determined by GPS (e.g. for a or mobile device). At power-on, before
the device can transmit in TV white space frequencies, the device must
contact a database, provide its geolocation and receive in return a
list of unoccupied or "white space" spectrum (for example, in a TV
White space implementation, the list of available channels at that
location). The device can then select one of the channels from the list
(note that it is possible they list is empty; there are no unoccupied
channels at the location of the device) and then begins to transmit and
receive on the selected channel. The device must query the database
again for a list of unoccupied channels based on certain conditions,
e.g. a fixed amount of time has passed, the device has changed location
beyond a specified threshold. The basic scenario is that before
transmitting in TV white space, the device must get permission from the
database.
This arrangement assumes that the device querying can complete a query
before it transmits, or some other entity is able to query the
database. A common arrangement for this kind of service is a fixed
tower with a wired infrastructure that provides Internet service to a
network of client devices. In this scenario, the tower has Internet
access from its upstream service, and can query the database for
channels within the tower service area. It can then provide beacon
service to its clients, and assign them channels within the list of
channels that the tower gets from the database.
Another arrangement might be an ad-hoc mobile network where one or more
members of the ad hoc network have an independent radio IP connection
(perhaps a commercial cellular wireless data network) which can be used
to query the database over the Internet.
A third possibility is a mechanism where the database is accessed on a
private IP network.
The low frequencies of the TV bands (470-790 MHz) have good propagation
characteristics. At these low frequencies, a radio signal will travel
~3 times further than traditional WLAN at 2.5 GHz, assuming the same
transmit power. Because of these characteristics and new cognitive
radio techniques, when TV white space becomes available, this will
enable new use cases and new business opportunities. Not only is the
capacity of new spectrum needed, but this propagation trait by itself
makes TV white space attractive for providing broadband wireless access
in rural, sparsely populated areas, as well as for extended range home
hot-spot coverage (similar to WLAN today, but with improved coverage).
In addition to propagation characteristics, the geolocation database
may provide new capabilities for devices that use TV white space. When
a device using TV white space registers its location in the database,
this simple act makes the location of the device available for location
based services.

Other spectrum that might also be available for sharing using white
space techniques exist in every country. A great many primary users
were allocated space a time when there were many fewer potential users
of the space, and the primary users are not making efficient (in
geospatial and time aspects) use of the space. In the past, relocating
existing primary users was the only feasible alternative. Using white
space techniques to share spectrum without imposing burdens on the
primary users is more attractive.

This document discusses the problem statement related to enabling the
"secondary" use of spectrum owned by a primary user without causing
interference to the primary user(s). One approach to avoiding
interference is to verify with a database about the available channels
and spectrum at a given location. This document also identifies various
issues that need to be addressed by the protocol between a white space
device and such a database.

2. Terminology

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.

TV White Space

   TV white space refers specifically to radio spectrum which has been
   allocated for over the air television 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 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.

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.

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.

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.

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.

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        -----------
        |WS Device|                        ------------
        |Lat: X   |\         .----.    /--------|Database X|
        |Long: Y  | \       (      )  /         ------------
        -----------  \-------/      \/               o
                      ( Internet )                   o
        -----------  /------(        )\              o
        |WS Device| /        (_____)  \         ------------
        |Lat: X   |/                   \--------|Database Y|
        |Long: Y  |                             ------------
        -----------
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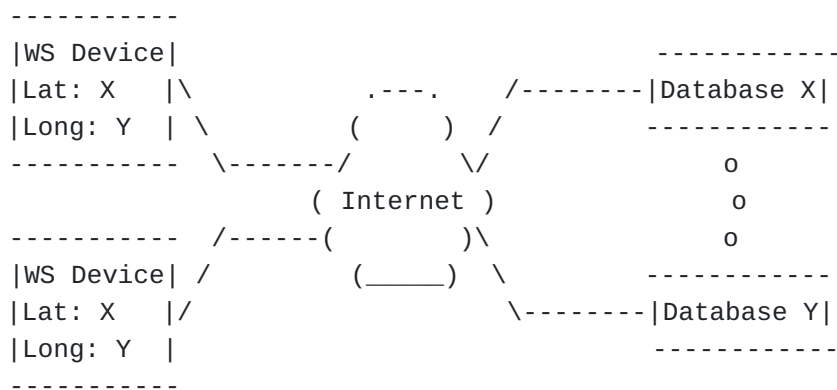
An example high-level architecture of the devices and white space
databases is shown in the figure below:
In the figure above, note that there could be multiple databases
serving white space devices. The databases are country specific since
the regulations and available spectrum may vary. In some countries, 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.
A database discovery mechanism needs to be specified. Reuse of existing
mechanisms is an option and could be adapted for meeting the specific
needs of cognitive radio technology.

4.3. 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 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.

4.4. Protocol

The protocol requirements are simple: registration and query
transactions are needed. In some circumstances, a registration
transaction is required prior to being able to query. The device
provides some identifying information, and the database responds with
an acknowledgement or error. The query protocol is a simple query/
response action (primarily location in, available spectrum out), with
some error conditions.
It may be possible to use existing protocols (e.g. LoST [RFC5222]) or
it may be more appropriate to define a new protocol for this purpose.
HTTP transport is probably appropriate.

5. IANA Considerations

This document has no requests to IANA.

6. 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.
This document describes the problems that need to be addressed for a messaging interface between white space devices and databases and does not by itself raise any security concerns.

7. Summary

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 locaion 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.

8. Acknowledgments

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