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| Project | **IEEE 802.16 Broadband Wireless Access Working Group** <**http://ieee802.org/16**> |
| Title | **Cognitive radio concepts for 802.16h** |
| Date Submitted | **2005-07-11** |
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| Re: | Call for Contributions, IEEE 802.16h Task Group on License-Exempt Coexistence, IEEE 802.16h-05/014 |
| Abstract | Propose cognitive radio signaling for coexistence with ad-hoc 802.16 systems |
| Purpose | |
| Notice |  |
| Release |  |
| Patent Policy and Procedures |  |

# Cognitive radio concepts for 802.16h

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## Overview

The 802.16h uses the Coexistence Identification Server concept and the Coexistence Protocol for separating the interference. This approach needs:

- An agreement between operators for using a Coexistence Identification Server
- The creation and maintenance of a Server.

Supplementary, the 802.16 Base Stations need to be provisioned with IP addresses, not being generally a problem for operator-like use of 802.16 systems. However, for ad-hoc 802.16 systems another approach should be provided, and this approach should work for different 802.16 PHY modes. In continuation it is proposed a signaling method, usable for ad-hoc 802.16 systems and for the coexistence of 802.16 systems with other users in the same frequency band.

## Cognitive Radio - Principles

In order to reduce the interference situations, in deployments in which may exist a combination of 802.16 systems using a Coexistence Protocol and 802.16 ad-hoc systems, the 802.16 ad-hoc systems will apply the Adaptive Channel Selection procedures and use cognitive radio signaling procedures to interact with systems wising a Coexistence Protocol. The ad-hoc systems obtain a temporary Community registration status, that has to be renewed from time to time.

## Registration

The 802.16h pro-active cognitive radio approach defines signals and procedures for the reservation of the activity intervals and registration of ad-hoc systems. The operational procedures are described below:

- 802.16h Community registered systems, using a Coexistence Protocol, will reserve the MAC frame Tx/Rx intervals by using, during the MAC Frame N, cognitive signals to indicate the MAC Tx_start, MAC Tx_end, MAC Rx_start, MAC Rx_end. These signals are transmitted by Base Stations and Repeaters. The specific MAC frame N is indicated in the BS data-base;
- During the MAC frame N+1, cognitive signals will indicate the beginning and the end of Master sub-frames, by transmitting signals indicating by their transmission start the Tx_start, Tx_end, Rx_start, Rx_end for the specific sub-frame; these signals are transmitted by Base Stations, Repeaters and those SSs which experiences interference, at intervals equal with $N_{cog}$ MAC Frames;
- During the MAC frame N+2, will be indicated the position of the time-slots, in each Master sub-frame, to be used starting with the MAC Frame N+3 for registration using cognitive signaling. The start of the "Rx_slot" signal will indicate the start of the slot.
- The start of the MAC frame N+4 is the start of a registration interval using the cognitive signaling; the registration interval has the duration of $T_{cr\_reg\ seconds}$;
- The ad-hoc transmitters shall use the marked slot for sending their radio signature. The radio signature will be used for the evaluation of the potential interference during the Master slot, to systems which use the sub-frame as Master systems.
    - An ad-hoc radio unit (BS, Repeater or SS) will send this signal using a random access mode for $T_{cr\_reg1}$ seconds, using the sub-frame intended for their regular transmission (BSs and SSs use different sub-frames for transmission).
    - The ad-hoc transmitters will have to use the registration procedures every $T_{ad\_reg}$ seconds.

- Registration replay
  - The radio units using the Master sub-frame will send a NACK signal, to be sent in a random mode during the next $T_{cr\_reg\_ack}$ seconds, if they appreciate that the ad-hoc transmitter will cause interference. Typically, to a registration signal sent during a DL sub-frame, the NAK will be sent by one or more SSs, while to a registration signal sent during UL sub-frame, the NACK signal will be sent by a Base Station. The radio units using the Master sub-frame will send their response in random mode.
  - The NACK signal indicates that the requesting ad-hoc device cannot use the specific sub-frame, while using the requesting radio signature
    Same device may try again, if using a different radio signature (for example, lower power).
  - Lack of response, for $T_{cr\_reg\_ack}$ seconds, indicates that the registration is accepted for transmission during the specific sub-frame.

## Selection of suitable reception sub-frames

An ad-hoc unit will find his suitable reception sub-frames, by using the ACS and Registration process in a repetitive way, searching for a suitable operation frequency. The practical interference situations, with synchronized MAC Frames are BS-SS and SS-BS interference. Assuming similar transmit powers, the above mentioned process will have as result finding Master sub-frames in which the path attenuation between interfering units is maximal.

## Signaling procedures for Cognitive Radio applications

## Discussion

The signaling procedures should use a PHY independent mode, with minimum overhead, and which will not require the definition of a new PHY, but rather the reutilization of the existing 802.16 PHY modes. The signals should be understood by systems operating with different channel bandwidths.

Here down is proposed an energy-based signaling method. Such signaling system is used in DFS application, by defining signaling patterns that are repetitive in time-domain. However, the patterns in time domain reduce significantly the spectral efficiency. In order to keep the spectral efficiency high, the energy distribution in frequency domain is more suitable.

## Proposal

For signaling and message exchange between an ad-hoc system and systems using a Coexistence Protocol, it is proposed to:
- Split the narrowest channel to be used (as defined in 802.16 Profiles) into 32 energy bins, as follows:
  - For 256FFT, to 8 sub-carriers/bin
  - For 512 FFT, to 16 sub-carriers/bin
  - For 1024FFT, to 32 sub-carriers/bin
  - For 2048FFT, to 64 sub-carriers/bin.

- Send an 802.16h MAC message, at a suitable rate, such that the MAC header will use 1 symbol and the data field will use another symbol; the MAC header and the data field will be built in such a way that the power distribution for different bins will be with at least 5dB higher for a bin marked in Table 1 with “H” than for bin marked with “L”.
The data field for both transmit and receive operations, taking into account possible FFT sizes, channel widths and the defined PHY modes, is defined in chap. t.b.d.

Due to the FFT guard sub-carriers, not all the bins are usable; we will use in continuation, from the bins numbered 0…31, where the bin#0 corresponds to the lowest frequency, only the bins 6…26.

In Table 1 were defined a number of cognitive signals, having low inter-correlation properties. The energy on the not-used bins can take any value, but not more than the energy on a bin marked with "H". This tolerance will allow finding adequate data mapping for each PHY mode. Obviously, if the energy on not-used bins will be minimal, the detection process will be easier.

Table 1 Cognitive signal definition

| Bin number /Signal number | 6 | 8 | 10 | 12 | 14 | 18 | 20 | 22 | 24 | 26 |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** (802.16h Cognitive MAC Header) | **H** | L | L | **H** | **H** | L | L | L | **H** | L |
| **2** (Tx_start ) | L | **H** | L | L | **H** | **H** | L | L | L | **H** |
| **3** (Rx_start or Rx_slot) | **H** | L | **H** | L | L | **H** | **H** | L | L | L |
| **4** (Tx_end) | L | **H** | L | **H** | L | L | **H** | **H** | L | L |
| **5** (Rx_end) | L | L | **H** | L | **H** | L | L | **H** | **H** | L |
| **6** (NACK) | L | L | L | **H** | L | **H** | L | L | **H** | **H** |
| **7** | **H** | L | L | L | **H** | L | **H** | L | L | **H** |
| **8** | L | **H** | **H** | L | L | **H** | L | **H** | L | L |
| **9** | L | L | **H** | **H** | L | L | **H** | L | **H** | L |

## Conclusion

The proposed Cognitive Radio procedures allow coexistence with 802.16 systems, deployed in an ad-hoc mode. These procedures allow to any system, using the defined cognitive signaling, to identify an 802.16h system and to avoid creating interference or being interfered by it.