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Title	Notes on an Emission Information exchange mechanism for License-Exempt 802.16 Cognitive Radio Networks
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Source(s)	John Sydor Communications Research Centre 3701 Carling Avenue, Ottawa, Canada K2H 8S2 Voice: 613-998-2388 Fax: 613-990-8369 john.sydor@crc.ca
Re:	IEEE 802.16's Study Group on License-Exempt Coexistence dated 2004-07-21 Re: IEEE 802.16le-04/01r1
Abstract	Description of the types of Radiated Emission information that a Licence Exempt 802.16 MAC packet should contain to allow cognitive radio networks to co-exist using avoidance and/or etiquette schemes.
Purpose	Initiate discussion on altruistic license-exempt cognitive radio networks based on 802.16
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Notes on an Emission Data Base exchange mechanism for License-Exempt 802.16 Cognitive Radio Networks

John Sydor
Communications Research Centre, Ottawa, Canada

The need for the distribution of an emission data base

Currently there is no mechanism to ensure that independent License-Exempt (LE) 5 GHz wireless networks deployed in an ad-hoc manner will not interfere with each other. However, if interference information is provided from/to all potentially interfering networks, cognitive radio algorithms (and even human – based interventions) can be designed which can act on such information and plan radio emission profiles that minimize co-channel interference within the locale of the networks.

How the cognitive algorithms work is beyond the scope of these notes; however they could, for example:

>control adaptive antennas or assign occupancy sectors;
>Choose modulation techniques;
>Aid in site selection and deployment approaches;
>Adjust and regulate EIRPs, timing characteristics (Tx/Rx intervals), and select channels for terminals;
>Initiate responses that would modify the behavior of interfering terminals; or
>Operate within the confines of an etiquette, recognizing a priority, protocol, etc.

Cognitive Radio and Altruism

Altruism within an assembly of independent cognitive co-band wireless networks or terminals deployed over a locale is defined as the process of sharing spectrum occupancy, radio emission, timing, and identity information amongst themselves. This information is used by the individual networks to control the interference they may introduce to other networks as they undertake processes to maximize the performance of their radio links.

Two Tiers of Interference Mitigation

Altruism allows a two-tiered approach to interference mitigation. The simplest and easiest to implement is interference avoidance. Networks avoid creating interference by preventing co-channel occupancy; limiting radiation using antenna sectoring or beam forming techniques or moderating EIRP for example.

The second tier of mitigation would be implemented in a more crowded environment. A protocol could be invoked in which priority is recognized and/or where inhibitory requests are passed amongst different co-channel networks leading to the negotiation for the use of common channels within a locale.

Both tiers of interference mitigation can be supported by cognitive networks.

Proposal for a commonly demodulated 802.16 datagram

It is proposed that every 802.16 Base Station broadcast with high regularity a downlink message that can be demodulated by all compliant 802.16 5 GHz LE terminals. The message should:
> Be transmitted at a QPSK Rate _ using a mandatory coding.
> Occupy a 20 MHz bandwidth (to comply with the de-facto 5 GHz channelization plan), and be
> Sent at the maximum EIRP that the terminal uses in its links.

Furthermore, to allow altruism and provide the data for the cognitive decision making process, the following information should be embedded within the message:

- DFS information (Re WRC 2003 expansion bands). Data fields should be provided indicating the channel and power in which a radar was detected. Radar signals can be detected at levels as low as -95 dBm, well below the regulatory threshold limits of -62/-64 dBm. Advance notice would allow more time to vacate channels and cause less disruption to active networks.
- Spectrum Occupancy Information. Each base station should provide a spectrum occupancy data field indicating the maximum power and frequency detected for each spectrum band in which it operates (one in the case of TDD, 2 in the case of FDD) (e.g., 128 data points in the 100 MHz bandwidth, in which power is measured within 800 kHz sub-bands). A time stamp would accompany each spectrum occupancy measurement. This information would provide adjacent networks of available bands and would augment their own spectral measurements.
- GPS Location and Height of Base Station. Allows for precise steering of antenna nulls; calculation of radiation effects of one networks' terminals on others; allows for prediction of interference effects as a function of EIRP, etc.
- Directivity and direction of transmit and receive antennas associated with the base station and an indication of the type of antenna (adaptive/ fixed/steerable,etc). The MAC data field should include 3 dB azimuth beamwidth and gain of the antennas, and the direction of the main beam with respect to North. With the location information described above, this would allow better interference estimation by terminals.
- Maximum EIRP of emission channels and channel number. Indicates what channels are occupied, provides other terminals with an estimate of propagation path loss and the development of isolation criteria between networks.
- For FDD systems, the receive channel numbers. An FDD system would transmit at a frequency other than the one that it receives. Adjacent networks would be informed of the existence of other bands which they would have to consider.
- For TDD systems, information that can be used to aid in time-division sharing of channel. For synchronization of uplink and downlink bursts to avoid co-channel interference with closely spaced adjacent networks.
- Duty Cycle Information. A general indication of how frequently a band is being used. Adjacent networks would opt to use channels that are being infrequently used rather than one seeing frequent use. This parameter could change on a daily or hourly basis.
- IP address of network controller to which interference control messaging can be sent.

First Come/First Claim Etiquette
(1) A network must check its intended space before it occupies it.
(2) When an empty space is claimed by the network, it has a first claim priority to that space.
(3) No other network can create interference to the network having first claim to a space.

How long can the “first claim” last? An issue to be debated but it could be:

> The duration of the burst or some fraction of time after the burst, or
> Much longer if the network was the first to use it (first come), and still uses it, or
> First claim is given to the network passing higher capacity than other competing network, etc..

How do we communicate occupancy and claim-to-space information to other networks and their terminals?:

> Insert a time stamp stating the time of occupancy in the DL Channel Descriptor..
(the time stamp derived from GPS location/timing measurement at the BS),or
> Insertion of a capacity indicator,etc...

Before we get too involved in a debate, we should remember that a license-exempt etiquette will only be necessary when crowding occurs. The WRC2003 provides considerable bandwidth and simple avoidance should always be the first action taken to achieve co-existence. Crowding may not be seen for some time in urban areas, or never in rural environments. Cell sizes will vary from 400-1400 meters radius given 5 GHz regulations and assuming typical subscriber terminal performance characteristics*. If we have 200-400 MHz of bandwidth available the use of an etiquette may not be required in un-crowded deployments

Summary

It is proposed that for LE 5 GHz operation 802.16 MAC information be broadcast to announce a terminal’s or network’s occupancy of a locale. The information broadcast should contain a set of information that will allow adjacent, and potentially interfering terminals and networks, to adjust their radiation characteristics in a manner that will facilitate sharing of the band. Such information could readily be used by cognitive networks that continually monitor the radio spectrum and take advantage of unoccupied space and frequencies.

*Omni directional 802.16 BS using 5 GHz/1 watt EIRP/QPSK (-80dBm/20 MHz)/ 10 dB margin/ PLE of 2.3-2.8 and SS using 19 dBi directional antenna