Cognitive Radio Research At Industry Canada's Communications Research Centre

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Our projects:

- Cognitive Radio standards development: IEEE 802.16h/e and IEEE 802.22… pre-standard implementation of experimental systems.

- Investigating CR overlays for WiFi (IEEE802.11 g/a/n) in support of improved municipal WLAN operation as well as very-low cost backhaul technologies.

- Investigation of new messaging and signaling sets for OFDMA, MIMO, and adaptive beamforming to improve performance using spectrum sharing and inter-system collaboration for interference mitigation.

Standards Development Projects

IEEE 802.22

A new air-interface standard for Wireless Regional Area Networks mainly aimed at extending broadband access in low population density rural areas by using the VHF/UHF TV broadcast bands for their better signal propagation characteristics (typical reach: 17-30 km, maximum reach: 100 km).

The cognitive radio capabilities of IEEE 802.22 are:

- RF sensing to detect the presence of broadcast incumbents on co-channel and adjacent channels as necessary to avoid interference:
  - 4 blind sensing schemes proposed for generic signal detection
  - 10 sensing techniques for ATSC DTV signal detection
  - 1 sensing technique for DVB-T DTV signal detection
  - 1 sensing technique for NTSC TV signal detection
  - 2 sensing techniques for wireless microphone detection
  - One wireless beacon standard (802.22.1) and one detection technique to acquire the wireless microphone beacon to better protect legitimate wireless microphone operation.

IEEE 802.22

More 802.22 cognitive radio capabilities are: (cont'd)

- Centralized reporting of the sensing results to the base station.
- Access to a common incumbent database to confirm incumbent operation.
- Centralized control at the base station of the change of operating frequency or the EIRP (TPC cap) to avoid interference to incumbents.
- Detection of similar WRAN operation in the area (WRAN coexistence).
- Synchronization of all WRAN systems to align RF sensing quiet periods and self-coexistence windows.
- Use of coexistence beacon protocol bursts to send scheduling information across WRAN cells to implement WRAN coexistence mechanisms.
- Choice of four MAC coexistence mechanisms:
  - (1) Interference-free scheduling
  - (2)Spectrum etiquette
  - (3)Adaptive on-demand channel contention
  - (4)Dynamic resource renting / offering

Standards Development Projects

- **IEEE 802.16h**

  A corrigendum to the IEEE 802.16 (fixed/mobile) that will provide WiMAX with the capability to:

- Implement collaborative networks by using a Co-Existence Control Channel,
- Share co-channel spectrum,
- Identify and avoid interference generated by other co-channel systems (non-WiMAX),
- Identify and control interference generated by similar WiMAXsystems,
- Trade bandwidth, and
- Coexist with 802.11y users in 3.65 GHz bands (US/FCC)

Standards Development Projects

What's in the 802.16h CR toolbox:

>control channel for inter-system signaling and quiet periods to monitor radio environment.

>Over-the-Air interference signaling to allow interfered-with terminals to determine the source of interference and its emission characteristics.

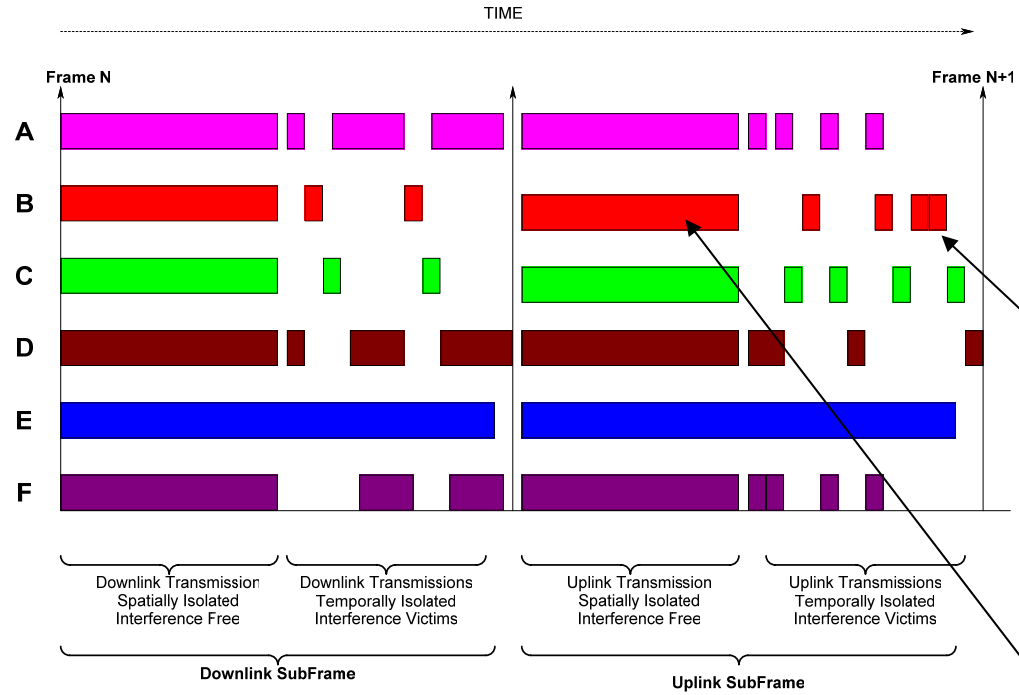
>IP based system-system messaging of interference events, information, etc.

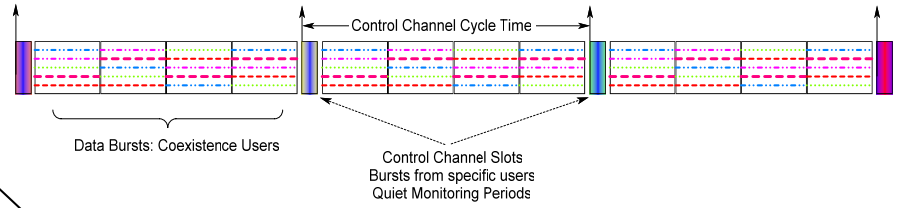
>a commonly shared data base containing characteristics all detected emitters.

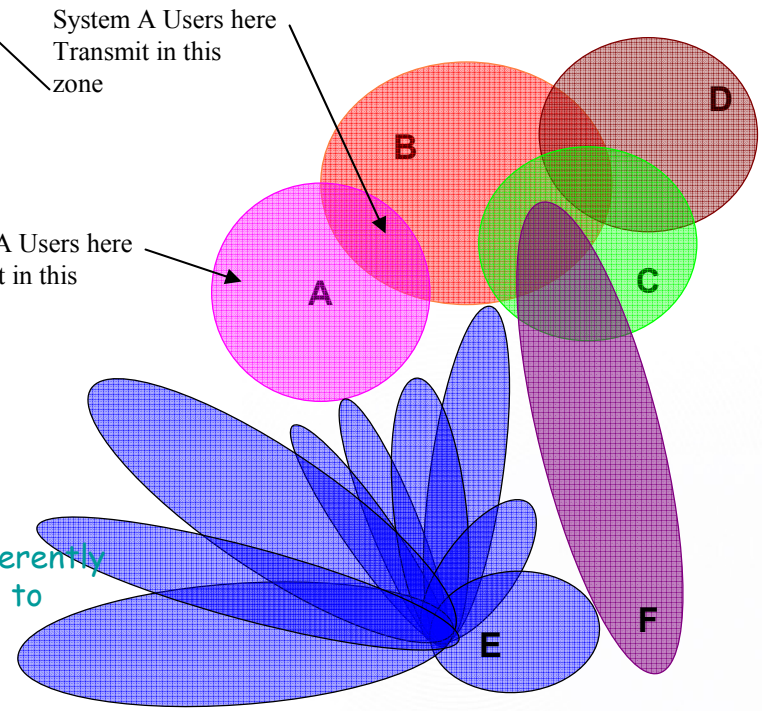
>spectrum evaluation to determine unoccupied channels

> A universal, synchronized TDD framing system that allow isolation of interference into special temporal zones

Temporal/Spatial Partitioning of a TDD co-channel using IEEE 802.16h coexistence messaging







Spatial Occupancy of Systems A-F

Cognitive Radio Spectrum Sharing features:

A Control Channel for synchronization & interference message,sensing

Messaging: All emissions are tracked by emission identification messages.

Emissions that don't interfere with any other terminal are scheduled differently than emissions which interfere. Interfering emission are scheduled to interference-free temporal zones.

CDOT/CRC implementation of 802.16h

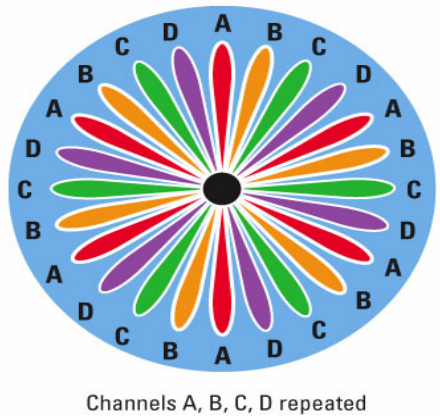
Implementation of 16h is being undertaken for Rosette Antenna systems having a 6x frequency reuse. Some features and attributes are:

- 802.16h messaging and synchronization which controls co-channel interference.
- CR attributes facilitate Rosette cell packing…allowing high density coverage.
- CR improves 2.4 and 5.8 GHz LE band performance, which has high interference.

The WiMAX based CR systems being implemented within a CRC/CDOT collaborative project in India. Similar, non-WiMAX implementations have been done in Canada, since 2003 (Milton Project).

Implementations

24 Petal 5.3/5.8 GHz Band (LE) Rosette Array



24 Beam Rosette with 6X frequency Reuse

2003 Installation of 5.3/5.8 GHz Rosette Array, Ottawa

2005 Installation of 5.3/5.8GHz Rosette In Bangalore,India (CDOT)

2.4 GHz LE WiMAX 24 beam Experimental Array; Bangalore, India.

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CR Overlays on WiFi Technology

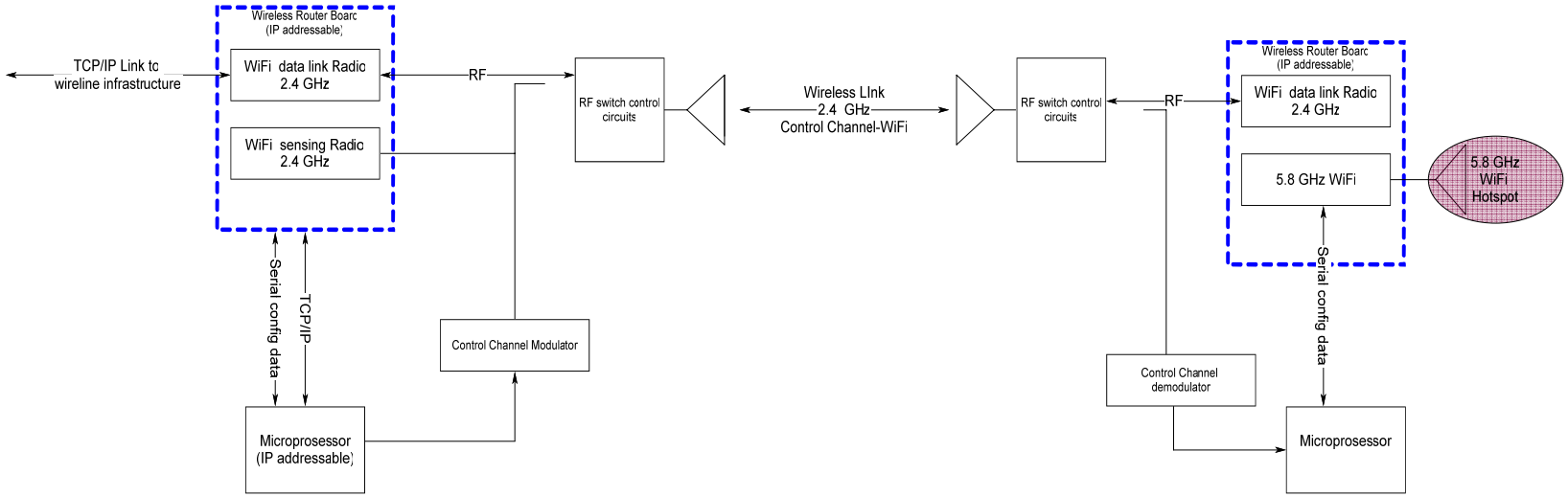
What is a "CR overlay" on WiFi…and what does it do?

- It's a RF signal "shell" around the WiFi radio…forcing the WiFi radio MAC into a specific type of operation that is still CSMA/CA in principle…but with temporal limits.
- The RF "shell" is controlled by a microprocessor that observes simple CR rules.
- A WiFi wireless router is programmed to support the CR rules.
- The WiFi MAC is left essentially unchanged…though certain allowable (standard acceptable) operations are emphasized.

What is the purpose of such radios?

- Backhaul data (especially VOIP/WiFi access) ; similar to WiMAX (fixed) but at lower cost.
- Improve License-Exempt band utilization.
- Ideal for applications having minimal service-provider intervention (such as remote-rural WLAN implementation in technical disadvantaged regions).

CR Overlays on WiFi Technology



Hub Side

Client Side

Wireless Router board contains 2 WiFi cards; one acts as the data link device, the other as the band occupancy sensor. Under control of the microprocessor, WiFi RF is constrained to a TDD-like output in which specific packets (identified by the router) are scheduled. Control Channel (not related to WiFi data link) is used to provide configuration/control/and monitoring of client units. Channel selection/interference identification is undertaken by the micro.

Wireless Router board contains 2 WiFi cards; one acts as data link device, the other as a WiFi hot spot access point. Control channel demodulator supports configuration and control of the device. Client side is slaved to the hub for such actions as uplink power control channel frequency and channel change. Hot spot created in LE band is a true (unmodified) WiFi.

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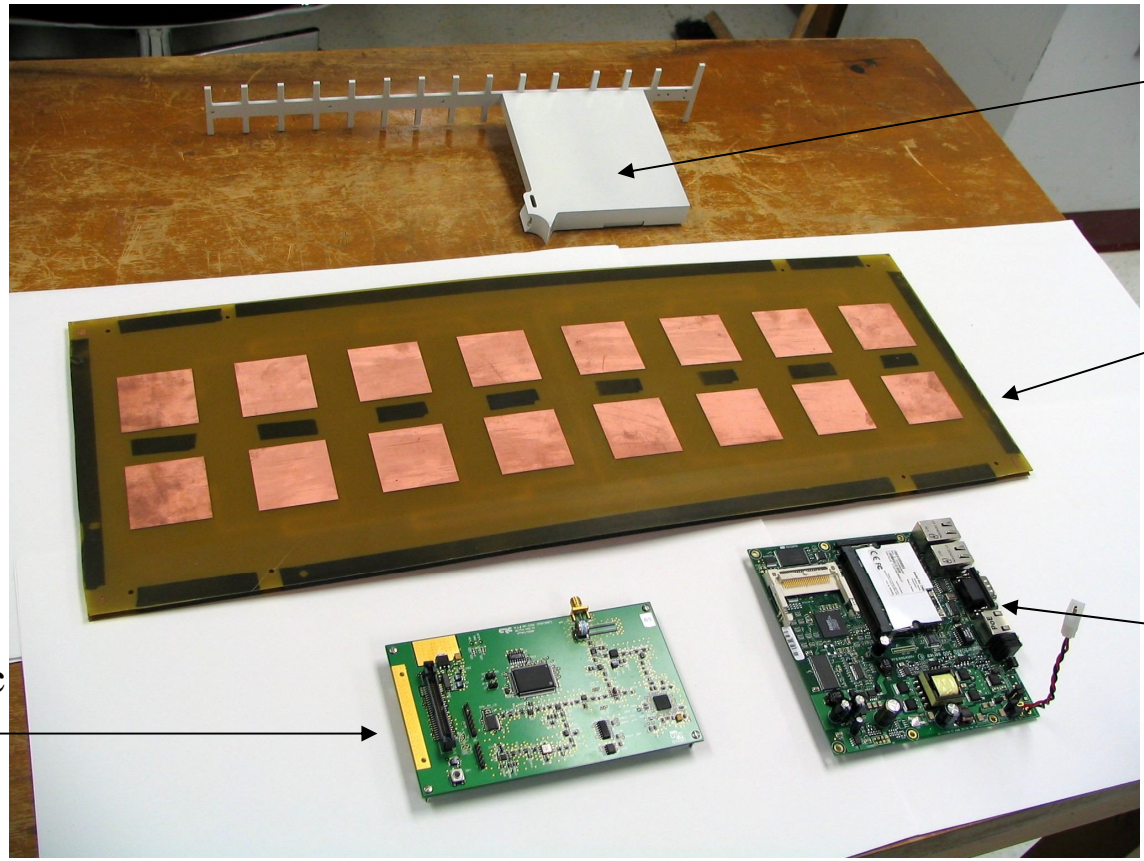
Experimental CR-WiFi equipment



14 dBi Client subscriber unit housing for outdoor mounting

16 dBi Microstrip Panel Hub Antenna On low-cost FR4

Off-the-shelf wireless router board with mini-PCI Jacks for WiFi (Hub) radios

Hub RF switch Circuits and logic with Microprocesor

CR-Mimo/Beamforming

Research is beginning to show that 4G systems may require a mix of MIMO and beamforming techniques to maintain high data links. Both of these techniques have overlapping requirements on issues related to spectrum resource management.

MIMO

- Needs high multipath (NLOS environment)
- Sensitive to Co-channel interference over and above modulation rate performance.
- Needs spectrum occupancy information at receiver.
- Needs regular channel matrix updates,

Beamforming

- Operates best in LOS environment
- Sensitivity to Co-Channel interference defined by modulation rate performance.
- Needs spectrum occupancy information at receiver.
- Optimal when locations of desired and interfering terminals are known.

CR-Mimo/Beamforming

CRC Work on Hybrid MIMO/Beamformers with CR:

- Collaboration with Canadian Universities to study issues of beamforming and MIMO implementation.
- Development of modified WARP OFDM(802.11) hardware from Rice University to implement a hybrid 2X2 MIMO and 2-4 antenna beamformer
- Implement a rudimentary MAC capable of supporting Cognitve Radio Signaling and interference messaging as detailed in IEEE 802.16h (specifically the CXCC and BSD/SSURF messages).
- Undertake MATLAB and SIMULINK simulations.

The near term purpose of this work is to:

- Implement a hybrid MIMO/Beamformer that smoothly transitions from one technique to the other.
- Implement interference ID to support MIMO/OFDMA subcarrier selection. (related to IEEE 802.16h messaging/control channel).

Final Words

Our experiments and work indicate that Radio Resource management by Cognitive Radio can be practically implemented.

The main requirement of these new radios is that they posses the ability to sense and quantify interference on or from other radio systems and that they be capable of establishing collaborative sharing of spectrum.

CR systems will be adaptive. In some instances the will be small, autonomous devices or networks operating using simple rules. In other instances they will be large networks of radios having centralized network controllers operating sophisticated space,time, and spectrum use schedulers…based on Artificial Intelligence.

Thank you !