Cognitive Radio

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15 June, 2004.

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Cognitive radio is an intelligent wireless communication system that is aware of its RF environment, and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the environment by making changes to adjustable parameters, namely transmit power, carrier frequency and modulation strategy, all in real time, with two objectives in mind :

- Reliable communication.
- Efficient utilization of the radio spectrum.

Motivation

- Only a very small fraction of the assigned spectrum is presently utilized efficiently, which is on the order of 6 percent.
- Cognitive radio provides a brain-powered approach to improve spectrum utilization whenever RF emitters are inactive.
- This improvement is made possible by exploiting four key technologies:

Signal processing
Machine learning
Communication theory
Network theory

The role of computing is so profound that a cognitive radio may be viewed as: “*A radio with a computer inside*” or “*A computer that transmits.*”

Funding

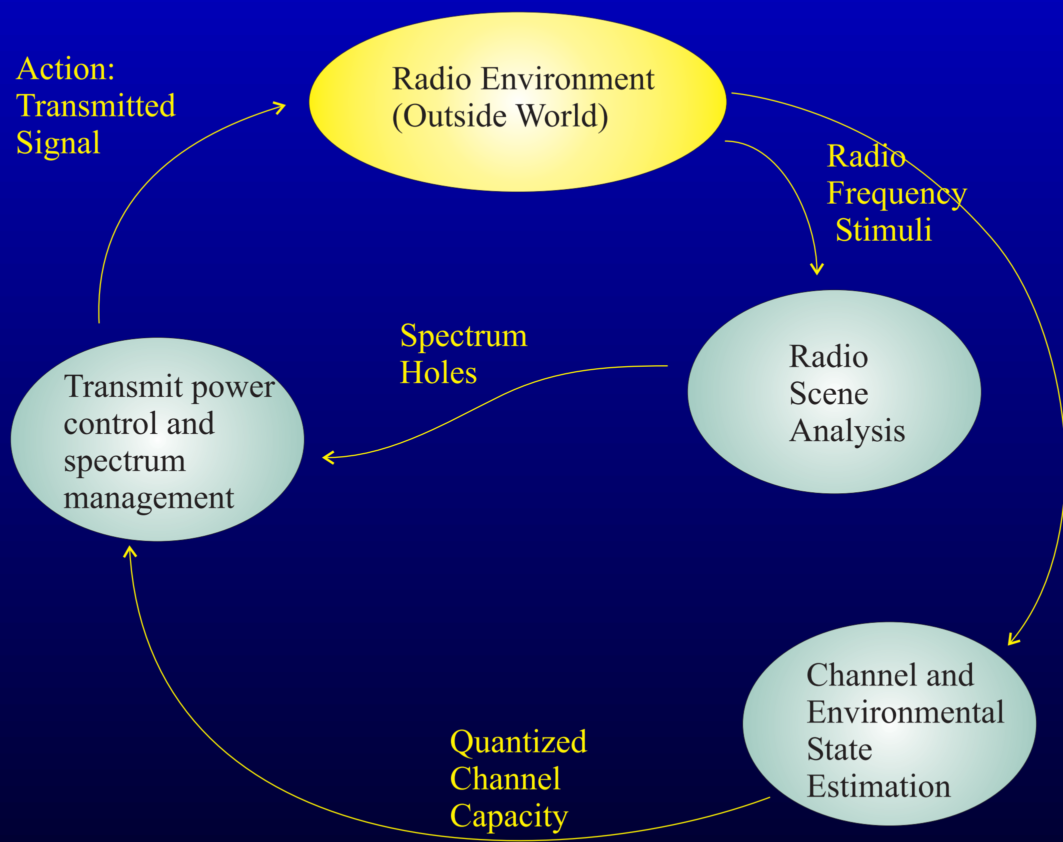
Proposal is underway for submission to NSERC with two significant Canadian partnerships:

- Wireless Division of Nortel Networks, Ottawa.
- Communications Research Centre, Ottawa.

Level of funding: 150 K Canadian dollars for each of 3 years, renewable on a yearly basis by Nortel.

Goals

To build a software prototype system that demonstrates the three phases of the cognitive cycle in its most basic form.



Goals

From the simulation test bed we will examine the technical reliability and practicality of cognitive radio deployment in incumbent user areas.

We hope to learn:

- Feasible behaviors of cognitive radio when operating in primary user environment.
- Ease of reconfigurability from:
  1. Ad hoc network to a Mesh network.
  2. As number of cognitive radios increases/decreases.
  3. As number of primary users increases/decreases, (resulting in a change of spectrum congestion).
- If primary user is receiving interference is it cognitive radios' fault? How can cognitive radio protect itself?
- Emergent behavior.

Linkage with the MURI project I: Short-term goals

In an invited paper entitled " Cognitive Radio: Brain empowered wireless communications" by Simon Haykin, to be published in a special issue of the IEEE JSAC, 2004, three major cognitive tasks are identified:

1. Radio scene analysis.
2. Channel state estimation and predictive modeling.
3. Multiple access control, comprising transmit power control and dynamic spectrum management.

McMaster, working in partnership with Nortel Networks and Communications Research Centre, is determined to make a major contribution in this exciting multidisciplinary area of wireless communications. Basic to the design and development of the prototype will be the emphasis on the dissemination of information in ad-hoc networks, an area of expertise that is central to the MURI project. To strengthen our capability in this new venture, we are looking forward to collaborate with faculty members in the MURI project.

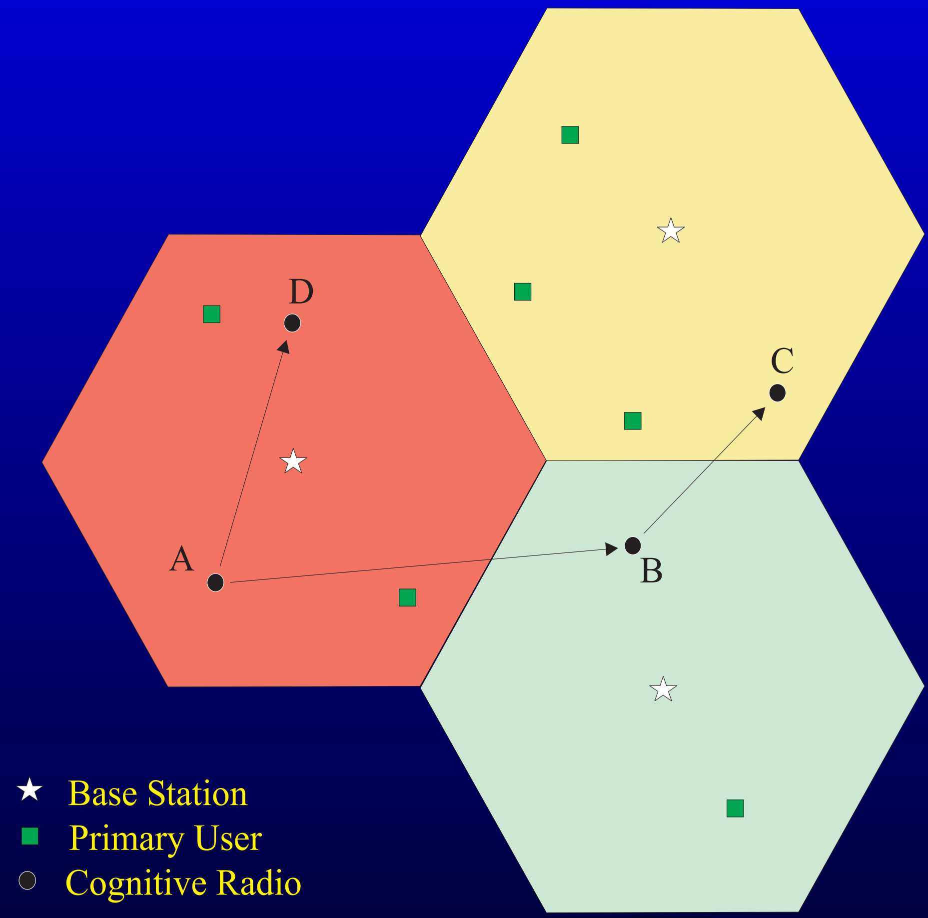
Disruptive, but *Unobtrusive*

Seminal goal of cognitive radio is to relieve spectrum overcrowding.

Considerations:

- Determine location of spectrum holes, (interference temperature).
- Reconfigurability;
  Ad hoc $\longrightarrow$ Mesh network $\longrightarrow$ Ah hoc $\longrightarrow$ ...
- Must NOT interfere with primary user.
- Must surrender spectrum as necessary.

Dynamic frequency allocation for cognitive radio is preformed from a receiver centric paradigm.



Traffic Considerations

- As mentioned cognitive radio is introduced in order to successfully and reliably share the spectrum with an incumbent primary user on a non-interference basis.
- Since a wireless environment is dynamic instantaneous measurements of the environment cannot guarantee accommodating an incoming burst of CR data.
- To avoid contention, we need to develop a traffic model of the primary user. The traffic model can then be used to predict the traffic pattern in the incoming burst period.

1. Arrival traffic and pattern of incumbent users.
2. Flow-control also influences the traffic pattern.
3. What if primary user demands the channel?

Traffic Considerations - Example

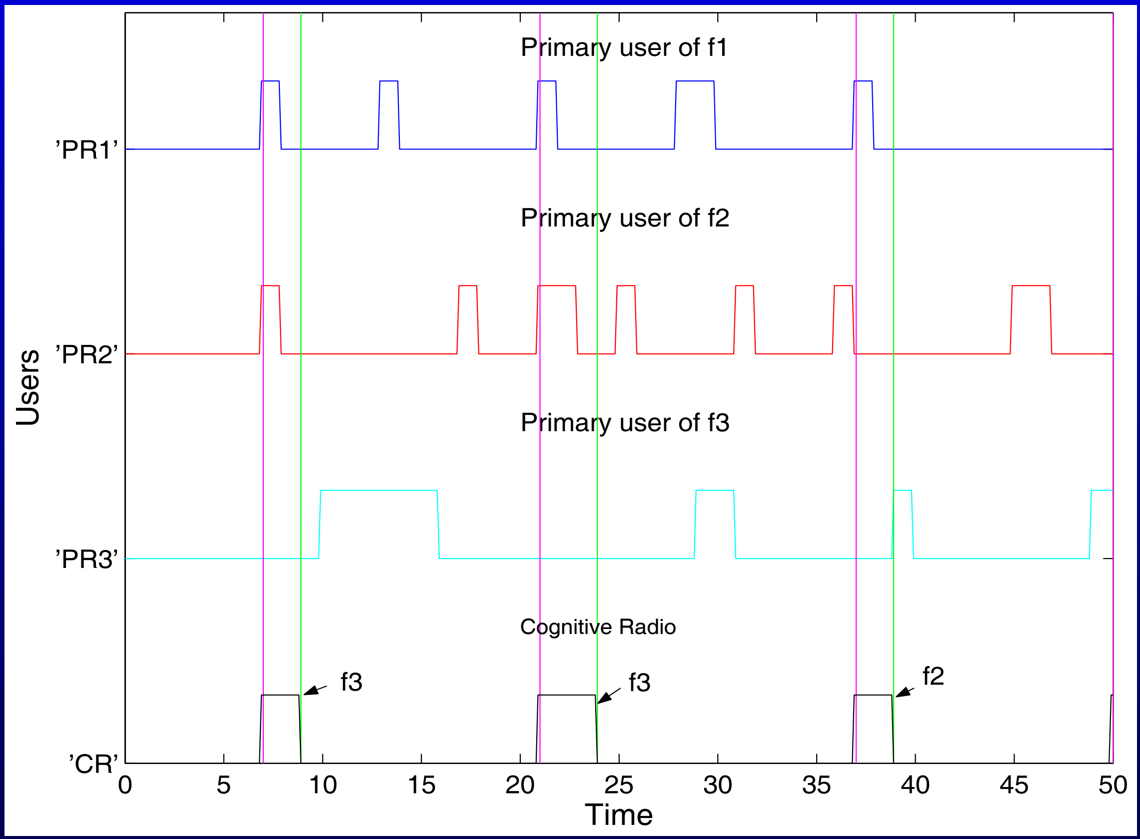


Figure 1: The cognitive radio adapts to confine itself to frequencies that are unused by the primary users.

Linkage with the MURI project II: Long-term goals

Extension of the cognitive radio receivers to include additional services:

- Turbo processing for improved quality of service. The Communications Research Centre, (CRC), Ottawa, not only did some of the early pioneering work on turbo processing but also has one of the strongest research groups in the world. This area is also of special interest to the McMaster node.

  Simply put, turbo processing, be that in the context of conventional or cognitive wireless, will provide a fertile research area for collaboration between MURI nodes, McMaster and with CRC through McMaster.

- Inclusion of MIMO architectures for enhanced beamforming and spatial multiplexing improvements.

  MIMO wireless communications is also of special interest to both McMaster and the CRC, Ottawa. (The early work on Turbo-MIMO was done at McMaster.) As with turbo processing, MIMO wireless communications provides another research for collaboration between MURI nodes, McMaster and the CRC through McMaster.

Research team

- Simon Haykin (Professer)
- Kris Huber (Research scientist)
- Lily Jiang (Ph.D. Graduate student)
- Post-doctoral fellow, specializing in networking (to be appointed)

Note: Simon Haykin already has a Discovery grant from NSERC that supports the Ph.D. studies of three additions graduate students: Nelson Costa, Stephen Fang and Robert Abipropjo.