Cognitive Radio Technology is Already Mitigating the "Spectrum Crisis"

Think outside the link!

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Spectrum Crisis is a Witch's Brew

Cognitive Radio Technologies

ITU: IMT-A

- **100 Mbit/s for high mobility**
- **1 Gbit/s for low mobility**
- **1Gbps/100MHz = 10 bps/Hz**

Massive Mobile Market Forces

- **5B mobile users by 2015, many broadband users**
- **"iPhone effect"**

Spectrum Regulation

The Pain

<=2 x 100 MHz bands

Solution?

- **spectrum pool among operators**
- **Operators will fiercely resist**

FCC Out Front

"Exclusive use"
Transferable Rights
- ***Static***
- ***Dynamic***

Market for Licenses/New business models

Multi-Operator Sharing

- *Heterogeneous* services: interruptible leasing of public safety spectrum
- *Homogeneous* Services: Cell/PCS

"Shared Use of Primary Licensed Spectrum"
Primary unaware of secondary

Spectrum Underlay= UWB

Spectrum Overlay (White Space Systems)

- IEEE 802.22 (54-806 MHz)
- DARPA xG
- Listen Before Talk

"Commons"
No Rights (Unlicensed)

User Coordination

- Open Access (ISM; U-NII)
- Managed Commons Band (3.65 GHz)
- Private (Premium Service)

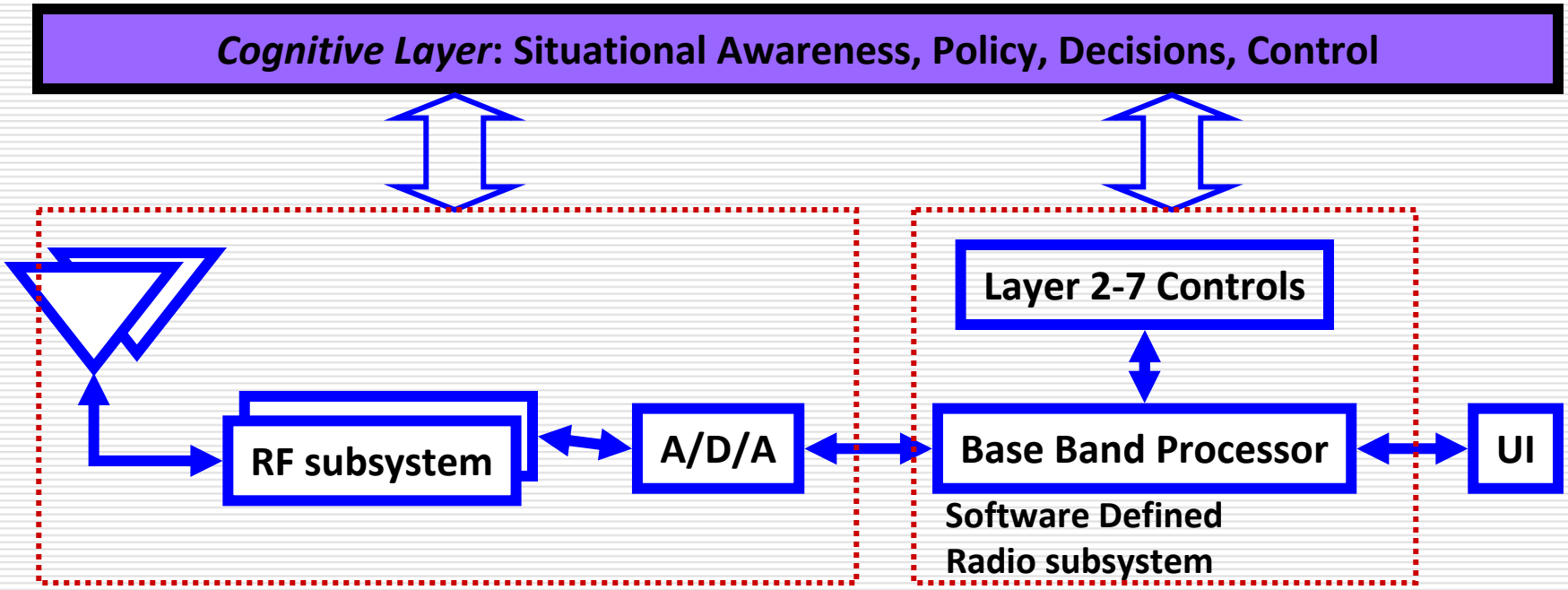
Major Challenge: Deployment of home base stations/femtocells (cooperative MIMO)

- **2nd Report & Order, 2004**
- **Report and Order, Docket 05-57, 10 MAR 05**
- **May 15, 2003, by Report and Order and NOPR (FCC 03-113)**

What is CR Anyway?

- From IEEE P1900.1, Draft 16 MAR 06
- "A radio or system that utilizes a cognitive control mechanism that can sense and autonomously reason about the surrounding radio environment and adapt to it accordingly.

Generic Cognitive Radio



- Integrated baluns, inductors
- Wide tuning
- Highly integrated SAW-less front ends
- Multi-Antenna processing
- Measure emitter power and location
- Dynamic band selection
- Transmit power control
- Programmable filters

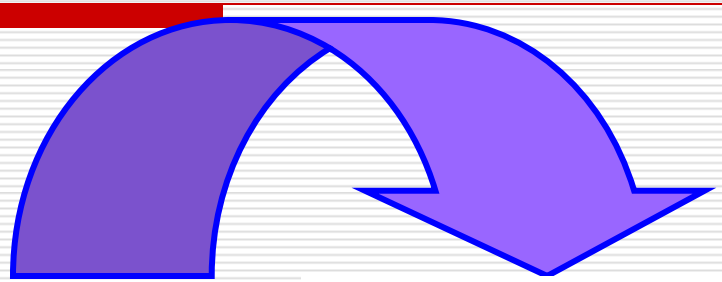
Situational Awareness & Control Parameters

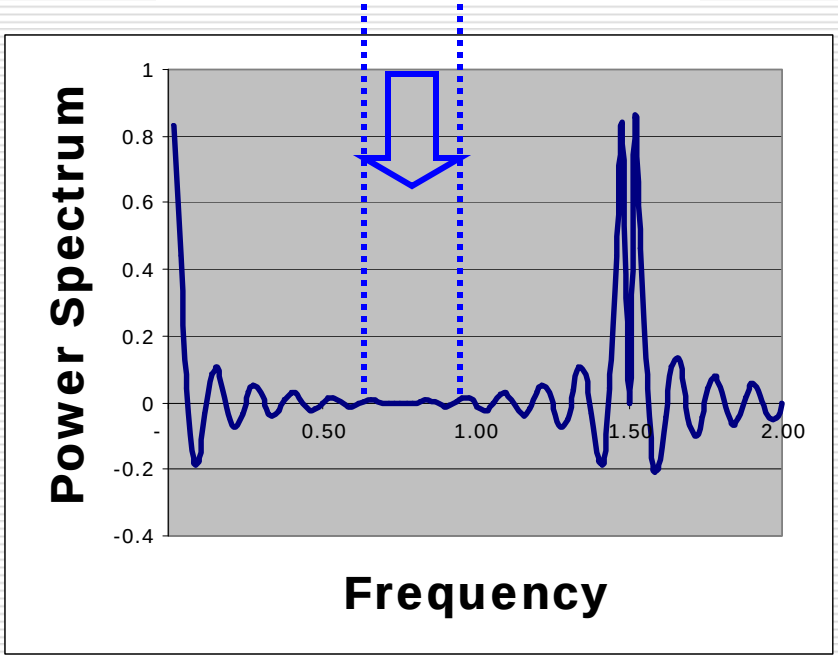
- **Measurements**
  - MAC
    - Frame error Rate
    - Data Rate
  - PHY
    - BER
    - SINR
    - Received signal power
    - Noise power
    - Interference power
    - Energy consumption
    - Fading statistics
    - Doppler spread
    - Delay spread
    - Angle of arrival

- **Controls**
  - MAC
    - Source coding
    - Channel coding rate and type
    - Frame size and type
    - Interleaving details
    - Channel/slot code allocation
    - Duplexing
    - Multiple access
    - Encryption
  - PHY
    - Transmitter power
    - Spreading code and type
    - Modulation type & Modulation index
    - Pulse shaping
    - Symbol rate
    - Carrier frequency
    - Frequency range
    - Sampling rate
    - Dynamic range
    - Equalization
    - Antenna directivity
    - Sensitivity &Selectivity
    - Stability
    - Spurious response

Spectrum Sensing: Find+Fill Holes, Kill Interferers

- MAX: Pr{Decide hole|hole} , subject to Pr{Decide hole|NOT_hole} < Pfa
- Cyclostationary feature detector
- Matched filter or correlator
- Energy detector
- Wavelet transforms
- Higher order statistics





CR: Hiding in Plain Sight