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MULTIPLE ACCESS COMMUNICATIONS

Cognitive Radio – A Technology for Enhancing The Utilisation of Radio Spectrum

Next Generation Networks and Base Stations Conference

Spectrum for 3G and Beyond Workshop

25 April 2008

Solutions For Wireless Communications

MAC Ltd and Cognitive Radio

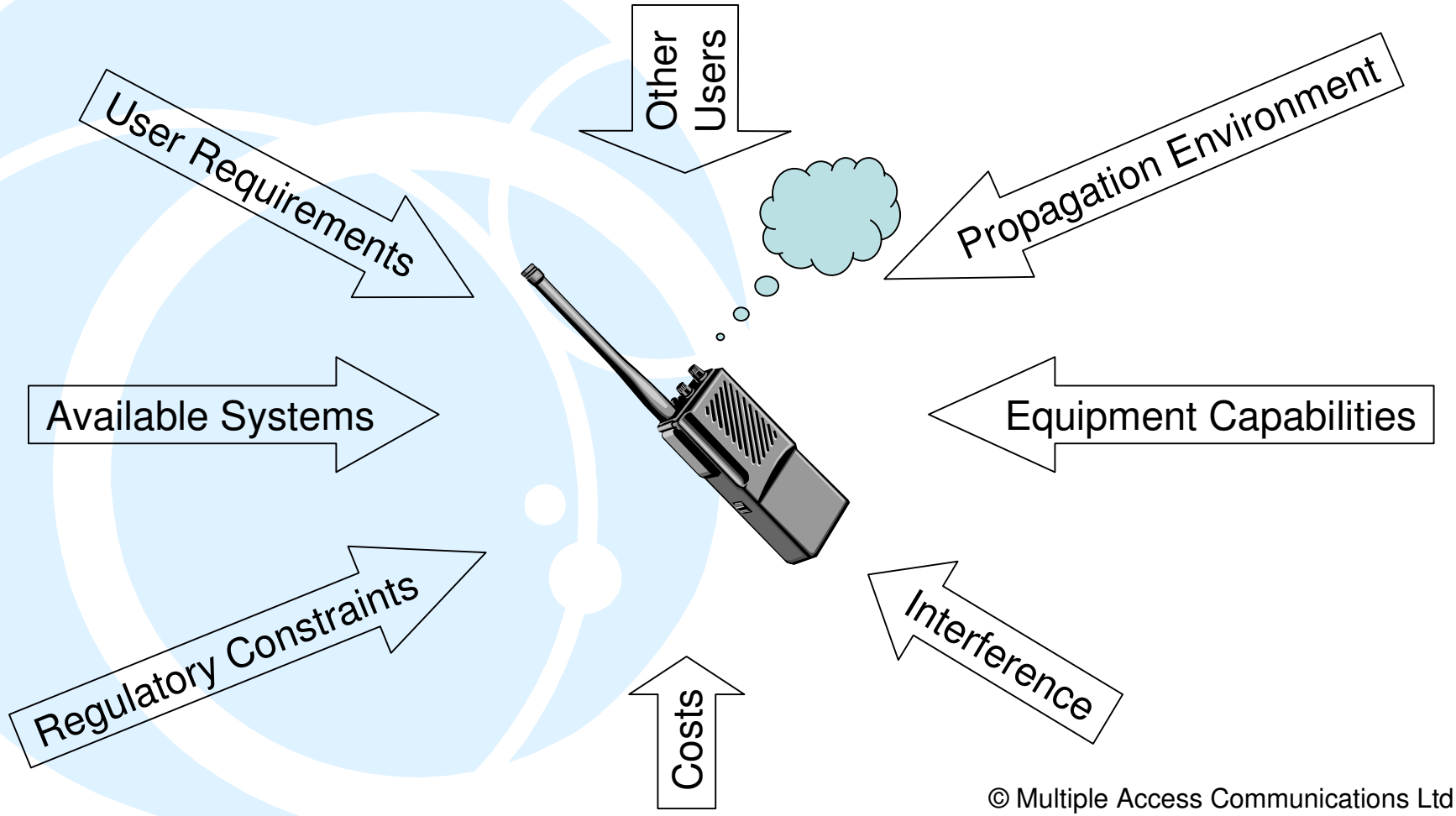
- MAC Ltd explored the concept of the 'Intelligent Multimode Terminal' for the Radiocommunications Agency (now Ofcom) in the early 1990's
- Recently formed part of a consortium to explore the Cognitive Radio technology for Ofcom under the Spectrum Efficiency Scheme (SES)
- Developed a system-level cognitive radio simulator as part of this project

Contents

- What is Cognitive Radio?
- Potential Benefits
- Possible Applications
- Sharing Scenarios
- Technical Hurdles
- Current Status

What is Cognitive Radio?

- In simple terms, a cognitive radio is a transceiver device that is able to understand and react to its operating environment



Mitola Definition

"the point in which wireless personal digital assistants (PDAs) and the related networks are sufficiently computationally intelligent about radio resources and related computer-to-computer communications to detect user communications needs as a function of use context, and to provide radio resources and wireless services most appropriate to those needs."

Joseph Mitola III, 'Cognitive Radio: An Integrated Agent Architecture for Software Defined Radio', Dissertation - Doctor of Technology, Royal Institute of Technology (KTH), Sweden

SDR Forum Definition

"a radio that has, in some sense,

awareness of changes in its environment

in response to these changes adapts its operating characteristics in some way to improve its performance or to minimize a loss in performance."

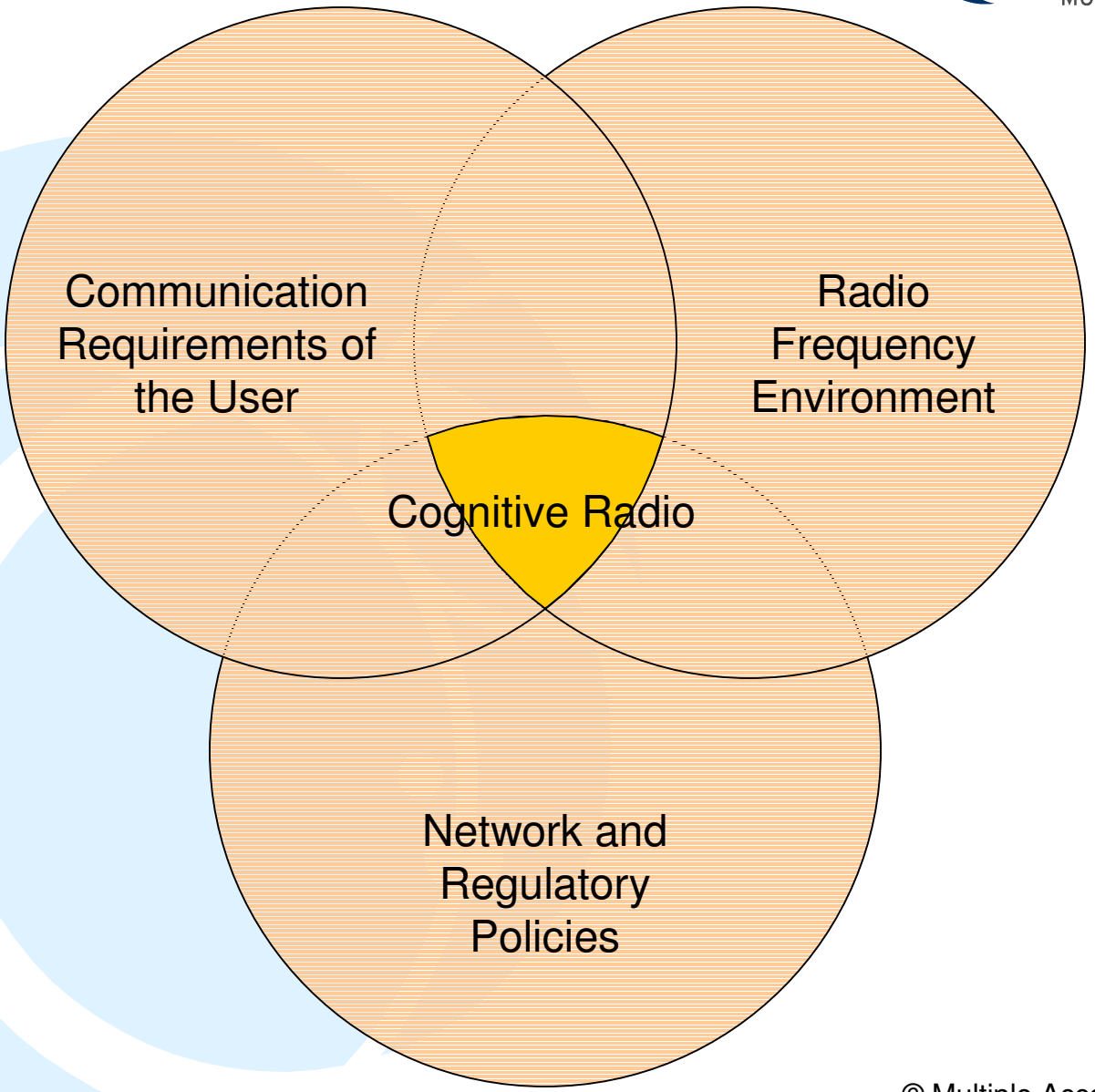
FCC Definition

"a radio that can change its transmitter parameters based on the environment in which it operates"

All Things to All People?

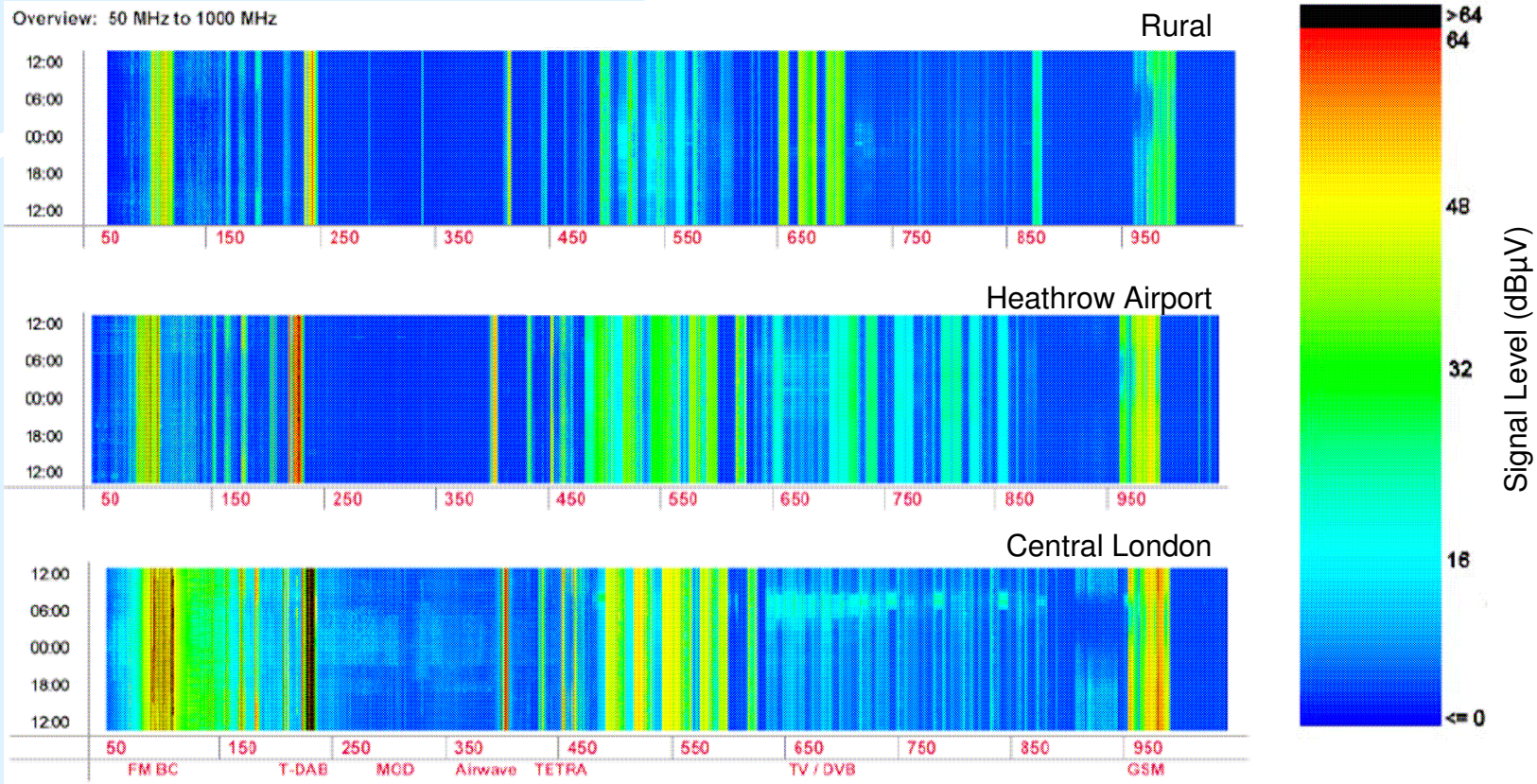
- There are many different types of device that can be considered to be a cognitive radio
- At one extreme we have an intelligent device that can reconfigure itself to interact with any radio network in the vicinity, depending on the requirements of the user, etc
- At the other extreme we have devices that can detect interference and change their operating frequency to avoid it
- Existing DECT cordless phones are an example of a very simple 'cognitive' radio (interference avoidance)

Key Elements



Potential Benefits

- Spectral occupancy measurements consistently show that some bands are under-utilised in some areas at some times



From Ofcom Web Site - http://www.ofcom.org.uk/research/technology/research/emer_tech/cograd/

Potential Benefits

- Increase in the utilisation of radio spectrum (use of spectrum holes/white spaces)
- Means for spectrum holders to exploit their valuable asset (sub-licensing)
- Supports new business models not tied directly to spectrum availability
  - Cellular spectrum has an eight-year horizon
- Facilitates spectrum trading (both at a macro and micro level)

Potential Benefits

- Expansion in the capacity of critical communications networks in emergency scenarios
- Make higher data rate services available to users
- Offer enhanced coverage to the user
- Facilitate more extensive device roaming than we see today
- Decrease the need for centralised spectrum management

Possible Applications

- Non real-time applications (eg, mobile multimedia downloads, email)
- Broadband wireless networking in hotspot locations
- Localised wireless multimedia distribution networks
- Priority emergency communications

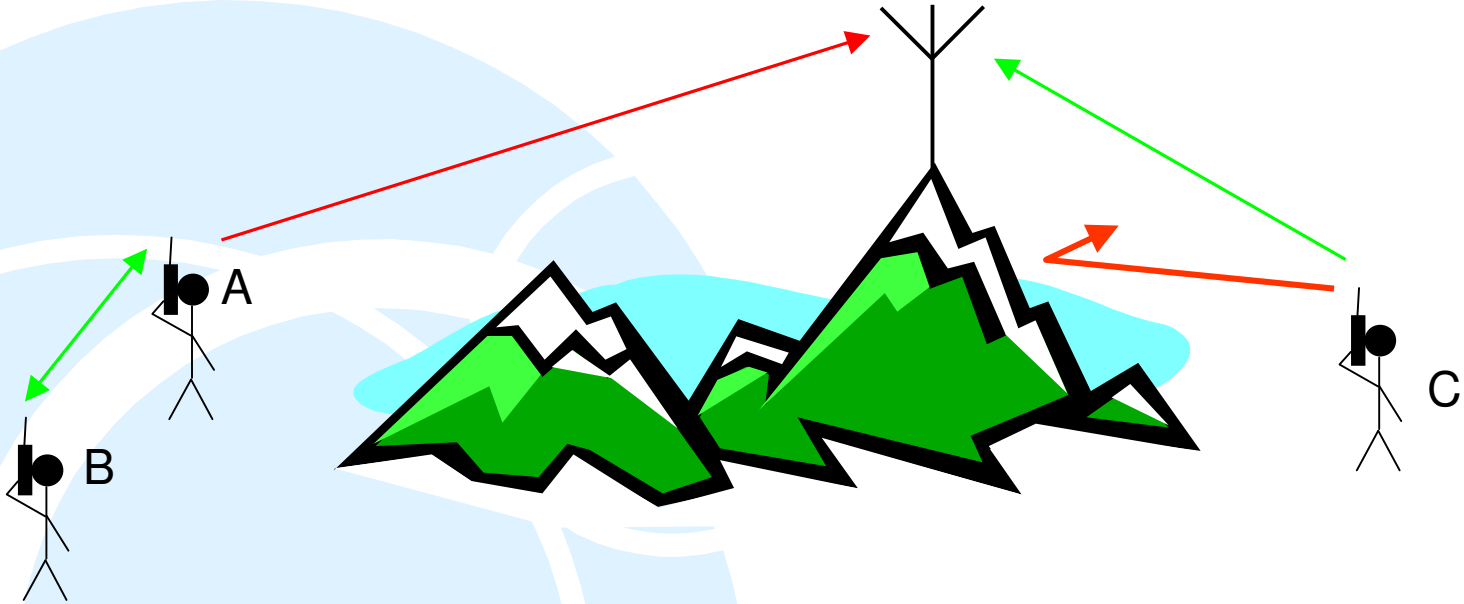
Sharing Scenarios

- Some Possible Bands
  - Analogue land mobile radio (148 – 470MHz)
    - Existing activity relatively low
    - Existing base station locations relatively well known
    - Local spectrum sensing to avoid interference
  - Television Broadcast
    - Interleaved spectrum potentially would offer national coverage
    - Transmitter locations well known
    - Local spectrum sensing to avoid interference
  - Radar
    - Consumes large amount of spectrum
    - Possibility of sharing spectrum when radar is pointing in different direction
    - Sophisticated sensing/synchronisation mechanism required
    - Data of radar locations also required

Technical Hurdles

- Protecting primary users (the 'hidden node' problem)
- Control mechanisms
- Spectrum mobility
- Regulation

The Hidden Node Problem



Users A and B cannot hear User C, so they think it is safe to transmit on User C's frequency. BUT, they cause interference to User C at the intended receiver

Hidden Node - Solutions

- Location-based restrictions
- Improved transmitter detection using a knowledge of the transmitted signal (matched filter, cyclostationary feature detection)
- Cooperative detection
- Separate distributed spectrum sensing networks

Control Mechanisms

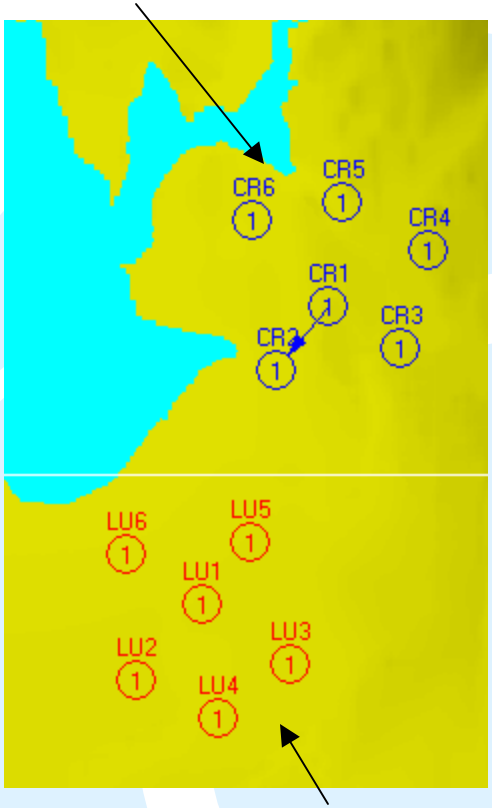
- Centralised or distributed control?
- Selecting optimum communications parameters
- Common control channels to negotiate initial bands
- Overlay or underlay spectrum sharing approach?
- Ensuring a fair allocation of resources (unlicensed bands)
- Access cost negotiation/micro-trading (licensed bands)
- Dealing with different propagation losses in different bands

Spectrum Mobility

- Fast primary user detection
- Fast negotiation of new band and spectrum handover
- Use of pre-assigned fall-back spectrum
- Use of multiple simultaneous bands
  - Benefit of lower power per band
- Management of higher layer protocols during spectrum handover

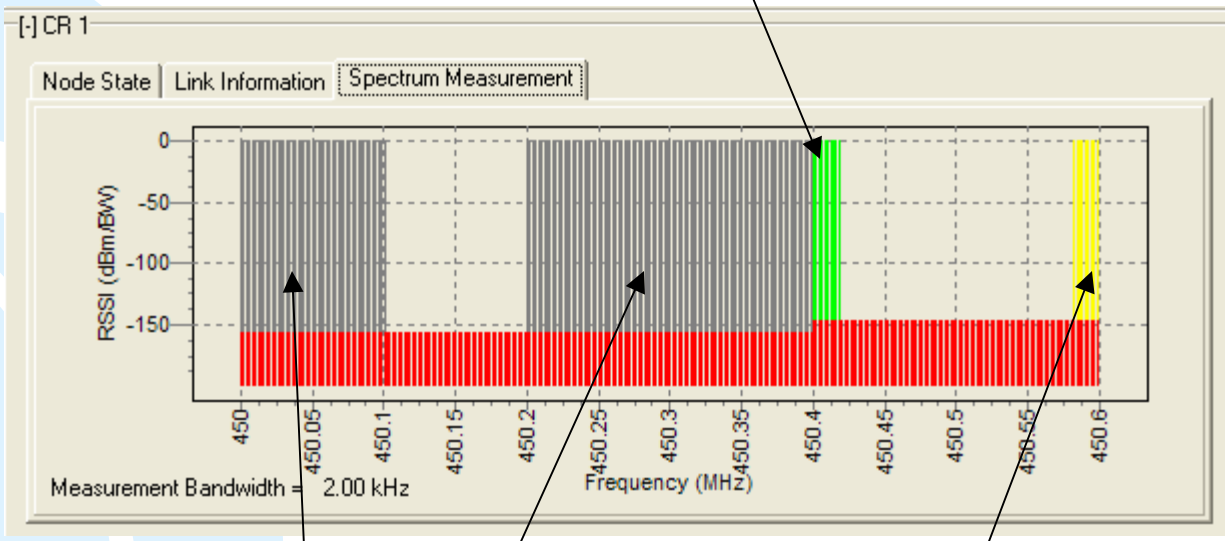
Spectrum Mobility – Example

Cognitive (Secondary) Users



Legacy (Primary) Users

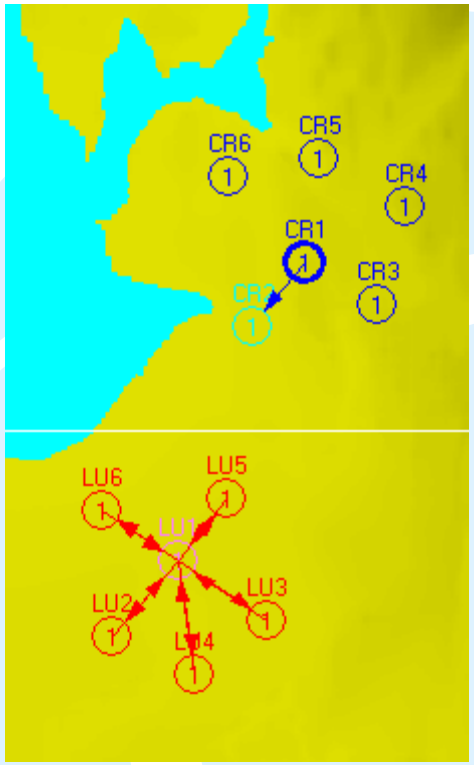
Main Channel

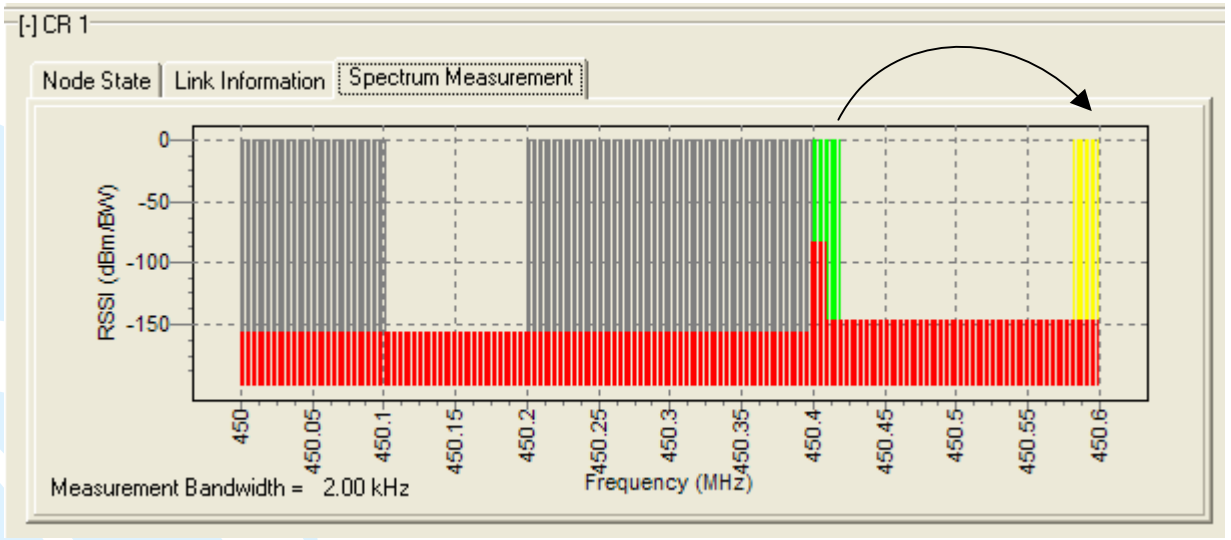


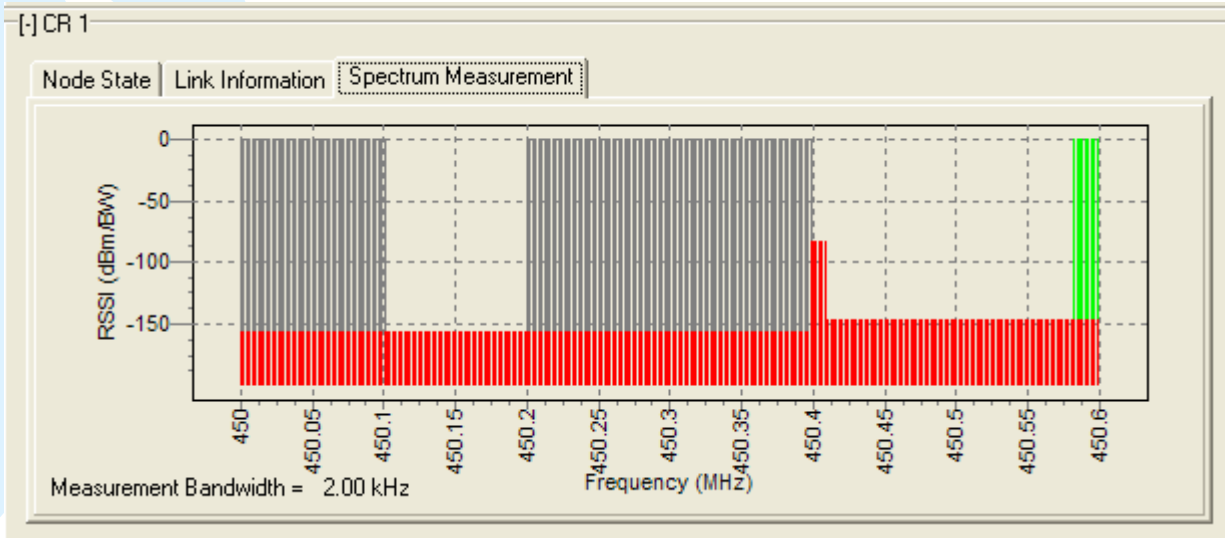
Forbidden Bands

Fallback Channel

Spectrum Mobility – Example







Regulation

- Challenges
  - Flexible devices with the ability to operate in a range of different frequency bands
  - Don't necessarily need a fixed infrastructure to operate
  - Available frequency bands will change from country to country
- Potential Solutions
  - Location-aware nodes with access to central regulatory database
  - Internationally agreed bands of operation
  - Local 'beacons' broadcasting regulatory information

Some On-Going Initiatives

- IEEE1900
  - Standard definitions
  - Interference and coexistence analysis
  - SDR conformance
  - Air interface
  - Device certification
- DARPA xG
  - System demonstrated at DySPAN last year
  - Technology being integrated into military systems
- IEEE802.22
  - Working on standards for use of 'white spaces' in television band

Cognitive Radio Regulation

- Two key areas: Spectrum and Equipment
- FCC
  - Adapting regulations to accommodate software defined radio and cognitive radio
  - Dynamic frequency selection in radar bands
- ITU
  - Examining regulatory issues associated with cognitive radio for consideration at WRC-11

Conclusions

- Cognitive radio is a promising technology that can significantly enhance the utilisation of radio spectrum
- It has the potential to facilitate new spectrum trading approaches and business models
- Limited cognitive radios are in operation today
- Intelligent reconfigurable cognitive radios are likely to emerge over the next five years
- There are still some significant technical and regulatory challenges to be met before widespread deployment can take place
- Fully adaptive cognitive radios are still some way off