NETWORK TECHNOLOGIES AND STRATEGIES research group

A Survey of Dynamic Spectrum Access

Signal processing, networking, and regulatory policy

Journal Club 2009-10
Session 1

Jelena Skulic
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Motivation

- huge number of WSN nodes that increases every day
- available frequency spectrum is limited and tends to be overcrowded
- best way to achieve high throughput is to address spectrum problem
- to make possible existence of overlapping WSNs
- to address interference problem and decrease number of collisions

Current situation with WSNs:

WSNs can use following spectrum:

- band between **(868-915)MHz**
(higher coverage, smaller power is used, small bit rate)

- **ISM** band on **2.4 GHz**
(interference, smaller coverage, higher power, higher bit rate)

Article Reference

Q. Zhao and B.Sadler

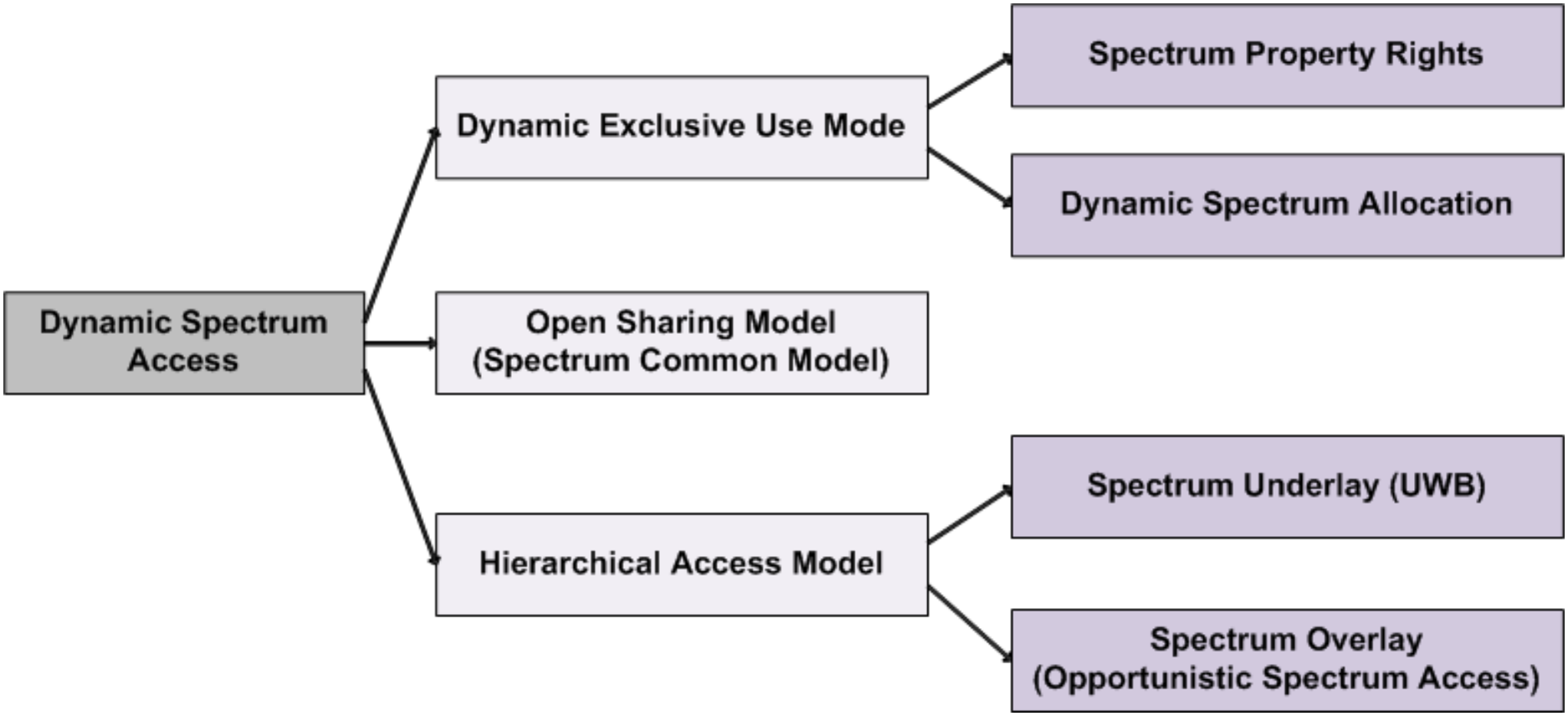
"A Survey of Dynamic Spectrum Access"

IEEE Signal Processing Magazine, Vol. 24 No 3

pp. 79-89, May 2007

Introduction

- as prize of spectrum reaches unbelievable sums the question imposes by itself: We are approaching spectrum capacity limit ?
- majority of time allocated spectrum lies idle !
- shortage of spectrum is provoked with bad management policy !


Dynamic Spectrum Access
Dynamic Exclusive Use Mode
Spectrum Property Rights
Dynamic Spectrum Allocation
Open Sharing Model (Spectrum Common Model)
Hierarchical Access Model
Spectrum Underlay (UWB)
Spectrum Overlay (Opportunistic Spectrum Access)

Dynamic Spectrum Access

- dynamic spectrum access vs. dynamic spectrum allocation
- spectrum property rights vs. spectrum commons
- opportunistic spectrum access vs. spectrum poling
- spectrum underlay vs. spectrum overlay
- cognitive radio != dynamic spectrum access

Dynamic exclusive use model

- based on current static spectrum management policy
- spectrum bands are licensed to exclusive users
    - **spectrum property rights**
        - licensees are allowed to trade with spectrum and freely choose technology
    - **dynamic spectrum allocation**
        - spectrum is dynamically assigned to the users, taking into account spatial and temporal traffic statistic of different services
- those models are not able to eliminate white space in spectrum

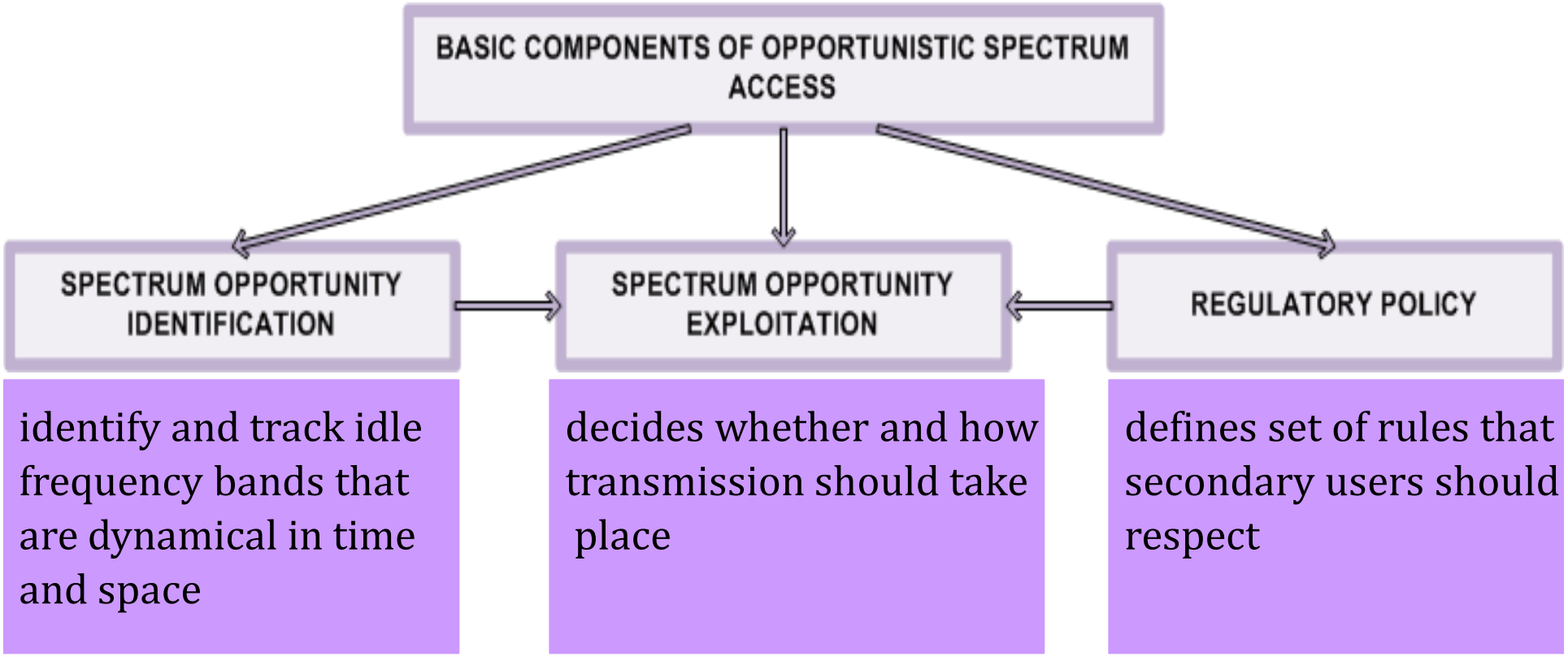
Open sharing model (*spectrum commons*)

- specter is managed by open sharing between peer users
- can be centralized and distributed
- technologies that are working in ISM band (WiFi, Bluetooth)were motivation

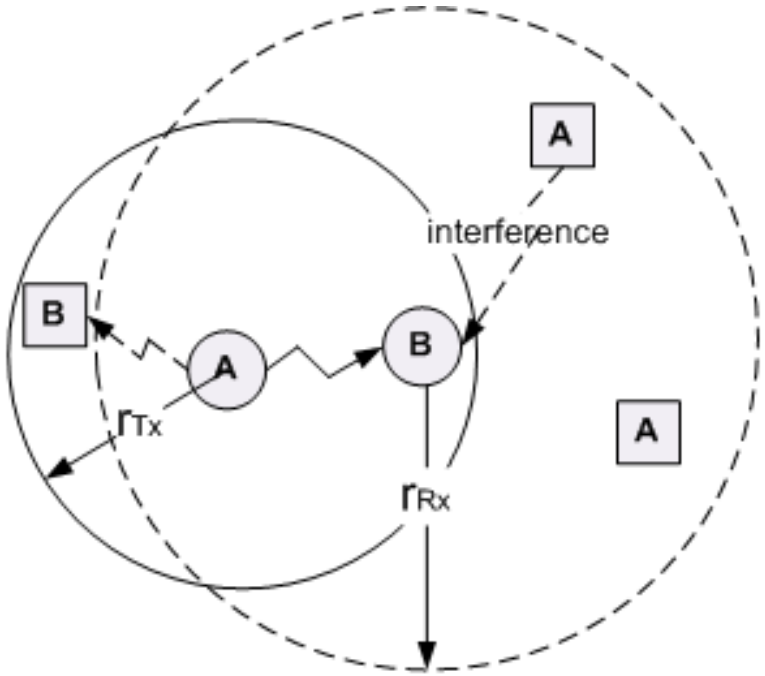
Hierarchical Access Model

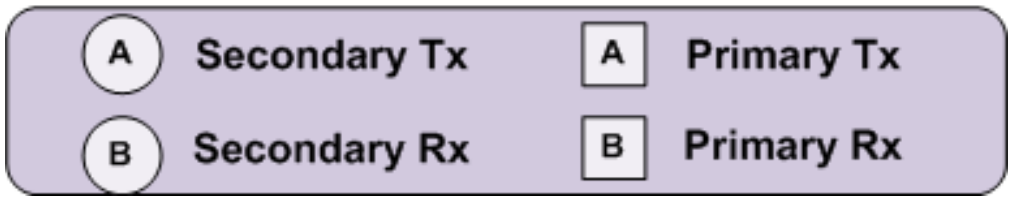
- licensed spectrum is being opened for the secondary users, while interference they are creating for the primary users is controlled
  - **spectrum underlay approach**
    - transmission power of secondary users is severely limited
    - they have to operate under noise floor of primary users
    - their signals are spread (UWB), range is short, data rate is high
    - no detection, no exploitation of spectrum white space
  - **spectrum overlay approach**
    - transmission power of secondary users is not constraint
    - but where and when they may transmit is important issue
    - spectrum white space are targets

Opportunistic Spectrum Access



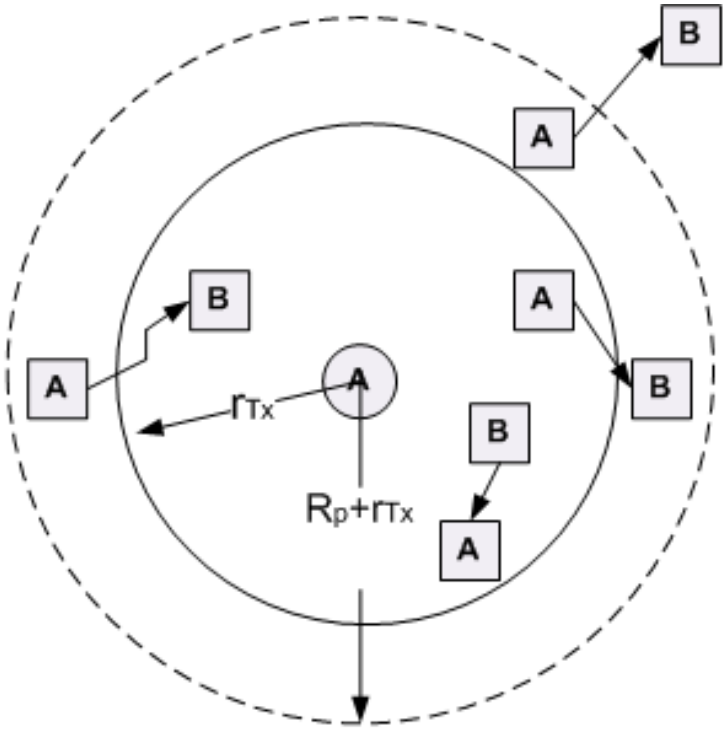
Spectrum Opportunity

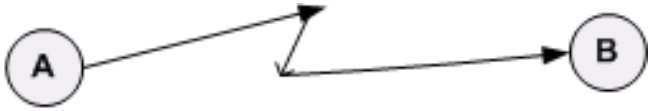




Channel is opportunity if primary users are not using it currently. Here, it refers that secondary users A and B can communicate over the channel, while their interference is below threshold prescribed by regulatory policy (A will not interfere with primary Rx, and B will not interfere with primary Tx). Non of primary users within r_{Tx} is receiving, and non of primary users within r_{Rx} is transmitting -> **channel is opportunity**.

Spectrum Opportunity Detection





1. A checks weather channel is available

2. A → RTS →

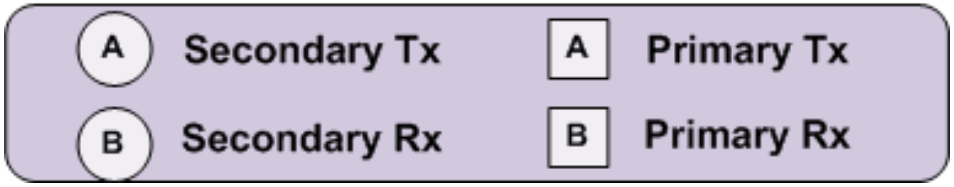
3. ← CTS ← B

4. opportunity detection -. finished

PRIMARY USERS DETECTION

Rp- primary user transmission range

A : " channel is available if no " A is detected within distance of Rp+rTx



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Spectrum Opportunity Tracking

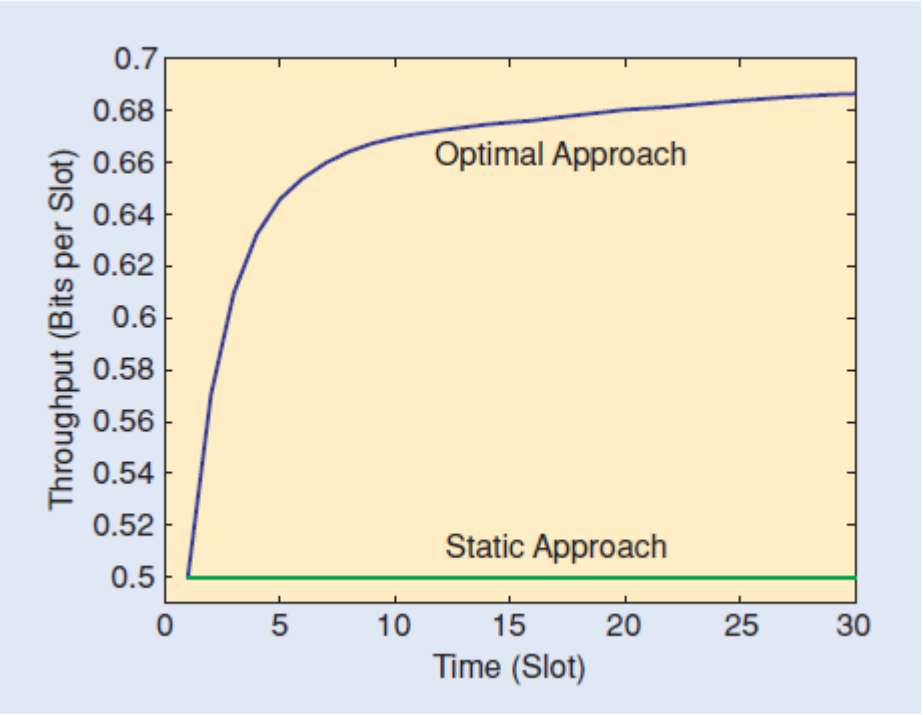
strategy:

Use a spectrum opportunity for immediate access and obtain statistical information of its occupancy, to make profit for future sensing decisions. In static approach it would just choose channel that is most likely to be free.

trade-off

Immediate access in the current slot or system state information for future

40% improvement over static approach

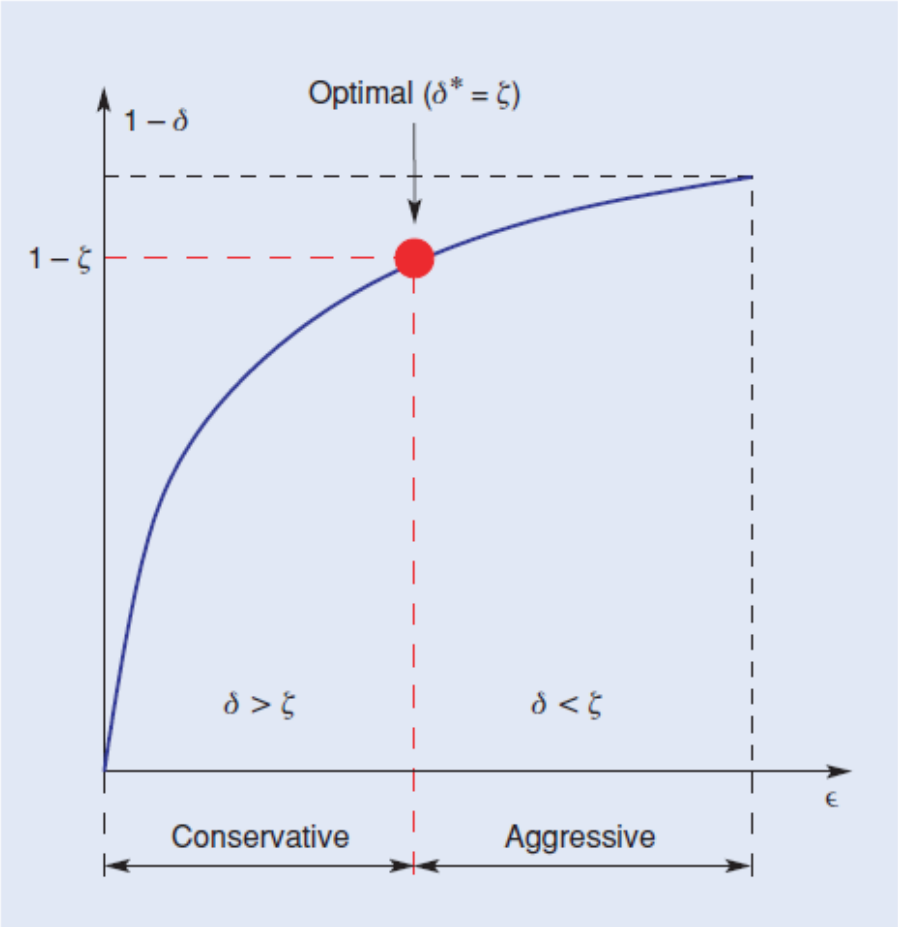


Spectrum Opportunity Exploitation

- **whether to transmit** (due to eventual opportunity detector mistakes)?
- what **modulation** to use?
- what **transmission power** to use?
- how to **share opportunities among secondary users**?
  (to achieve optimal results in network)

Whether to access spectrum ?

How much and when to trust to the detector ?



conservative

Busy channel is often estimate as idle, access policy should be conservative to suppress additional collisions

aggressive

false alarms are not rare, policy should be aggressive to decrease number of missed opportunities

optimal

detector is totally reliable

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How to access ?

- most convenient modulation type is OFDM , because secondary users should fill gaps in the spectrum, left behind primary users.

- if secondary transmitter A can detect primary receivers within range d:

$$P_{Tx} \leq \eta d^{\alpha}$$

η - maximum interference level allowed

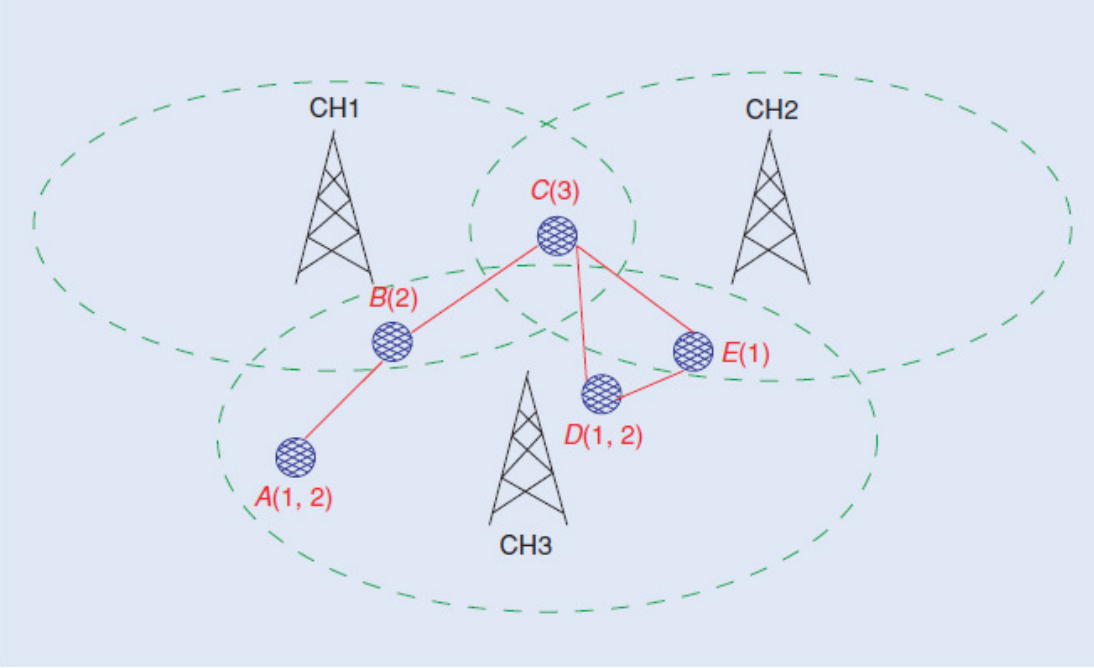
α - path attenuation factor

- if secondary user can detect primary transmitters within range d:

$$P_{Tx} \leq \eta (d - R_p)^{\alpha}$$

R_p – transmission range of primary users

Opportunity Sharing Among Secondary Users



- secondary user and primer user within its area can't use the same channel
- secondary users interfere with each other if they try to access the same channel
- spatial opportunity allocation is equivalent to graph coloring

Regulatory Policies

- when detection errors are possible, the access strategy need to decide how much and when to trust the spectrum detector
- policies must be implemented on radio devices
- it's desirable to have policy reasoned (PR)
- PR imposes constraints to radio, that should be satisfied, in order to transmit successfully (e.g. transmit power and duration limits)

Conclusions

- there are numerous problems to be overcome
- opportunistic spectrum access will be the pioneering technique that addresses the very core of spectrum problem, while all the rest have been dealing with its outcomes
- this technique, together with MIMO and WSNs is likely to be hot topic in the Wireless Networks in the following ages

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