Spectrum Sensing Techniques in Cognitive Radio Networks

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Presentation Outline

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- Dynamic Spectrum Access
- Cognitive Radio Network
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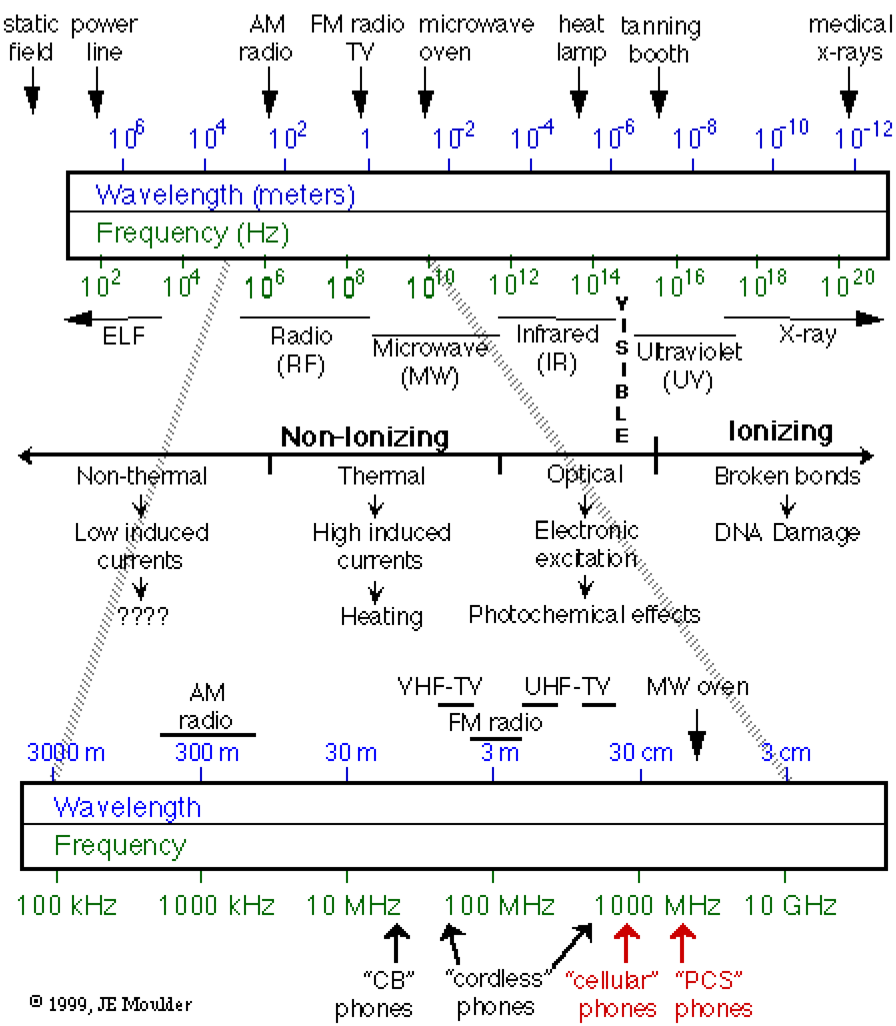
Introduction

The electromagnetic spectrum

Spectrum is not actually a thing. It is simply the range of possible frequencies for electromagnetic radiation.



Spectrum scarcity

- Control structure of frequency allocation
  - Fixed amount of spectrum **versus** growing number of wireless applications/users
  - License holders maintain exclusive rights to their allocated spectrum
    - Purchased during a spectrum auction
    - Allocated via government decree, e.g., military, television
- Inefficient spectrum management

Static spectrum allocation regardless of its usage has led to scarcity of the spectrum. However, various research groups have shown that only 25% of the spectrum is well utilized in most of the spectrum bands, and the spectrum scarcity is the result of the inefficient spectrum management

2 Dynamic Spectrum Access

Dynamic Spectrum Access

- Dynamic spectrum access methods are introduced as a solution to the problem of the scarcity of spectrum.

- We can categorize these methods based on the regulatory status:
  - Dynamic licensing: The rights of using the spectrum band is given exclusively to a network operator for a specific period of time.
  - Dynamic sharing: The rights of use the spectrum band is given to more than one network operator at the same time.
  - There are two types of dynamic spectrum sharing, namely:
    - Horizontal sharing
    - Vertical sharing (Cognitive Radio)

3 Cognitive Radio Network

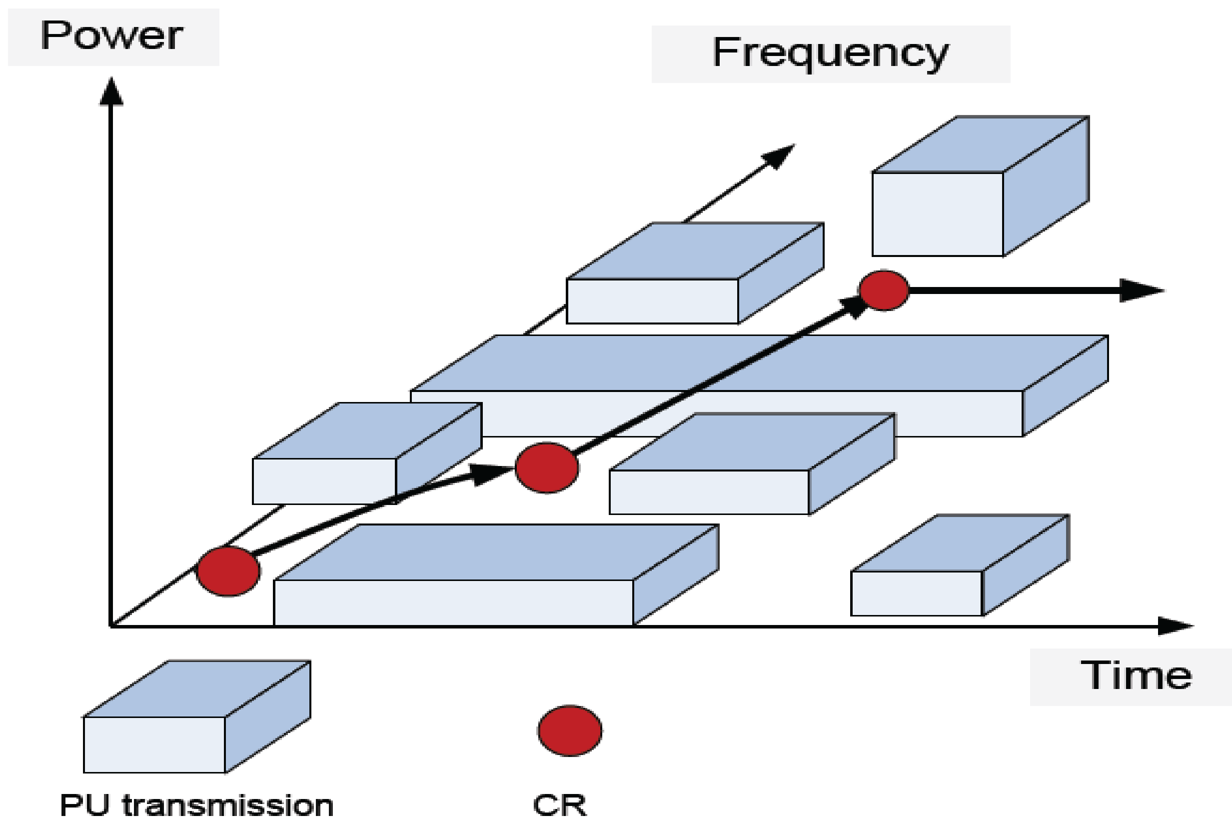
Cognitive radio Networks

- Cognitive radio network is a new paradigm that provides the capability to share or use the spectrum in an opportunistic manner.

- The cognitive radio networks (CRNs) is introduced to make use of parts of the spectrum, which are used sparingly and inefficiently, by operating unlicensed networks over the licensed spectrum bands.

- The licensed users are called primary users (PUs)
- The unlicensed users are called secondary users (SUs).

Concepts of a spectrum hole and opportunistic spectrum sharing



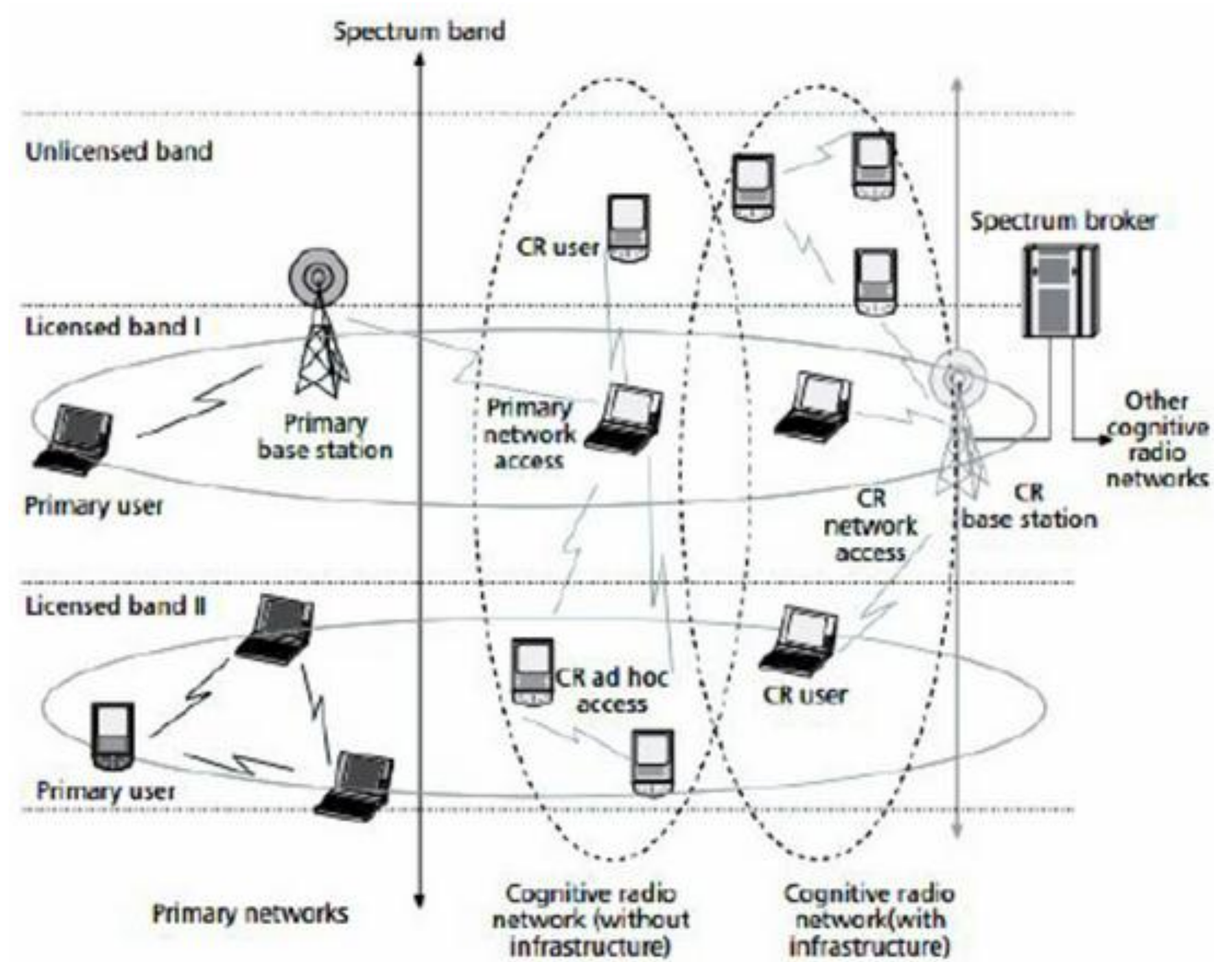
4 Cognitive radio network architecture

Components of CRN

The cognitive radio networks (CRNs) basically deploy in a primary network, therefore, their components have to serve the requirements of both licensed and unlicensed applications. The basic components of CRNs are:

- Primary network:
  - Primary users: Primary users have the license to operate in certain spectrum bands
  - Primary base station: Controls the access of primary users to spectrum
- Secondary network:
  - Secondary users: Secondary users have no licensed bands assigned to them.
  - Secondary base-station: A fixed infrastructure component with cognitive radio capabilities and provides single hop connection to secondary users.
  - Spectrum broker: Scheduling server shares the spectrum resources between different cognitive radio networks.

Cognitive radio architecture



5 Functionalities

Functionalities of a CRN

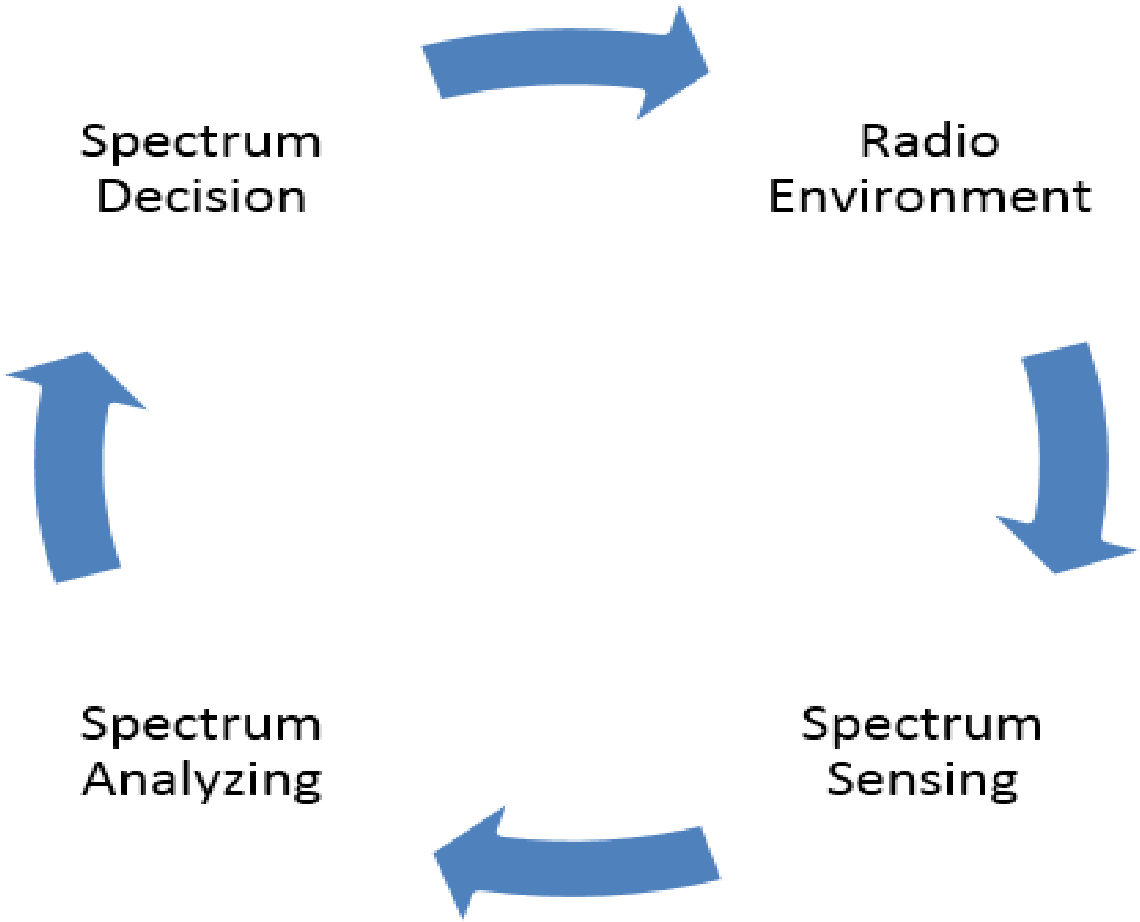
- **Spectrum sensing:** The ability to detect the unused spectrum at any time and location and sharing it without harmful interference with other users.

- **Spectrum management:** Spectrum analysis and spectrum decision.

- **Spectrum mobility:** CR user shall vacate the spectrum in the presence of any primary user and move to next best available spectrum band.

- **Spectrum sharing:** CR network has to provide a fair and optimal spectrum allocation method among multiple CR users.

Cognitive Radio operation



6 Spectrum Sensing

Spectrum sensing

- Spectrum sensing imperative to the primary and secondary users.
- The secondary users have to abandon that channel when the primary users are detected.

- When the secondary users detect the presence of a primary user which is in actuality not there, it is referred to as false alarm.
  - Probability of false alarm must be minimum

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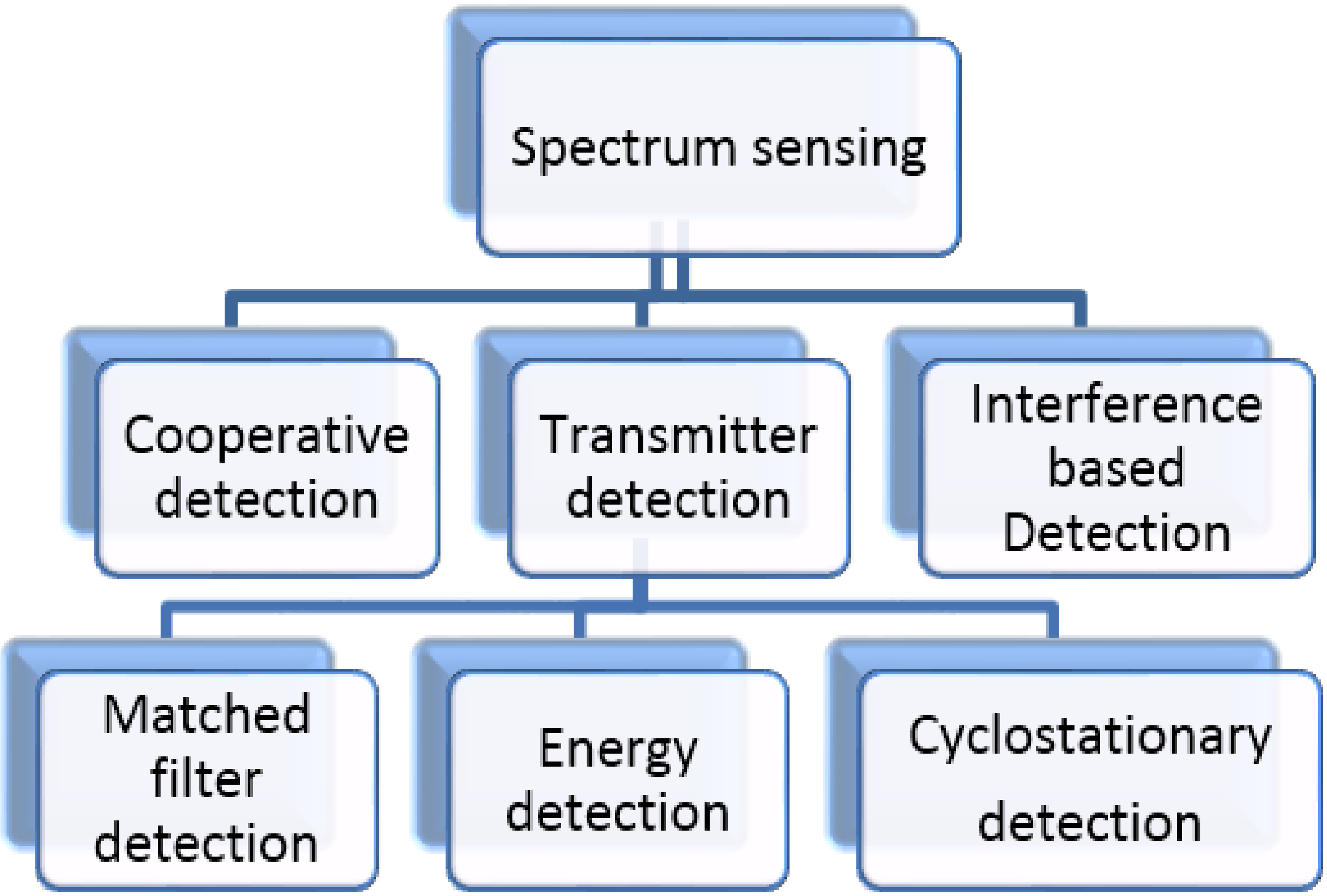
Spectrum Sensing Techniques

Spectrum sensing techniques

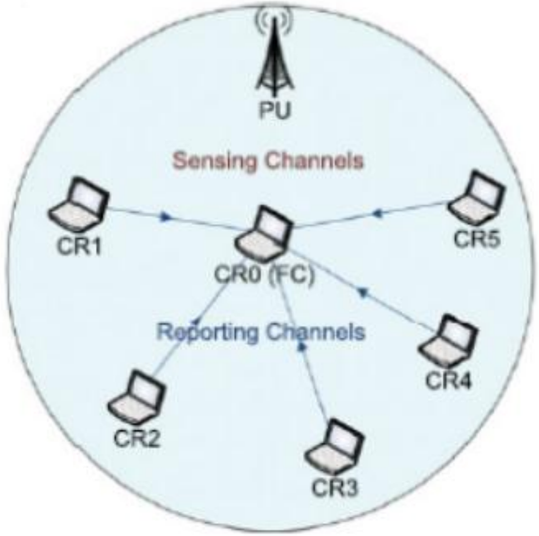


Cooperative sensing

- Information combined from multiple cognitive radio users for primary user detection.
- By cooperation, CR users can share their sensing data for making a combined decision more precise than the individual decisions.
- The main idea of cooperative sensing is to improve the sensing performance by abusing the spatial diversity in the observations of spatially located CR users.
- Cooperative spectrum sensing is classified into three categories based on how cooperating CR users share the sensing data in the network:
- *Centralized.*
- *Distributed.*
- *Relay-assisted*.

Cooperative sensing

- In centralized cooperative sensing: Central Manager (BS or AP) collects CR sensing data and makes a decision on channel state, i.e. idle or busy.

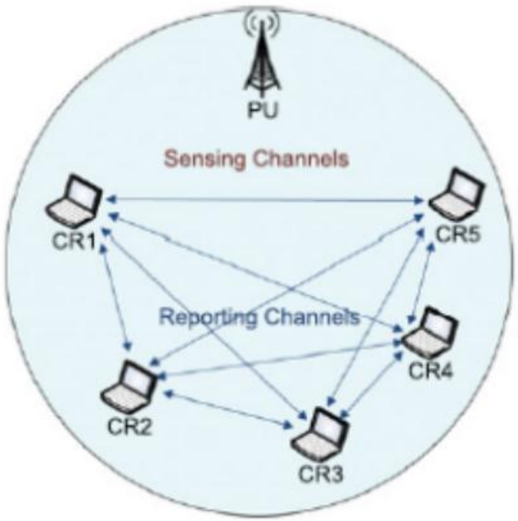


Pros and Cons:

- High cost of transmission sensing data.
- If the Central Manager fails, the network will fail.

Cooperative sensing

- In Distributed (Decentralized) cooperative sensing: Each CR makes decision itself.

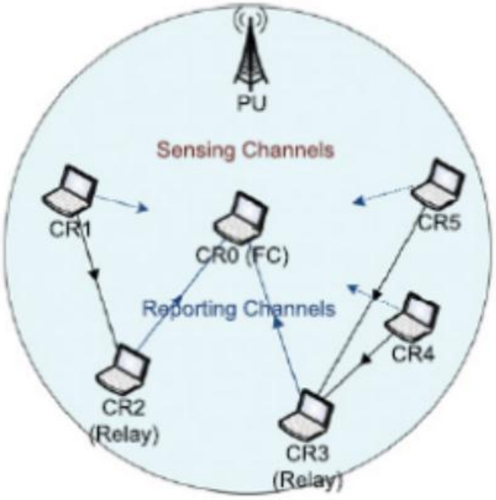


Pros and Cons:

- May take several iterations to reach the unanimous cooperative decision.
- Increased sensing reliability at the expense of increased communication overhead.

Cooperative sensing

- In relay-assisted cooperative sensing: It can be considered as multi-hop cooperative sensing. When the sensing results need to be forwarded by multiple hops to reach the intended receive node, all the intermediate hops are relays.



Pros and Cons:

- The relay-assisted cooperative sensing incurs extra reporting delay because the sensing data is transmitted through multiple hops.

Transmitter Detection

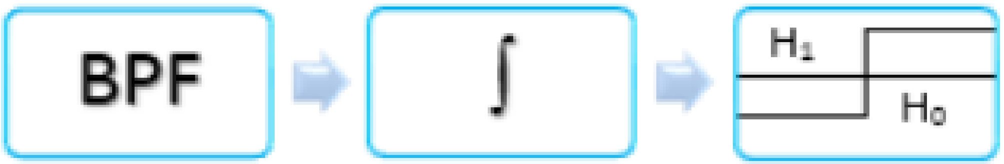
- By this way, the sensing depends on signal received at secondary users from primary users.

- Examples of this approach are:

  - Energy detection
  - Matched filter (MF)

Energy Detection

- By this approach, we compare between the energy of radio resource and predefined threshold level.
- In case the energy level is above of threshold level, it's considered as occupied. While when the energy is less than of threshold level, it's considered as unoccupied.



$$H_0: \quad y(n) = w(n) \quad \ldots\ldots \quad 1$$

$$H_1: \quad y(n) = s(n) + w(n) \quad \ldots\ldots \quad 2$$

H_0: The channel is idle, there is no PU signal

H_1: The channel is occupied, there is PU signal

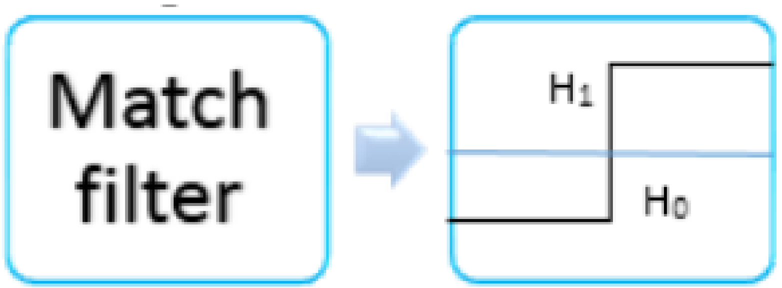
w(n): Noise

s(n): PU signal

y(n): Measured signal

Matched Filter detection

- This method is easier to make a decision about the presence of the signal of primary users or not.
- In this method, the signal passes through a filter Designed specifically to maximize the useful signal and minimize the noise at the same time.
- Therefore, in the case of presence the signal of primary user, it will be a large difference between the useful signal and noise.
- While in the case the primary user is absent, no such large difference will appear.



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Challenges

Challenges in spectrum sensing

- Needs to high efficiency hardware requirement.
- Hidden primary user problem.
- Decision fusion in cooperative detection.
- Detection capability: Very necessary to detect the primary user (Pus) in a very short time.
- The required SNR for detection may be very low.
- Primary users' detection in spread spectrum.
- The noise.
- Security issues.

THANK YOU

References

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