

# Review Paper on Spectrum Sensing in Cognitive Radio

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**Abstract – Cognitive Radio has become more prominent technology over time for the solution of spectrum scarcity problem in wireless communication. It is hard to imagine life without wireless applications and wireless devices. This results into increase in number of users requiring access of wireless system and services but wireless spectrum is limited, which leads to spectrum scarcity. To overcome these issues Cognitive Radio (CR), a wireless system is designed that communicate in an efficient and reliable manner by sensing the environment. This paper presents the spectrum sensing techniques.**

**Index Terms – Cognitive Radio, Spectrum, Scarcity, Communication.**

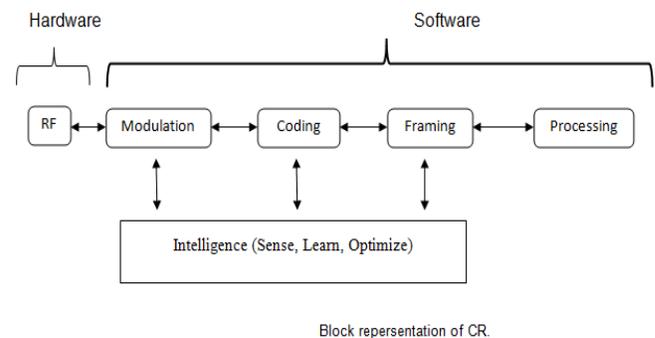
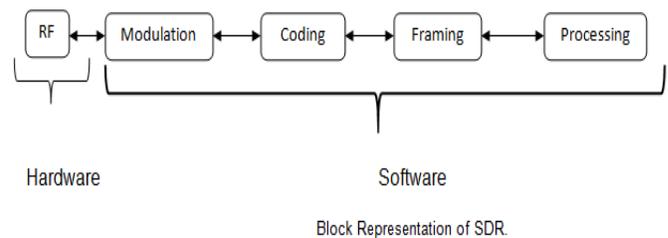
## 1. INTRODUCTION

The concept of cognitive radio was first presented officially article by Joseph Mitola III and Gerald Q. Maguire, Jr in 1999 [1,2].According to Mitola “CR as a radio capable of analysing the environment, learning and predicting the most suitable and efficient way of using the available spectrum. SDR- Software defined radio were the confined softwares which were capable of handling the emerging technologies of radio.

## 2. CR vs. SDR

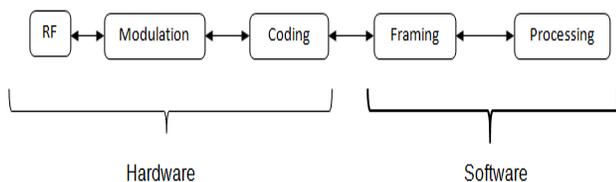
The term SDR coined by Mitola in 1992. SDR is a reconfigurable radio system in which radio parameters. SDR support broad range of frequencies, air interfaces, application software and has ability to change initial configuration to satisfy user requirements [3]

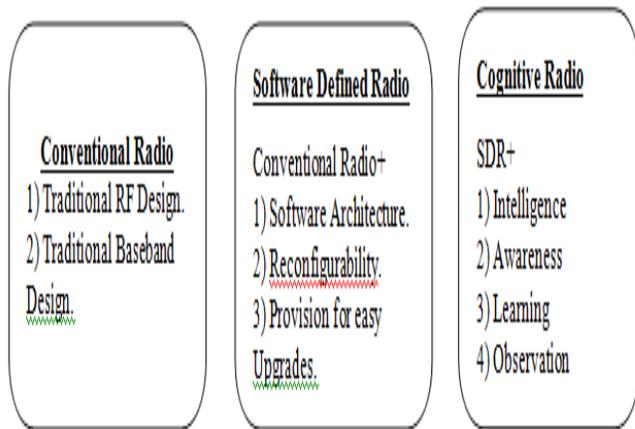
CR is built on SDR platform and can sense and react to environment changes. CR not only offer dynamic spectrum access but also provides ability to reconfigure its parameter according to changing environment conditions [3].



<p><b>Conventional Radio</b></p> <ol style="list-style-type: none"> <li>1) Support fixed no. of systems.</li> <li>2) Reconfigurability decided at time of design.</li> <li>3) May support multiple services, but chosen at the time of design.</li> </ol>	<p><b>Software Defined Radio</b></p> <ol style="list-style-type: none"> <li>1) Dynamically support multiple variable system, protocols, and interface.</li> <li>2) Provide a wide range Of services with variable QoS.</li> </ol>	<p><b>Cognitive Radio</b></p> <ol style="list-style-type: none"> <li>1) Adjust operation to meet the QoS required by application for signal environment.</li> <li>2) Can create new waveform on its own.</li> <li>3) Can negotiate new Interfaces.</li> </ol>
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Application based comparison of Conventional radio, SDR and CR.





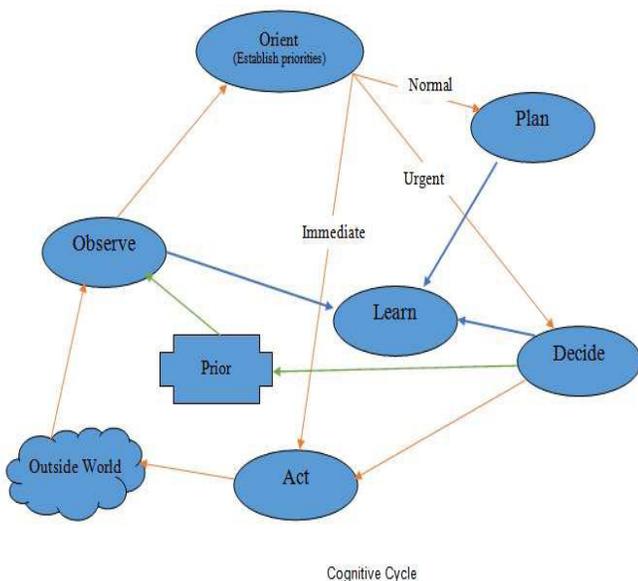
Design based comparison of Conventional Radio, SDR and CR.

### 3. COGNITIVE RADIO

CR architecture is based on fundamentals design rules by which sensors, Autonomous Machine Learning and SDR may be integrated to create a aware and adaptive system. To provide fundamental cognitive capabilities CR architecture is integrated with machine learning. Fundamental capabilities require to observe (sense, perceive), to orient, to plan, to decide, to act and to learn.

These capabilities are shown by a sequence of events called cognitive cycle

**SPECTRUM HOLE:** Lower frequency band is highly utilized and at higher frequency spectrum utilization is poor. This poor spectrum utilization is termed as spectrum hole. CR search unoccupied frequency band and allocate it to opportunistic user.



Cognitive Cycle

In radio spectrum frequency band are classified in three categories:

- Black Space: occupied by high power interferers and should always be avoided.
- Grey Space: partially occupied by low power interferes.
- White Space: free band only noise may present

Spectrum hole can be classified in two categories:-

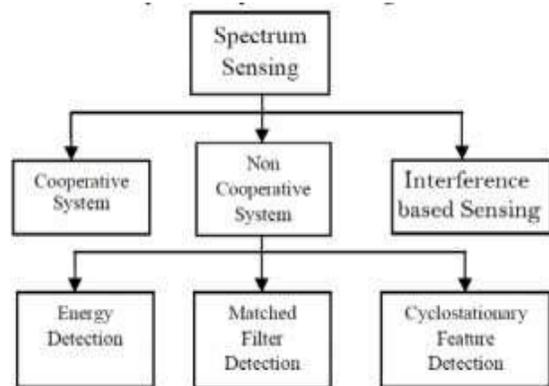
- Temporal Spectrum hole: A temporal spectrum hole i.e. time based, occurs when no PU signal is detected in specified band of frequency over a period of time.
- Spatial Spectrum Hole: A spatial spectrum hole i.e. space based, is generated when the PU transmissions is limited to a certain area

The main challenge of cognitive radio is the spectrum sensing which need to detect spectrum holes in radio environment for secondary users.

### 4. SPECTRUM SENSING

The main function of spectrum sensing is to sense the availability of the free spectrum. At times when PU's are not using the defined bandwidth then if the availability of the spectrum is sensed it can be utilized effectively.

We have various techniques to sense the spectrum [4].

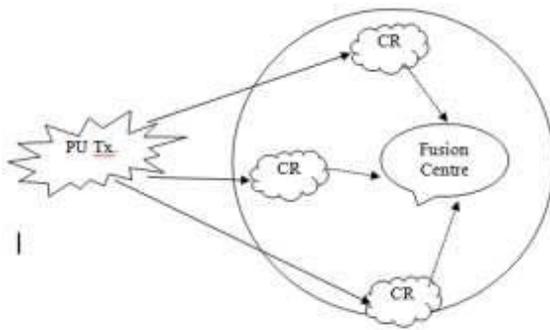


### 5. COOPERATIVE SENSING

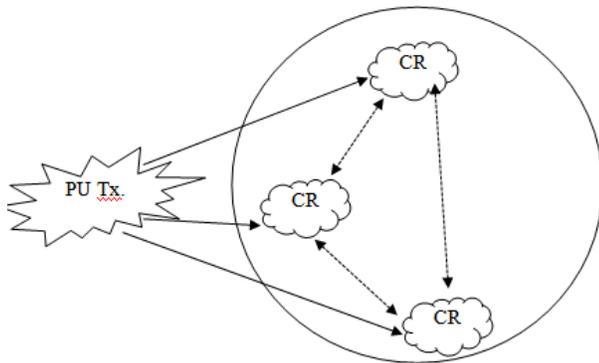
Decision about presence or absence of PU is made on the basis of sensing information provided by other SU/CR users present in same network, having stronger PU signal.

We have various techniques of cooperative sensing such as:-

Centralized and Distributed sensing Decision is based up on local environment sensing by different SU/CR users [5, 6]. This spectrum hole information is conveyed to all participating CR's

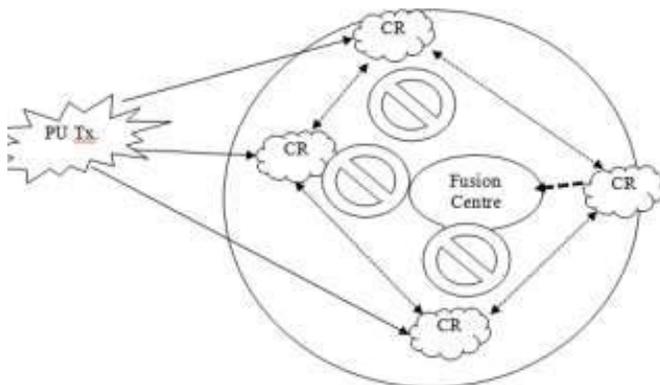


Centralise Cooperative SS



Distributed Cooperative SS.

Cooperative Sensing using relay Some receivers (CR1, CR2 and CR3) have strong SC(sensing channel) but weak RC(reporting channel) and some receivers have strong RC and weak SC.



Relay assisted cooperative SS.

In such situations CR having weak RC, sensing information to FC is transmitted via intermediate CR, these CR work as a relay. This scheme is called SS using relay [36].

### Single-Hop and Multi-Hop Sensing

In single hop there is direct one to one link between PU and Su i.e. sensing information are directly available to SU.

In multi hop scheme sensing data reaches the intended SU through multiple hops, all the in-between CR act as relays.

### 6. NON-COOPERATIVE SENSING

In Non-Cooperative sensing, Cognitive Radio works on its own, it does not have coordinate with the other side of the channel in case of sensing the channel. Energy Detection

Energy of received signal is compared with predetermined threshold to make decision about spectrum occupancy.

Energy detection decide among two hypotheses H0 and H1 by comparing  $T(y)$  with predefined threshold voltage  $\lambda$  as

$$T(y) \geq \lambda \Rightarrow H1$$

$$T(y) < \lambda \Rightarrow H0$$

If threshold  $\lambda$  is low,  $P_f$  increases which result into poor spectrum utilization and a higher value of  $\lambda$  leads to higher  $P_m$  which in turn cause increase interference.

o Cyclostationary Feature Detaection signals to be transmitted is coupled with high frequency carrier, spreading sequence or hopping sequence etc.

This make signal cyclostationary, cyclostationary means certain statistical properties of signals repeats itself after a period of time.

o Coherent Sensing

Matched filtering and waveform based sensing are example of coherent detection SS techniques.

Matched filter Detection

Matched filter detection [7] is an optimal approach as it offers maximized SNR at output. The output of matched filter is compared with a predefined threshold to decide PU is active or inactive. It require prior knowledge.

Waveform Based Sensing

This approach consists of correlates at receiving end which compare incoming signals with copy of signals already stored.

This approach is less complex [8]

### 7. CONCLUSION

This paper provides a broad idea about how a CR operates and the most important part of CR operation i.e. SS has been discussed. Spectrum Sensing techniques also have been discussed here briefly. Observing both cooperative and noncooperative we hence conclude that there is a wide scope in both the techniques. Although there are many challenges to be faced in both the techniques but they are good in their own way. As in non-cooperative sensing cyclostationary is consider to be powerful over others but if only problem that can be ignored

then it can be nice technique. As we know need of spectrum is going on day by day with enormous increase in the users of wireless communication. So this demand will go on increasing the need to sense and manage the spectrum will also be in demand.

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