INTRODUCTION

Cognitive Radio (CR) is relatively a new technology, which intelligently detects a particular segment of the radio spectrum currently in use and selects unused spectrum quickly without interfering the transmission of authorized users. Cognitive Radios can learn about current use of spectrum in their operating area, make intelligent decisions, and react to immediate changes in the use of spectrum by other authorized users. The goal of CR technology is to relieve radio spectrum overcrowding, which actually translates to a lack of access to full radio spectrum utilization. Due to this adaptive behavior, the CR can easily avoid the interference of signals in a crowded radio frequency spectrum [7].

According to a statistical analysis, the spectrum utilization by the licensed users is as low as 15%. Thus, the licensed spectrum is seen to be a panacea for spectrum scarcity, thereby enabling coexistence of unlicensed users with the licensed ones. This motivates the cognitive radio technology which allows unlicensed users, known as secondary users (SUs), to utilize the licensed spectrum opportunistically. The cognitive radio senses the environment and allocates the idle bands, not used by the licensed users, to the SUs thereby increasing spectral efficiency. Opportunistic spectrum usage is discussed in the context of spectrum sharing. The idle bands, also referred to as white spaces or holes, is a set of frequencies which are assigned to the primary users (PUs) but are not utilized during a given time duration. In this scenario, SUs can utilize these white spaces for transmissions while also mitigating interference to the PUs[12].

Basic components of Opportunistic Spectrum Access (OSA) include spectrum opportunity identification, spectrum opportunity exploitation, and regulatory policy. The opportunity identification module is responsible for accurately identifying and intelligently tracking idle frequency bands that are dynamic in both time and space. The opportunity exploitation module takes input from the opportunity identification module and decides whether and how a transmission should take place. The regulatory policy defines the basic etiquette for secondary users to ensure compatibility with legacy systems[13]. The overall design objective of OSA is to provide sufficient benefit to secondary users while protecting spectrum licensees from interference. The tension between the secondary users’ desire for performance and the primary users’ need for protection dictates the interaction across opportunity identification, opportunity exploitation, and regulatory policy [9]. The optimal design of OSA thus calls for a cross-layer approach that integrates signal processing and networking with regulatory policy making.

Wireless networks are regulated by a fixed spectrum assignment policy, i.e. the spectrum is
regulated by governmental agencies and is assigned to license holders or services on a long term basis for large geographical regions. In addition, a large portion of the assigned spectrum is used sporadically as illustrated in the Figure 1, where the signal strength distribution over a large portion of the wireless spectrum is shown [9].

![Figure 1: spectrum occupancy graph](image)

The spectrum usage is concentrated on certain portions of the spectrum while a significant amount of the spectrum remains unutilized. According to Federal Communications Commission (FCC), temporal and geographical variations in the utilization of the assigned spectrum range from 15% to 85%. Although the fixed spectrum assignment policy generally served well in the past, there is a dramatic increase in the access to the limited spectrum for mobile services in the recent years. This increase is straining the effectiveness of the traditional spectrum policies.

**Areas Covered under Cognitive Radio Paradigm[42]:**

The main functions of Cognitive Radios are:

- **Spectrum Sensing:** detecting the unused spectrum and sharing it without harmful interference with other users. It is an important requirement of the Cognitive Radio network to sense spectrum holes. Detecting primary users is the most efficient way to detect spectrum holes. Spectrum sensing techniques can be classified into three categories:
Transmitter detection: cognitive radios must have the capability to determine if a signal from a primary transmitter is locally present in a certain spectrum. There are several approaches proposed:

- matched filter detection
- energy detection
- cyclostationary feature detection

Cooperative detection: refers to spectrum sensing methods where information from multiple Cognitive radio users are incorporated for primary user detection.

Interference based detection.

Spectrum Management: capturing the best available spectrum to meet user communication requirements while not creating undue interference to other (primary) users. Cognitive radios should decide on the best spectrum band to meet the Quality of service requirements over all available spectrum bands, therefore spectrum management functions are required for Cognitive radios. These management functions can be classified as:

- spectrum analysis
- spectrum decision

The practical implementation of spectrum management functions is a very complex and multifaceted issue in itself, given that it has to address a mixture of technical and legal requirements. An example of the former is choosing appropriate sensing threshold to detect other users, while the latter is exemplified by the need to meet the rules and regulations set out for radio spectrum access in international (ITU Radio Regulations) and national (Telecommunications Law, etc.) legislation.

Spectrum Mobility: is defined as the process when a cognitive radio user exchanges its frequency of operation. Cognitive radio networks target to use the spectrum in a dynamic manner by allowing the radio terminals to operate in the best available frequency band, maintaining seamless communication requirements during the transition to better spectrum.

Spectrum Sharing: providing the fair spectrum scheduling method. One of the major challenges in open spectrum usage is the spectrum sharing. It can be regarded to be similar to generic media access control MAC problems in existing systems.