CHAPTER 2
COGNITIVE RADIO NETWORK: AN OVERVIEW

Cognition i.e. the ability to reason and learn has been incorporated in CR devices. A CRN observes its surroundings and accordingly change its characteristics based on its learning and reasoning ability. Thus, we can say that CRN is an adaptive data network that can observe its surrounding environment, learn and build knowledge base dataset which can be further used to modify network decisions accordingly. This chapter provides a brief overview of CRN discussing its significance and open issues in this field of research.

2.1 COGNITIVE RADIO NETWORK

Cognitive/Intellectual/Smart radio networks have unprecedented level of intelligence and skill as CRs have the ability of monitoring, sensing and acting upon the surrounding environmental conditions. They dynamically reconfigure their individual physiognomies in the best possible way based on those conditions [28-30]. To ensure augmented communication to users they can regulate their communicating parameters like output power, modulation and frequency. Fig. 2.1 shows how a CRN alters parameters according to its environmental conditions [31]. Four cases i.e. voice over internet call, streaming video, data overhead and voice over internet call with different frequency are enlightened discussing their network parameters. Interference by interferes are observed in second, third and fourth cases. So, CRN capable of adjusting its parameters alters/adjusts its parameters as shown in Fig. 2.1.

The design of conventional or dumb radios was based on the assumption that they are operating in an interference free environment. On the contrary, CRs function in challenging conditions, viewing their surrounding environment in great detail to identify the vacant spectrum and quickly tune to that frequency for trans-receiving signals. They also possess the ability to search for another vacant spectrum if interference is perceived on the frequency being used [32]. Fig. 2.2 illustrates how CRs operate differently from
conventional radios showing spectrum analyzer’s reading. Parameters represented in red color demonstrates adjustment of parameters based on surrounding environment.

**Fig. 2.1: Demonstration of adjustment of parameters by Cognitive Radio Network**
Fig. 2.2: Conventional vs. Cognitive Radio

Conventional Radio sees the congested spectrum with hefty interference, predominantly unusable while Cognitive Radio sees it as an opportunity, analyzing in great detail and identifying unused gaps for transmitting signals [33].

2.2 ARCHITECTURE

There are two types of network in CRN architecture defined as Primary (constitutes PUs) and Secondary (constitutes SUs) Networks. PUs are accredited users having right to access a certain spectrum band at any time while SUs are unlicensed ones which share the spectrum with licensed users. The primary network may be centralized in infrastructure or distributed ad-hoc. PUs have higher priority than SUs with respect to spectrum usage. Thus they do not provide any cooperation with SUs. The primary network is non-intrusive in nature hence the primary transmission should not be affected by SUs. In order to assurance promised enactment level to legitimate users, primary network outlines an upper bound for CRN activities in their licensed bands in terms of maximum power levels [34-35]. The
secondary transmissions by SUs must adhere to the constraints imposed by legitimate users.

![Diagram of Centralized CRN](image)

**Fig. 2.3: Centralized CRN**

The CRN may be centralized in infrastructure or distributed ad-hoc [34]. In centralized CRNs, CR base stations or FC control and coordinate the secondary transmission activities of SUs by collecting all the spectrum related information which further makes global decision regarding spectrum access for all nodes as shown in Fig. 2.3. Alternatively, in distributed ad-hoc CRNs, all cognitive nodes communicate with each other via ad-hoc point-to-point connections as shown in Fig. 2.4. In this scenario, cognitive nodes does not rely on central fusion unit. However, the infrastructure cost is reduced by such network but at the cost of increased networking complexity. All the CRs or SUs jointly coordinate spectrum access decision to opportunistically access the available spectrum [46]. Thus, need for global mechanism such as network-wide synchronization for coordinating spectrum access arises.
Fig. 2.4: Distributed ad-hoc CRN

However, relay-assisted detection for improving the communication among users have been mentioned in the literature. The practical scenarios like noise and fading may degrade the system performance. Hence, good detection with accurate and precise decisions need to be made while dealing with detection of signals in the communication network. In this case, relays have been deployed among network for seamless communication among users improving the system performance.

2.3 FUNCTIONALITIES

The SUs must possess cognitive functionalities to share the licensed spectrum. The chief objective of a SU is to carry out DSA efficiently and intelligently. The cognitive tasks of SU are demonstrated in Fig. 2.5 of Cognition Cycle which is initiated with SS. Detection of vacant spectrum or holes is the primary and key function of cognition cycle. Moreover,
inspecting accurate and precise decisions regarding PU’s existence are of prime importance for the successful functioning of the overall CRN system.

The SU observes the status and movement of PU in the spectrum by periodical sensing of the spectrum. SS involves identification of spectrum hole or white spaces (i.e. time, frequency band, location) and accessing way (i.e. accessing duration, transmit power) without causing any interference with legitimate user’s communication. Upon receiving information from SS, a decision is made to access bandwidth, transmit power, frequency, modulation mode, time duration and location of spectrum. Spectrum sharing is the process of sharing the spectrum among multiple SUs [47]. When the PU reenters the licensed spectrum, the SU should vacate that band and shift to alternative band. This task is basically
changing of current operating frequency band of SUs and is termed as spectrum handoff or mobility [48].

2.4 ADVANTAGES

The main advantages offered by CRN are listed below:

1) Spectrum Efficiency: Efficient utilization of spectrum is achieved by CRN as spectrum holes can be used by SUs avoiding interference to PUs. It incapacitates spectrum scarcity issue.

2) Switch to power saving protocol: CRs conserve power when low data rates are needed by switching to protocols that trade-off between lower power consumption and lower bandwidth.

3) Improved QoS: As CRs sense the surrounding environment, they select the frequency channels with high a Signal to Noise Ratio (SNR).

4) Benefits to service provider: There will be more consumers in the market hence profiting the service provider.

5) Benefits to regulator: Regulators can lease the available licensed spectrum to third party.

6) Improvement in traffic capacity: CRs meet the increasing demand for bandwidth requirement by providing access as and when it is free.

2.5 APPLICATIONS

The practical applications of CRN [26], [49-51] are discussed briefly in this section.

1) Smart grid network: Traditionally, electricity system is centralized distributed over large geographical area involving numerous devices (from power distribution unit to consumer). Smart grid is a two-way communication which involves integration of electrical power system with new wireless technologies. It is installed over hefty geographic expanse, hence adjusting manifold networks over single smart grid.
2) **Public safety services:** CR has the potential to resolve problems pertaining to public safety communications. The main aspect among immediate or emergency responders (police, fire, safety departments) that needs to be addressed is interoperability issue. The rescue situation involves different network nodes like vehicles, helicopters, emergency workers, each having different physical layer requisite thus involving need for interoperability to work collaboratively. CR effectively deals with such an issue. Another aspect is to reach the needy or victim which is taken care by CR.

3) **Wireless medical network:** CR is helpful in medical field. Sensors are installed on the body of patient to monitor temperature, blood oxygen, pulse rate, heart rate, blood pressure etc and notify the doctor for patient’s vital information thus enabling doctor to act instantly. Patient’s condition is recognized at initial stage itself thus appropriate medication can be given to the patient using wireless network. Replacement of wires and tubes with wireless networks for patient monitoring reduces chances of infection and increases patient’s mobility.

4) **Cellular network:** HetNet (Heterogeneous Network), called cognitive cellular network employs CR techniques. It is a network entailing different nodes with diverse characteristics like power transmission, radio-frequency coverage area. Low power and high power micro nodes are managed under same operator thus improving overall capacity of the network and ensuring effective network coverage.

5) **Disaster relief and emergency networks:** During emergency like natural calamity, war or terrorist attack, the existing communication system gets overloaded due to heavy communication traffic as there are calls from concerned citizens as well as help calls in a very span of time. Though there are frequency bands for emergency services but they often get overcrowded due to limited bandwidth. Thus advanced
CR communication system provides helping hand in accessing white spaces for uninterruptable communication.

6) Military/ defense applications: CR satisfies the need for interference-resistant, mobile and scalable wireless communication. In dubious expanses or battlegrounds, communication channels are often encountered with jamming signals. With the usage of CR technology, frequency bands with jamming signals can be eluded.

2.6 LIMITATIONS

The limitations or open issues for deployment of CRN are as follows:

1) Accurate sensing of spectrum
2) Conveying the information of vacant slot to needy SU.
3) To stop the SU from using spectrum whenever PU start communicating again.
4) To assign another spectrum to that SU to continue.
5) Safeguard the network from malfunctioning of SU, malicious users or security attacks.

2.7 SUMMARY

This chapter provides a general overview of CRN. CR sees the licensed spectrum as ‘window of opportunity’ as it occupies the licensed spectrum band whenever PU is not utilizing it, thereby enhancing spectrum utilization. Types of CRN architecture based on infrastructure have been discussed. Advantages, functionalities and real-time applications of CRN have been presented. Further, we have documented the limitations or open issues for deployment of CRN.