International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 5, Issue 8, pp 71-74, August-2021

https://doi.org/10.47001/IRJIET/2021.508012

Cognitive Radio

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***Abstract* - Cognitive Radio can be programmed & configured dynamically to use the most effective wireless channels in its vicinity to avoid user interference. The CR is capable of altering parameters like "waveform, protocol, operating frequency, etc.". The CR functions as an autonomous system in the communication environment, while exchanging information in its cognitive network with other cognitive radios. This paper discusses how to improve the spectrum utilization & how spectrum holes in space-time frequency multiple dimensions should be exploited accurately & efficiently.**

Keywords: Cognitive Radio, interference, spectrum, autonomous.

I. INTRODUCTION

A cognitive radio is a device that can be programmed to use the best wireless channels nearby to avoid interference and congestion. A radio that automatically identifies and changes the reception and transmission parameters of available wireless spectrum allows more concurrent wireless communication in a given area. This process is a form of a dynamic spectrum management.

II. HISTORY

2.1 Proposing the idea

The concept of cognitive radio was first proposed in 1998 by Joseph Mitola III at Royal Institute of Technology in Stockholm. It was a novel approach to wireless communications.

2.2 Foreplaning with Cognitive Radio

The concept of the CR is to enable the developers to create software that can be easily manipulated to deliver the best output. CR usually aims the unused band gaps present in the live spectrum to transmit messages.

III. NEED OF COGNITIVE RADIO

Spectrum scarcity is a major issue faced by wireless applications today. The increasing number of applications & the complexity of the task have made the problem worse.

Frequency utilization increases the likelihood of introducing dual-mode or dynamic spectrum allocation (CR). This technology permits the simultaneous use of both primary and licensed users. Frequency sensing with minimum duration and best resolution is a fundamental requirement for time.

A good quality CR system should have sensing functions that can detect signals with high accuracy. However, due to uncertainties in the channel environment, it can't detect signals with perfect accuracy.

3.1 Frequency Detection

The bandwidth required for cognitive radios is typically a superimposition of the TV tuner frequency range and the wireless LAN frequency range.

Table 1: Frequency Band Allocation

Frequency Band (MHz)	Services
0-87.5	Mobile, Aeronautical Navigation, Cordless Phones
87.5-108	FM Radio Broadcast
109-173, 230-450	Broadcast Vans, Aeronautical Navigation
585-698	TV Broadcast
806-960	GSM and CDMA Mobile Services
960-1710	Aeronautical and Space Communication
1710-1930	GSM Mobile Services
1930-2010	Reserved for Defence Forces
2025-2110, 2170-2300	Satellite and Space
2400-2483.5 (Unlicensed)	Wi-Fi, Bluetooth
2483.5-3300	Space Communication
3600-10000	Space Research, Radio Navigation
10000 onwards	Satellite Broadcasts, DTH Services
174-230, 450-585 699-805, 2010-2025 2110-2170, 2300-2400 3300-3600	Not Allocated

IV. SPECTRUM SPACES

White spaces

The unused spectrum is the part of the wireless spectrum that is used for television broadcasting. It is used to deliver high-speed internet access.

Gray spaces

This gap gives the permission to the devices for using the spectrum which has already been used. Here, in the gray

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space, the interconnected systems are more interdependent on each other compared to white space.

Blank spaces

Secondary users can opportunistically get the permission to have the access of the licensed.

V. TYPES OF COGNITIVE RADIO

5.1 Depending upon transmission and reception parameters

Full Cognitive Mode – Commonly known as Mitola Radio, considers each and every detailed parameter visible under observation by the wireless network while network sensing.

Spectrum Sensing Cognitive Mode – During the operation, the consideration is given to only radio frequency spectrum.

5.2 Depending upon spectrum availability

Licensed Band Cognitive Radio – Capable of using bands assigned to licensed users which can be operated on unused television channels known as TV White Spaces.

Unlicensed Band Cognitive Radio– This type exploits the unlicensed part of the radio frequency spectrum for greater benefits.

Spectrum Mobility Cognitive Radio– A process type of radio where in the frequency is changed under the operation.

Spectrum Sharing– The cognitive radio network is shared by the network among other cognitive radios which establish and utilize only licensed band under the threshold power.

VI. FUNCTIONS OF COGNITIVE RADIO

This function is used in "spectrum sharing cognitive"

Power Control – The space which is used by the Primary Users have the exclusive right over the band with proper license. The Secondary Users are not allowed in this spectrum, especially when its licensed. The temporal spectrum holes exist in gray region and Radio" to increase the capacity of Secondary Users with respect to the Primary Users so as to avoid interference.

Spectrum Sensing – CR has the ability to detect empty spectrum in the surrounding bands of its network. It detects unused spectrum and shares the same with its co CRs in its network. The CR carefully avoids the interference with other signals so as to look out for any harmful effect on its information as well as to other network which belong to non-CR network.

Wide Band Spectrum Sensing – Sensing spectrum over large scale of bandwidth, typically around Megahertz to Gigahertz.Since current ADC technology cannot afford such high sampling rate along with high resolution, it requires revolution techniques, e.g. - compressive sensing.

Null Space Based Cognitive Radio– The number space in the bandwidth is detected using multiple antennas, this null-space is used by the CR to transmit information without affecting primary users' band.

Spectrum Management– To meet the quality of the information demanded by the user, the CR adjusts its parameters to give the best possible output.

VII. THE COGNITIVE CYCLE

It is a particular process which follows a particular methodology of set of behavioral characteristics consisting of four sequential cooperative phases which interface and work together synchronously to create a highly efficient system.

The four main phases are classified as follows, Sensing, Analyzing, Decision Making, and Execution.

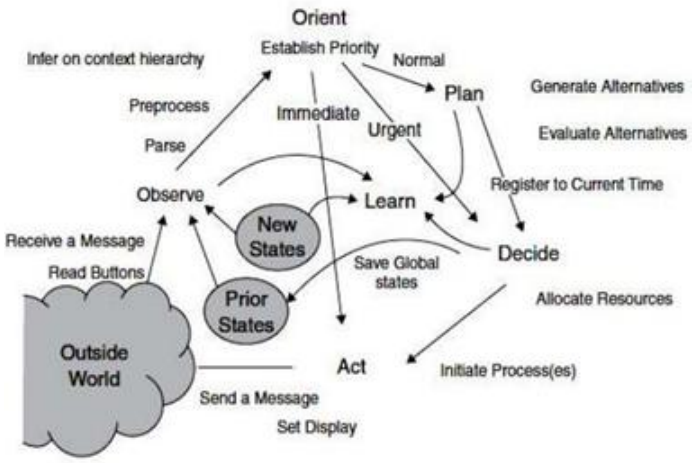

Figure 1: Cognitive cycle

Summing up, the CR has the better quality and type of information compared to any other resource which it perceives by capabilities to Observe, Orient, Plan, Decide, Act & Learn in radio frequency & in other user classed domains.

VIII. PROPOSED ARCHITECTURE OF COGNITIVE RADIO

Its basic architecture tells us about the design rules by which software defined radio i.e. SDR, sensors, perception & automated machine learning (AML) may be integrated to create Aware & Adaptive cognitive radios (AACR's).

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SDR is a radio communication system where components that have been traditionally implemented in hardware are instead implemented in software on a PC or using an embedded system.

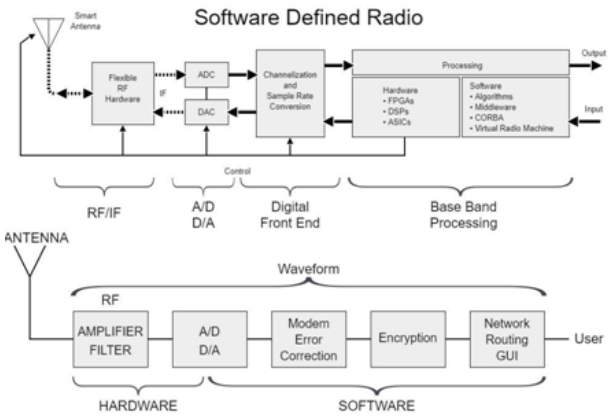

Figure 2: Block diagram of Software Defined Radio

The design of CR consists of two units i.e. a cognitive unit which has SDR & a Sensing Antenna Unit to measure the signal environment to determine the presence of users & other service providers. The cognitive unit is further divided into two other subunits.

Cognitive Engine – It tries to find a solution for the problem of scarcity of spectrum, manages it & gives the best solution out of it.

Policy Engine – It is used to ensure that the solution provided by the cognitive engine doesn't disturb other spectrum users & doesn't violate any rules and regulations enlisted.

Thus, the CR uses intelligent algorithms to process & execute the calculated results using its physical layer. This layer includes carrier frequency, duty cycle, and transmission power, digital modulation mode, processing gain, spectrum bandwidth, channel coding rate & waveform of the transmitted wave.

IX. CHALLENGES IN COGNITIVE RADIO

The radio frequency spectrum is a valuable resource that is kept under control by the government in order to avoid complications. The spectrum bands were allocated under fixed licensed policy. As the technology is progressing ahead nonstop, the number of devices requiring RF spectrum to work are increasing. The licensed policies have created scarcity of the spectrum. Due to practical world the materials do not behave theoretically, and causes error in the circuits of Cognitive Radio. This error limits the capabilities of the Radio itself towards its own Cognitive Network. The researchers have proposed the framework for future spectrum occupancy measurements covering the frequency range from 700 to 2700 MHz.

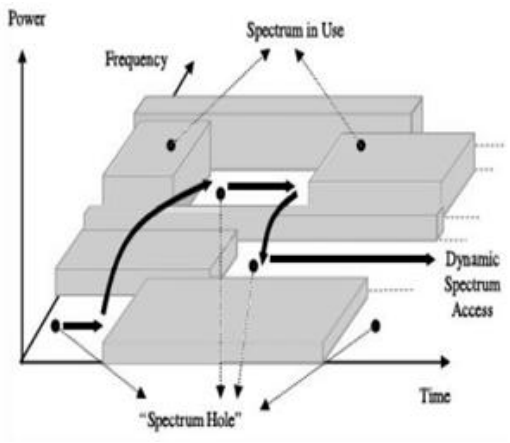

Figure 3: Spectrum hole sensing

9.1 Issues in Cognitive Radio

The main purpose of CR is to achieve the dynamic access of the idle spectrum in order to achieve a proper communication. However, implementation of such an advanced technological radio is a challenging task.

A typical cognitive radio consists of Secondary Users and Primary Users that coexist with each other in the Cognitive Network. Primary Users have the combined legal rights of the spectrum to be accessed, whereas the Secondary Users opportunistically access the spectrum during the interval of Primary Users for avoiding delays, with strict rules for avoiding interference within the Users.

Main Issues in CR

Spectrum Sensing – The circuit of CR has to sense the idle band in the radio environment in order to use these channels for its data transmission. The sensing operation should be able to detect incoming access of Primary User while working with Secondary User, so as to give access to the Primary User.

Primary Transmitter Detection – The CR should be able to detect even the weakest signals from the Primary Transmitter in its surrounding through its detection.

Matched Filter Detection – CR is programmed to have the characteristics of the incoming Primary User signal to detect its presence or absence with high accuracy. Here the disadvantage is that incomplete knowledge of the signal (frequency, modulation format) may lead to errors.

Energy Detection – Assuming the CR having zero information about the signal, will lead to mismatch of the energy at the transmitter and receiver simultaneously.

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Cooperative Spectrum Sensing – The local sensing result from multiple CR users is utilized to analyze the presence of a Primary User Signal. This approach of analyzing, invites harmful effects like fading, shadowing, noise, interference.

X. ADVANTAGES OF COGNITIVE RADIO

Overcome radio spectrum scarcity – By sensing utilization, cognitive radios can broadcast on unused spectrum, while avoiding interference with public units.

Avoid international radio jamming scenarios – Sensing white spaces by avoiding channel traffic, CRs can evade jamming by switching its parameters to higher quality channels.

Switch to power saving protocol – By trying different combinations of its data, CRs choose the combination consuming lowest power for lower bandwidth.

Improves quality of service – By sensing environmental and man-made interferences, CRs may select higher frequency channels with high SNR (Signal to Noise Ratio).

XI. APPLICATIONS OF COGNITIVE RADIO

i. Using it in the emergency and public safety situation by instantly detecting white spaces.
ii. To execute DYNAMIC SPECTRUM ACCESS (DSA).
iii. Military actions
   - Chemo-biological and Radiological Investigations.
   - Nuclear Attack Detection.
   - Obtaining secret information of Battle damage evaluation
   - Intelligence like Intelligent Antenna.
   - Modelling and simulation is the only effective way for the simulation of complex behavior in a given CR Network environment.

XII. CONCLUSION

Thus, the paper explains the importance of cognitive radio in the wireless communication field along with its various aspects, benefits, advantages & disadvantages. The advancement in this field has already been started and no doubt coming generation will be successful in it under few decades.

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Citation of this Article:

Anuj Sarode, Priyanka Ojha, "Cognitive Radio" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 5, Issue 8, pp 71-74, August 2021. Article DOI https://doi.org/10.47001/IRJIET/2021.508012

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