Achieving Cognitive Radio for Improved Spectrum Utilization: An Implementation

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Abstract - *To achieve an efficient communication system, need for dynamic spectrum allocation capability is required. Cognitive Radio technology helps the current communication network to identify the issues and can make intellectual decisions. Spectrum Sensing, an important factor to achieve Cognitive Radio, periodically monitor the frequency spectrum to find out unused frequency user bands. This paper proposes a full Cognitive Radio Package which consists of different communication parameters like protocols, networking, modulation format etc.*

Key Words: Software Defined Radio, Cognitive Radio, Spectrum Sensing, Opportunistic sharing, Dynamic Spectrum Management, Distributed Coordination Function.

1. INTRODUCTION

This Frequency allocation scheme used in the communication network is static in nature. To utilize the frequency spectrum efficiently, we need dynamic spectrum allocation methods. The frequency allocation methods are dynamic within the technologies but are static in between. IEEE 802.22 is a consortium where it provides the rules for the access of secondary users. The unused primary bands which is called white spaces have to be found out in turn the secondary users can be opportunistically shared.

To identify the white spaces, there are lot of techniques available like database registry, beacon signals, spectrum sensing etc. But the first two methods give primary user, the job of providing information about the availability of white spaces in turn results the system more complex. Considering this, Spectrum Sensing is an efficient method for this purpose.

Spectrum Sensing is a periodically monitoring process in which it gives the status of the frequency band whether a primary user is available on a specific period or not. It can be done using Software Defined Radio. Software Defined Radio is a radio system where the hardware components which is traditionally implemented which is instead implemented on software like processors, embedded system etc.

A higher version of Software Defined Radio is Cognitive Radio which can implement an efficient communication system by changing various communication parameters. It is capable of reprogramming in a dynamic manner. This results for selecting better channels. It helps to reduce congestion and interference in communication networks.

Cognitive Radio are of two types: First, Full Cognitive Radio which can improve the communication system by changing the communication parameters like networking, protocol, modulation format etc. Second, Spectrum Sensing Cognitive Radio which is only concentrated on spectrum sensing and not any other parameters. Cognitive Radio protocols are cross layered; so that any change in the lower layer will cause same impact on upper layers. This is a major challenge in implementing cognitive radio networks. Because the cognitive radio can control a variety of parameters, it makes the testing time increased dramatically. Testing of each parameter make the cognitive radio system more complex for implementation. And, the new functions implemented in the cognitive radio like spectrum sensing, handoff need to be embedded in the simulator also.

2. SOFTWARE DEFINED RADIO

Software Defined Radio is a system where we can implement software technologies which is capable of functioning as hardwares. The SDR have all the operating functions of a radio. These can operate on technologies like General Purpose Processors, FPGA etc.

3. COGNITIVE RADIO

Cognitive Radio [2] is a radio communication system which can sense the electromagnetic environment by adjusting the communication protocol dynamically to use the best wireless channels. To achieve Cognitive Radio, the important component which we must consider is spectrum sensing. The main aim of spectrum sensing is to reduce congestion and interference. The unused primary bands can be efficiently utilized by this method. Sharing of frequency bands can be done either by opportunistic sharing or by power control. The frequency which are allowed for specific applications are rarely used in current scenario. Fixed frequency allocation schemes denied the usage of rarely used frequencies even though the unlicensed user does not result in congestion and interference.

Decision should have taken by regulatory bodies to allow the unlicensed users to use the unused licensed band to allow smoother functioning of the system. We can automatically detect the unused frequency bands through a technology called Dynamic Spectrum Management. Once detected it changes its parameters according to the need for application. This cognition process which reduce congestion in communication network was put forward by Joseph Mitola.

Radio system parameters comprises of waveform, protocol, operating frequency and networking. Based on self-monitoring performance, it uses this information to determine channel conditions, link performance etc. Cognitive Radio can adjust the parameters with the help of user requirements, operational limitations and regulatory constraints.

4. IMPLEMENTATION

As stated earlier, this paper implemented a full cognitive radio where the parameters like spectrum sensing, modulation format, networking etc. are considered. This process is done by various APIs connected to different blocks. We can change operating time by writing start time and stop time as a pair.

4.1 BUILDING BLOCKS OF COGNITION PROCESS

A) Spectrum Manager- It is considered as black box which consists of various information of all the process done in cognition. It is linked to all other blocks. The information has been always passing through various blocks and spectrum manager block decides according to the current scenario. All the layers in the network keep a reference to the spectrum manager.

B) Spectrum Sensing- This block is otherwise called Database Query which is responsible for checking whether a primary user exists in a given channel at a specific period. It starts working before the simulation starts. Primary User Database consists of a text file which comprises of different information like the number of primary users currently occupied in the channel, the power which determines the range of primary users, on and off times, etc.

C) Spectrum Decision- We can implement different policies in spectrum decision block according to the application. This block decides whether a handoff should be performed or not. Decisions are taken based on the spectrum sensing block. This block is responsible to determine to which channel the handoff should happen. Global repository is a database file which consists of various information about the users and frequency bands. This database helps the secondary users to use the bands which are not engaged by other secondary users.

D) Spectrum Mobility- The role of spectrum mobility block is to initiate the spectrum handoff if the spectrum decision block decides to perform the handoff.

E) Spectrum Sharing- This block is linked to the spectrum manager in which it ensures the sharing of frequency spectrum is done in a collision free manner. Sharing of frequency bands can be done in two different ways. First one, Cooperative Spectrum sharing in which the secondary users are allowed to access the primary users' frequency band when they are not in use. Second, Spectrum sharing using power control. Secondary users are allowed to use the unused primary bands, but in any occasion when they need back, the secondary user has to either hop to any other unused bands or they can exist in the same frequency band but with a low power so that they will not interrupt the primary users' operation. We can use different modulation formats based on channel conditions and applications. Cognitive Radio can switch different modulation schemes according to various constraints. QPSK prefers other formats because of the good noise immunity. Bandwidth required by QPSK is reduced to half for the same bit rate and has higher transmission.

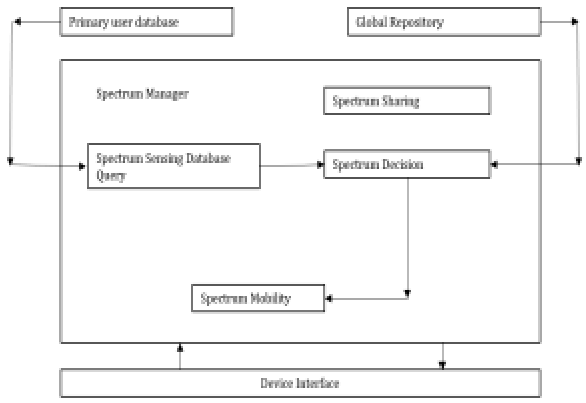

Fig -1: Block Diagram for Cognitive Radio

The frequency of transmitter and receiver must be same for the correct modulation and demodulation purpose. If the receiver has not any Cognitive Radio functionality, then the information must be sent before hopping.

5. COGNITION PROCESS

To initiate the cognition process, one would start a call to API from any layer in the network. Depending upon the information, Spectrum Sensing/Database Query Block starts sensing and find out the current status of primary users in the channel using the primary user database file. If the users are in the same range, then check the channel and time factors. After checking channel, range and time if the interference level is low, which can be tolerable by the primary users, then the frequency is available for secondary users. If anyone of these factors is not same, then can use the channel by the secondary user. Once sensing is completed, the information is passed to the spectrum decision block; Spectrum decision block decides whether a handoff should be taken or not or which channel the handoff should performed according to the different policies implemented. Here two types of policies are implemented: Decision policies and Spectrum policies. Frequency hopping and Queuing are the two decision policies. Round Robin and Random Switch are two spectrum policies implemented here. These results will be passed to the spectrum mobility block where it initiates the handoff based on spectrum decision block results. All processes are sensed by spectrum sharing block, whether to check the sharing is done in a collision free manner. Once the cycle is completed, the transmission process can be resumed.

Every equipment is always in a state of operation. Here there are eight states during the operation of Cognitive Radio. They are: a) IDLE- ON state but it's not active b) CCA BSY- Clear Channel Assessment, Channel is busy, so to be wait in a queue. c) TX- Data is actively transmitting. d) RX- Data is actively receiving. e) SWITCHING- Switching to and from different states. f) SLEEP- Non-urgency hardware is in OFF state. g) OFF- Physical and MAC layer is in OFF state. h) SENSING- State related to the Cognitive Radio.

If one user in idle state, it can switch to the sensing state so that they can find out the unused frequency band. But if in any other states DCF has the job to give permission for the usage of secondary users.

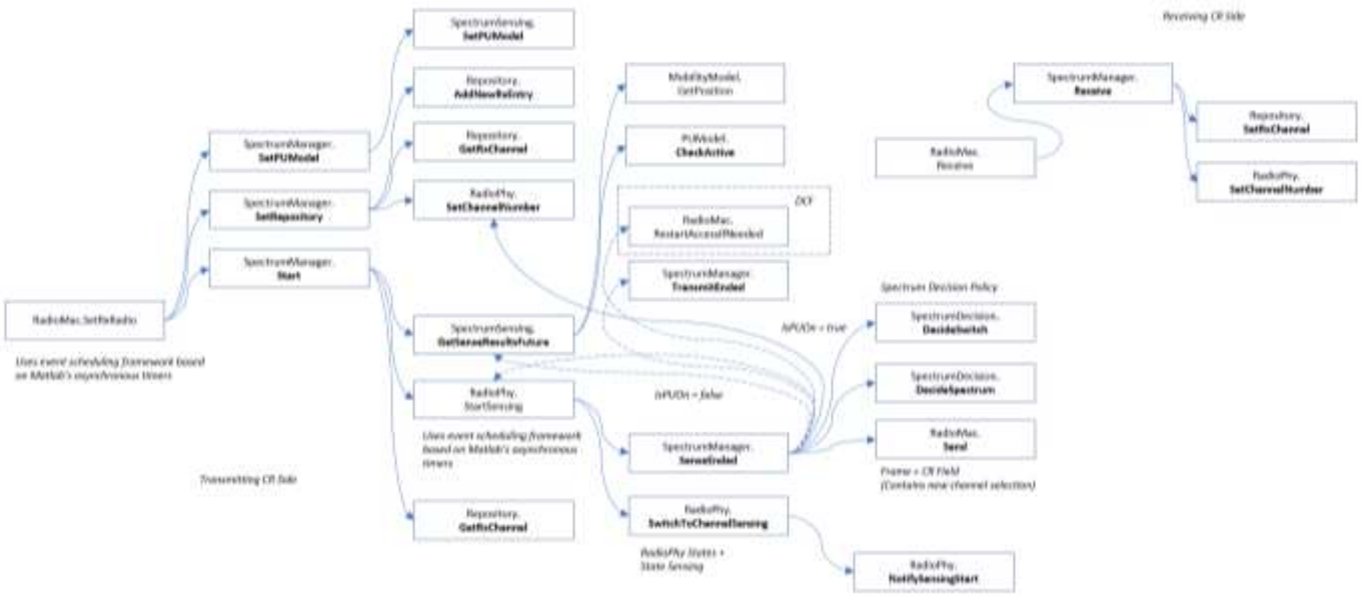

Fig -2: Functional Block Diagram.

6. LAYERS IN COGNITIVE RADIO

6.1 Higher layers

Cognitive Radio interfaces are not directly linked to upper layers. L1 and L2 are physical and Mac layer in networking interconnection. When considering networking, upper layers L3 and L4 must be considered. Spectrum manager is interconnected with all layers.

6.2 Lower Layers

Here, Cognitive Radio parameters are implemented on lower layers like Link and Physical layers. A new concept is introduced known as cognitive interface which can be connected to lower layers. A cognitive radio node can be connected to any number of cognitive interfaces. Each cognitive interface consists of three separate PHY-MAC layers. Each physical and MAC layer is interconnected as a pair. The first layer is for control packet information for a common control channel. This is known as control interface. This interface is considered for transmitting and receiving control packets. And it is responsible for handoff process. The second layer is for transmitting interface which is switchable in nature. It is used for transmission and reception of packets between different layers which are destined to different nodes. The third PHY-MAC layer is intended for reception. The receiving interface is mostly concentrated on primary user activity like the handoff when detected unused primary bands, hence it is called as a sensing interface.

Transmission interface is connected to different routing protocols. Receiving and Control interface are excluded from the routing protocol implementation. Routing protocol provide information regarding different interfaces on a computer.

Distributed Coordination Function (DCF) [1] is also serves and functions as spectrum manager. These blocks help in the smoother functioning of network layers. It gives a reference for cross-layer functionalities in different layers in the network. IEEE has formed a consortium (IEEE 802.22) to provide a standard interface in which demands a centralized database in order to get all user information globally for the smooth functioning of spectrum sharing.

Cognitive Radio monitors any one of the frequencies at a specific time in the spectrum. Each frequency is allocated to different users. Even if the primary user database consists of information of all users, we need three interfaces which is for control, transmission and reception. For all users even if it's primary or secondary, there are two separate nodes for transmission and reception. To check the current environment during transmission the interface which helps is Cognitive Radio interface.

Cognitive Radio technology is not practically implemented for the current communication network. And the implementation is a big challenge because every equipments must be flexible with new technology which is impractical for some extent. The information of users like ON and OFF times, power which determines range, presence and absence of primary users etc. are stored in a primary user database. But there are devices which are not flexible with new standards which results in system error. So, to get accurate information, we need a control interface to sense channels also during the transmission process. This interface helps to sense the frequency spectrum and provide uninterrupted services to the secondary users.

7. APPLICATION

The Cognitive Radio can effectively use in emergency and public safety communications by utilizing white space by spectrum sharing. Cognitive Radio allows dynamic spectrum access which makes the communication network flexible and efficient. This can make huge application in military services that is for command control, evaluation of battle damage, intelligence etc.

CONCLUSION

In this paper we introduce a Cognitive Radio package which leads to dynamic spectrum management which helps to reduce congestion and interference for congested communication network. The unavailability of new frequency spectrum leads problems for smooth functioning of the communication network. Cognitive Radio comprises of different parameters like modulation format, networking, frequency etc. which can change to use the best wireless channels to reduce congestion and system interference. This paper can extend by changing other parameters in cognitive radio thereby we can achieve a full cognitive radio.

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