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VHDL Implementation of MAC for Reconfigurable Applications

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***Abstract* — Cognitive Radio is the best technology to improve spectrum utilization of wireless communications by exploiting under-utilized licensed spectrum. The core concept of cognitive radio is designed to address the problems faced in allocating spectrum efficiency and it provides wireless users to adapt their spectrum (band of frequencies) operating factors and sharing spectrum with the help of information from the adjacent radio environment. This paper deals with the cognitive radio (CR) sensing, analysing, understanding and deciding. This type of technique has its own potential to further improve the performance of cognitive networks, especially for spectrum sensing. The proposed system implements modulation designed and debugged in modelsim using VHDL. Also reconfigurable CR channel are created which adapts low, medium and high traffics. Core concepts to handle the high traffic handling is created in the CR module and analysed with the simulation results. Expected results to solve the high traffic user with the use of reconfigurable MAC transmitter and CR.**

Keywords— Cognitive radio, spectrum, VHDL, , MAC.

I. INTRODUCTION

One of the major challenges for today's wireless user's communication is to meet a fast growing demand for enhancing the number of advanced wireless applications and users with limited spectrum (not restricted) resource. It is very difficult to find more unused spectrum for future mobile communications; the only feasible way is to explore the potential of existing spectrum by improving spectrum efficiency of wireless systems while sharing them with primary users. The latest regulations to open up authorized (licensed) radio spectrum, cognitive radio (CR) have been introduced to improve wireless communication systems making use of access in a neat spectrum not wasted, frequency, and spatial domains. CR has been widely incorporated as an efficient way to improve spectrum of wireless communication systems. The main principle of Cognitive Radio is to allow cognitive users to access authorized (licensed) spectrum without making clash on the communications of existing users, such that certain level of spectrum can be utilized more efficiently for that environment.

Idea of CR gives lot of solutions by which efficient spectrum utilization has high probability of being implemented by applying the optimistic spectrum sharing techniques. The concept of cognitive radio was first proposed by J. Mittola in 1999. The cognitive radio is a spectrum agile system which has the capability to sense the communication environment dynamically and it can intelligently adapt the communication parameters they are carrier frequency, bandwidth, power, coding schemes, modulation scheme etc. Cognitive radio must be capable of searching or checking the environment for the estimation of available resources and application requirements and could adapt their performance parameters according to user (mobile or antenna) request and available resources (spectrum). Newly (cognitive) joined user will access the licensed spectrum (available white spaces) without affecting the priority utilization (primary users) of the spectrum by primary user.

Multiple Input Multiple Output technology uses multiple inputs (users) to make use of reflected signals to provide high gains in channel dynamism and high throughput. Even now many there are MAC wireless routers on the market, and as this technology is becoming more widespread, more MAC routers and other items of wireless MAC equipment has been marketed. radio offers stable communication that is resistant to noise and since it can be achieved at relatively low cost, it's often used for specified low-power radio. is digital modulation, but the theory is similar to analog frequency modulation, and the modulating signal is digital instead of analog. In addition, in a normal radio use environment, the receiving wave undergoes amplitude and phase fluctuations due to multipath factors, but the frequency modulation system is resistant to related errors.

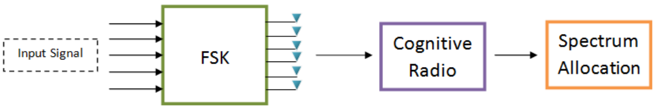

Figure 1: Shows modules involved in MAC CR

Here n number of inputs is given to the unit and also m number of output is taken from the to transmitter. Cognitive radio will make action according with the decision of its cycle by the completion of each signal modulation ().

II. PROPOSED SYSTEM

A. MAC

The underutilization of spectrum under the current static spectrum management policy has stimulated a flurry of existing research activities in searching CR MAC protocols. Recently, several attempts were made to develop MAC protocols for CRNs [17]−[29]. One of the key challenges to enabling CR communications is how to perform opportunistic medium access control (MAC) while limiting the interference imposed on PUs [15], [16]. The CRN MAC protocol proposed in [17] jointly optimizes the multichannel power/rate assignment, assuming a given power mask on CR

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transmissions. How to determine an appropriate power mask remains an open issue. A cognitive MAC protocol for multichannel wireless networks (C-MAC) is proposed in [18], which operates over multiple channels, and hence is able to effectively deal with the dynamics of resource availability due to PUs and mitigate the effects of distributed quiet periods utilized for PU signal detection. A distributed cognitive radio MAC (DCR-MAC) protocol for wireless ad hoc networks is proposed in [19] that provides for the detection and protection of incumbent systems around the communication pair. DCR-MAC operates over a separate common control channel and multiple data channels; hence, it is able to deal with dynamics of resource availability effectively in cognitive networks. A simple and efficient sensing information exchange mechanism between neighbor nodes with little overhead is proposed. CR based multichannel MAC protocols for wireless ad hoc networks (CRM-MAC) is proposed in [20], which integrate the spectrum sensing and packet scheduling. In their protocols each SU is equipped with two transceivers. One of the transceivers operates on a dedicated control channel, while the other is used as a CR that can periodically sense and dynamically utilize the identified unused channels. CR-enabled multichannel MAC (CREAM-MAC) protocol is proposed in [21], which integrates the spectrum sensing at physical layer and packet scheduling at MAC layer, over the wireless networks. In the proposed CREAM-MAC protocol, each SU is equipped with a CR-enabled transceiver and multiple channel sensors. The proposed CREAM-MAC enables the SUs to best utilize the unused frequency spectrum while avoiding the collisions among SUs and between SUs and PUs. Distributed CR MAC (COMAC) protocol is presented in [22] that enable unlicensed users to dynamically utilize the spectrum while limiting the interference on PUs. The main novelty of COMAC lies in not assuming a predefined SU-to-PU power mask and not requiring active coordination with PUs. A decentralized cognitive MAC protocol (CogMAC), which is based on the multichannel preamble reservation scheme is proposed in [23]. The protocol dynamically selects an available communication channel using a distributed channel selection scheme and allows nodes to be completely asynchronous to each other. CogMAC does not require a common control channel or a cooperative infrastructure.

B. COGNITIVE RADIO

A cognitive radio is the key technology that allows a cognitive wireless terminal to dynamically access the available spectral opportunities. A cognitive radio was defined by Mitola in his seminal work as "a radio or system that senses, and is aware of, its operational environment and can dynamically and autonomously adjust its radio operating parameters accordingly". This definition was generalized by the FCC to be "a system that sense the surrounding electromagnetic energy in environment and can dynamically and simultaneously adjust its radio operating parameters to modify system operation, such as maximize throughput, mitigate interference, facilitate interoperability, access secondary markets". From these definitions, a cognitive radio has two key features that distinguish it from a traditional radio: the cognition capability and the reconfigurability. This illustration is referred to as the cognition cycle that is continually run by the cognitive radio to observe spectral opportunities, create plans to adapt it, decide, and act to explore the best opportunities.

In the earlier days of modem deployment, designers are developing modems on the basis of different applications being proposed and different spectrum as per requirement. This leads to repeat the same work for large area and the system increases in cost due to various reasons. Most of the beginning development was purely based on hardware component. After the incorporation of SDR (software defined radio), required RF transmitter and receiver hardware, baseband transmitter and baseband receiver algorithms are configured using software. All has become in the software control, this also a reason of invention of cognitive radio. The research after software defined radio concept is on cognitive radio in which timing intelligence is build to allow cognitive radio to sense consecutive spectrum in terms of radio spectrum and track changes accordingly and utilize white space (empty) RF spectrum.

The grateful job in designing cognitive radio is to design efficient spectrum sensing algorithm so that unutilized spectrum can be efficiently used by various wireless technologies. This is because spectrum is scarce resource. Information sharing between cognitive radios can be achieved efficiently.

III. COGNITIVE RADIO CYCLE

The cognition capability of a cognitive radio is defined as the ability of the cognitive radio transceiver to sense the surrounding radio environment, analyze the captured information and accordingly decide the best course of action(s) in terms of which spectrum band(s) to be used and the best transmission strategy to be adopted. Such a cognition capability allows a cognitive radio to continually observe the dynamically changing surrounding radio environment in order to interactively come up with the appropriate transmission plans to be used. The three main components of the cognitive radio cognition cycle can be briefly explained as follows.

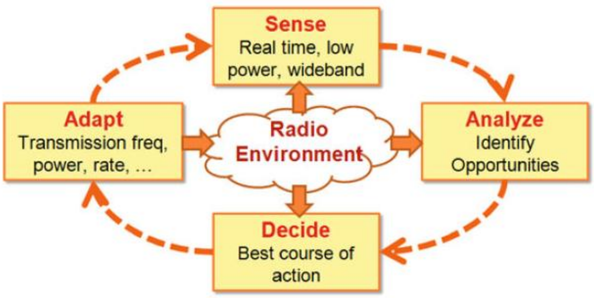

Figure 2: Functional architecture of a cognitive radio

A. SPECTRUM SENSING

Spectrum sensing refers to the ability of a cognitive radio to measure the electromagnetic activities due to the ongoing radio transmissions over different spectrum bands and to capture the parameters. Spectrum sensing is the most crucial actions of a cognitive radio as it gives the alert signal of the spectrum usage in that environment. A cognitive radio must make real-time decisions about which spectrum to sense, when, and for how long it is utilized. The sensed spectrum

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details should be sufficient enough for the cognitive radio to reach accurate conclusions regarding the radio environment. Furthermore, sensing of available spectrum should be fast in order to track the instant variations of the spectrum usage in a certain environment. Such requirements of spectrum sensing put direct perception of requirements on the hardware implementation of cognitive radios in terms of the sensing bandwidth, the processing power, the radio frequency (RF) circuitry, etc. The proposed spectrum sensing mechanism is depends on detecting the activities of the primary (existing) transmitters. Such schemes are generally classified to matched filter detection, spectrum energy detection, feature detection, and interference temperature measurement.

A. SPECTRUM ANALYSIS

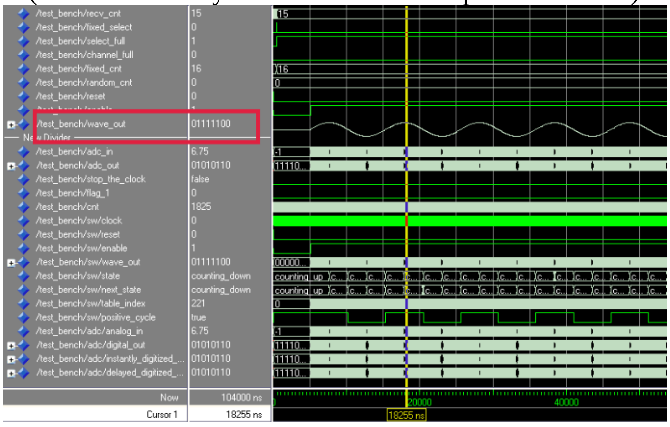
Spectrum analysis is to inform and understand the existing spectral opportunities in the surrounding signal environment based on the sensed radio environment parameters. A spectral opportunity is conventionally defined as a spectrum that is not being utilized by the existing user (primary users) of that spectrum at a particular time in a specific geographical area. However, such a definition is not basically enough as it covers only three dimension of the spectrum space: frequency, time, and space. Other dimensions of a given spectrum can be exploited. For example, the coding dimension which utilizes spread spectrum coding techniques to create spectral opportunities over a given spectrum band currently utilized by its licensed users. Similarly, the angle dimension creates spectral opportunities through the use of beamforming to allow the cognitive radio users to simultaneously transmit over a currently utilized band. Furthermore, the recent advancements in radio transmission techniques, such as the use of Multiple-Input Multiple-Output (MAC) at the physical layer, present new dimensions in the definition of a spectral opportunity. For instance, stream control and antenna selection can be used to allow cognitive radio users to simultaneously transmit with the primary licensed users without degrading the performance of such legitimate users. Due to the existence of different dimensions of a spectrum, we use the following generalized definition a spectral opportunity in the remainder of the book: A spectral opportunity is “a theoretical hyperspace occupied by radio signals, which has dimensions of location, angle of arrival, frequency, time, and possible others”.

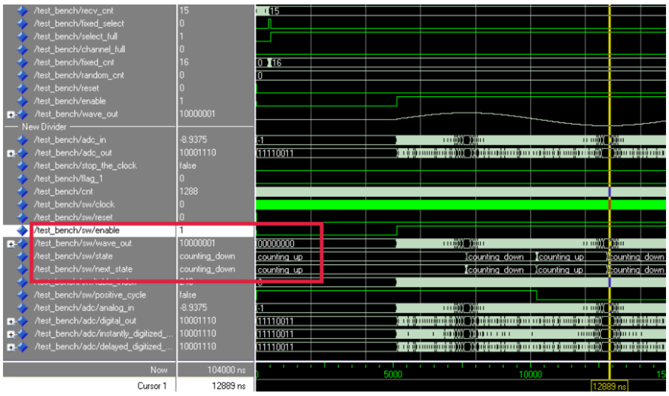
B. SPECTRUM ACCESS DECISION

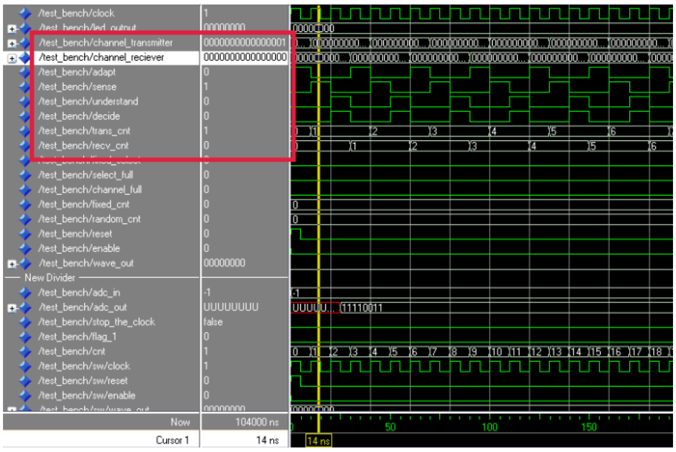
The last step of the cognition cycle of a cognitive radio is to decide the set of transmission actions to be taken based on the outcome of the spectrum sensing and analysis procedures. More specifically, a cognitive radio utilizes the information gathered regarding the spectrum bands identified as available spectral opportunities to define the radio transceiver parameters for the upcoming transmission(s) over such frequency bands. The set of transceiver characteristics to be decided depends on the underlying transceiver architecture. Examples of the spectrum parameter set can include which band of frequencies is more feasible for an upcoming transmission, the time instant a transmission over a certain spectrum should start, the maximum transmission power, modulation rate, the spread spectrum hopping scheme, the angle of arrival for all (360°) directional transmissions, and the number and identity of the antennas to be utilized in MAC systems, etc. Based on the sensed spectrum information and the transceiver architecture, a cognitive radio defines the values of the parameters to be configured for an upcoming transmission.

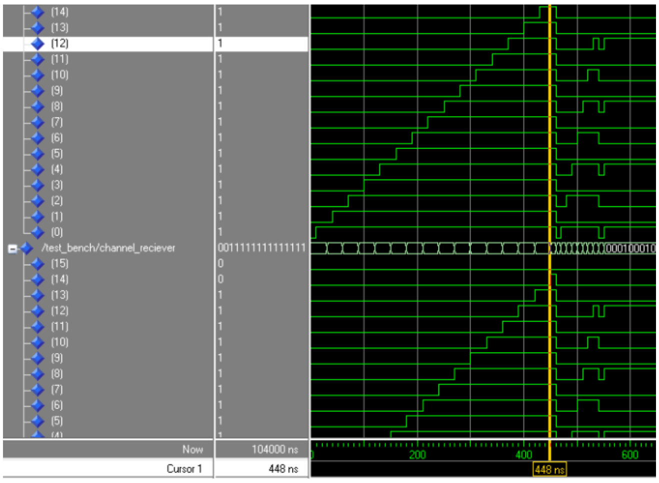
IV. RESULTS

(**Details about your simulation results placed below**)









V. FUTURE WORK

It is worth pointing out there are several aspects in need of improving for communications in cognitive networks in future work, that is distributed or low-complexity cooperation: cooperative techniques require the information exchange between the nodes, resulting in the increase of signalling overheads. The future of cognitive radio is high speed communications with low cost, and dynamic spectrum selectivity. To reduce the overhead, it is better to design the distributed or low complexity cooperative techniques.

The future systems will be intelligent in terms of spectrum utilization but the legacy systems cannot be changed. Therefore, the introduction of cognitive radio capabilities in the future wireless networks should have no impact on the existing networks. There is a constant need for radio regulation, especially as the operation environment is changing toward cognition, but the forms of regulation and the spectrum access mechanisms may be different in the future.

Further minimization in sensing energy may be done exploiting compressed sensing or compressive sampling followed by reconstruction of PU signal at CS assuming CS is equipped with sufficient computing power. In future, wireless services are provided by networks, and thus the problem of spectrum scarcity will be severer. Due to different network structures and service types, the design of such cooperation is different from the aforementioned intra-network cooperation. It is necessary to design a novel scheme for inter-network cooperation.

VI. CONCLUSIONS

Cognitive radio is the great achievement for upcoming wireless communications with reliable high speed communications, versatility, and additional bandwidth for fast developing data applications. Cognitive radio has the capability of sensing the spectrum environment without the intervention of the user or hardware parts, CR will adapt to the user's data traffic (communication) needs while conforming their data transmission. In theory, the number of spectrum in nature is infinite; But practically, for signal navigation in certain environment and other aspects of CR is finite because of the desirability of certain spectrum portions, this desirability is depends upon the number of users in the coverage area. Allocated spectrum has lot of space from being fully occupied, and efficient spectrum use is a growing context; CR offers lot of solutions to this problem. We designed efficient MAC based cognitive radio that prevent spectrum not to be wasted.

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