A Study of Cognitive Radio based on WARP Platform

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Abstract— Cognitive Radios (CR) are wireless transceivers that have the intelligence to sense the medium and detect whether a channel is occupied or free. If occupied, the CR modifies its own parameters and moves to a free channel. This feature of Cognitive Radio helps to efficiently use available frequencies of the Spectrum thereby efficiently utilizing the spectrum. An extensively used platform for conducting research in this field is the Wireless Open-Access Research Platform (WARP) developed by RICE university. This report introduces the WARP framework for cognitive radio networks, documents the attempt to implement Channel sensing and spectrum sensing using WARP and presents the results obtained during the experiments.

Keywords- Cognitive Radio, WARP, transmitter, spectrum sensing.

I. INTRODUCTION

Wireless Communication has grown at a very fast rate in the real world. Management of the available spectrum is required to fully exploit the advantages of wireless communication. The spectrum is allocated on licensed basis. The licensed users have the primary authority over the spectrum. They are known as the Primary Users (PU). If the Primary user is not using the spectrum it can be used by the Secondary user. The secondary user should vacate the channel, once the Primary User again starts its communication in that particular channel. This helps in sharing the same spectrum amongst several users thereby optimizing the use of available radio-frequency (RF) spectrum while minimizing interference to other users.

Cognitive Radios (CRs) are autonomous wireless devices capable of flexibly changing their transmission parameters and learning certain communication behaviors and patterns in accordance with the environment in which they operate. Their fundamental functions comprise spectrum sensing, spectrum management, spectrum sharing and spectrum mobility. [1]

Spectrum Sensing is the basic responsibility of Cognitive Radios. It aims at finding unused channels of the spectrum and using them without interfering with the Primary Users. The spectrum management function refers to the challenge imposed to the CRs to best meet the communication requirements in the detected unoccupied spectrum holes. Spectrum Mo-bility is the function responsible for freeing the oc-cupied spectral band once the PU appears. Lastly, Spectrum Sharing is needed to optimize the use of spectrum among multiple users

II. LITERATURE SURVEY

To better understand CR, the following documents have been studied:

A. IMPLEMENTATION OF SPECTRUM SENSING ON WIRELESS OPEN-ACCESS RESEARCH PLATFORM

The above report [1] documents the attempt to implement spectrum sensing on the wireless open-access research platform (WARP). It introduces the WARP framework for cognitive radio networks, elucidates different challenges faced in the laboratory implementation and presents the results obtained during the experiments. The report mentions the procedure to implement continuous transmission of signal from one node to another at a given frequency and analyze the results using wireless communication.

B. WILDNET: DESIGN AND IMPLEMENTA-TION OF HIGH PERFORMANCE WIFI BASED LONG DISTANCE NETWORKS

WiFi-based Long Distance (WiLD) networks with links as long as 50 to 100 km have the potential to pro-vide connectivity at substantially lower costs than traditional approaches. However, real-world deployments of such networks yield very poor end-to-end performance due to two reasons. First, the current 802.11 MAC protocol has fundamental shortcomings when used over long-distances. Second, WiLD net-works can exhibit high and variable loss characteristics , thereby severely limiting end-to-end throughput.

The paper [2] describes the design, implementation and evaluation of WiLDNet, a system that overcomes these two problems and provides enhanced end-to-end performance in WiLD networks. To address the protocol shortcomings, WiLDNet makes several essential changes to the 802.11 MAC protocol, but continues to rely on standard WiFi network cards. To better handle losses and improve link utilization, WiLDNet uses an adaptive loss recovery mechanism using FEC and bulk acknowledgements.

Based on a real-world deployment, WiLDNet pro-vides a 2_5 fold improvement in TCP/UDP through-put (along with significantly reduced loss-rates) in comparison to the best throughput achievable by conventional 802.11 MAC. WiLDNet can also be configured to adapt to a range of end-to-end performance requirements. (bandwidth, delay, loss, jitter).

C. BEYOND PILOTS: KEEPING RURAL WIRELESS NETWORKS ALIVE

The paper [3] takes a broad systemic view of the problem of failure of deployed computer systems in Rural areas, documents the operational challenges in de-tail, and present low-cost and sustainable solutions for several aspects of the system including monitor-ing, power, backchannels, recovery mechanisms, and software. It details the work done in the last three years that has led to the deployment and scaling of two rural wireless networks:

(1) The Aravind telemedicine network in southern India which supports video conferencing for 3000 rural patients per month, and is targeting 500,000 patient examinations per year, and

(2) The AirJaldi network in northern India which provides Internet access and VoIP services to 10,000 rural users.

D. WEBSITE FOR WARP - http://warp.rice.edu/trac/wiki

The above link[4] is a repository of information about the WARP board. The board developed by Rice university can be used to conduct experiments related to wireless communication and analyze the results. Rice University's WARP is a scalable and extensible programmable wireless platform, built from the ground up, to prototype advanced wireless networks. The website provides a rich source of information ranging from tutorials for getting started with the usage of WARP Board to Platform Support, OFDM Reference designs, Hardware Platforms, Code and Forums to provide support for queries.

III. WIRELESS OPEN-ACCESS RESEARCH PLATFORM

The wireless open-access research platform has been developed at the Center for Multimedia Communications (CMC), Rice University. Rice University's WARP is a scalable and extensible programmable wireless platform which allows for the implementation of a custom physical layer as well as a prototype of advanced wireless network algorithms.

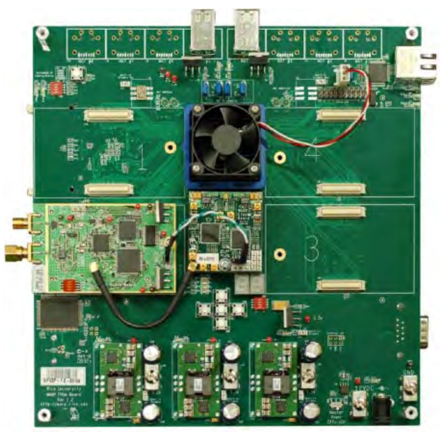

Figure 1: WARP Board[5]

IV. EXPERIMENTS PERFORMED USING WARP BOARD

WARP FPGA board presented in Figure 1 is the main board in the WARP platform. The board has four daughter card slots which can be radio cards or custom user I/O cards. With more than one radio card, multiple-input multiple-output (MIMO) operation is possible. CMC offers a reference design for WARP. [1]

A. CONTINUOUS TRANSMISSION/ENERGY SENSING USING WARP BOARD - SET UP AND IMPLEMENTATION

In a WARPLab system, each node's FPGA consists of four large buffers (one per antenna) that each hold 2^{14}samples. The PowerPC on the FPGA is used to facilitate the communication between MATLAB and the FPGA buffers by transferring data between the host PC and the buffers along with handling control signals that instruct the node to transmit or receive (along with setting other configuration parameters).

To perform Continuous Transmission using WARP board the following steps need to be administered:

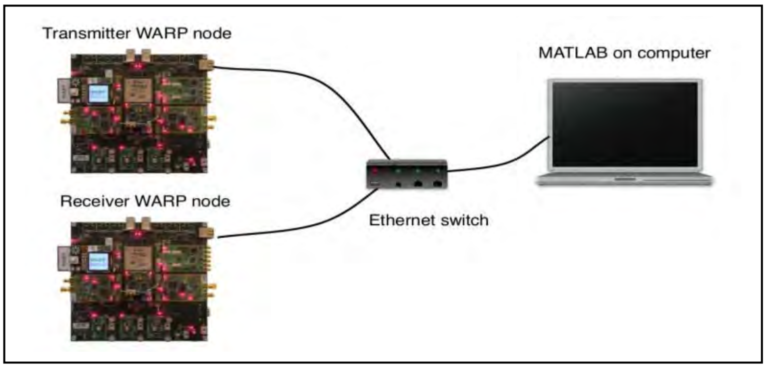

Figure 2. Energy Sensing Setup using Two Warp Boards

1. Make appropriate connections between the WARP Board, Matlab PC and the PC with XIL-INX Software.
2. Connect JTAG Cable between the WARP Board and the PC with XILINX software.
3. Set the DIP switches of WARP nodes to 0 and 1.
4. After making the connections download the bit stream(OFDM Reference Design) from the PC to the WARP node. Repeat this for the second WARP node also.
5. Connect the two WARP nodes and Matlab PC to an Ethernet switch for transmitting the data.
6. Generate the Samples to be transmitted in MATLAB.
7. Baseband processing of signal to be transmitted is performed in MATLAB (i.e. the PHY layer protocol to be tested is applied to the transmit-ting signal).
8. MATLAB downloads the processed signal to the buffers on the transmitting WARP node over ethernet.
9. MATLAB sends the "Enable Transmit" and "Enable Receive" control packets to the appropriate WARP nodes to prime the nodes for an OTA transmission.
10. MATLAB then transmits a "Sync" packet to all of the transmitting and receiving nodes simultaneously
11. Once the nodes receive this "Sync" packet, the transmitting node immediately flushes its buffers through its radios while the receiving nodes immediately loads its buffers with data streamed in through its radios
12. After the OTA transmission is complete, the receiving WARP nodes upload the received signals along with received signal strength indicator (RSSI) readings to the host PC where the resulting data is post-processed in MATLAB to take the desired measurements

B. OBSERVATIONS AND CONCLUSIONS

Continuous over the air (OTA) Transmission is established using the two WARP boards. The WARP boards used are version 2.2. The code for controlling the nodes is in MATLAB and is executed in a controlling PC that is connected to the two nodes through an ethernet switch. The results observed demonstrate that the transmitted signal is received with a little addition of noise.

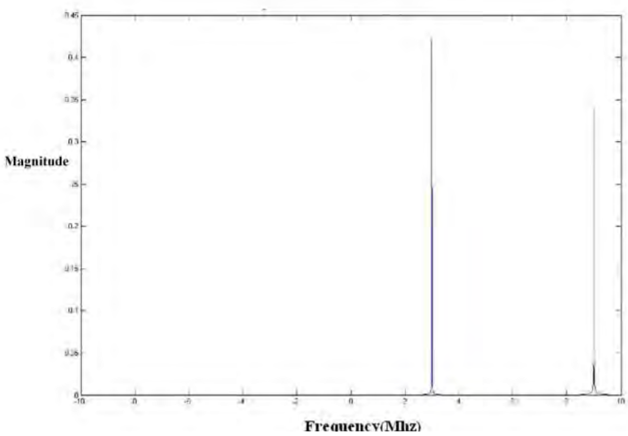

Figure 3. Continuos FFT Plot for Transmission

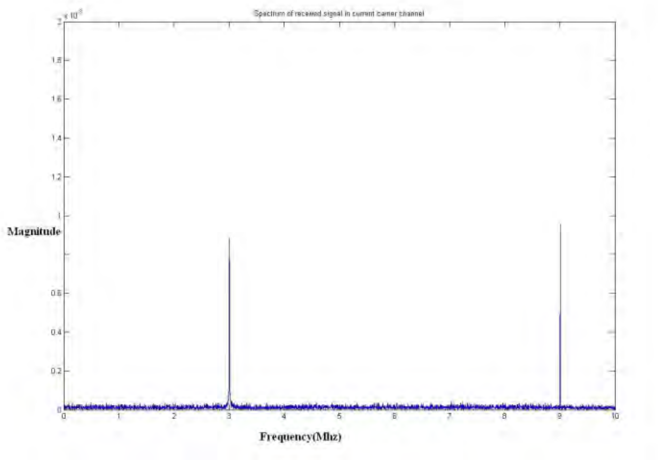

Figure 4. Continuous FFT Plot for Reception

C. CHANNEL SENSING USING WARP BOARD - SETUP AND IMPLEMENTATION

Channel sensing is used to _nd occupied channels of the spectrum. Once the occupied channels are found, the remaining channels (free) also known as White spaces can be used for communication by the secondary users(SU). The SU however, would continue to sense the channel at specific intervals that may be decided according to the available knowledge about PU transmission. The below steps need to be performed for Channel sensing

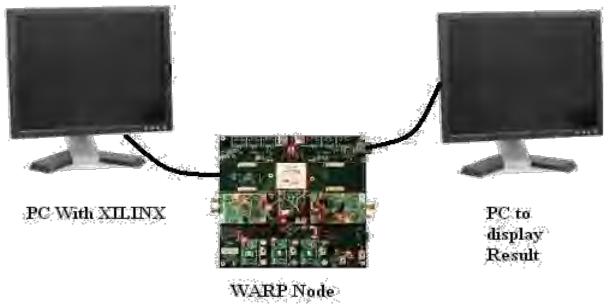

Figure 5. Channel Sensing using Warp Board

1. Connect the WARP board to Power supply and make a JTAG connection between the WARP board and PC having XILINX software.
2. Connect the serial cable between the WARP board and PC to transfer the output of channel sensing.
3. Download the bitstream (OFDM reference de-sign) onto the WARP board.
4. Tools such as TERA TERM PRO could be used to view the output.

D. OBSERVATIONS AND CONCLUSIONS

The spectrum was sensed for various power levels of signal. The output for these threshold levels was ob-served to ascertain the availability of the channel. A particular threshold value was set for detection of the signal each time. Whenever a transmission was detected, the channel was reported as 'occupied'. As a preliminary output a graph has been plotted between the threshold and the reliability of the channels sensed. It has been observed that the reliability of detection increases with the increase in thresh-old value till the optimal threshold is reached after which the reliability again decreases. The reliability decreases because the threshold becomes greater than the power level of signal which can be detected. This was observed by conducting experiments in which the threshold value was set upto 9000. The above experiment has been performed using radio cards operating in the 2400- 2500 MHz band.

The 14 channels of the spectrum were sensed to detect the occupied channels. Detection was carried out for 10 seconds per iteration for a given threshold. The threshold was varied from 1000 to 9000. During every iteration the following norms were followed to avoid the effects of noise and other parameters which may also get detected to some extent:

1. A positive detection occurring less than three times out of fifty times was discarded as arbitrary. This is based on a series of experiments conducted that showed that on rare occasions, various noise sources may be detected in addition to the authentic transmissions. The aver-age number of such detections was found to be three(3) in a set of 50 experimental readings.
2. A positive detection for more than ten times out of fifty was taken as channel being used for communication by the PU.
3. A positive detection of two (2) to ten times out of fifty was taken as a false alarm or an inefficient detection by the CR.

On this basis, the results obtained are as below: Reliability of detection = Number of Confirmed

Detection/ (Number of Inefficient) + (Number of Confirmed detection)

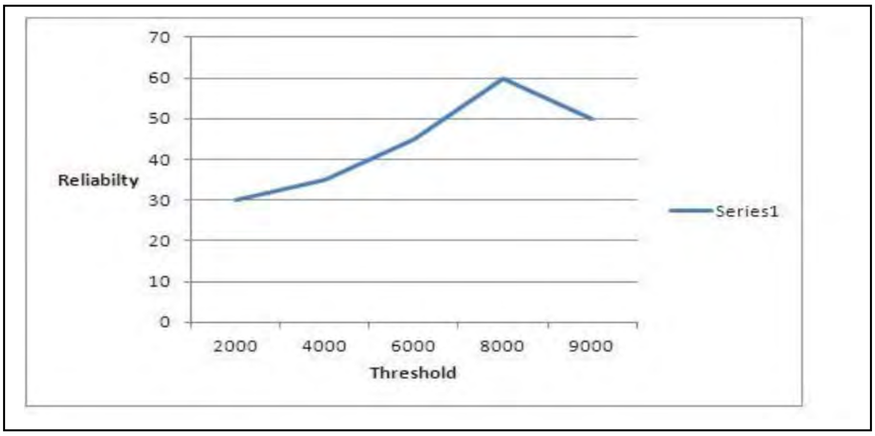

Figure 6 is the graph of reliability vs Threshold:

V. ACKNOWLEDGEMENT

The results obtained in the above report have been possible due to the facilities and training provided by the Department of Computer Science, IIT Delhi.

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