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Cognitive Radio Wireless Smart Sense Technology

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ABSTRACT: The growing demand of wireless applications has put a lot of constraints on the usage of available radio spectrum which is limited and precious resource. However, a fixed spectrum assignment has led to underutilization of spectrum as a great portion of licensed spectrum is not effectively utilized. This paper “COGNITIVE RADIO WIRELESS SMART SENSE TECHNOLOGY” put forth a novel way to improve utilization efficiency of available electromagnetic spectrum. Spectrum sensing helps to detect the spectrum holes (Underutilized bands of the spectrum) providing high spectral resolution capability. A cognitive radio transmits upon bands detected as being free, leaving them whenever a primary user is sensed. This work focuses on the practical implementation of a cognitive radio for dynamic frequency selection. A power detector is chosen to sense the spectrum. After sensing, the cognitive radio will transmit on one of the free channels. Detection and transmission are implemented in parallel at the cognitive transmitter.

KEYWORDS: Cognitive Radio (CR), Spectrum Sensing, Primary Users (PU), Secondary Users (SU).

I. INTRODUCTION

In wireless communication systems, the right to access the spectrum is generally defined by frequency, transmission power, spectrum owner (i.e., licensee), type of use, and the duration of license. Usually, a license is assigned to one licensee, and the use of spectrum by this licensee must be conformed to the specification in the license. In the older spectrum licensing schemes, the license cannot change the type of use or transfer the right to other licensees. Moreover, the radio spectrum is licensed for larger regions and generally in larger chunks.

All these factors in the current model for spectrum allocation and assignment limit the use and result in low utilization of the frequency spectrum. Because the existing and new wireless applications and services are demanding for more transmission capacity and more data transmission hence, the utilization of the radio spectrum needs to be improved.

The main technological objective for our presented solution is the usage of Cognitive Radio. The issue of spectrum underutilization in wireless communication can be solved in a better way using Cognitive radio (CR) technology. Cognitive radios are designed in order to provide highly reliable communication for all users of the network, wherever and whenever needed and to facilitate effective utilization of the radio spectrum. Lower utilization of the licensed spectrum is largely due to inefficient fixed frequency allocations rather than any physical shortage of spectrum.

Cognitive radio includes four main functional blocks: spectrum sensing, spectrum management, spectrum sharing and spectrum mobility. Spectrum sensing aims to determine spectrum availability and the presence of the licensed users (also known as primary users). Spectrum management is to predict how long the spectrum holes are likely to remain available for use to the unlicensed users (also called cognitive radio users or secondary users). Spectrum sharing is to distribute the spectrum holes fairly among the secondary users bearing in mind usage cost. Spectrum mobility is to maintain seamless communication requirements during the transition to better spectrum.

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II. LITERATURE SURVEY

Dr. Ayubi Preet and Dr. Amandeep Kaur in “Cognitive Radio Networking and Communication” proposed a solution for the reduced overall quality of service for the users in a particular allotment due to the overcrowded spectrum. The potential solution to this problem is Cognitive radios, which performs two major tasks. First, it searches the spectrum and determines which parts are unoccupied, a technique known as spectrum sensing. Second, it determines a method of assigning secondary users to the unoccupied spectrum without interfering with primary users. Muhammad Tariq Sadiq in “Spectrum Sensing and Management in cooperative cognitive radio” proposed to accommodate communication systems or secondary users within the available spectrum band, efficient utilization of the radio spectrum is very important. Since most of the spectrum has been allocated, this increases the demand to deploy DSA techniques. CR dynamically performs spectrum analysis and based on this analysis makes decisions for communication of both primary and secondary users simultaneously and seamlessly which ultimately increases the spectrum utilization.

III. COGNITIVE RADIO TECHNOLOGY

Cognitive radio is an exciting promising technology which not only has the potential of dealing with the inflexible prerequisites but also the scarcity of the radio spectrum usage. Such an innovative and transforming technology presents an exemplar change in the design of wireless communication systems. It is currently experiencing rapid growth due to which various Wireless device manufacturers (e.g., Motorola, Eriksson, and Nokia), telecommunication operators (e.g., BT, France Telecom), and chip makers (e.g., Intel) are all beginning to invest in this new technology, especially with respect to research and development. There are two types of spectrum users: A. Primary users: These wireless devices are the primary license holders of the spectrum band of interest. In general, they have priority access to the spectrum and are subject to certain quality-of-service (QoS) constraints that must be guaranteed. B. Secondary users: These users may access the spectrum, which is licensed to the primary users. They are the secondary users of the wireless spectrum and have lower priority. These cognitive users employ their cognitel abilities to communicate while ensuring the communication of primary users is kept at an acceptable level. Cognitive radio offers a novel solution to overcome the underutilization problem by allowing an opportunistic usage of the spectrum resources. Here, a SU can access spectral resources of a PU when the PU is not using them. However, the SU has to vacate the frequency band as soon as the PU becomes active so that negligible interference is caused to the PU.

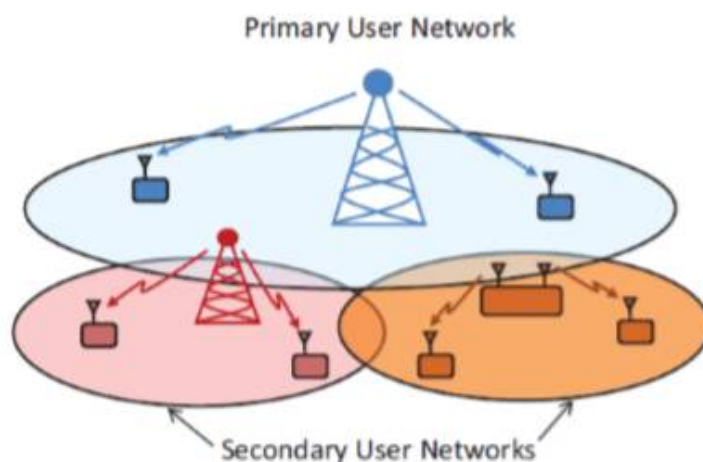


Fig 1: Coexistence of multiple primary and secondary user networks.

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The observations published by FCC have described two types of spectrum holes: temporal spectrum holes and spatial spectrum holes. A temporal SH appears when there is no PU transmission during a time period and the SUs can use the spectrum for transmission. A spatial SH appears when the PU transmission is within an area and the SUs can use the spectrum outside that area. By sensing and adapting to the environment, a CR is able to fill in spectrum holes and serve its users without causing harmful interference to the licensed user. Thus, CR is designed to identify and scavenge the spectrum holes in the licensed spectrum bands. The cognitive radio has unique cognitive capability and reconfigurability. Cognitive capability refers to the ability to sense and gather information from the surrounding environment. With this capability, secondary users can identify the best available spectrum. Reconfigurability refers to the ability to rapidly adapt the operational parameters according to the sensed information in order to achieve the optimal performance. By exploiting the spectrum in an opportunistic fashion, cognitive radio enables secondary users to sense which portion of the spectrum are available, select the best available channel, coordinate spectrum access with other users, and vacate the channel when a primary user reclaims the spectrum usage right.

IV. COGNITIVE RADIO ARCHITECTURE

The typical cognitive radio architecture consists of three sub-systems:

- Digital transceiver
- Channel monitoring and spectrum sensing module
- Communication management and control unit

The digital transceiver further consists of RF front end and baseband processing unit as shown below

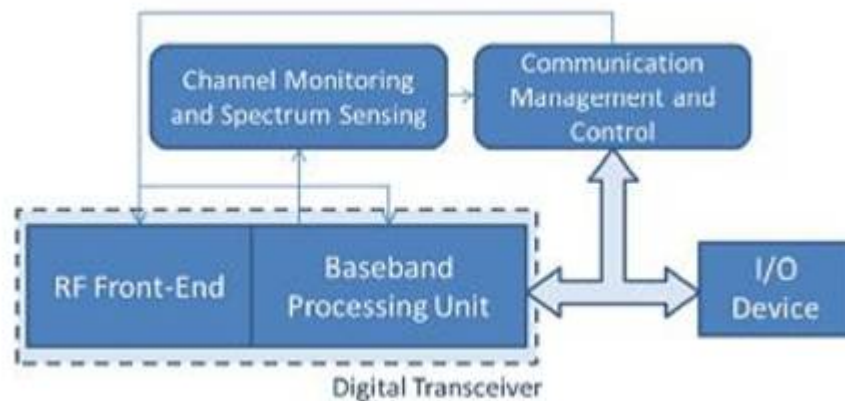


Fig 2: Cognitive Radio Architecture.

The RF front-end module corresponds to the hardware part of CR whose function is the reception, down conversion, amplification, mixing, filtering etc. The RF front-end consists of the receiver and the transmitter analog functions. The receiver and transmitter generally consist of frequency up converters and down converters, filters, and amplifiers. Sophisticated radios will choose filters and frequency conversions that minimize spurious signals, images, and interference within the frequency range over which the radio must work. The front-end design will also maximize the dynamic range of signals that the receiver can process, through automatic gain control (AGC). The baseband processing unit is implemented in software and is responsible for all the necessary digital processing of the signal like modulation and coding. The channel monitoring and spectrum sensing module is capable of spectrum sensing and sending information to communication management sub-system so that the CR can adjust its operation parameters. The communication management and control subsystem manage all CR operations namely switching mode decisions.

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V. COGNITIVE RADIO CYCLE

The CR exploits the dynamic spectrum environment requiring information about the changing conditions of spectrum environment. The requisite steps for the functioning of CR lead to the cognitive cycle consisting of various spectrum management functions. The CR network performs the following four functionalities; Spectrum Sensing, Spectrum Decision, Spectrum Sharing and Spectrum Mobility.

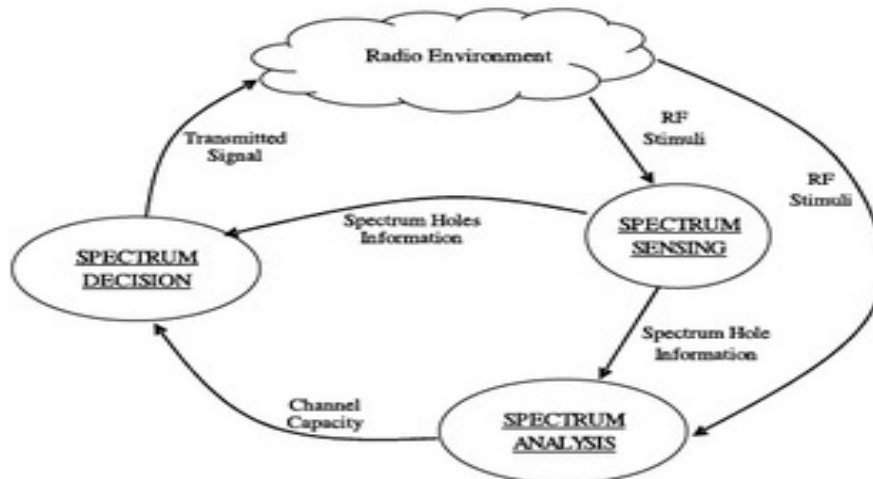


Fig 3: Cognitive Radio Cycle.

- **Spectrum sensing:** A Cognitive Radio based device is not allowed to allocate spectrum wherever it desires but only on those portions of the spectrum where it does not interfere significantly with the primary. This is a very important requirement to ensure coexistence with the primary, and to fulfil the spectrum sharing requirements. The continuous sensing of the wireless environment is mandatory for the secondary devices to fulfil such functions. Thus, a CR user can be allocated to only an unused portion of the spectrum. Therefore, a CR user should monitor the available spectrum bands and then detect the spectrum holes. Spectrum sensing is a basic and crucial functionality in CR.
- **Spectrum decision:** The availability of certain spectrum band may be known based on the sensing information. The allocation of the spectrum band does not depend only on the availability but also takes into account the regulatory policies. The decision to allocate the spectrum is taken based on these facts. Once the available spectrums are identified, it is essential that the CR users select the most appropriate band according to their QoS requirements. It is important to characterize the spectrum band in terms of both the radio environment and the statistical behaviours of the PUs.
- **Spectrum sharing:** Since there may be multiple CR users trying to access the spectrum, their transmissions should be coordinated to prevent collisions in overlapping portions of the spectrum. Thus, Spectrum sharing provides the capability to share the spectrum resource opportunistically with multiple CR users, which includes resource allocation to avoid interference caused to the primary network. For this reason, game theoretical approaches have also been used to analyse the behaviour of selfish CR users.
- **Spectrum mobility:** In fact, the Cognitive Radio devices are considered as the visitors to the spectrum. The secondary device may use any band of the spectrum, but a PU is detected in the specific portion of the spectrum in use, CR users should vacate the spectrum immediately and continue their communications in another vacant portion of the spectrum. For this reason, either a new spectrum must be chosen or the affected links may be circumvented entirely. Thus, spectrum mobility necessitates a spectrum handoff scheme to detect the link failure and to switch the current transmission to a new route or a new spectrum band with minimum quality degradation so as to have seamless communication during transition to better spectrum.

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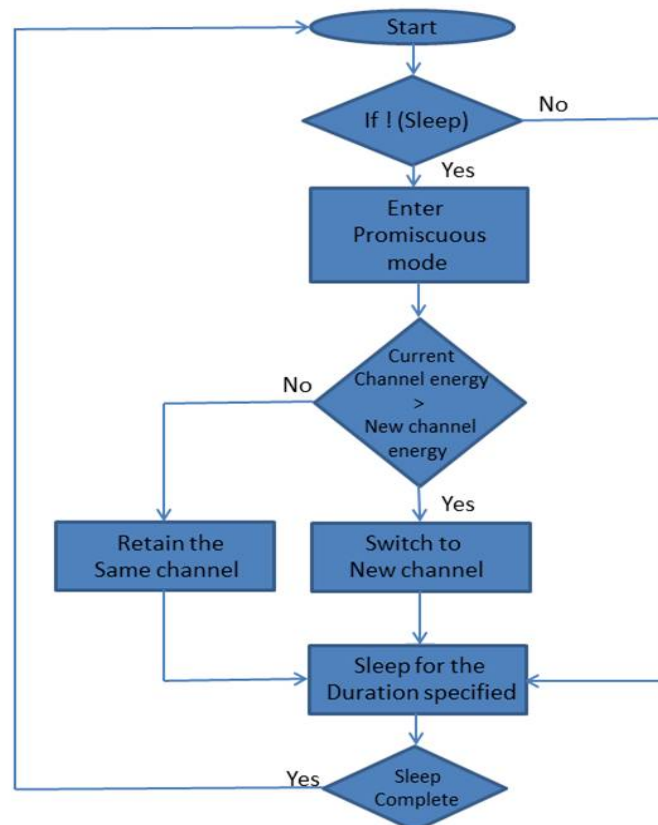
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VI. SPECTRUM SENSING METHODS FOR COGNITIVE RADIO

Some of the most common spectrum sensing techniques in the cognitive radio is:

1. **Energy Detector Based Sensing:** Energy detector-based approach which is also known as radiometry or period gram, is the most common way of spectrum sensing because of its low computational and implementation complexities. It is more generic method as receivers do not need any knowledge on the primary users' signal. The signal is detected by comparing the output of the energy detector with a threshold which depends on the noise floor.
2. **Waveform-Based Sensing:** Patterns known are usually utilized in wireless systems to assist synchronization or for other purposes. A preamble is a known sequence transmitted before each burst and a mid-amble is transmitted in the middle of a burst or slot. In the presence of a known pattern, sensing can be performed by correlating the received signal with a known copy of itself. This method is only applicable to systems with known signal patterns, and it is termed as waveform-based sensing or coherent sensing.
3. **Cyclostationarity-Based Sensing:** Cyclostationarity feature detection is a method for detecting primary user transmissions by exploiting the cyclostationarity features of the received signals. Cyclostationary features are caused by the periodicity in the signal or in its statistics like mean and autocorrelation or they can be intentionally induced to assist spectrum sensing.
4. **Matched-Filtering Technique:** Matched-filtering is known as the optimum method for detection of primary users when the transmitted signal is known. The main advantage of matched filtering is the short time to achieve a certain probability of false alarm or probability of miss detection as compared to other methods. Matched-filtering requires cognitive radio to demodulate received signals. Hence, it requires perfect knowledge of the primary users signalling features such as bandwidth, operating frequency, modulation type and order, pulse shaping, and frame format.

VII. ALGORITHM OF DFS (ENERGY DETECTOR BASED SPECTRUM SENSING)



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Energy detection (also denoted as non-coherent detection), is the signal detection mechanism using an energy detector (also known as radiometer) to specify the presence or absence of signal in the band. To adjust the threshold of detection, energy detector requires knowledge of the power of noise in the band to be sensed. The CR casually selects a channel and compares both current channel energy with the new channel energy. If the current channel energy is more compared to the new channel energy the channel is switch otherwise the same channel is retained and then goes to sleep and the cycle continues for the Energy detector-based spectrum sensing. Compared with energy detection, matched filter detection and cyclostationary detection require a priori information of the PUs to operate efficiently, which is hard to realize practically since PUs differ in different situation. Energy detection is not optimal but simple to implement, so it is widely adopted.

VIII. HARDWARE AND SOFTWARE DETAILS

HARDWARE REQUIREMENTS

- Cognitive Radio Board (CRB) is used as a Router board in the Broad Band.
 1. 8 M Byte flash single-chip memory,
 2. 128 Mega Byte NAND flash memory.
 3. 256 Kbit M24256 serial EEPROM.
 4. SD connector to interface with SD memory card in SPI mode.
- Interfaces 10/100/1000 Base T Ethernet ports.
- PCI - 32-bit PCI interface running at up to 66 MHz.
- Three 32-bit 3.3 V mini PCI slot connected to PCI bus.
- Dual UART ports supports two UARTs up to 115200 bps for console display.
- Real-time clock on I2C bus.
- 6-layer PCB routing (4-layer signals, 2-layer power and ground).



Fig 4: Cognitive Radio Cycle.

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SOFTWARE REQUIREMENTS

Teraterm - TeraTerm is an open-source, free software implemented terminal emulator (communications) program. It emulates different types of computer terminals, from DEC VT100 to DEC VT382. It supports telnet, SSH 1 & 2 and serial port connections. It also has a built-in macro scripting language and a few other useful plug-in.

Putty - Putty is a free and open-source terminal emulator, serial console and network file transfer. It supports several network protocols, including SCP, SSH, Telnet, rlogin, and raw socket connection. It can also connect to a serial port (since version 0.59).

INSSIDER - INSSIDER gives visibility to Wi-Fi environment. This Wi-Fi network discovery tool displays every wireless hotspot's MAC addresses, encryption, signal strength and channel, and is the standard troubleshooting tool for millions of Wi-Fi users throughout the world.

IPERF (Throughput Measurement) - Iperf is a tool for active measurements of the maximum achievable bandwidth on IP networks. It supports tuning of various parameters related to timing, buffers and protocols (TCP, UDP, SCTP with IPv4 and IPv6). For each test it reports the bandwidth, loss, and other parameters. This is a new implementation that shares no code with the original Iperf and also is not backwards compatible.

IX. THROUGHPUT MEASUREMENT

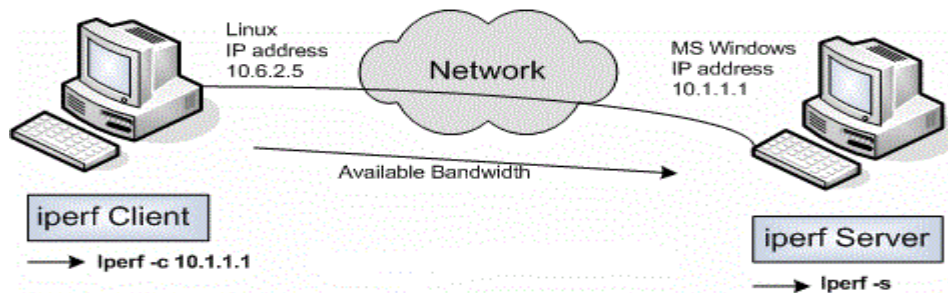


Fig 5: Throughput Measurement.

Server	Throughput protocol	client
iperf -s	Tcp	iperf -c <serverip> -t 10 -i 1
iperf -s -u	Udp	iperf -u -c <serverip> -t 10 -i 1 -b 50m

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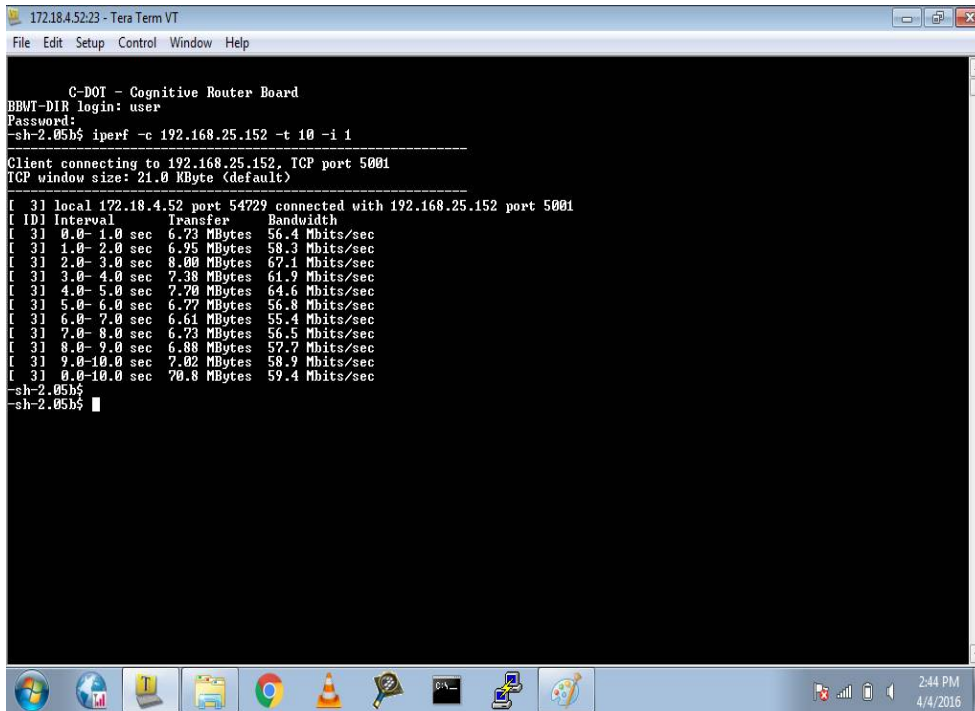


Fig 6: Throughput TCP.

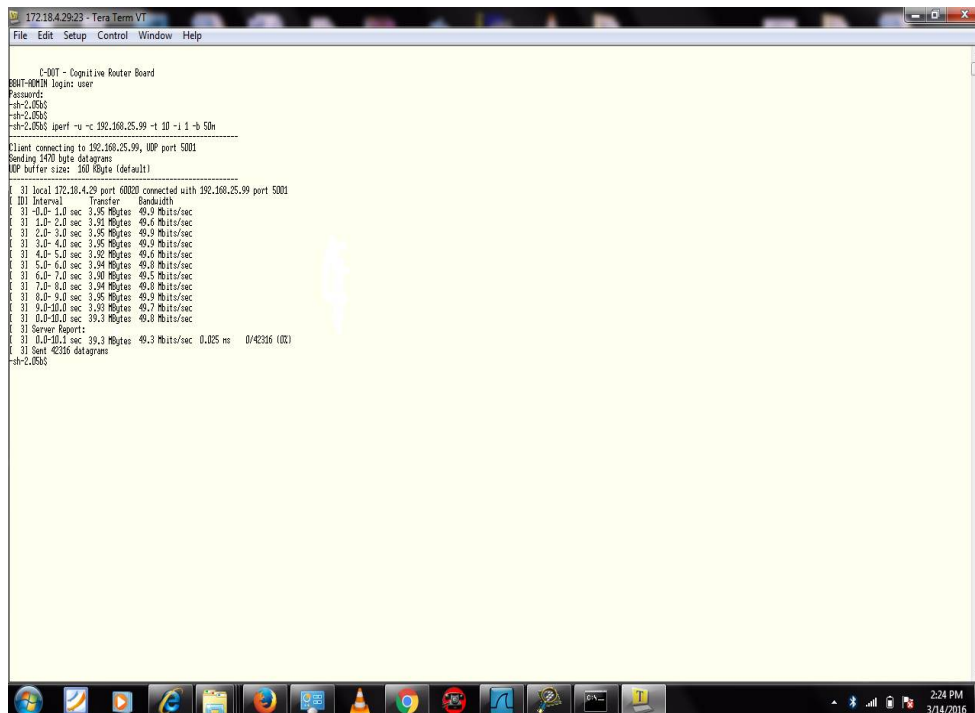


Fig 7: Throughput UDP without DFS.

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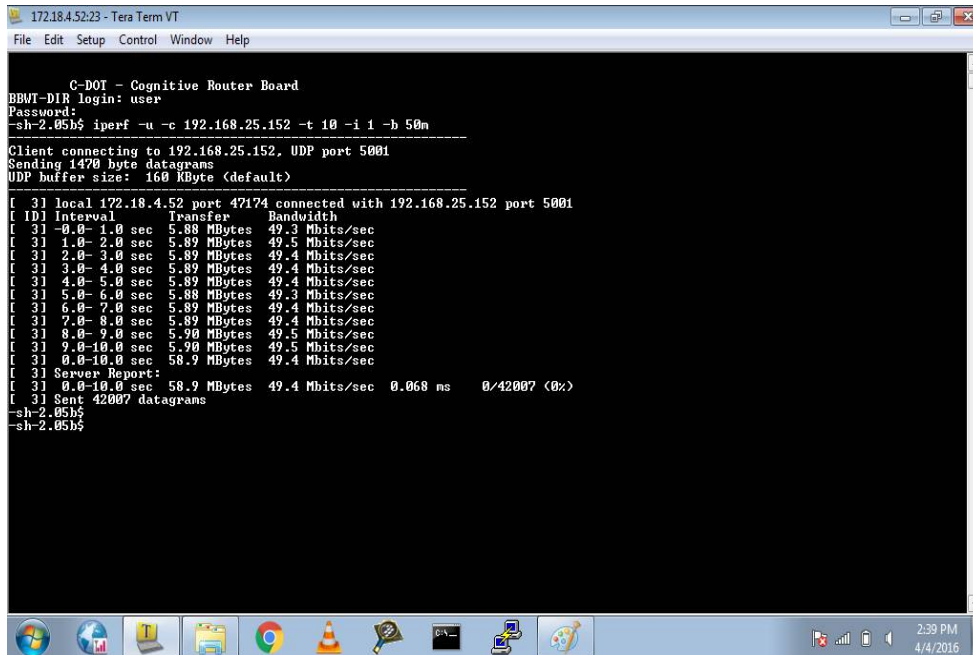


Fig 8: Throughput UDP with DFS.

X. RESULTS

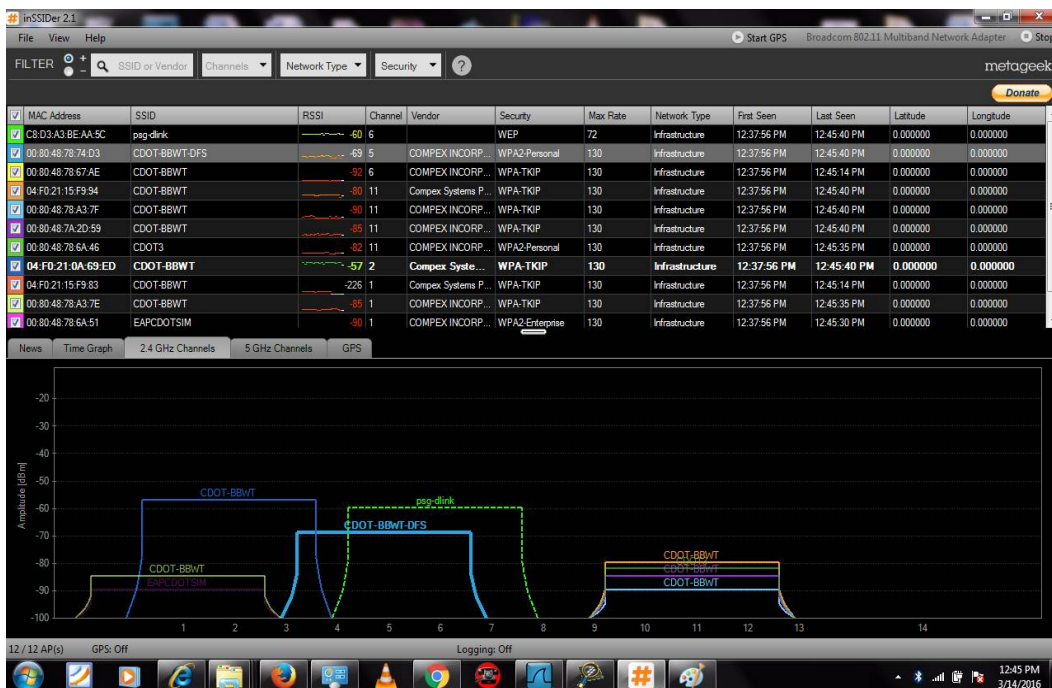


Fig 9: inSSIDer view of channel 5 (Current).

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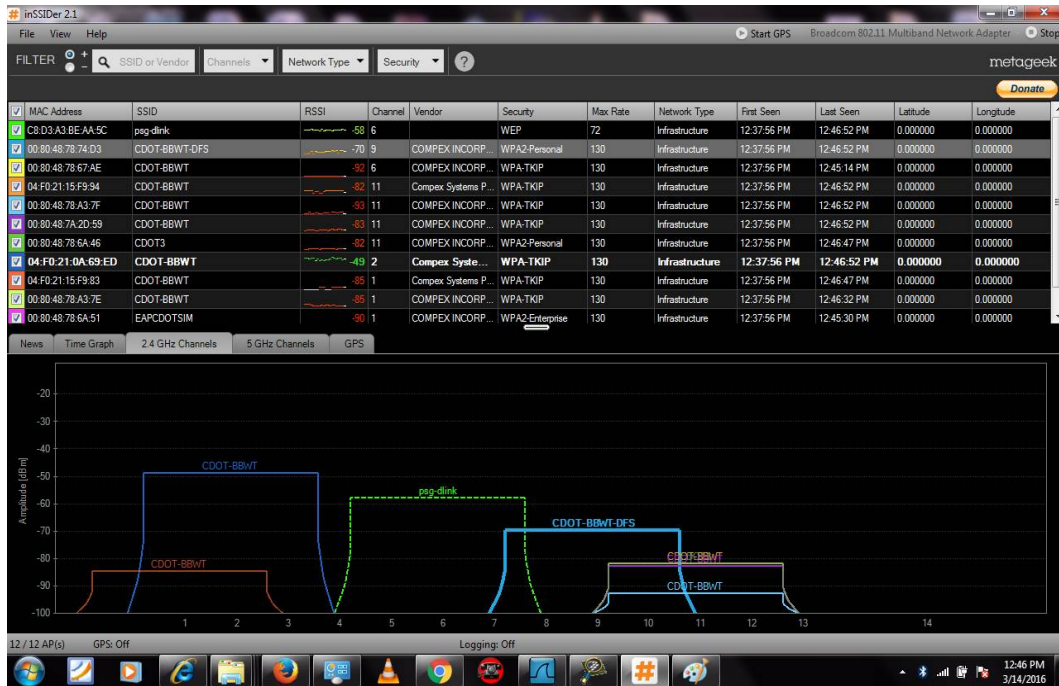


Fig 10: inSSIDer view of channel 9 (Switched to a different channel).

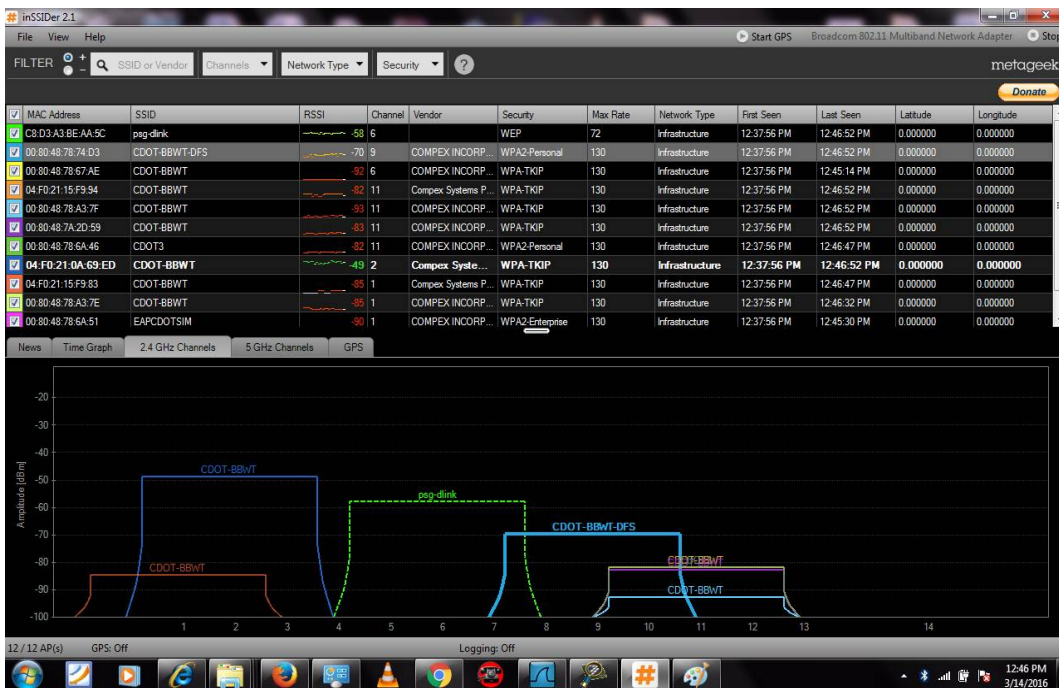


Fig 11: inSSIDer view of channel 9 (same channel Retained).

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XI. CONCLUSION

Cognitive radio is a novel technology that can potentially improve the utilization efficiency of the radio spectrum. Cooperative communication can play a key role in the development of CR networks. Cooperative spectrum sensing is considered and shown to be a powerful method for dealing with the hidden terminal problem. However, under realistic scenario, where the reporting channels are subject to fading and shadowing, the performance of cooperative spectrum sensing can be severely limited. To address this and other cooperative spectrum sensing challenges, various potential solutions were processed.

Dynamic spectrum can be fully utilized through a number of cognitive relay nodes. This so-called cognitive wireless relay network can support seamless data service for cognitive users while causing zero interference to primary systems. In order to fully utilize the scarce spectrum resources, with the development of cognitive radio technologies, dynamic spectrum sharing becomes a promising approach to increase the efficiency of spectrum usage.

Cognitive radio, which is one of the efforts to utilize the available spectrum more efficiently through opportunistic spectrum usage, has become an exciting and promising concept. One of the important elements of cognitive radio is sensing the available spectrum opportunities. In the new spectrum Management paradigm, licensed users can share their spectrum with unlicensed users (referred to as secondary users), thereby increasing the efficiency of spectrum utilization. This method of sharing is often called Dynamic Spectrum Access (DSA).

XII. FUTURE WORK

CR networks are still in its early stage of development and there are many complex issues which still needs to be resolved in future especially regarding common control channel (CCC) and sensing policies of MAC protocols.

Moreover, in future it will be interesting to develop another cross-layer based protocol which can get different type of information from higher layers like current bandwidth consumption and future requirement. This will require the more intelligent sensing module of CR which can sense and adapt according to the requirements and such a protocol will be more flexible and effective in real CR networks.

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