# Fuzzy logic power Control for Zigbee Cognitive Radio

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**ABSTRACT -** Spectrum sharing without interfering to the primary users is one of the challenging issue in cognitive networks, at the same time power control is one of the feasible solution for spectrum sharing without disturbing the primary user to achieve required performance at cognitive radio.

In this paper one Zigbee is configured as primary user and another Zigbee as secondary user which together forms a cognitive network. Here the implementation of the designed setup is carried out by analyzing signal strength , transmit power level assignment and routing algorithm on specific transceiver model of IEEE 802.15.4/Zigbee on Arduino board which leads to better performance of cognitive radio to access spectrum.

**Keywords—**CR (Cognitive Radio), PU (Primary User), SU (Secondary User), TPC(Transmit power control), (RSSI)Received signal strength indicator.

## INTRODUCTION

Today wireless systems take up more and more of the frequencies that are available. Most of them are licensed to high speed wireless internet, telephone and mobile operators internet[1]. There is a need to develop the new system due to high demands on frequencies as there seems to be lack of free frequencies while new wireless systems are developed One such technology is called Cognitive Radio, which allow the re-use of spectrum.[2]

The idea for cognitive radio has come out of the need to utilize the radio spectrum more efficiently, it is possible to develop a radio that is able to look at the spectrum, detect which frequencies are clear, and then implement the best form of communication for the required conditions thus one can say Cognitive Radio (CR) is a form of wireless communication in which a transreciever can intelligently detect which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. This optimizes the use of available radio-frequency (RF) spectrum while minimizing interference to other users. [2].

In an underlay CR system the secondary users (SUs) protect the primary user (PU) by regulating their transmit power to maintain the PU receiver interference below a well defined threshold level. The limits on this received interference level at the PU receiver can be imposed by an average/peak constraint [3].

Power control in CR systems presents its own unique challenges. In spectrum sharing applications, SU power must be allocated in a manner that achieves the goals of the CR system while not adversely affecting the operation of the PU. In [4], a distributed approach was used for power allocation to maximise SU sum capacity under a peak interference constraint. Fuzzy logic decision has been to choose the most suitable access opportunity for various transmit power levels using Zigbee to dynamically adjust to various power levels to analyze the interference scenario effectively[5]

In this paper hardware system is proposed with Zigbee modules in the ISM band and microcontroller ATMEL ATMEGA328P based Arduino board to control the transmit power levels and spectrum sensing in order to provide a reliable communication by reducing the interference w.r.t to the power levels to the primary user unit of the cognitive radio thus to design a system to limit the interference w.r.t to transmit power levels

The outline of the paper is as follows. Section II describes system model of primary user system and cognitive secondary user system with respect to receiver and transmitter and their working model. Section III shows the experimental setup. Experimental measurements and results are shown and described in section IV. Section V tells about the future work.

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**SYSTEM MODEL**

In this paper we consider scenario in which a primary system is licensed service and cognitive secondary system present in the same area along with primary system using opportunistic radio spectrum access which should not increase level of interference observed by primary system. Here the cognitive system consists of two units namely Surveilling Unit and Regulating/Supervising Unit.

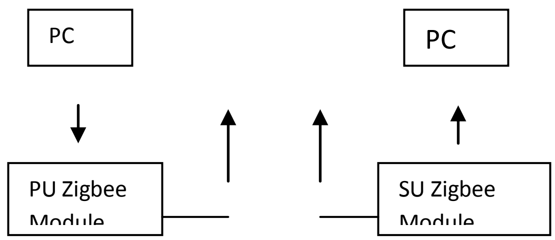


Fig 1 : Surveilling Unit

Surveilling Unit consists two Zigbee module one for each primary user and secondary user which are connected to PC and monitored through the X-CTU software.

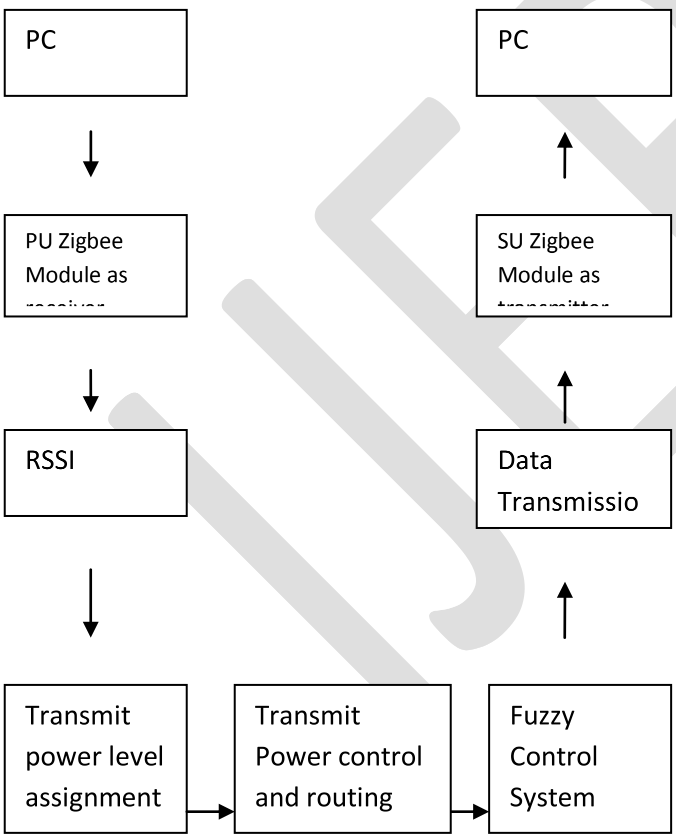


Fig 2 : Regulating/Supervising Unit

Regulating/Supervising Unit consists of a microcontroller to which two Xbee modems are connected one as primary user unit as a receiver/end device and another as secondary user unit as a transmitter/coordinator. The microcontroller used is ATMEL ATMEGA328P based Arduino board called Duemilanove programmed using wiring programming language operating at 16 MHz . The RSSI of the last received packet i.e. the detected signal is evaluated. Received signal strength indicator (RSSI) is the signal strength level of a wireless device measured in –dBm of the last received packet [6]. Next the transmit power level assignments are done with the help of analyzation of RSSI values of various received signal packets. Transmit power level assignment is done with the help of Friis transmission equation [7]. Using the Friis transmission equation, the ratio of the received power *Pr* to the transmission power *Pt* can be expressed as

$$P_r = P_t \times G_t \times G_r \left( \frac{\lambda}{4\Pi d} \right)^2$$

where, *Gt*, *Gr* are gain of transmitter and gain of receiver respectively. λ is a wavelength, and *d* is the distance between the sender and receiver, w.r.t square of the distance the signal strength degrades in free space. The Regulating/Supervising Unit each router then sends its link quality data along with its battery charge to the coordinator, which performs the transmit power level assignment and routing algorithm. Next the fuzzy logic is applied to dynamically adjust the transmit power control ratio of the specific secondary user in cognitive network according to the changes in transmit power level assignment, transmit power control and routing algorithm.

## EXPERIMENTAL SETUP

Fig1 and Fig 2 shows the experimental setup established in the paper. In Surveilling Unit two Xbee Series 2, 2mW modules from Digi International, model XB24-ZB is used each as a primary user module and secondary user module. Each module is equipped with a wire antenna. XBee offers transmission range of 40 m in indoor scenarios and 140 m in outdoor.

X-CTU, a free software provided which is provided by Digi International is used for programming each unit i.e. primary user unit and secondary user unit. A user can renew the parameters, enhance the firmware and perform communication testing readily using this software. Communication with XBee modules i.e. primary user unit and secondary user unit is done via XBee Interface board connected using a USB cable to a personal computer (PC).

In Regulating/Supervising Unit one Xbee modem as a end device and another as a coordinator is connected to microcontroller where programming is done in Arduino IDE software version 0022.

## EXPERIMENTAL MEASUREMENTS AND RESULTS

Firstly transmission and reception of the signals are analyzed using Xbee-series 2 transreciever module and X-CTU software which are shown in fig 3 and fig 4. Next the same transmission and reception of the signals is established between Xbee-series 2 transreciever and microcontroller ATMEL ATMEGA328P based Arduino board where programming is done in Arduino IDE software version 0022 with the help of Xbee-series2 .

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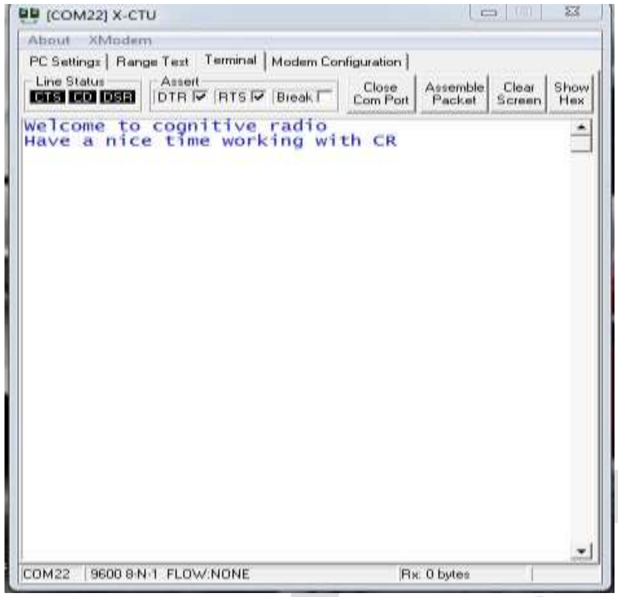


Fig 3 : Transmission of signals using X-CTU


Fig 4 : Reception of signals using X-CTU

Next the RSSI values of the different signals is obtained and analyzed with the help of X-CTU and AT command ATDB w.r.t to the distance between two Xbee's and without interference between them which is shown in the fig 5. From the graph one can interpret that as the distance increases the RSSI decreases.

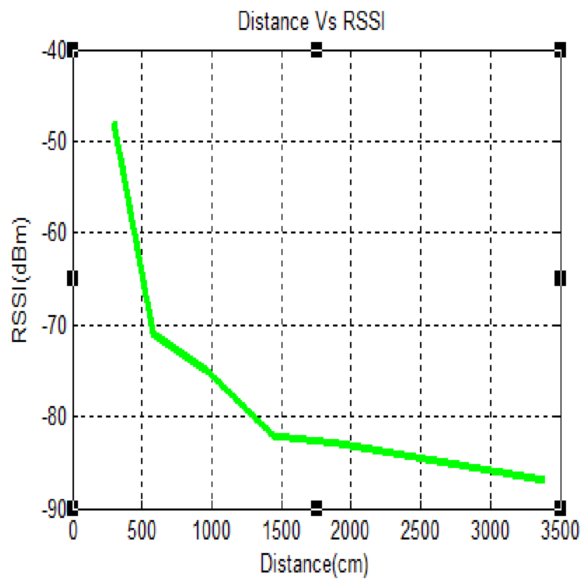


Fig 5: Signal strength of various signals without interference

with respect to distance.

Further RSSI values of different signals is obtained using XBee power levels for transmission with the help of AT command ATPL which sets the XBee at one of its power level for transmission. Here the RSSI values that obtained are w.r.t to the distance at three different values for transmit power Pt : (i) -8 dBm, (ii) -4 dBm, and(iii) 2 dBm. as shown in the fig 6

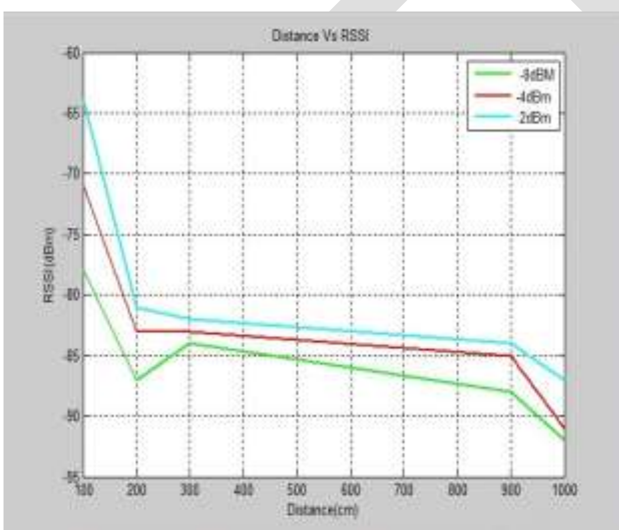


Fig 6. Measured RSSI values versus distance at different values of transmit power.

With respect to the transmit power levels the RSSI degrades with the square of the distance from the sender. The fluctuations on the graph at distance between 200-300m with *Pt* of -8dBm can be associated with the presence of reflection and multipath phenomenality due to the presence of interference like wall and from Wi-Fi Routers located between the Zigbee's. Thus reasonably increase in transmit power leads to a better performance.

## FUTURE WORK

The future implementation and application will be done to reduce the harmful interference to the primary user unit with the help of transmit power control and suitable routing algorithm on specific transceiver model of IEEE 802.15.4/Zigbee on Arduino board which could be one of the feasible solution for spectrum sharing with interference minimization upon that implementing the fuzzy logic to dynamically adjust the transmit power control ratio of the specific secondary user in cognitive network both in homogeneous and heterogeneous environment according to the changes of desired Zigbee parameters which could lead to achieving the required performance at cognitive radio secondary users and minimizes battery consumption of mobile terminals for next generation wireless networks and services.

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