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Efficient Allocation of TV White Spaces for Cognitive Radio in Pakistan

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ABSTRACT

The spectrum utilization is a function of time and location. Hence, at different times and locations the utilization of spectrum might be different. The TV band 52-862 MHz has been the most crucial frequency band in Pakistan that remains unoccupied most of the time. The unoccupied frequency chunks in the TV band are termed as TV White Spaces (TVWS). In this paper, energy detection technique for spectrum sensing is implemented to locate the TVWS available in Pakistan and overall situation of the spectrum is analyzed. For this purpose, the whole frequency band is scanned with Universal Software Radio Peripheral (USRP2) hardware as well as spectrum analyzer to validate the results of the USRP2 and to investigate the potential of cognitive radios in Pakistan.

Keywords: *TVWS, USRP2, Cognitive Radio, TVWS in Pakistan, Energy Detection, Spectrum Sensing.*

1 INTRODUCTION

Cognitive radio is an emerging field to address the issue of spectrum scarcity. According to FCC there is a large portion of spectrum that remains unoccupied most of the times [1]. On the other hands, high demand for bandwidth and increasing number of customers has led to the spectrum shortage [2]. According to [3], there are following ways to address this issue; one is to reschedule the whole distribution, which is impossible due to enormous investment of companies, second is to devise some means of communication that could utilize the underutilized band opportunistically. The second approach is achieved using the concept of "Cognitive Radio" [4].

Cognitive radio is a smart user that detects the unoccupied spectrum and starts its communication on the unoccupied spectrum. In the cognitive radio terminology, the smart user is categorized as the Secondary User (SU) that accesses the spectrum opportunistically and the licensed user is called Primary User (PU). However, there is a condition imposed on the SU as well that the SU should not interrupt the primary user at any cost [5].

Recently quite a lot of developments from the industry as well as the academia across the world have emerged to investigate this innovative technology. IEEE 802.22 Wireless Regional Area Network (WRAN) is the standard defining all the requirements and developments. A technological consortium CogNea has been developed by the industry [6]. FCC has introduced comprehensive approaches to optimize the use of underutilized frequency spectrum and allowed CR operation in TV White Spaces [7]. Adaptrum, Motorola, I2R, Microsoft and Philips have proposed their models and prototypes of cognitive radios [8].

Operation in TV band is legally allowed by the FCC if the cognitive radio user does not interfere with the licensee [9]. The opportunistic access is meaningful in terms of spectrum utilization and copes up with the spectrum scarcity issue. High speed applications and broadband requirements are contributing for the demand of increased bandwidth. Pakistan is a country where the demand for the bandwidth is increasing rapidly hence; it becomes obvious to investigate the ways to accommodate high traffic [10]. For this purpose, a scanning of the band is required to make a feasibility report introducing cognitive radio effectively in the country. An algorithm is developed that scans the band efficiently and finally the outcomes are presented in appropriate ways.

The paper is organized as follows. Section I is introduction. In section 2, a detailed and comprehensive discussion regarding the operation of cognitive radios in TVWS made. It is followed by the algorithm development in section 3 and finally in section 4, the simulation environment and experimental results are discussed.

2 WHAT ARE TV WHITE SPACES?

It is a well-known fact that TV operators operate in UHF and VHF bands. In the developed countries, a process named Digital SwitchOver (DSO) has been completed that basically vacates the UHF and VHF bands as they have started TV broadcasting in Digital band. This vacated spectrum is referred to be as TV White Spaces (TVWS) [11]. As in the case of Pakistan, no DSO has been completed hence determining the TVWS is challenging but we should realize that only two TV operators are presently using the spectrum [12]. After the digital switchover in modern countries, a larger band is vacated which is termed as TV White Spaces [13]. TV band spans over a very large frequency of 60-852 MHz. A large band is dedicated to only two TV operators that is wasteful. According to the spectrum allocation and regulatory authority i.e. Frequency Allocation Board (FAB), following three chunks are allocated to the TV operators i.e. 61-68MHz, 174-230 MHz and 470-598 MHz and interestingly both the operators are based on analog communication [14]. The utilization of the spectrum is the function of time and location:

$$\alpha = f(t, l) \qquad (1)$$

Where α is the utilization of spectrum in percentage, t is the time and l is the location. Hence, for different times and locations, the value of α is different.

3 ALGORITHM & METHODOLOGY

There are different ways to locate TV White Spaces in the spectrum such as spectrum sensing, Geolocation database system or beacon signal method [15]. Spectrum sensing is the original concept of the cognitive radio proposed by J. Mitola [16]. It further involves three main methods to sense the spectrum i.e. energy detection, Cyclostationary feature detection and matched filtering [17]. Our proposed algorithm is based on energy detection. It is the most important spectrum sensing technique. The energy detection involves the implementation of Fast Fourier Transform (FFT) on the received signal that results in the energy of the signal as:

$$E = \int |FFT|^2 \qquad (2)$$

Once the energy of the received signal is computed, it is compared with a threshold; if the energy is above the threshold the channel is said to be occupied otherwise it would be vacant. So, it is a binary operation explained below as:

$$X(t) = n(t) \qquad H_0 \quad (3)$$

$$X(t) = S(t) + n(t) \quad H_1 \ (4)$$

For equation 3, n(t) is the noise, Ho defines the absence of the signal and s(t) defines the signal therefore H1 represents the signal's presence in equation 4. So, it is a binary decision whether the signal is present or not.

The spectrum sensing technique is implemented using hardware Universal Software Radio Peripheral (USRP2). USRP2 is a hardware that provides RF-Front end. The daughterboard used is (Wideband Transceiver) WBX, Flex 900 and antenna used for the simulations are Vert. 400, and Vert 900. This is the first attempt according to our knowledge that investigates the frequency holes available in the country.

The algorithm developed works as follow:

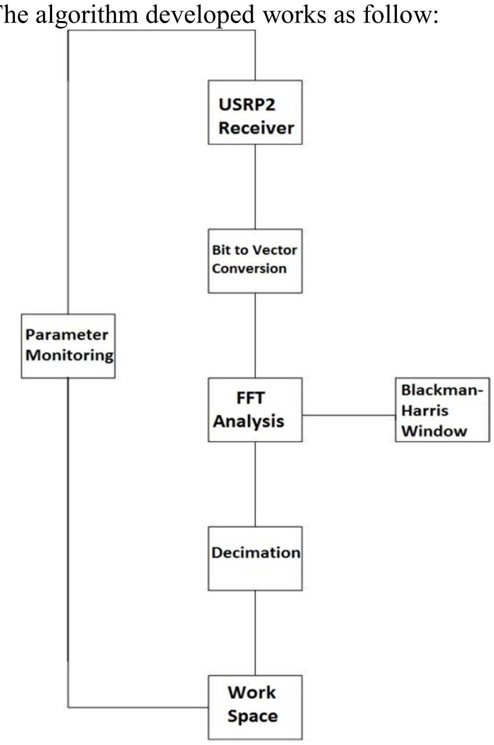

Fig. 1. Sensing Algorithm

First of all, the signal is received by the external antenna from the environment; the motherboard of the USRP2 performs Analog to Digital Conversion (ADC) and passes through the band pass filter. Once the signal is passed through the band pass filter, the process of bit to vector conversion is performed followed by FFT analysis which yields the energy of the signal as explained in equation (2) giving a spectrograph with frequency on X-axis and energy in dB/dBm on Y-axis, Blackman-Harris window is applied which removes the leakage of the spectrum. Decimation factor is applied on the output which performs downsampling on the signal. Decimation is the reverse process of interpolation.

4 EXPERIMENTAL SET UP AND RESULTS

The experimental setup consists of a USRP2 interfaced with MATLab/Simulink and experiments carried out for one week. Spectrum scanning is also done using spectrum analyzer and then finally the results are compared. The whole frequency band was divided into multiple small chunks because of the hardware limitation. The bandwidth of USRP2 is 25MHz. The simulation results are shown as:

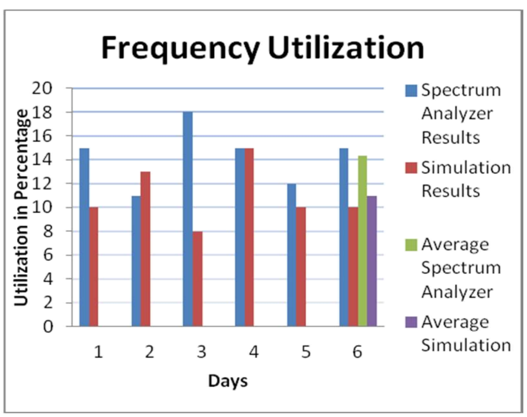

Fig. 2. Average utilization of band 50-250 MHz

It is clear from the above figure that only a fraction of the band is being utilized in Pakistan. Most of the times, the activities were observed in FM band, TV band and few other channels. It is clear from the above graphs that the average utilization is only 11 percent according to our simulation results and 14.3 percent when results are taken from the spectrum analyzer. The reason for variation in the results is time and location factor of the experiments as described in equation 1.

Figure 3 shows the results of the spectrum utilization for the band 250-400 MHz taken from the spectrum analyzer as well as through the simulations and an average is shown against the number of days.

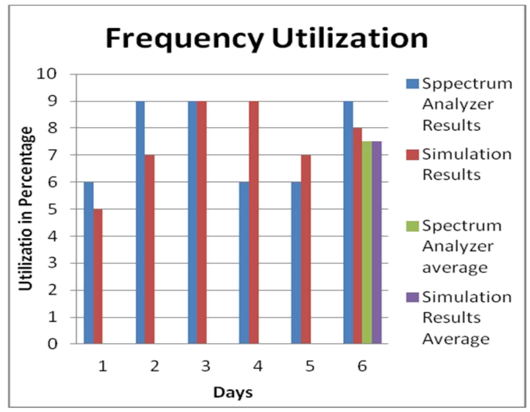

Fig. 3. Average utilization of band 250-400 MHz

From the above graph, it is clear that the frequency band 350-400 MHz is even underutilized with the maximum utilization of 9 percent on day2 and 6. The average of the spectrum analyzer results as well as simulation results clearly shows that a large portion of the spectrum remained unoccupied.

The frequency band 400-600 MHz is scanned afterwards. The results are shown as:

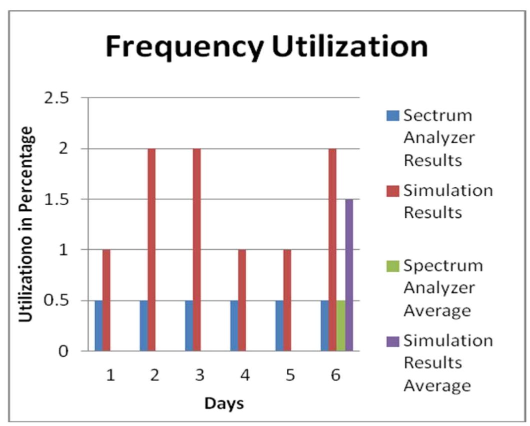

Fig. 4. Average utilization of band 400-600 MHz

The results of the above figure show that only 0.5% of the larger part is utilized. The activity observed on 472 MHz most of the time giving the notion of TV operators' presence.

Interestingly, when the portion between the 600-800 MHz observed for the whole week, not a single activity observed which depict clearly that the whole band is unoccupied.

The overall situation of the whole band is shown in the figure below:

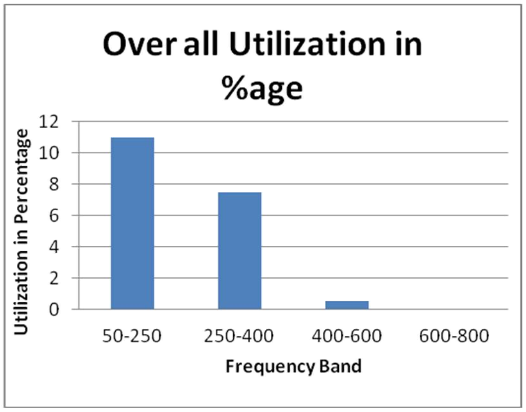

Fig. 5. Overall Spectrum Utilization

5 CONCLUSION & FUTURE WORK

From the experiment results, it is clear that a large band allocated to the TV operators remains unoccupied and a number of frequency holes are detected in the band. This results into large TV White Spaces in Pakistan, which ultimately raises the need of Cognitive Radio Networks. Total band of about 800 MHz is utilized only 17 percent overall.

As seen through the results, the situation regarding use of frequency band in Pakistan is evident that Pakistan has a large potential to deploy Cognitive Radio Network to get benefit from this large precious natural resource. In our future work, we are determined to devise a test-bed of cognitive radio that could utilize the available TVWS in Pakistan to accommodate broadband services to promote the health and education facilities in rural areas of Pakistan such as Interior Sindh, FATA, and Baluchistan.

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