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FREQUENCY SPECTRUM MEASUREMENT AND OCCUPANCY ANALYSIS

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Abstract - *Dynamic Spectrum Access (DSA) offers capabilities for sensing and dynamic reconfiguration that optimize the use of white spectrum holes. Effective spectrum sensing techniques are critical on the way to systems that use idle spectrum bands in an opportunistic way and improve overall spectral quality. In this paper we report on a large-scale measurement campaign in Pune, India. A high dynamic range spectrum measurement, data storage and the measurement of spectrum occupancy in all bands from 700 MHz to 2,700 MHz were included in the Pune mission. These observations were conducted over a span of two days. While these studies are important in deciding the bands have low usage and developing an algorithm for new spectrum strategy such as Cognitive radio network. Occupancy is assessed as the quantity of spectrum detected above a certain received power threshold. The threshold determination is based on the signal-to-noise ratio, which determines the particular threshold for the different bands used. The findings of this study indicated that this spectrum survey review is preliminary in nature, and potential long-term research needs to be conducted in order to determine any possible secondary use of these non-active channels. GSM 900 spectrum band occupancy is 26.7485%, which is highest form other bands are used.*

Key Words: Spectrum Sensing, spectrum occupancy, SNR threshold, Dynamic threshold, Noise estimation.

1. INTRODUCTION

Cognitive Radio (CR) is a method of wireless communication in which a transceiver can identify intelligently which channels of communication are in use and which are not in use, and switch automatically through empty channels while avoiding populated ones. CR can respond to their surroundings dynamically and incorporate different knowledge in order to make intelligent decisions [1]. In both the complexity of wireless technology and the laws affecting wireless networking and connectivity, urges are taking place. Government regulation policies are expanding unlicensed spectral bands to expand diverse spectrum connectivity applications such as smart radios and to investigate ways that would provide access to 'white spaces' in various bands [2]. Wideband spectrum sensing results in non-negligible time delays and spectrum decision based on real-time sensing results compromises the reliability of spectrum use due to time delays introduced by spectrum sensing and spectrum decision. We have to analyse the continuum because of these challenges [3]. Over measurement duration, the spectrum occupancy of multiple frequency bands was calculated. We report general use and evaluate the occupancy of the spectrum. In addition, we determine the technical threshold of SNR. Energy detection measures the energy obtained to a typically predefined threshold in a certain frequency band. The effect of the judgment threshold is addressed on the basis of our observations.

2. MEASUREMENT SETUP

At the top of the main building, the measurement campaign is set, which proves to be an optimal location for such a function. There is a direct line of sight on the terrace with several FM transmitters, analogue and DVB-T TV transmitters, GSM and UMTS base stations and several other stations at an altitude of at around 400 meters. The equipment used for measurement in this study consisted of a R&S FSH3 spectrum analyzer, an Omni-directional discone antenna, RS-232-C optical interface cable (RES II), and a laptop computer. The antennas were connected to the pre-selector.

Fig-1 : Observations set up deployed on the roof of the Sinhgad College of Engineering, Pune

A long RF cable, a control and power cable, and a pre-selector power cable are connected .The enclosure contained a 3 GHz spectrum analyzer, a laptop computer, and power supplies. Power was provided to the equipment using an extension cord plugged into a 230 volt AC outlet [4].

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2.1 Data formats

We measured the frequency range from 700 MHz to 2700 MHz in general, where most wireless networks are currently operating. Based on the bandwidth characteristics of the antennas chosen and the fact that there are many different wireless networks, such as GSM we use channels with a bandwidth of 200 kHz. For opportunistic use, spectrum white spaces of a very rough resolution bandwidth of 200 kHz are a fair [5][6]. The band from 700MHz to 2.7GHz range is chosen for scanning during the first 2 days of the measurement campaign allocated for the RF band. The program is written in the remote control software of FSH (R&S FSH-Remote) for data collection using the commands of FSH-Remote software. The entire 700MHz to 2.7GHz band is broken into 34 sub-bands, each of which has a frequency range of 60MHz. There are 301 frequency points in this 60 MHz frequency span. Therefore, 301 X 34 = 10234 is the cumulative number of frequency points in the entire band. In 1.5 minutes, the entire band is scanned. The files are gathered in the format .CSV (comma-separated values).

This spectrum scanning for whole spectrum is carried out at the same location for 2 days (48 hours) continuously. Also the noise measurements were taken in the same location. The data is then processed and viewed for further analysis and comparison. To monitor the calculation, save the data and eventually evaluate it, the PYTHON software package and its instrument control toolbox were used.

2.2 Measurement site

The measurement location for this study was the top of the Sinhgad College of Engineering Kondhwa, Pune center of the city. Figure 1 shows the measurement setup with the background terrace location. Figure 2 shows a map of the measurement area illustrating the location of the building.

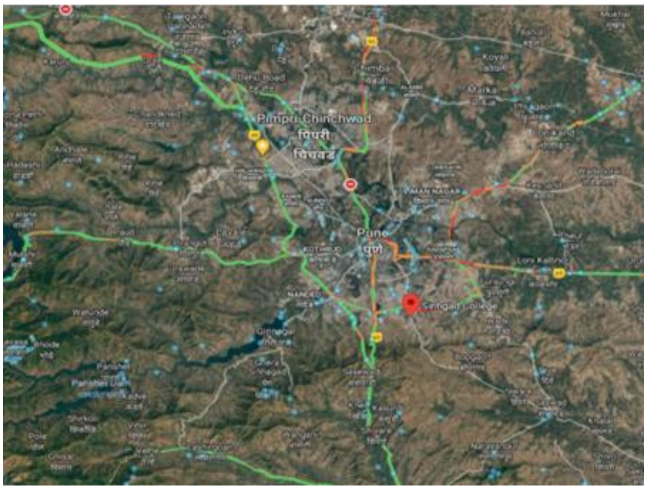

Fig-2 : Location of measurement

3. SPECTRUM MEASUREMENTS AND THRESHOLD IDENTIFICATIONS

Spectrum sensing is one of the most important components of cognitive radio networks. Spectrum sensing enables a cognitive radio to have information about its environment and spectrum availability. The most widely used spectrum sensing methods are energy detection and matched filter detection.

Energy detection is the most widely used method since it has low complexity and it does not require prior information about of the primary signals. In the energy detection process, the spectrum occupancy decision is based only on the threshold obtained depending on the noise. The threshold is compared with the perceived energy and it is decided whether the primary user is present or not. It aims essentially to decide between two states: primary user signal is absent, denoted by $H0$, or primary user signal is present, denoted by $H1$. The decision of energy detector is the test of the following hypothesis:

$$H0 :(n) = W(n) : \text{primary user absent}$$

$$H1 :(n) = S(n) + W(n \quad : \text{Primary user present (1)}$$

Where (n) is the signal received by the secondary user and (n) is the primary user's transmitted signal, $W(n)$ is the Additive White Gaussian Noise (AWGN) with zero mean [7].

Threshold value specification is a very critical parameter, since the threshold value explicitly influences the occupancy of the spectrum. Owing to the high decision threshold and the low decision threshold, two big issues have occurred: underestimation and overestimation of spectrum occupancy. Threshold determination method is proposed to increase the spectrum sensing performance of spectrum sensing methods and to minimize the total error probability. The optimum decision threshold is the most important parameter to decide the presence or absence of the primary user [3][8]. Spectrum Measurements are a proper means to evaluate spectral occupancy and other statistical characteristics of wireless communication. The particular channel is said to be occupied when the received power level exceeds a threshold level.

Received signal intensity is an estimated measure of the power level that is received from the connection point or router from the RF client interface. At larger distances, the signal becomes weaker, resulting in lower average data throughput. For the mixed network used -70 to -80 dBm is the best network and noise is assumed to be below the threshold values. The primary user is considered to be present if this energy is higher than this threshold; otherwise, the primary user signal is believed to be absent. To maximize the spectrum sensing efficiency of spectrum sensing methods and to decrease the overall likelihood of error, the threshold determination procedure is suggested [8].

This approach is quick, because no prior knowledge of the primary user signal is needed. If the power level exceeds a predetermined threshold, it will be called a signal; otherwise it will be considered a random noise. The threshold determination technique is proposed in order to optimize the spectrum sensing performance of spectrum sensing approaches and to reduce the total probability of error.

4. SPECTRUM OCCUPANCY

Spectrum occupancy indicates the degree to which the frequency band is occupied during the measurement cycle. In our work, the occupancy of the spectrum is characterized as the fraction measured in time and frequency measurements where the obtained signal intensity reaches the decision threshold. This section presents the spectrum occupancy details from the spectrum measurement survey of the bands allocated to the different wireless services. The average received signal power variation above the threshold with respect to the frequency span of the measurement study is depicted into the plot, which is shown in figure 3.

The plot shows the spectrum usage mostly, low with some patchy spots of spectrum use. The overall occupancy is the occupied spectrum divided by the total available spectrum. When the obtained signal intensity of the channel at some point in the measuring equipment is above the determination threshold, the channel at that time is said to be occupied. If it is below, it is assumed to be either free or idle. The assessment threshold is a very critical criterion, which has a direct effect on the estimation of spectrum occupancy. The selection of a high decision threshold can lead to an underestimation of spectrum occupancy and an overestimation of the low decision threshold. The existing literature survey indicates that most of the measurement campaign kept the decision threshold at a certain dB above the noise level of the measurement equipment [9]. The instrument noise level is measured by terminating the equipment by a 50 ohms resistor. The decision threshold in this work is taken as 3.5 dB as all outliers and weak signal removed and tested no doesn‘t effect on received signal values.

The back-ground noise varies with the frequency so the decision threshold is not fixed for the entire band of the measurement. We use a different threshold in order to address the different background noise levels, and also to achieve a realistic estimate of spectrum utilization. The entire band of 700-2700 MHz is divided into different bands.

Occupancy (%) = (Number of Signal above threshold level)/ (Total number of received signal)* 100

5. SPECTRUM RESULTS

Spectrum use is not continuous over time and the frequency range of the measurement. Certain spectrum bands record further use over a longer span of time; some portion of the spectrum tends to be of rare or null use.

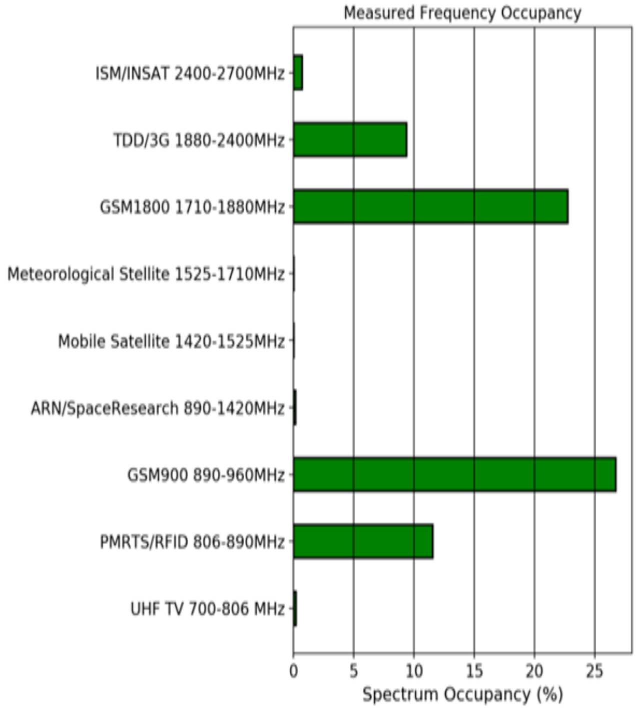

Fig- 3: Spectrum Occupancy

The first frequency 700 to 806 MHz is part of the 470–960 MHz band, which is dedicated mainly to terrestrial television transmission, fixed and mobile networks in India. The Doordarshan conducts short distance UHF connections in the frequency bands 735–755 MHz and 775–795 MHz which are depicted in fig 3 . The total occupancy for this spectrum band is just 0.40 %.

The next band is 806–890 MHz allocated to Public Mobile Radio Trunked Service (PMRTS), Digital Cellular Services and Radio Frequency Identification (RFID) under the Indian National Frequency Allocation Plan. The Wireless Cellular Transmission System, which operates in the 824-889 MHz range and uses the Code Division Multiple Access (CDMA) technology, has an asymmetric pattern of occupancy between uplink (0.68 %) and downlink (43.12%).

Measurement result for the GSM 900 band (880-960MHz) is presented in Fig.10 The decision threshold was selected 3.5 dB above the average noise floor to analyses the GSM 900 band. The 890-960 MHz band and 1710-1880 MHz have been allocated for the GSM 900, and the GSM 1800 services respectively. These two bands have average spectrum occupancy of 26.74%, and 22.76% respectively.

Table -1 : Summary of spectrum occupancy

Band	Services	Average percentage occupancy
700-806 MHz	UHF TV, Fixed, and Mobile services	0.20%
806-890 MHz	PMTRS, Cell Phone, RFID	11.56%
890-960 MHz	GSM 900,Cordless Phones	26.74.%
960-1420MHz	Aeronautical Radio Navigation, Radio Navigation Satellite, Earth Exploration Satellite, , Space Research	0.18%
1429-1525 MHz	Fixed/Mobile, Mobile Satellite	0.125%
1525-1710 MHz	Mobile Satellite, Meteorological Satellite Aeronautical Radio Navigation	0.045%
1710-1880 MHz	GSM 1800	22.76%
1880-2400 MHz	TDD,3G,Fixed/ Mobile, BWA	3.15%
2400-2700 MHz	ISM,BWA,INSAT	0.38%

Hence, the moderate spectrum occupancy for the GSM 1800 band is analyzed. The uplink and downlink spectrum occupancy is found to be 0.08%, and 51.50% respectively.

The low-occupancy on the uplink may be because of the low transmit power from the mobile terminals. Most of the mobile terminals operate at ground level, and the location of the antenna used in this work is at high altitude, and causes more signal attenuation. The system works on the energy detection principle, and cannot detect such weak signals.

The 2400-2700 MHz band has very poor spectrum use at an occupancy rate of just 0.38 %. This band comprises common unlicensed Commercial, Science and Medical (ISM) bands (2400-2483.5 MHz), Broadband Wireless Access (BWA), Indian National Satellite System (INSAT) and other networks. Occupancy of satellite networks is very poor since the signal reached at ground level may be very small and the measuring device may not be able to detect it.

Spectrum use is not continuous over time and the frequency range of the measurement. Certain spectrum bands record further use over a longer span of time; some portion of the spectrum tends to be of rare or null use.

6. CONCLUSION AND FUTURE WORK

We consider the features of spectrum occupancy in detail for the exploitation of the free spectrum. Our calculations have shown that spectrum occupancy is strongly dependent on the position of the instrument and the decision threshold chosen to discriminate between the idle and the used bands. The spectrum occupancy for this measurement period is very low 5.96 % that means 94.04% of the allocated spectrum is completely unutilized. Low occupancy was recorded in bands assigned to aeronautical radio navigation, radio navigation satellite, earth exploration satellite, radio, space research, cell satellite, meteorological satellite, and 3G.

In Future work, we aim to predict spectrum using machine learning algorithms, thus reducing sensing time and energy consumption. A CR customer forecasts the quality of the channels in terms of idle probabilities, idle durations, and other properties in predictive-based spectrum judgment, and then selects a high-quality sensing and access channel to improve the efficiency of its dynamic spectrum access.

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