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Spectrum Occupancy Measurement, Analysis and Observation of Cellular Networks in India

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***Abstract*— Cognitive radio (CR) has been seen as a promising futuristic radio technology to reduce the spectrum scarcity problems. Here the unlicensed users can utilize the licensed spectrum until the licensed users are detected. In this work spectrum occupancy measurement campaign and its analysis for cellular service provider in India has been done. Measurement results shown that the spectrum band is under-utilized. Hence cognitive radio network CRN can be foreseen as a potential solution to reduce the spectrum scarcity paradox and to optimize the spectrum utilization. The measurement results show that the spectrum occupancy for Vodafone 900, Vodafone 1800, Airtel 1800, Idea 1800, Tata 1800, Reliance Jio 850, Reliance Jio 1800 and Reliance Jio 2300 band are 49.5017% , 26.5781%, 25.5814%, 30.5648%, 27.9070%, 11.9601%, 35.8804% and 36.2126% respectively. Out of the eight cellular bands most occupied cellular band is Vodafone 900 band which occupied 49.5017% spectrum band. It means that near about 51% spectrum is unutilized. The less occupied spectrum band out of eight bands is Reliance Jio 850 band which occupied 11.9601% only. Furthermore the results show that the bandwidth utilization of cellular service providers is not 100% even when the cellular operators in India are growing rapidly.**

Index Terms— *Cognitive Radio, Spectrum Occupancy Measurement, Cellular Bands.*

I. INTRODUCTION

An efficient use of spectrum is essential to solve the spectrum scarcity issue which arises due to traditional fixed frequency allocation policy. On the other hand, the quick expansion of the applications of wireless communication and devices demand for more radio waves. Recently the cognitive radio has become known as a promising solution to reduced the spectrum scarcity , in which the licensed user can used a licensed band or allocated band but the unlicensed user can also utilize the licensed band until its transmission do not interrupt with the transmission of licensed user.

In addition, the spectrum utilization varies from 15% -85% in the 0-6 GHz band, thus resulting in spectrum wastage [1] these studies conducted by the Federal Communications Commission (FCC). Cognitive radio (CR) enables the hopeful use of under-utilized spectrum holes or white space of the spectrum by allowing unlicensed users to access the licensed spectrum while not interfering with the transmissions of the licensed users. To sweep the spectrum holes or white spaces and utilize these spectrum holes or white spaces in an idealistic manner cognitive radio need to performs the spectrum sensing [1]-[2]. Mark A. McHenry [3] describe the spectrum occupancy measurement perform by the shared spectrum company in concurrence with the wireless interference lab of the Illinois institute of technology in Chicago on November 16 to 18, 2005. That site was purposely selected as a setting with assuming high level of wireless activity. The research was funded by the national science foundation under its computer and information science and engineering organization and specifically nit's NeTS-ProWIN program. Measurement was taken for all bands in 30MHz to 3000MHz range.[4] measurement were taken for all bands in 30MHz to 300MHz range . The measurement was taken during a normal work week which concludes to be a high usage period. A wideband spectrum occupancy campaign was [5] conducted to understand the utilization of radio frequency spectrum in indoor and outdoor environment simultaneously. The measurement was performed in the range of 700-3000 MHz frequency band over three days for both the locations concurrently. And the results show that spectrum utilization for indoor and outdoor environment is significantly different and these differences are quantified. [6] Cognitive radio (CR) [7] is as expected to expressively increase current spectrum utilization. However, this paradigm can become turn into reality, before this, a full understanding of the dynamic usage of spectrum is must required. The current spectrum utilization has been evaluated in some measurement campaign.. The measurement campaign was conducted in Spain, were The related studies [8] referenced earlier provide a information about a spectrum occupancy in Chicago, new York, Washington D.C. and a few rural locations. The results [9] are common in the sense that the spectral occupancy guess are based on multiple years of observations, while previous studies produced occupancy members based on short term snapshot measurements, repeatedly of a few hours duration. The main objective of the paper was to present year by year first order statistic about the spectral occupancy across multiple bands , but more details are presented about radio usage in few bands like the TV band. region. The two main types of measurements were performed [10] with utilization parameter is calculated for a specific group of services not only for the whole band. Firstly, For spectrum sensing there are three techniques are used listed as energy detection, matched filter and cyclostationary detection technique. Based on the occupancy measurement campaign [11] the cognitive

radio could not operate on 2.45 GHz ISM band in the area of Oulu.. Unlike previous spectrum survey [13] which mainly focused on average spectrum occupancy, they analyze the usage of TV band from the comprehensive view. [14] show that the use of the band is rather low denote that there is may be potential for mobile communication system to share this band with the incumbent under the LSA approach. The spectrum occupancy measurement in the range 2.3 to 2.4 GHz band gives the useful insight into the current use of the band which is very low. The results [15] obtain from the measurement campaign conducted in the urban environment in Bucharest;. In order to solve the problem of spectrum scarcity [16] arises due to the rapid growth of wireless communication system need to access the spectrum dynamically. The measurement campaign was conducted for 700MHz to 2746.6MHz band and outcomes are observed for indoor and outdoor location respectively. They have discussed Max-Noise, m-dB and PFA threshold technique. Using this technique the spectrum occupancy in percentage was 9.83, 41.25, 13.92 and 12.48, 18.52, 15.83 for indoor and outdoor location respectively. Also they have provided comparative study of past and current measurement at year 2011 and 2017. The results shows that the occupancy is change from 2.3% to 9.83% for indoor location and 4.40 to 12.48% for the outdoor location.

In this paper, the spectrum occupancy measurement of the GSM cellular operators of India is performed. The measurements are taken at the electronics and Telecommunication Department (E&TC) of sinhgad academy of engineering (SAE) during day time for indoor location. vs. frequency for each cellular band and its bandwidth utilization in percentage. The rest part of the paper is organized as follows.

Fig. 1: measurement setup

II. MEASUREMENT SETUP AND METHODOLOGY

A. *Measurement setup*

The spectrum occupancy measurement was taken at 3rd floor of E&TC department using Rohde & Schwarz FSH3 handled spectrum analyzer with frequency range is from 100 KHz to 3GHz. The spectrum occupancy measurement setup configuration is as shown in figure 1, which shows that a AOR DA5000 antenna is connected to the spectrum analyzer via optical cable and the spectrum analyzer is connected to the laptop via USB optical cable. The measurement has been taken for a two hrs for each cellular band during day time. The spectrum analyzer and antenna specification are shown in table 1 and 2 respectively. Frequency range of spectrum analyzer is start from 100KHz to 3GHz.The Rohde & Schwarz FSH Remote and MATLAB software are used to record and plot the spectrum occupancy measurement respectively.

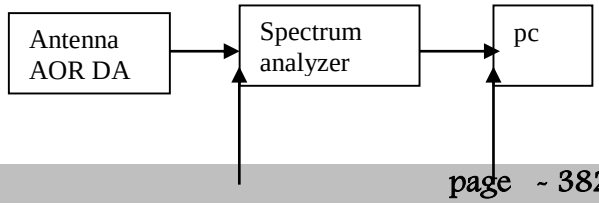
Table 1: Specification of Spectrum Analyzer

PARAMETER	**RANGE**
Frequency Range	100KHz to 3GHz
Frequency Span	0Hz,100Hz to3GHz
Sweep Time Span=0Hz Span>0Hz	1ms to 100s 20ms to 100 0s, Min.20ms/600MHz
Video Bandwidths	10Hz to 1MHz in 1,3 steps
RF Input	N female
Input Impedance	50 Ohm
Optical Interface	RS-232-C
Baud Rate	1200, 2400, 9600, 19200, 38400,57600, 115200 baud
Resolution Bandwidths	100 Hz to 1 MHz

Table 2: Specification of AOR DA5000 antenna

Frequency coverage	700MHz - 3GHz
Aerial gain (max)	2.5dB (max.)
Impedance	50 Ohm
Overall height	240mm
Wind endurance	40m/S
Coaxial cable	Use low loss
Horizontal element	16
Termination	N-socket, female
Radial elements	8

The spectrum occupancy measurement setup configuration is as are shown in figure 1.



Coaxial cable optical cable
RS-232-c

Fig. 2: Measurement setup configuration

B. Laptop Interface

In order to take a measurement, the spectrum analyzer is connected to a laptop with the Installed software. The process of preparing the setup is as following:

1. Turn on the laptop and FSH3 Spectrum analyzer.
2. Make sure that both are charged and connected to an AC power supply.
3. Insert the FSH view CD that comes with the analyzer package in the laptop.
4. Install FSH view and FSH remote control software on the laptop.
5. Connect the optical cable to the FSH3 and the USB end into the laptop while the CD is still in the laptop.
6. Automatically install the driver, this should occur TWO times.
7. Open the Hardware Management in the windows system.
8. Reassign the USB serial port of the FSH3 to one of the unused ports (e.g. COM2).
9. Open the FSH Remote control
10. Connect to the same port that you assigned
11. Now the software is connected and ready to use.
12. Put the equipment in weather protection.
13. Place the equipment on a high ground, with no obstacles.

C. Procedure for Antenna Reading

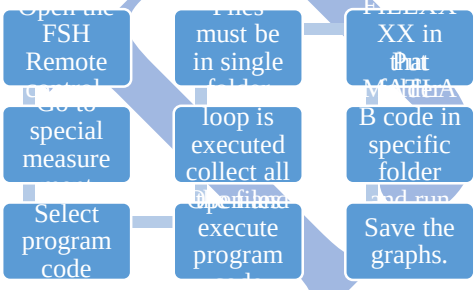


Fig.3: Procedures for Antenna Readings

D. Procedure for Noise Reading

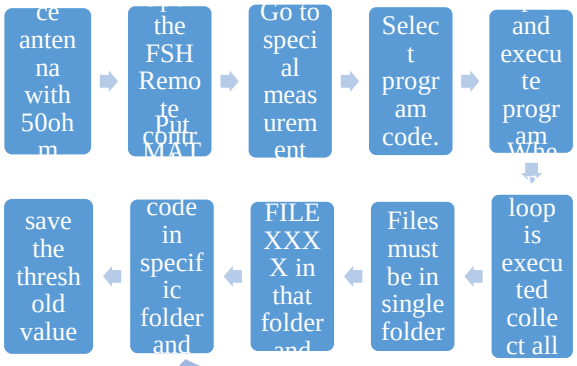


Fig.4: procedure for noise readings

E. Cellular Operators in India

There is several GSM cellular service providers are in India, out of them in this paper we have taken measurement for Vodafone, Idea, Airtel, Tata and Jio for different bands. The frequencies allocated to these cellular operators are shown in table 3

Table 3: uplink and downlink frequencies for cellular operators in India

Sr. no.	Operator	Uplink frequency in MHz	Downlink frequency in MHz
1	Vodafone 900	890-915	935-960
2	Vodafone 1800	1710-1781.5	1805-1876.5
3	Airtel 1800	1751.5-1756.5	1846.5-1851.5
4	Idea 1800	1761.5-1763.5	1856.5-1858.5
5	Tata 1800	1756.5-1761.5	1851.5-1856.5
6	Reliance Jio 850	824-849	869-894
7	Reliance Jio	1750-1785	1805-1880
8	Reliance Jio 2300	2300-2400	2300-2400

III. DATA PROCESSING

In this section the data collection should be carried out for short period of measurement. We carried out measurement for short term such as for continuous 2 hours. For data collection, the program is written in R&S FSH remote using the command of FSH remote software. Each band is divided into some sub-bands with frequency span of 60 MHz, the whole band is scanned in 6 seconds, and the files are collected in .CSV format. This files can be open and edited in Microsoft excel.

A. Threshold selection

The selection of the threshold value is very important parameter as the threshold value is directly impact on the spectrum occupancy. There are two major problems arrived due to high decision threshold and low decision threshold these are underestimation and overestimation of spectrum occupancy respectively.

The particular channel is said to be occupied when the received power level exceeds threshold level. In order to determine the threshold value there are three criteria namely, MaxNoise, mdB and PFA. Here we are using a mdB criteria. To measure mean $\mu_x(f)$, minimum $X_{min}(f)$ and maximum $X_{max}(f)$ values, the antenna have been replace bye 50ohm matched load and spectrum analyzer gives different noise values.

B. *m-dB criteria*

To take care of this issue, an optional alternative is to settle the choice limit m decibels above mean of the noise level:

$$Y(f)=\mu X(f)+mdB$$

IV. MEASUREMENT RESULTS AND DISCUSSION

The results of the spectrum measurements are illustrated in power spectral density (PSD) vs. frequency. The power spectral density can be calculated by averaging all the recordings which are collected during the two hours of measurement span for each cellular band. The spectrum occupancy is calculated by selecting the threshold level. The threshold level is calculated by adding 3 dBm in the minimum received power values. The threshold value and the minimum received power value of each measured spectrum band are listed in table 4.

Table 4: Minimum received power value and threshold value with occupancy in percentage

Sr no.	Operator	Minimum received power value(dBm)	Threshold Value (dBm)	Occupancy in %
1	Airtel 1800	-94.2537	-91.2537	25.5814
2	Idea 1800	-93.9969	-90.9969	30.5648
3	Reliance jio band3(1800)	-94.3851	-91.3851	35.8804
4	Reliance jio band5 (850)	-93.7209	-90.7209	11.9601
5	Reliance jio band40 (2300)	-92.0039	-89.0039	36.2126
6	Tata 1800	-93.9349	-90.9349	27.9070
7	Voda900	-92.9652	-89.9652	49.5017
8	Voda1800	-93.6113	-90.6113	26.5781

A. *Vodafone 900&1800 Band:*

Since 2011, Vodafone launched 3G network using 900 MHz and 2100 MHz on 28 June 2012 Luck now is the first to received 3 G service in Uttar Pradesh. Vodafone launched a new international roaming package under which the users shall have not to pay multiple rentals in the countries they are visiting. On 19 May 2015, TRAI announced that Vodafone had been awarded spectrum in 9 circles for 3G coverage, bidding around 11617.86 million for the spectrum. On 8 December 2015, Vodafone announced the roll out of its 4G LTE coverage in India on 1.8 GHz and 2.1 GHz bands starting from Kochi. The service became available to customers in India nationally in 2017, with plans for further expansion. Vodafone now starts 2100 MHz and 2500 MHz for 4G by which customers will get superior 4G speed than previous. Vodafone is expected to launch VoLTE services by the end of 2017. As of August 2016, Vodafone India has a market share of 18.42% with approximately 212.52 million subscribers and is the second largest mobile telecommunications network nationally after Airtel. The spectrum measurement results of the Vodafone 900 and Vodafone 1800 bands are illustrated in figure 4-9.

B. *Airtel 1800 band*

Bharati Airtel cellular is operates in 16 countries worldwide including South Africa and Africa. The airtel cellular provided with the 2G, 3G, 4G, LTE and VoLTE. Airtel had also launched its VoLTE technology across seven telecom circles namely Mumbai, Maharashtra and Goa, Madhya Pradesh, Chhattisgarh, Gujarat, Andhra Pradesh & Telangana, Karnataka, Chennai and Kolkata in India and should roll out the technology in rest circles by end of August 2018. It is the third largest network in the world and the largest mobile network operator in India with 25.85% market share and over 429 million subscribers. The measurement results for airtel 1800 band are shown in figures 10 to 12 and the spectrum occupancy for the airtel 1800 spectrum band is 25.5814.

C. *Idea 1800 band*

Idea Cellular started in 1995, as Birla Communications Limited with GSM licenses in Gujarat and Maharashtra circles. Idea changed its name to Birla IN 1996 AT&T Communications Limited following joint venture between Grasim Industries and AT&T Corporation. In 2001 it changed name to Birla Tata AT&T as a joint venture between aditya Birla group, Tata group and AT&T wireless. The company named its brand Idea in 2002. *Idea Cellular* Ltd. is the third largest wireless operator by subscribers in *India* with a Revenue *Market Share* of approximately 15.9% of the *Indian* mobile telecommunications services industry in Q3 December 2017. The spectrum measurement result of the idea 1800 band are illustrated in figure 13 to 15, the spectrum occupancy of idea 1800 spectrum band is 30.5648%

D. *Tata 1800 band*

Tata Teleservices Limited (TTSL) is an Indian broadband and telecommunications service provider based in Mumbai, Maharashtra, India. It is a subsidiary of the Tata group, an Indian conglomerate. It operates under the brand name Tata docomo in various telecom circles of India. Tata Indicom in April 2009 crossed the 35 million subscribers mark in the wireless category with an overall subscriber base of over 36 million. The measurement results for Tata 1800 band are shown in figures 16 to 18 and the spectrum occupancy for Tata 1800 band is approximately 27.9070%

E. Reliance Jio 850,1800&2300 band

Reliance has started its communication service during end of the year 2016 in India. it is located in new Mumbai . It is a subsidiary of Reliance Anil Dhirubhai Ambani Group. The services it provides include 2G, 3G, and 4G depending upon its areas of operation in India. The company plans to shut down its 2G and 3Gservices including all voice services and only offer 4G data services from December 29, 2017.Reliance Communications is the ninth largest telecom operator in India with 12.10 million subscribers, as of 31 January 2018. Spectrum measurement results for the jio 850, 1800 and 2300 band are listed in figures 19 to 27. The spectrum occupancy for jio 850, 1800 and 2300 bands are 11.9601%, 35.8804% and 36.2126% respectively.

1. *psd vs. frequency plot for Vodafone 900 band*

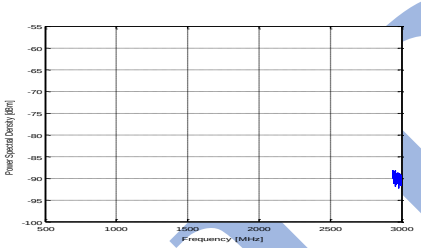


Fig 5: PSD for Vodafone 900 band

2. *ccdf vs. signal strength plot for Vodafone 900 band*

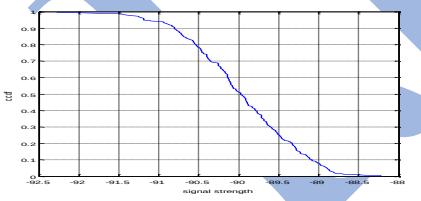


Fig 6: CCDF plot for Vodafone 900 band

3. *Psd vs. frequency plot for Vodafone 1800 band*

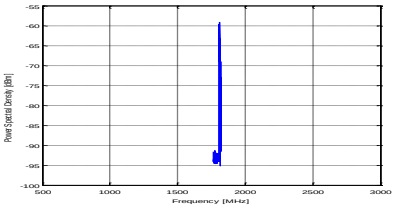


Fig 7: PSD for Vodafone 1800 band

4. *ccdf vs. signal strength plot for Vodafone 1800*

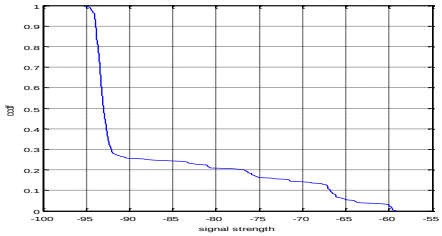


Fig 8: ccdf plot for Vodafone 1800 band

5. *Psd vs. Frequency plot for Airtel 1800 band*

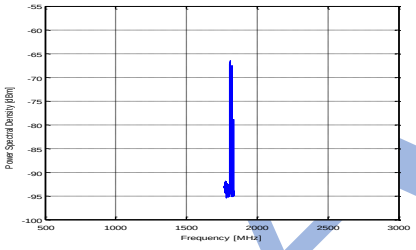


Fig 9: PSD for Airtel 1800 band

6. *Ccdf vs signal strength plot for Airtel 1800 band*

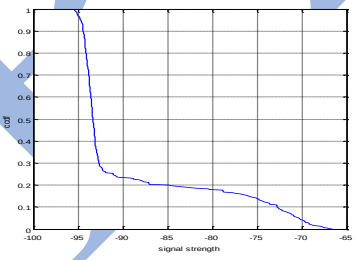


Figure 10: Ccdf plot for airtel 1800 band

7. *Psd vs. frequency plot for Idea 1800 band*

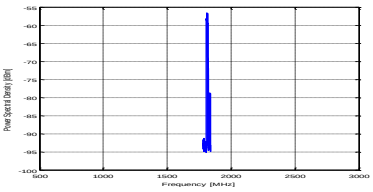


Fig 11: psd plot for idea 1800 band

8. *ccdf vs. signal strength plot for idea 1800 band*

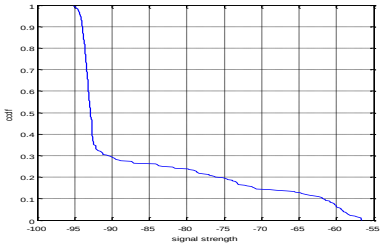


Fig 12: ccdf plot for idea 1800 band

9. *psd vs. frequency plot for Tata 1800 band*

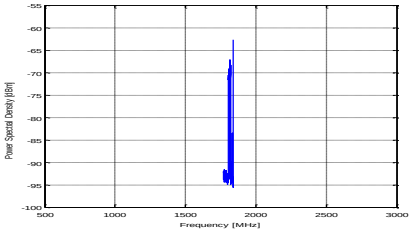


Fig 13: psd plot for Tata 1800 band

10. ccdf vs. signal strength plot for Tata 1800 band

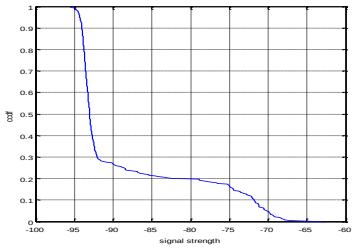


Fig 14: ccdf plot for Tata 1800 band

11. psd vs. frequency plot for jio 1800 band

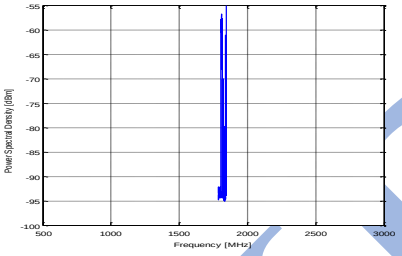


Fig 15: psd plot for jio 1800 band

12. Ccdf vs. signal strength for Jio 1800 band

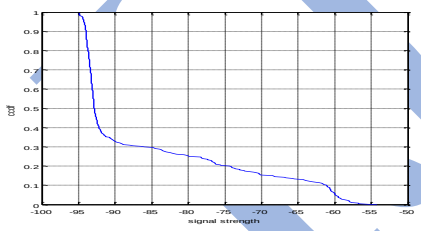


Fig 16: ccdf plot for jio 1800 band

13. psd vs. frequency plot for jio 850 band

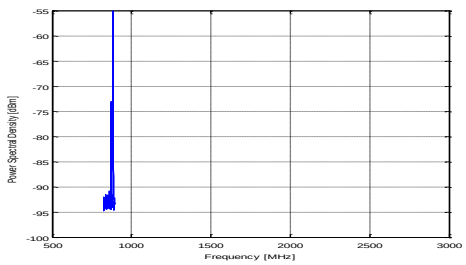


Fig 17: psd plot for jio 850 band

14. ccdf vs. signal strength plot for jio 850 band

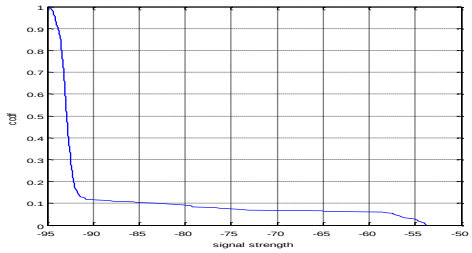


Fig 18: ccdf plot for jio 850 band

15. Psd vs. frequency plot for Jio 2300 band

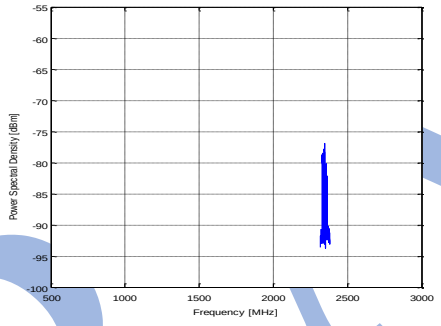


Fig 19: psd plots for jio 2300 band

16. ccdf vs. signal strength plot for jio 2300 band

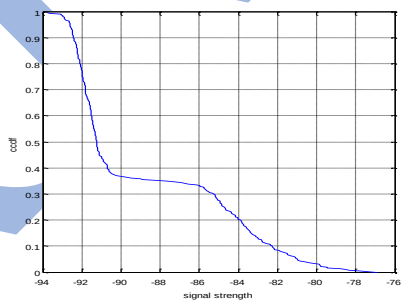


Fig 20: ccdf plot for jio 2300 band

V. CONCLUSION

Spectrum occupancy measurement for cellular networks in India is conducted in this paper. The measurement results show that the spectrum occupancy for Vodafone 900,Vodafone 1800, Airtel 1800, Idea 1800, Tata 1800, Reliance Jio 850, Reliance Jio 1800 and Reliance Jio 2300 band are 49.5017% , 26.5781%, 25.5814%, 30.5648%, 27.9070%, 11.9601%, 35.8804% and 36.2126% respectively. Out of the eight cellular bands most occupied cellular band is Vodafone 900 band which occupied 49.5017% spectrum band. The less occupied spectrum band out of eight bands is reliance jio 850 bands which occupied 11.9601% spectrum only. Furthermore the results cleared that the bandwidth utilization of cellular service providers is not 100% even when the cellular operators in India are growing rapidly. Thus, cognitive radio is the best solution to improve the spectrum utilization of cellular spectrum bands of India.

The spectrum scarcity is one of the major problems to wireless communication technology. Therefore it will be helpful to measure the spectrum occupancy of different allocated license band in real time. This will provide a better idea about the spectrum utilization, future spectrum

utilization and it helps to provide service to more users in the limited spectrum.

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