Cognitive Radio in GSM

Shaibal Khastagir[1], M. Ahsan Ullah[1], Md. Abu Al Syeed Shikder[1] and Mohammed Moshiul Hoque[2]
[1]Department of Electrical & Electronic Engineering, Chittagong University of Engineering & Technology (CUET)
[2]Department of Computer Science & Engineering, Chittagong University of Engineering & Technology (CUET)
e-mail: shaibalrony@yahoo.com, ahsan@cuet.ac.bd, shikder896@yahoo.com and moshiulh@yahoo.com

ABSTRACT
The current wireless world is indeed a realm of GSM (Global System for mobile communication). To keep pace with the brisk & accelerated world of wireless technology, we need to pay our attention to improve its capacity, coverage, service & performance. So we must adopt some chic & dapper approaches to make it acceptable throughout the increasing mobile subscribers. In this paper we try to emphasize Cognitive Radio (CR) (IEEE 802.22) as a winsome solution to come over the winch of current technologies. We estimated four operators in a small area & try to measure & compare their performance with the existing technologies & shows how they can improve with the execution of cognitive technology.

KEYWORDS: Cognitive Radio, GSM, Poisson's Formula, Erlang's B. Formula, Spectral Efficiency, Frequency Planning and GoS.

1. INTRODUCTION

With all the abiding technologies and systems for mobile communication GSM prove itself a paramount one by increasing its popularity throughout the subscriber. With the increase of the number of subscriber, the GSM operators need to enhance their grade of services to make it acceptable for future generation by giving satisfactory services throughout the current subscriber. But the main enigma is how to satisfy maximum user with the available frequency resources. Cognitive Radio (CR) is a device with an intelligent RF transceiver that changes its radio operating parameters dynamically and autonomously based on its operating environment. The concept of cognition technology comes from two important ideas of spectrum pulling and bandwidth harvesting [2-6]. Spectrum pulling is the concept of using an available frequency by a non-licensed radio user when his licensed frequency is busy. There are two approaches of this spectrum pulling. The license owner is aware of other radios using this allocated frequency band and it may avoid other radios but has the right to reclaim any frequency. On the other hand, the license owner is completely unaware of the presence of other radios and cannot involve in their activities. To be familiarized with the concept of bandwidth harvesting we at first analyze Fig.1 where we find that only a few number of frequency in the entire spectrum are in heavy use, some others are in medium use and most other are not used. So we want a technology which can utilize those sparsely used frequency and this utilization is known as bandwidth harvesting. CR significantly improves spectrum efficiency by allocating the frequency usage in a network, assisting secondary markets with frequency use, implemented by mutual agreements, negotiating frequency usage between users, providing automated frequency coordination, enabling unlicensed users when spectrum not in use, overcoming incompatibilities among existing communication services. Rest of the paper is arranged as follows:

At section 2, we will discuss some statistical approaches of GSM technology in South Asia. Section 3 contains text about the frequency planning for a particular area with existing operators and at section 4, we will discuss some parameter base comparison between CR and existing technology like SNR, spectral efficiency, channel capacity, grade of service (GOS) etc. which will flourish a clear idea of the necessity of deployment of CR technology in wireless world.

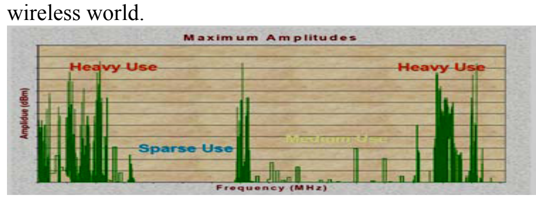

Fig.1: Spectrum access (Source: FCC, spectrum policy task force, technology advisory council (TAC), December - 2002)

2. STATISTICAL APPROCHES OF GSM TECHNOLOGY

In Fig.2 we see the comparative percentage of GSM subscriber with others. In the following section we give a detail picture of them.

2.1. Worldwide Statistics of GSM Subscriber

The cellular world is indeed a monarchy of GSM because of its flexibility in various services with user friendly features. In Fig.2, we see the statistics of different schemes of cellular subscriber and in Table 1 we see the tabular form of those data.

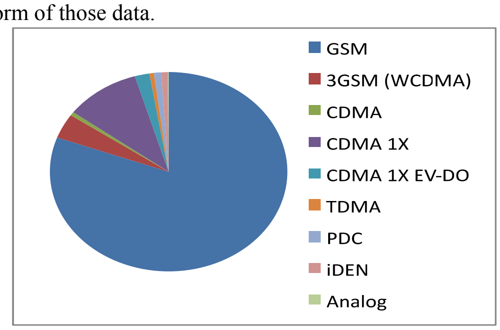

Fig.2: Worldwide cellular subscriber by technology

2.2 Growth of GSM in Asia

Although GSM has a maternal relationship with Europe, it keeps its popularity at the Everest in Asia Pacific which is given in a pictorial and tabular form in Table: 2 and Fig.3. Market penetration [14] is another parameter to specify the density of cellular subscriber and we will see the market penetration in South Asia at 2007 in Table 3, which clarify the growth of GSM subscriber of the South Asian country

ISBN 984-300-002131-3

and specify the urgent need to eye through the problems of frequency resources.

Table1: Worldwide Cellular Subscriber in 2007(Source: Wireless Intelligence [1, 14])

World Cellular User	2 ,831,345,390	
GSM	2 ,278,095,380	80.5%
3GSM (WCDMA)	114,664,827	4.0%
CDMA	18,138,942	0.6%
CDMA 1X	289,963,166	10.2%
CDMA 1X EV-DO	57,376,347	2.0%
TDMA	16,235,932	0.6%
PDC	27,857,370	1.0%
iDEN	26,494,743	0.9%
Analog	2,518,683	0.1%

Table 2: Cellular Subscriber by region in 2007

World	2, 392,760,207	
Africa	208,498,137	9%
Americas	234,821,455	10%
Asia Pacific	924,047,562	39%
Europe: Eastern	349,952,186	15%
Europe: Western	444,426,302	19%
Middle East	136,649,157	6%
USA/Canada	94,365,408	4%

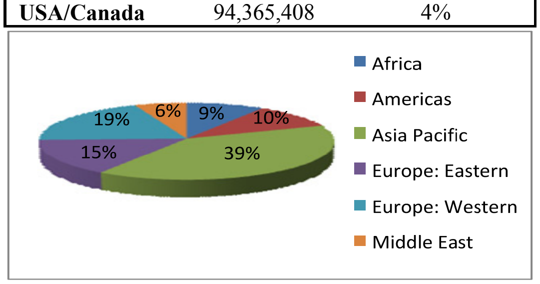

Fig.3: World Wide GSM Subscriber by Region

Bangladesh ranks among the most densely populated countries on the globe, but its fixed-line teledensity remains the lowest in South Asia. With teledensity at less than 1%, only a relatively small proportion of the population has had access to any telecom facility. Almost 99% of homes lack a telephone and there is a four year waiting list for a fixed-line service. The situation is worse in the rural villages, with more than 90% of Bangladesh's telephone services located in urban areas. This has set the scene for a massive expansion of the country's mobile market. There have been a number of consecutive years of strong growth (138% in 2005, 90% in 2006) [14], and growth was continuing at 100%+ coming into 2007. Mobile penetration was still only 16% (20 million mobile subscribers) by March 2007.

3 FREQUENCY PLANNING

The world wide GSM operators are allocating GSM 900 and 1800 bands [7, 13] for providing services throughout the subscriber. The frequencies allocated to the operators in these bands are shown in Fig.4. Now we consider 4 GSM operators for a specific country and highlight their performance of a small area of 12Km^2 as shown in Fig.5.We will pay our attention to Table 4 which shows the frequency allocated to each operator with its total number of serving 200 KHz channels and the number of traffic channel.

Table 3: South Asian GSM statistics in 2007

Country	Penetration	Annual change	
Afghanistan	8%	2.2	100%
Bangladesh	16%	23.9	104%
Bhutan	3%	0.06	53%
India	14%	153.5	72%
Maldives	73%	0.3	22%
Nepal	4%	1.2	88%
Pakistan	33%	55.5	104%
Sri Lanka	30%	6.0	62%

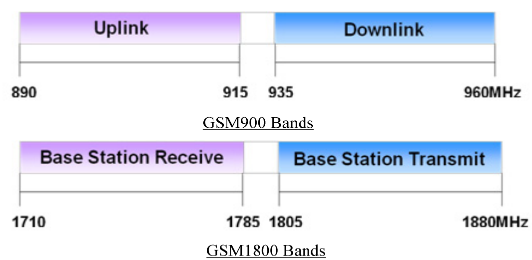

Fig.4: GSM 900 and 1800 Bands

The total number of channels can be represented as

$$C = \frac{BW}{Spacing} - 1 \quad \text{.......................... (1)}$$

Here, spacing of each channel is 200 KHz and we subtract one in Eq.1 because 890MHz and 1710MHz are used as guard band. Since GSM deploy 8 time slot for each frequency to which one is used as a signaling channel. So, we can calculate no of traffic channel by Eq.2 [7, 12].

$$No.of\ trafic\ Channel = C \times 7 \quad \text{.................. (2)}$$

Now we assume that all the operators uses their available frequency in 7 cells as shown in Fig.6 to avoid interference. So the frequency reuse factor (N) in this case is seven. Now we calculate the number of channels and also traffic channels available to each cell by Eq.3 and Eq.4 [7, 13].

$$K_c = \frac{C}{N} \quad \text{............................. (3)}$$

$$K_t = C \times 7 \quad \text{........................... (4)}$$

Where K_c and K_t are the number of channels dedicated to each cell and the number of traffic channel for that cell respectively where as N is the frequency reuse factor and C is the total number of channels available. We enlisted this information based on operator in Table 5. Now we presume the frequencies used in this area by the dedicated BTS, which are enlisted in Table 6.

4. PERFORMANCE EVALUATION

In this section we try to calculate and compare the performance of current technology and cognitive

ISBN 984-300-002131-3

technology by simulation. For some calculation we estimated 2% blocking statistics for the cell area of 12Km2.

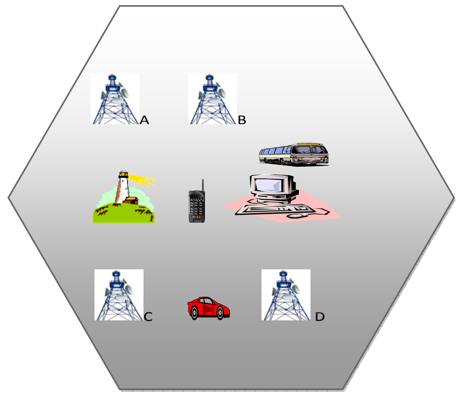

Fig.5: 4 GSM operators (A, B, C and D) are operate in a cell

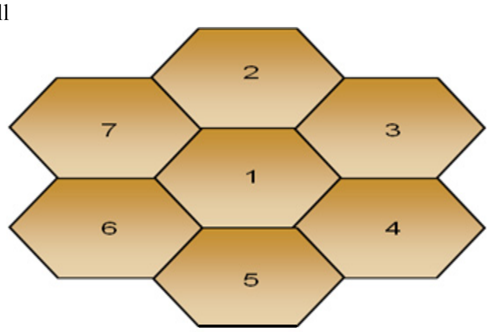

Fig.6: A 7 cell frequency reuse pattern

Table 4: Different operators & their allocated frequencies

Operator	GSM 900 (MHz)	GSM 1800 (MHz)	No. of Channel (Both Band)	No. of Traffic Channel (Both Band)
A	891-897	1711-1726	105	735
B	898-906	1727-1744	125	875
C	907-915	1745-1760	115	805
D	×	1761-1785	120	840

Table 5: No. of Voice & Traffic Channel for Each Cell

Operator	K_c (Both Band)	K_t (Both Band)
A	15	105
B	18	126
C	17	119
D	17	119

4.1 Calculation of SNR

SNR (Signal to Noise Ratio) is an agreeable parameter to estimate the performance of a communication system. Greater the SNR means the greater the channel capacity and vice versa. To calculate SNR we deploy famous Claude Shannon's formula of channel capacity as seen in Eq.5 and calculating SNR is in Eq.6.

$$C_c = B.\log_2(1+S/N) \quad \text{.........................} \ (5)$$

$$\text{then} \quad S/N = \exp^{(C_c/1.44B)} - 1 \quad \text{...........} \ (6)$$

Where C_c is the channel capacity in binary unit and S/N is the signal to noise ratio. As discussed in section 1 we find that CR can use the entire available channel at a given time, thus significantly improves the channel capacity. Now we remunerate our attention to SNR as shown in Fig.7 which clearly implies that CR increases SNR and thus the capacity of the existing system.

Table 6: Spectrum usage by different operator in this area

Operator	GSM900(MHz)	GSM1800(MHz)
A	892.2-892.8	1713.4-1715.4
B	901.2-902.2	1729.2-1731.4
C	908.4-909.4	1748.6-1750.6
D	×	1765.8-1769.0

4.2 Maximum Number of User Supported

We have already mentioned a value of 2% blocking is considered for each operator. Thus grade of services (GoSs) is equal to 0.02.Traffic intensity per user can be evaluated from Eq.7 [13].

$$A_u = \Phi \times H \quad \text{……………….…….. (7)}$$

Where Φ is the average number of calls completed each subscriber in an hour and H is the call holding time.

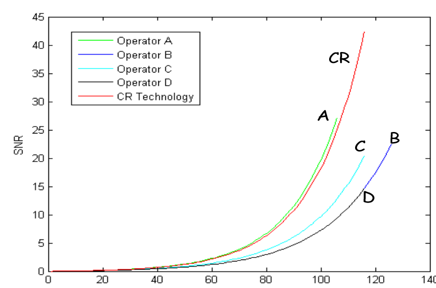

Fig.7: Comparison of SNR between existing technology and CR environment.

For calculating of other performance criteria we assume that for each operator and each subscriber averages 2 calls per hour with average call duration of three minutes. So A_u=0.1 Erlang. Now we employ the Erlang's B. Chart to calculate the carried traffic A_t since GoS and number of serving channel per cell is known. Number of user supported by the operator with a cell, N_u can be easily calculated from Eq.8.

$$N_u = \frac{A_t}{A_u} \quad \text{…………….………….. (8)}$$

All of this calculated data are enlisted in Table 7. From Table 7 it is pellucid that the performance of CR is superior to all other 4 operators; i.e., the 4 operators' altogether supported 415 users in that area where as CR technology supported 563 users alone thus increases 35.7% of its capacity.

4.3 Calculating Spectral Efficiency

Spectral efficiency of a cellular system can be calculated in many ways. We will see some approaches to calculate the spectral efficiency.

ISBN 984-300-002131-3

Table 7: Calculating maximum number of user supported

Operator	GoS	A_u(Erlang)	A_t (Erlang)	N_u
A	0.02	0.1	9	90
B	0.02	0.1	11.5	115
C	0.02	0.1	10.5	105
D	0.02	0.1	10.5	105
CR	0.02	0.1	56.3	563

Modulation efficiency [7-11] is a good measure to imply either a given spectrum is utilized efficiently or not. The spectral efficiency can be represented as

$$\eta_m = \frac{A_t}{BW \times A} \text{ Erlangs/MHz/Km}^2 \ldots\ldots\ldots\ldots\ldots\ldots \text{(9)}$$

Here, η_m is the modulation efficiency, A_t is the carried traffic, BW is the one way bandwidth of specific operator and A is the coverage area. We assume at first that A is equal to 12Km^2.The value of A_t and BW can be found from Table 7 and Table 6 respectively. Using CR technology specific operator can handle large load (56.3 Erlang) with the same allocated BW (Assume 3 MHz for each cell who use CR technology).We enlisted the results in Table 8 which shows how much spectral efficiency can be improved using CR technology.

Table 8: Spectral efficiency of different operators

Operator	A_t (Erlang)	BW (MHz)	η_m Erlang/MHz/Km^2
A	9.0	2.6	0.2885
B	11.5	3.2	0.2995
C	10.5	3.0	0.2917
D	10.5	3.2	0.2734
CR	56.3	3.0	1.5639

Now we have to represent the spectral efficiency [7] in other consideration that might be expressed as Eq. 10.

$$\eta = \frac{N_u \times R}{BW} \text{ bits/Hz/sec} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(10)}$$

Where N_u is the number of user per cell, R is the information bit rate and BW is the allocated band width. N_u and BW can be found from Table 7 and 6 respectively. We assume a constant value of bit rate of 9.6 Kbps for voice transmission through the wireless channel. Table 9 enlisted the value of spectral efficiency and the Fig. 8 shows the comparison of spectral efficiency among the existing operator and CR operator. It should be noted that for Eq.10, BW implies the total BW of that system for that BW of CR technology is the sum of all available BW; i.e.,12MHz whereas in Eq. 9, we consider it 3MHz since here BW means BW of specific operator.

5. CONCLUSION

In this paper we try to establish cognitive radio as supreme approaches to solve current problem of spectrum scarcity in wireless industry. We try to find out the improvised performance shown by CR technology in GSM but it is also equally applicable to other field of wireless industry (like CDMA & OFDM etc.). Cognitive radio is aimed to solve the spectrum scarcity problem caused by the regulatory spectrum allocation. It may be a good candidate for future mobile systems considering that more and more wireless systems will compete with each other to use the spectrum. Thus it will be a colossus in wireless industry in the coming future.

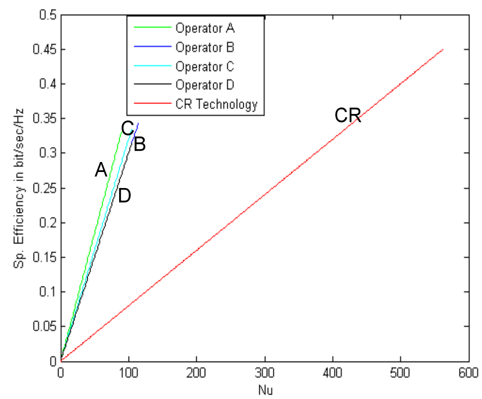

Fig. 8: Comparison of spectral efficiency between Existing Technology & CR.

References

[1] ITU, World Telecommunication Indicators Database, 7th Edition 2003.

[2] Joseph Mitola III, 'Cognitive Radio Arch. the Engineering Foundation of Radio XML', J.Wiley 2006

[3] Bruce A. Fette, 'Cognitive Radio Technology' 1st Edition, 2006.

[4] Michael J. Marcus, 'Cognitive Radio: The Next Wi-Fi or the Next HiperLAN', www.marcusspectrum.com

[5] Jeffrey H. Reed, Charles W. Bastian, 'Understanding the Issues in Software Defined Cognitive Radio', Virginia Tech, October-2005.

[6] Dr. Joseph Mitola III, 'The Future of SDR Adaptive, Aware, or Cognitive Radio OMG Workshop', Washington DC, 14 Sep. 2004.

[7] Vijay K. Garg and Joseph E. Wilkes, 'Principals and Applications of GSM', Pearson Education Pte. Ltd, 2002.

[8] ….. 'A Handbook of Teletraffic Engineering', ITU–D, Study Group 2, Geneva, January 2005.

[9] Villy B. Iversen, 'Teletraffic Engineering and Network Planning', Uni. of Denmark, DK2800 Kgs. Revised May 11, 2006.

[10] ECC Report 42, 'Spectrum Efficiency of CDMA-PAMR and Other Wideband System for PMR/PAMR', Granada, February 2004.

[11] Jurusan Teknik Elektro, 'Module 10 Analyzing Traffic Mobile 2", May-2006.

[12] Theodore S. Rappaport, 'Wireless Communications Principals & Practice', 2nd Edition, 2002.

[13] "GSM SYSTEM SERVEY", Student text, Ericsson AB. 2007-2008.

[14] Wireless Intelligence: 'cellular subscriber in 2007', www.wirelessintelligence.com