Assessment of Spectral Efficiency about 900 MHz using GSM and CDMA Technologies for Mobile Cognitive Radio

S.B.Mule[1] **G.C. Manna[2]** **Neeta Nathani[3]**

[1]*Research Scholar, Department of Electronics Engineering, G.H. Raisoni College of Engineering, Nagpur, India.*

[2]*Senior General Manager, Indian Telecommunication Service, BSNL, Jabalpur, India.*

[3]*Research Scholar, Department of Electronics Engineering, G.H. Raisoni College of Engineering, Nagpur, India.*

mulesb1@gmail.com , gcmanna@gmail.com, neeta_nathani@yahoo.com

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***Abstract*:** **Basis of cognitive radio is to exploit unused frequency channels in licensed bands. Recently standardised IEEE 802.22 set of cognitive radio protocols envisages fixed and nomadic receivers at below 800 MHz bands. Existing mobile communication system uses CDMA in 800 MHz band and GSM in 900 MHz band. Research works has established that there are some vacant channels in these mobile communications bands which are permanently available and can be deployed as cognitive control channel (CCC) and cognitive pilot channel (CPC). Dynamically available vacant channels in these frequency bands can be deployed for cognitive traffic. In the present study, conventional Radio frequency scanners available for different bands and dedicated engineering handsets are used for measurement of data speed in these bands. Drive tests were carried out in dense city of Kolkata across the length and breadth and spectral efficiency value was measured from data speed. The results can be utilized to take decision for appropriate radio access technologies (RAT) to deploy for mobile cognitive radio in uplink and downlink directions in these frequency bands.**

Section I: Introduction

Mobile communication was initially introduced for voice service in sub GHz band. For GSM-900, downlink is from 935 MHz to 960 MHz and uplink is from 890 MHz to 915 MHz and thus 25 MHz is the bandwidth with 20 MHz band gap. Each RF channel has 200 kHz width which works in TDM mode and provide 8 physical channels in 8 Timeslots. For CDMA, downlink is from 869 to 889 MHz and uplink is from 824 to 844MHz and thus 20MHz is bandwidth with 25 MHz band gap. Each RF channel has 1.25 MHz width which works in CDM mode and provides 64/128 code channels. For data services, GSM introduced GPRS service with GMSK modulation which was extended to EDGE service with 8PSK modulation and different coding scheme rates which helped to generate top speed of 59.8 KHz per timeslot. Similarly CDMA introduced 2000 1x which provided 144kbps top speed per channel in normal mode. When one RF was dedicated for data services, a CDMA variant, called EVDO was developed which promised upto 3.2 Mbps throughput with all 16 codes utilized.

Environmental conditions and weather places caps on use of selective frequency bands for efficient communication purposes, particularly for use of common man, on economic reasons. Frequencies have been allotted at 900 MHz, 1800 MHz, 2000MHz and 2300 MHz bands for public land mobile communication systems on license basis but they are getting exhausted very fast. To accommodate more applications in mobile communication bands, attempts are made to use the unused channels in the licensed bands, at least temporarily, as and when a channel is free. Cognitive radio technology has been developed to exploit these features and in an efficient manner. Extracting maximum bits per Hz is a challenge to Radio engineers to design access technology for cognitive radio. OFDM has been chosen as radio access technology in IEEE 802.22 specification for cognitive radio in TV band from 400MHz to 600MHz. Next higher licensed bands exists between 824 MHz to 960MHz for exploitation by cognitive radio, access technology for it is yet to be finalized. For data service, CDMA 2000 1x EVDO and GSM EDGE technologies are used in this band area. Spectral efficiency or, in other terms, throughput at a location depends upon signal to interference ratio and signal strength at a particular location. In the present paper, we have studied variation of path-loss with distance from base station to assess signal strength and variation of data throughput with signal to interference ratio. The objective of present paper is to formulate data throughput obtainable from EDGE and EVDO technologies with variation of signal to interference and noise ratio at a location. This formula will be treated as threshold profile and the data traffic channel of new cognitive radio technology should have spectral efficiency better than this threshold profile at each location where carrier to interference profile is available.

The remaining paper is organized as follows: Section II discusses literature survey on cognitive radio channels, EVDO and EDGE throughputs and pathloss models. Section III formulates a hypothesis on data speed. Propagation Path loss model applicable has been studied in Section IV. Data throughput for EVDO and EDGE has been studied at Section V and section VI respectively. Discussion on obtained results and verification of hypothesis is available in section VII followed by conclusion at section VIII.

Section II: Literature Survey

Spectrum utilization in licensed band has been studied by several researchers and availability of vacant channels has been established.In Romania, corresponding to the downlink communication direction i.e. for 880 - 960 GSM, E-GSM, Military bands, occupancy level was found by Authors to be 46.80%[3]. Availability of quasi-permanently vacant channels to the minimum extent of $1/8^{th}$ part of the total band in GSM and CDMA has been established in [4] which can be used as fixed channels of cognitive radio technology for control channel purposes. Cognitive Radio uses Cognitive Pilot Channel (CPC) to push information to cognitive radio nodes about operators, policies, access technologies etc and Cognitive Control Channels (CCC) to broadcast local availability of different bands, spectrum sensing information, spectrum needs of different systems, rules for accessing specific bands etc [6]. Dynamically available vacant channels can be used as cognitive radio traffic channels for which endeavour will be to maximize throughput or, in other words, maximize spectral efficiency. Spectral efficiency is defined as number of bits obtainable per Hz of bandwidth of the allocated channel. It depends on availability of good signal strength, sustainable modulation and coding rate[5]. Researchers of Rysavy has indicated about limitation of spectral efficiency according to Shannon channel limit and measurable in terms of signal to noise ratio (SNR); however, Shannon limit can be exceeded by use of efficient antenna techniques e.g. MIMO and beam steering. Measurement of signal strength at a distance from base station can better be estimated through Path Loss models stated by Okumara-Hata and Walfisch-Ikegami in city environments in 800 MHz to 2000 MHz bands[7]. For EVDO, one second measurement to establish a relationship between DRC request and SINR by mobile terminal for throughput lead to no conclusion to authors [2]. However, in 2000 1x EVDO, when being served, the mobile calculates its Signal-to-Interference-plus-Noise Ratio (SINR) and determines the highest data rate supportable among 11data rates with the calculated SINR at every slot[9]. For EDGE, with the measured C/I and SNR values and the knowledge of CS/MCS the effective throughput per user can be derived [1] .Variation of throughput with SIR for different MCS has been plotted by authors in [8].

It is eminent from above that there is no thumb rule to assess data throughput from knowledge of signal to interference and noise ratio for EDGE and EVDO technologies. In the present experiment, we try to establish a simple relationship for the same.

Section III : The Hypothesis

Modernisation is fast changing the environmental scenario. There are usually irregular structures around base station. So, signal strength may be very low even when mobile terminal is very close to base station. Also, there are tiny scatterers and moving vehicles which intermittently disturb the channel profile between transmitter and receiver leading to continuous variation in signal to interference ratio. The profile change is more complex when the terminal is mobile. Even under these circumstances we can state that throughput at a location can be calculated when-

1) Pathloss model is applicable and hence signal strength at a distance from base station can be calculated using pathloss model,
2) Throughput has linear relationship with signal to interference and noise ratio provided signal strength is reasonably good for both EDGE and EVDO. Thus we can write throughput (T) as:

$$T(CINR)=a*CINR +b$$

when RxLevel $\geq$ RxLevelThreshold+10 dbm ; a and b are constants. CINR is carrier to Interference and Noise ratio. The throughput for cognitive radio technology can be written as:

$$T_{CR}\,(CINR) \geq T(CINR) \quad \text{for all CINR.}$$

For practical purposes, we will use spectral efficiency and throughput interchangeably; also for CINR , C/I and SNR as per terms used in appropriate technology.

Section IV: Propagation Pathloss model

Propagation pathloss models were initially established by Okumura and modified by Hata which is known as Okumara-Hata model. This model includes effects of antenna heights and additional loss for urban and dense urban areas. The models were modified by several researchers by taking into consideration several factors e.g. green leafy area, hilly area, penetration through walls, glass windows etc. Walfisch-Ikegami model took diffraction through multiple rooftops into consideration which is better fit for urban areas and laid down a model in their own name.

In the present experiment, drive test was carried out through dense city of Kolkata, from South to Central location. It encountered through 4200 records of a typical cell through which it passed. Actual pathloss has been calculated as trans power-receive power and shown as green dots. Maximum distance from serving cell was found to be 329.40 meters which has pathloss as 122.32 dbm which is normal cellsize in city areas.

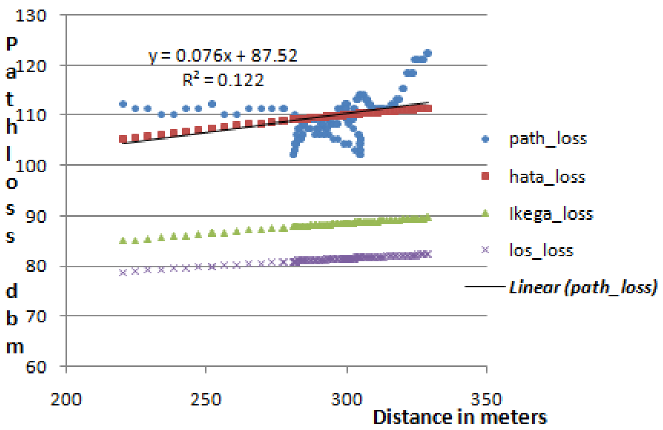

Fig 1. Comparision of pathloss models

Pathloss was also calculated at different distances based on line of sight pathloss (LOS_pathloss), Walfisch-Ikegami pathloss(Ikega_loss) and Hata path loss(hata_loss)(red). A trend line(black line) was drawn for pathloss data and it was found to be almost collinear with Hata loss data. Also, minimum receive level was (43 dbm antenna output +17 dbm antenna gain-122.32 dbm maximum pathloss) -62.32 dbm which is appreciably good for mobile communication where minimum specified signal strength is -95 dbm for speech and higher values for higher degree of modulation.

Section V : EVDO Throughput model

An experiment was carried out in northern part of Kolkata which consisted of a cluster of 8 base stations. Fig 2 shows

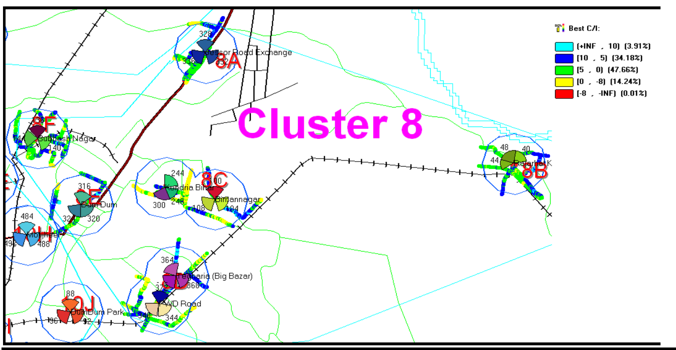

Fig 2: C/I plot for 8 base station clusters

C/I plot for the cluster. Mostly the tests were carried out close to the base stations. C/I varied from -8 to 0 (yellow), 0 to 5 (green) and 5 to 10 (blue) with respective counts as 1715, 5741 and 2867 respectively of total 12047 recorded counts. For data processing, user count was set to 1 to ascertain maximum throughput of the system. The available data for throughput was averaged in steps of 1 dbm and corresponding throughput was also averaged. Similarly throughput was averaged for SINR at steps of unity.

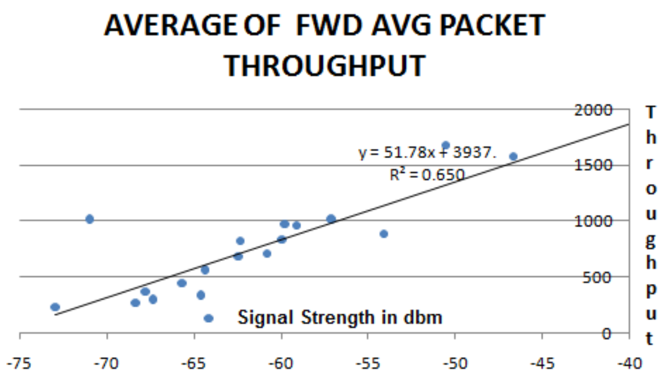

Fig 3. Throughput Variation with signal strength

Fig 3 shows variation of throughput with signal strength where minimum signal strength was found to be -72.96 dbm and throughput is 229.63 kbps and the corresponding maximum signal strength was -46.65dbm at throughput of 1573.45 kbps.

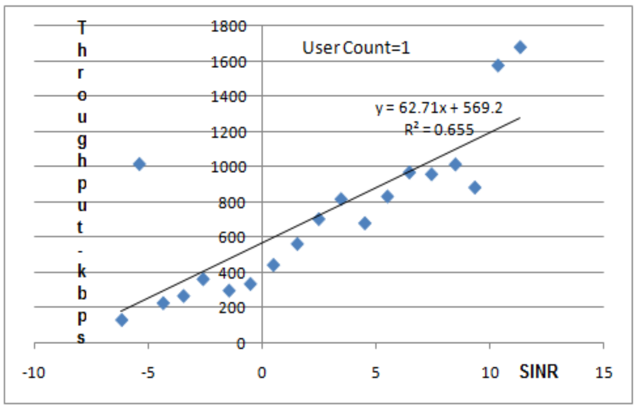

Fig 4: Throughput vs SINR

Variation of throughput with SINR is shown in Fig 4. At minimum average SINR of -6.195 throughput is 134.21 kbps and at maximum SINR of 11.7325 throughput is 1676.545 kbps. Trendline shows an increase of 62.71 kbps per dbm SINR and 596.2 kbps at zero SINR.

EVDO uses one complete RF of bandwidth 1.2228 MHz. Specral efficiency achieved at different SINR level has been drawn in Fig 5.

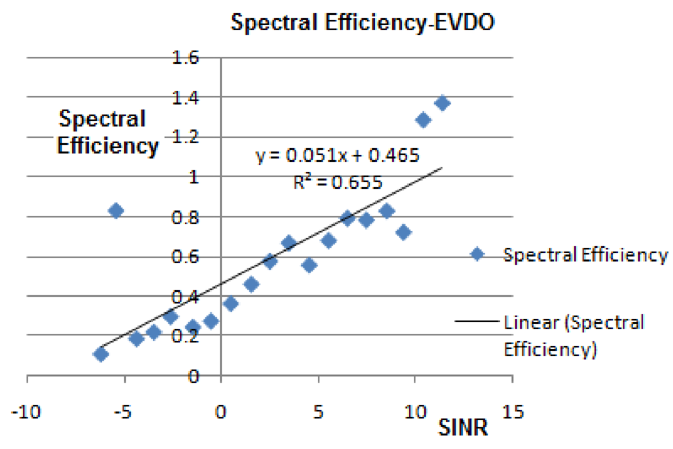

Fig 5: Spectral Efficiency Vs SINR in EVDO

Section VI : EDGE throughput model

The measurement was carried out from south to central Calcutta and 1290496 records of data was collected. For proper graphical representation of different parameters, average of each parameter against single value of C/I was calculated.

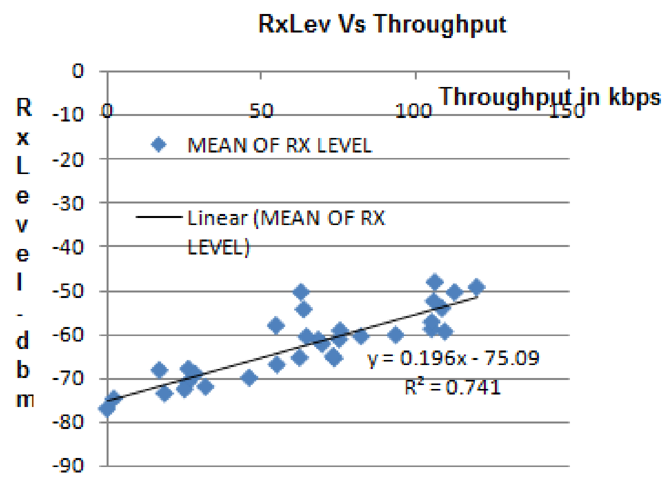

Fig 6: Receive signal level vs throughput

Signal level was found to vary between -50 dbm to -75 dbm and throughput increased linearly as shown in Fig 6. Coding and modulation changes with change of signal quality and throughput is adjusted accordingly; this aspect has been depicted in Fig 7. Spectral efficiency has been calculated with 4 TS doubled to get one complete RF of 200 kHz.

Section VII: Results and Discussion

Propagation pathloss is independent of technology deployed and shown in Fig 1. It is seen that the pathloss at different distances are not regular in nature which indicates that environment is highly unpredictable, however, Hata model is still grossly applicable.

Throughput variation with signal strength has been shown in fig 3 and fig 6 with an upward trend, however, it can be said with confidence that good throughput will be available only when signal strength and much above the threshold levels.

Irregularity in throughput is observed at values of -2 and 4 of CINR in fig 4 and between 7 to 10 and 15 to 20 of C/I as seen in Fig 7. They are due to coding and modulation change by system at different SINR and C/I in EVDO and EDGE respectively.

Spectral efficiency changes are observed in fig 5 and fig 8 for EVDO and EDGE respectively. For EVDO, it is observed that spectral efficiency gradient is 0.051 bits/Hz/dbm and for EDGE, it is 0.034 bits/Hz/dbm.

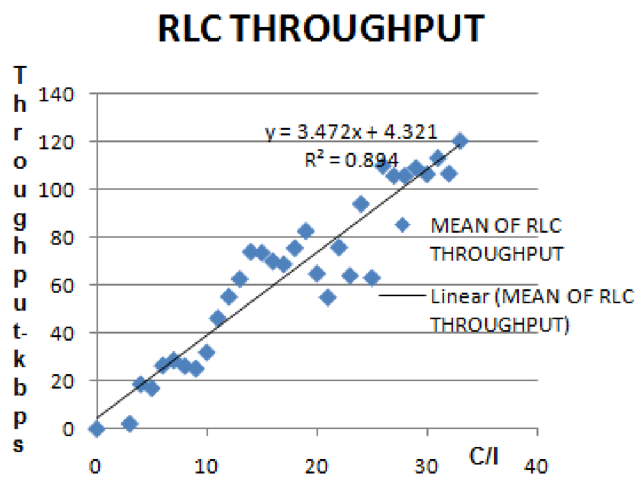

Fig 7: Variation of throughput with C/I

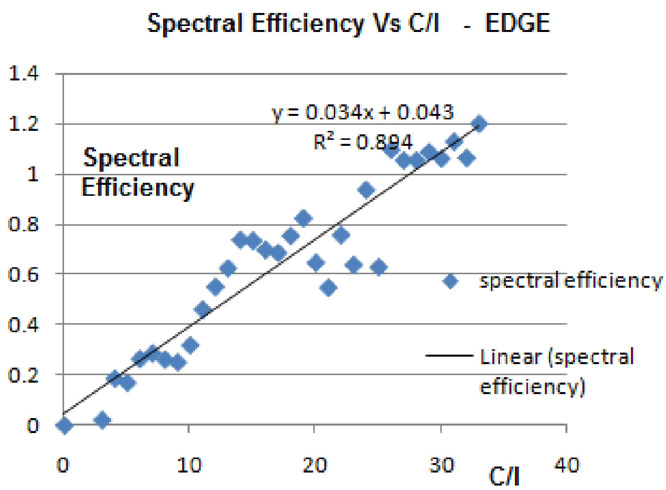

Fig 8: Variation of spectral efficiency with C/I

Section VIII: Conclusion

From above results, it is observed that carrier to interference ratio at a location is the tool to assess spectral efficiency and hence to calculate the throughput. It is also concluded that the more the bandwidth, the spectral efficiency gradient is more, as in EVDO in present case over EDGE. However, Cognitive Radio proposes to deploy OFDM whose channel bandwidth is of the order of 14 KHz only and hence, for better spectral efficiency, Future radio engineers shall have to smoothen the environment through deployment of MIMO and provide service through several base station servers around a single CR receiver.

Section IX: References

[1] H. Buddendick, A. Weber, M. Tangemann, "Comparison of data throughput performance in GPRS, EGPRS, and UMTS", Alcatel SEL AG, Research & Innovation, Stuttgart, Germany, AWE Communications GmbH, Moltkestr. Gaertringen, Germany.

[2] Zhe Zhou, Mark Claypool and Robert Kinicki, "Characterization of a 3G EV-DO Network - a Measurement Study'', Computer Science Department at Worcester Polytechnic Institute,Worcester, MA USA, {jeffz,claypool,rek}@cs.wpi.edu.

[3] Alexandru Marțian, Calin Vladeanu, Ioana Marcu, Ion Marghescu, "Evaluation of Spectrum Occupancy in an Urban Environment in a Cognitive Radio Context", International Journal on Advances in Telecommunications, vol 3 no 3 & 4, year 2010, http://www.iariajournals.org/telecommunications.

[4] Neeta Nathani, G.C. Manna, S.B.Mule, **"**An Empirical Assessment of Quasi-Permanently Vacant Channels in Mobile Communication Bands for Cognitive Radio", 15th International Conference on Advanced Communication Technology,2013,Korea ;IEEE-Xplore.

[5] Rysavy Research, "Efficient Use of Spectrum" , May 4, 2011, http://www.rysavy.com.

[6] Report ITU-R M.2225 (2011) "Introduction to Cognitive Radio Systems in Land Mobile Service" , M series, Mobile, radiodetermination, amateur and related satellite services, International Telecommunication Union.

[7] J. S. Lee and L. E. Miller, CDMA Systems Engineering Handbook. Boston: Artech House, 1998; and NTIA's LMS calculator help file.

[8] Nelson Sollenberger Li Fung Chang Paul Lu, "The BCM2132 GSM/GPRS Handset Baseband ASIC with Integrated EDGE and Media Functions".

[9] Eun Ho Choi, Wan Choi, and Jeffrey G. Andrews **, "**Throughput of the 1x EV-DO System with Various Scheduling Algorithms", Wireless Networking and Communications Group Department of Electrical and Computer Engineering The University of Texas at Austin, Texas.