A Review on Wireless Mobile Communication Systems Generations and   Integration

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Abstract: Computers, computational devices and data acquisition systems are confined at a location. Captive data has limited utility. Data communication among devices, for shared usage and further processing, revolutionized the world through Information and Communication Technologies. Data communication systems piggy backed on the telecommunication network and went on with it from wireless to wireline domain. GPRS/EDGE, EVDO/WCDMA, mobile WiMAX/LTE are the three generations of mobile wireless access technology domains in the local area .The backhaul transport system consists of optical fibre links and nodes with route switching systems called Routers. Routers also acts as add/drop nodes where data processing devices, called servers, are connected which serves application services data to user community. Pure wireless data communication networks has also been evolved as wi-fi network which covers very small area but provide very large bandwidth and functions in ISM band. Wi-Fi networks are considered equivalent to fourth Generation access network. The generation of technologies has been designed based on commitments of data throughputs and environmental conditions. The present paper analyses the throughputs available in practical conditions for GPRS, EDGE, EVDO, WCDMA and WiMAX. The paper also discusses integration of all the three generations in a heterogeneous environment. The 3GPP recommendations for machine type communications with cellular network as backhaul has been discussed as part of 5G network.
Keywords: GPRS, EDGE, EVDO, WCDMA, OFDM, WiMAX, LTE

1. Introduction

Wireline communication between sender and receiver are guided through defined media. Radiated Energy from transmitter is radiated in wireless communication systems which attenuates following inverse square law. Also, several copies of the same transmitted signal reaches the receiver through direct, reflected, refracted and diffracted paths which constitutes a complex waveform profile. The profile moves when there is relative motion between transmitter and receiver. Signal to noise ratio at the receiver limits the channel capacity according to Shannon limit. Depending upon environmental conditions, distance of receiver from transmitter, receiver speed etc., dynamic coding at transmitter is required to be done to optimize data throughput. All these impairments has ben addressed in different access technologies like GSM, CDMA and OFDM. Generic network architecture has been added at the end of this topic.

2. Wireless Impairments

Path loss is the difference between transmitted and received power.
Path loss = Transmitted power + Antenna gain – Received power.
In practice, we use the transmitting power of antenna as 40 dbm per RF and transmit antenna gain of 17 dbi. Path loss is the reduction in signal strength when it propagates from Transmitter to Receiver. Various factors reduces the receiver signal strength viz. antenna height, distance between Transmitter and Receiver, obstacles such as trees, buildings etc. Many researchers like Hata, Okumara, Walfisch, Ikegami etc. has laid down specific formula which are suitable for different environmental conditions and frequency ranges.
A general pathloss model is given as
$PL(dB) = PL(d0) + 10\ \gamma\ \log(\ d/d0\ ) + \sigma$
Where, $PL(d0\ )$ is the path loss at reference distance $d0$ usually taken as 100 m for outdoor conditions, γ is the path loss exponent and $\gamma >2$, σ is the standard deviation of received signals for small and large scale fading and d is the distance between Transmitter and Receiver. Losses are measured in dBm and d in meters. In free space $\gamma=2$ and in near open field area, γ has a value nearly 3.

Multiple paths exist between a pair of transmitter and receiver; one may be direct path and others reflected. This constitutes an RF channel. Hence, same signal transmitted from a transmitter reaches the receiver

at different instant of time and hence necessarily at different phases. Change in phase depends on frequency and hence wireless channel is called frequency selective. For example, if the time difference between direct path and a reflected path is 1µSec, the path difference is 3*108*1*10- 6= 300m and if frequency used for this channel 1MHz, the two signals will constructively combine and if the frequency if 500KHz, they will combine destructively. So, for every channel, there is a range of frequency for which channel response is flat between 3db points on both sides. This bandwidth is called channel coherence bandwidth. If the bandwidth used is less than channel coherence bandwidth, there will be no loss of signal due to frequency selective fading. For outdoor propagation, normally delay spread is assumed between 1 to 3 µSec and for this; the coherence bandwidth is about 450 KHz at 900 MHz band operation. When there is a relative motion between transmitter and receiver, the channel profile moves. An average speed of 30 km per hour vehicle movement is taken into consideration in existing technologies.. When relative velocity between transmitter and receiver exceeds about 450 km/hour, effect of Doppler frequency spread become appreciable. This leads to the effect of channel coherence time. For most practical purposes, when transmission is fixed base station oriented, we may ignore this effect.

Signal to noise ratio(S/N) at the receiver is the most dominant factor. This is used to calculate effective bandwidth which will be available at S/N threshold using Shannon Channel limit. S/N is estimated by the transmitter at regular intervals during active communication for dynamic coding. Channels may be multiplexed by time division as in GSM, code division as in CDMA or frequency division as in OFDM. We explain below the data throughputs practically available in these technologies through several experimentation carried out by the authors, under different carrier to interference ratio conditions.

3.   GSM (GPRS/EDGE)

Mobile communication was introduced for voice in sub GHz band. For GSM-900, downlink is from 935 MHz to 960 MHz and uplink is from 890 MHz to 915 MHz. The 25 MHz bandwidth is used for transmitter and receiver with 20 MHz band gap. Each RF channel has 200 kHz bandwidth which works in TDM mode and provide 8 physical channels through 8 Timeslots. Because , it has low band width, frequency selective fading is not applicable. For data services, GSM introduced GPRS service with GMSK modulation and 4 coding schemes viz. CS-1 to CS-4 depending upon S/N value and theoretically achieves 9kbps to 21.4 kbps for one timeslot i.e. channel. If a handset or dongle can use all 8 channels, a top speed of 171 kbps shall be achievable. In Evolved GPRS or EDGE service, with MCS coding scheme and 8PSK modulation, helped to generate a top speed of 59.2 Kbps per timeslot and maximum of 473.6 kbps in 8 time slots or channels. In Evolved EDGE, 16QAM and 32 QAM coding scheme were used to enhance data speed upto 1 mbps but not much commercially successful.

Measurements taken in a very dense city is shown in figure 1. In dense cities, the Transmit stations are placed as close as at 500m seperation. Transmit signal strengths are adjusted in such a way that signal strength is good everywhere in the sector i.e. between -55dbm to -75dbm whereas GSM defined threshold is -95dbm. C/I in dense city situation is usually not good due to presence of numerous scattering objects. Engineering handset with 4 timeslots were used for the measurement. Throughput at radio link control (RLC) plane with corresponding C/I has been plotted in the figure 1. Irregularity in throughput is observed at values between 7 to 10 and 15 to 20 of C/I . They are due to coding scheme change by system at different C/I in EDGE system. It is observed that a peak value of 120kbps is available at 32 dbm C/I for 4 TS structure which can be extrapolated to conclude that 240kbps speed can be practically achievable in EDGE system with 8 TS[1].
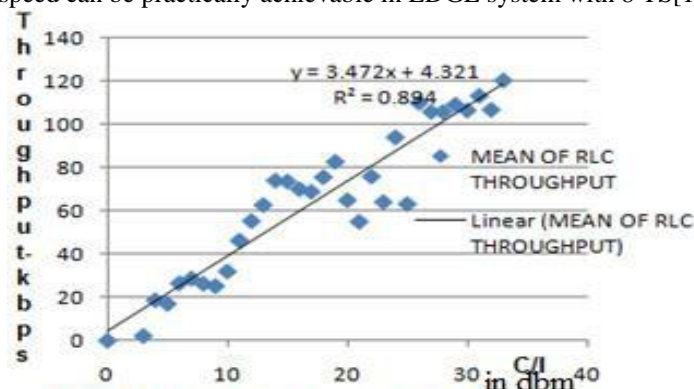

Figure 1: Throughput vs C/I at RLC plane

4.   CDMA (EVDO/WCDMA)

For CDMA, downlink is from 869 to 889 MHz and uplink is from 824 to 844MHz. Thus 20MHz

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bandwidth is available in CDMA with 25 MHz band gap. Each RF channel has 1.25 MHz width which works in Code Division Multiplexing mode and provides 64/128 code channels. CDMA suffers from frequency selective fading and hence it uses RAKE receiver for receiving six dominant signals through different paths. CDMA introduced 2000 1x which provided 144kbps top speed per channel in normal mode. A CDMA variant, called Evolution Voice and Data Optimised (EVDO) was developed with 16 codes to provide 3.2 Mbps throughput when one complete RF is dedicated for data services.
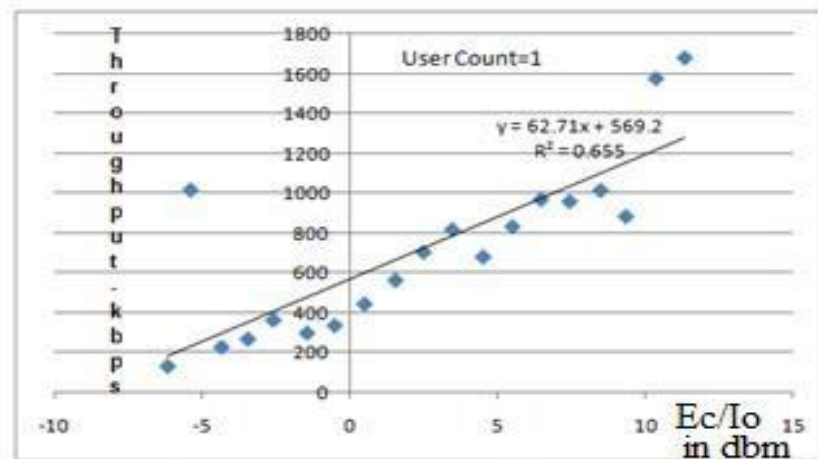

Figure 2: Throughput Vs Ec/Io

Fig 2 shows C/I in terms of Ec/Io plot for a cluster of base stations. Mostly the tests were carried out close to the base stations. C/I varied from -8 to 0 dbm, 0 to 5 dbm and 5 to 10dbm with respective counts as 1715, 5741 and 2867 respectively.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. As shown, at minimum average Ec/Io of -6.195, throughput is 134.21 kbps and at maximum Ec/Io of 11.7325, throughput is 1676.545 kbps. Trend line shows an increase of 62.71 kbps per dbm and 596.2 kbps at zero SINR [2].Wideband CDMA (WCDMA) has been designed based on IMT 2000 recommendations. It is more popularly known as Third Generation (3G) mobile technology. This is the most dominant technology from 2000s and till date. It is based on 5 MHz duplex bandwidth which works in 2000MHz band. It's uplink frequency range is 1939-1979 MHz and downlink frequency is 2129-2169 MHz. This employs upto 512 Walsh codes, however, for data part, it uses a section of code tree with less number codes. In general, it uses only 16 codes for data and effectively 15 codes are available for users. Roughly 900 kbps is maximum throughput specified per code with 64QAM modulation and upto 5/6 RS codes in very good environmental conditions.
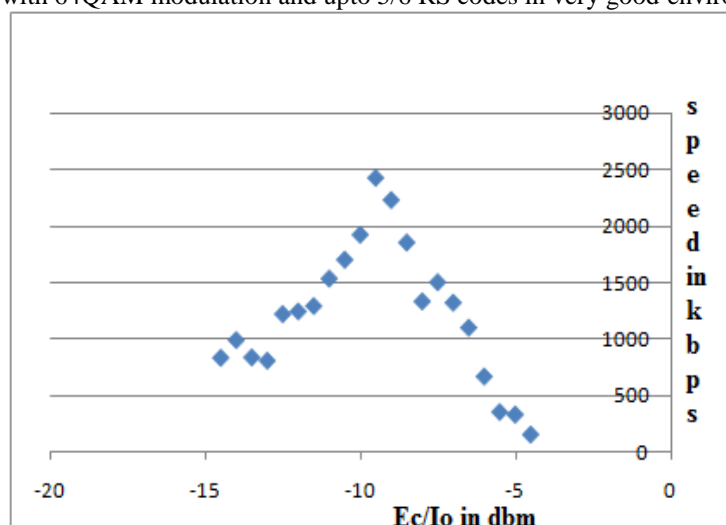

Figure 3: Throughput variation in WCDMA

It uses 6 finger RAKE receiver to accommodate multipath channels. WCDMA receiver sensitivity is specified

as -105dbm. However, for data, a better throughput is expected when signal strength is more than -90dbm. Ec/Io is the chip power to total interference power from all other codes working in same band and measured in dbm in absolute scale. Figure 3 above shows the result of Ec/Io vs throughput in dense city environment. In the experiment, the engineer's data set used which was capable of handling 5 codes at a time and hence theoretical maximum speed it can achieve is 4.5 Mbps under ideal conditions. In the experiment, total about 73000 data was collected with over 10000 effective data during which measurements were taken. Throughout measurements, the Received Signal code power level was better than -90dbm and mostly in range of -80 to -70dbm throughout. The figure 3 shows steady increase of datarate from -15 dbm to -10dbm, but it drops from -10dbm to -5 dbm. The drop may be due to the reason when the test set is nearer the tower, received power is high, Ec/Io is also high and hence system wants to move to higher coding and modulation zone but fails resulting in lower throughput. Peak data rate achieved is 2.5 Mbps whereas theoretical maximum is 4.5 Mbps .In other experiments also, similar behavior of the technology is noticed, however, the maximum achieved speed is dependent on RSCPwhere it is found to be 1239 mbps at -9 Ec/Io when RSCP was -91 dbm.

5. OFDM (WiMAX / LTE)

Orthogonal Frequency Division Multiplexing (OFDM) technology has 5 MHz bandwidth which is divided into number of subcarriers e.g. 256/512 etc. This works similar to multi carrier modulation, each carry one symbol at a time. The gain obtained is that flat fading is obtained in respect of each sub-carrier. It operates at different frequencies, but the predominant practical implementations like Worldwide interoperability for Microwave Access (WiMAX) and Long Term Evolution (LTE) work respectably in 2600 MHz and 2300 MHz bands respectively. However, multipath introduces Inter Symbol Interference (ISI) which is mitigated through use of Guard Period at the end of each symbol. Guard period depends on symbol duration and usually it is 1/8th part of symbol duration. It also introduces Inter-Carrier Interference (ICI) for which trail part of the signal is fed back to the leading part of the signal in the guard period of the previous signal. All these factors make OFDM channel virtually immune from fading and multi-path effects. UMTS Advanced promises a maximum data speed of 50 mbps in uplink and 100mbps in downlink direction through use of 8X8 MIMO, 64QAM ½ rate coding, advanced error correction etc. These have been implemented by IEEE 16m recommendation as WiMAX and 3GPP forum recommendation as LTE for mobile communication.
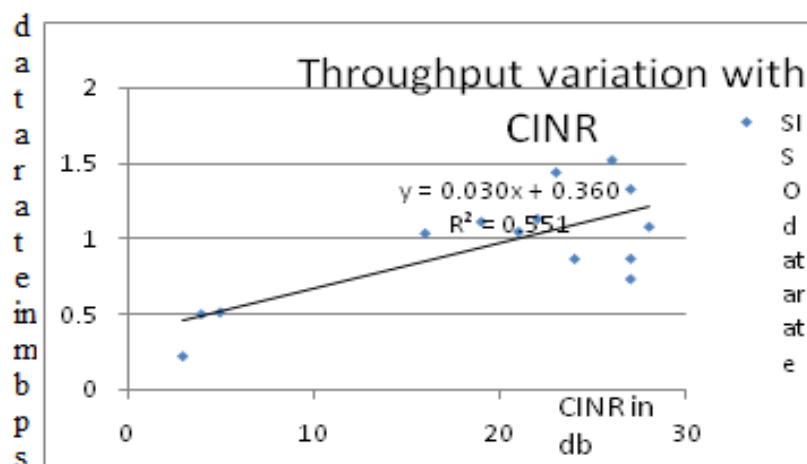

Figure 4 -Throughput variation in OFDM

For WiMAX, download data throughput obtained is from 2 transmitters at base station and single receiver at dongle receiver. Download throughput for 1X1 SISO configuration has been considered through a conversion formula using Shannon Channel capacity for 2X1 MIMO and MIMO gain factor for each CINR value. It is observed from fig(4) that in most of the observations, CINR is 20 where throughput is near 1 mbps for 90 carriers (1/4 th part of traffic carriers of 5 MHz allocated bandwidth) due to dongle capacity limitation. A distance of nearly upto 3kms was considered in the measurement drive [3].

6. 4G System in Legacy Network

A complex heterogeneous network consisting of 2G,3G and 4G network are shown in the figure 5. User Equipment (UE) connects to Base Transceiver Station(BTS), Node B(NB) and evolved Node B(eNB) with respective generations. Base Station Controller (BSC) used in 2G connects to many BTSs and it divides data

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and speech where speech part is send to Mobile switching Centre(MSC) and data part to Serving Gateway Support Node(SGSN) which works as Router for packet network. Traffic from 3G UE is sent through Radio Network Controller (RNC) and Media Gateway (MGW) where data and speech are sent through appropriate signaling conversion. Short Message Service Controller (SMSC), Wireless Access Protocol Gateway (WAP GW) for low speed internet, Service Delivery Platform (SDP) for miscellaneous audio- video and other services are the user service equipments of the network. Home Location Register(HLR) keeps all fixed and dynamic information of each customer in the network in conjunction with Visitor Location Register(VLR) which normally remains integrated with MSC. SSTP is versatile Signaling Transfer Point which acts as gateway for speech traffic to Ethernet network. In Long Term Evolution (LTE)-4G implementation of IMT Advanced Recommendation, eNB combines the role of NB and RNC. Mobile Management Entity (MME) plays most important role of keeping track of the mobile, particularly for managing speech traffic and data traffic. The basis of such monitoring depends on capability of the UE handset i.e. it can function simultaneously with 2G/3G network for speech path and 4G network for datapath OR the UE can solely depend on 4G network where Voice over LTE (VoLTE) type of service will be available for speech purpose.

Serving Gateway (S GW) routes traffic to Packet gateway (P-GW) where traffic is controlled for each user based on directions from Policy Charging and Rules Function (PCRF) unit. Home Subscription Server (HSS) is the master database for subscribers which supports IP Multimedia Subsystem (IMS). WiMAX UE or Dongle provides mainly data services through WiMAX BTS and Access Service Network Gateway (ASN GW). The user services are verified through Authentication, Authorization and Accounting (AAA) server and traffic is routed based on route IP address available from Domain Name Server.
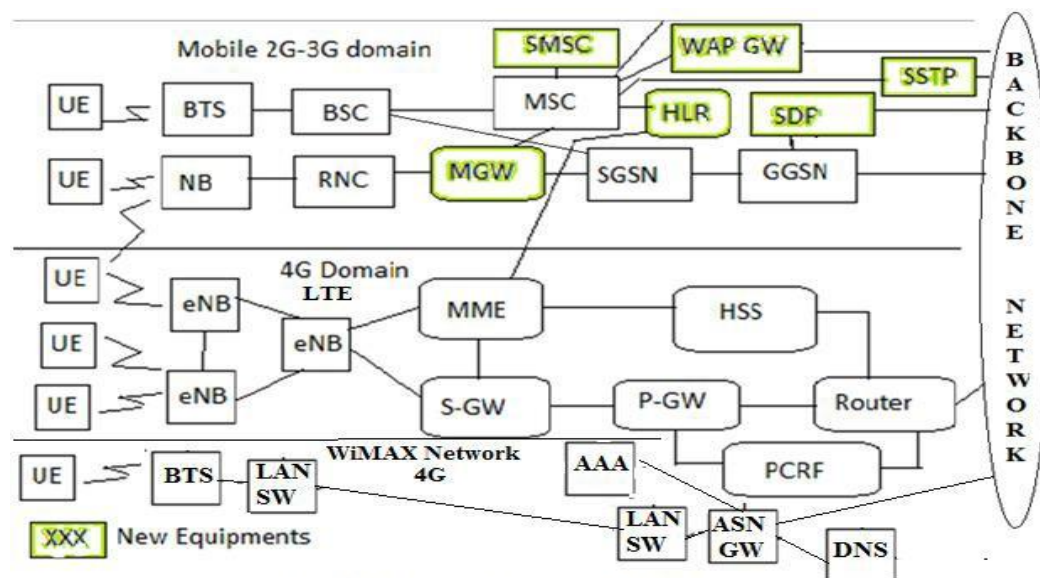

Figure 5 : Mobile Network Subsystem Architecture

7. 5G Network and M2M Communications

The need for speed at the wireless backhaul will be an important criterion during 2020 and beyond for which bands above 6 GHz has already been identified by different countries. This will provide high speed data communication between devices with low latency requirements. On the other hand, there will be machines with very low throughput, occasionally transmit and receive with very low but long-life power supply requirements. These equipments will be of RFID type, connected through wireless personal area network (WPAN) and connect to a Gateway (GW). 3GPP uses Machine Type Communication (MTC) Gateway which connects to a 2G/3G/4G type cellular networks. However, the GWs can also connect to a WiMAX type of network deploying Wi-Fi type of communication deploying low power wireless communication type of platform. Legacy networks may deploy MTC AAA and other support services for effective control of the 5G service requirements. The servers for 5G shall be connected to back bone network like other web based services.

8. Conclusion :

Through generations of mobile technology, the coding and modulation techniques were instrumental for providing more bits per Hertz but under no circumstances, it is possible to enter Shannon Channel limit region. It is now the turn of Multiple Input Multiple Output (MIMO), fifth Generation (5G) access and cloud

eNB technologies to rule the road of mobile broadband network. Performance of newly developed technologies and devices for PAN and MTC will decide the strength of future mobile network.

References:

[1]. S.B.Mule, G.C. Manna , Neeta Nathani: Assessment of Spectral Efficiency about 900 MHz using GSM and CDMA Technologies for Mobile Cognitive Radio: IEEE International Conference on Pervasive Computing (ICPC) , (2015).

[2]. S.B.Mule, G.C. Manna , Neeta Nathani; Comparision of Spectral Efficiency of Mobile OFDM-WiMAX Technology with GSM and CDMA for Cognitive Radio Usage: ICAC3'15, ELSEVIER.

[3]. S.B.Mule, G.C. Manna , Neeta Nathani: Measurement of Spectral Efficiency of mobile OFDM-WiMAX Technology at 2600 MHz band in Green Field Area: IEEE International Conference on Pervasive Computing (ICPC), (2015).

[4]. 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.

[5]. 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.

[6]. Alexandru Marţian, 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.

[7]. 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.

[8]. Telesystem Innovations Inc. , "Fundamentals of WiMAX: A Technology Primer",2010

[9]. WiMAX Forum, "Mobile WiMAX – Part I: A Technical Overview and Performance Evaluation", February 21, 2006

[10]. Alina Elena STANCIU, Lăcrămioara-Mihaela NEMŢOI, Ilona Madalina MOISE, "Considerations regarding the spectral efficiency of orthogonal frequency division multiplexing", International Conference on DEVELOPMENT AND APPLICATION SYSTEMS, Suceava, Romania, May 17-19, 2012.