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CELLULAR MOBILE COMMUNICATION REVIEW

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Abstract

Mobile communication is continuously one of the hottest areas that are developing at a booming speed, with advanced techniques emerging in all the fields of mobile and wireless communications. This thesis deals with the comparative study of wireless cellular technologies namely First Generation, Second Generation, Third Generation, and Fourth Generation. A cellular network or mobile network is a radio network distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a cell site or base station. In a cellular network, each cell uses a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed bandwidth within each cell. The First Generation were referred to as cellular, which was later shortened to "cell", Cell phone signals were based on analog system transmissions, and First Generation devices were comparatively less heavy and expensive. Second Generation phones deploy GSM technology. Global System for Mobile communications or GSM uses digital modulation to improve voice quality but the network offers limited data service. The Third Generation revolution allowed mobile telephone customers to use audio, graphics and video applications. Fourth Generation is short for fourth-generation cell phones or/and hand held devices.

Keywords: Cellular network, First Generation, Second Generation, Third Generation, and Fourth Generation

I. Introduction

The past few years have witnessed a phenomenal growth in the wireless industry, both in terms of mobile technology and subscribers. The first generation mobile systems were the analogue (or semi-analogue) systems, which came in the early 1980s - they were also called NMT (Nordic Mobile Telephone). They offered mainly speech and related services and were highly incompatible with each other. 1G refers to analog cellular technologies; it became available in the 1980s. 2G denotes initial digital systems, introducing services such as short messaging and lower speed data. CDMA2000 1xRTT and GSM are the primary 2G technologies, although CDMA2000 1xRTT is sometimes called a 3G technology because it meets the 144

kbps mobile throughput requirement. EDGE, however, also meets this requirement. 2G technologies became available in the 1990s. 3Grequirements were specified by the ITU as part of the International Mobile Telephone 2000 (IMT- 2000) project, for which digital networks had to provide 144 kbps of throughput at mobile speeds, 384 kbps at pedestrian speeds, and 2 Mbps in indoor environments [I-III]. UMTS-HSPA and CDMA2000 EV-DO are the primary 3G technologies, although recently WiMAX was also designated as an official 3G technology.

A cellular network or mobile network is a radio network distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a cell site or base station. In a cellular network, each cell uses a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed bandwidth within each cell. When joined together these cells provide ratio courage over a wide geographic area. This enable a large number of portable transceivers (e.g. mobile phone, pagers etc.) to communicate with each other and with fixed transceiver and telephones anywhere in the network, via base station even if some of the transceiver are moving through more than one cell during transmission [IV].

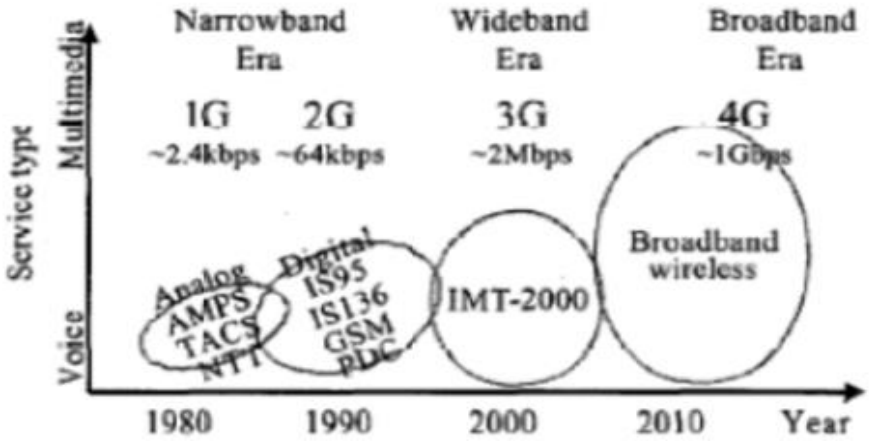


Fig. 1. Evaluation Of Mobile Cellular Networks [VII]

II. Review of 1st Generation Technology 1 G:

The first generation (1G) mobile communications technologies had limited capacity, serving only niche markets for the military, certain government agencies and users in special industries (e.g. loggers, construction foremen, realtors and celebrities). In the 1960s and 1970s, this service was geographically limited and the mobile device was too large, so it was usually mounted in cars or trucks; the smallest was a briefcase model. This form of mobile communications were not ready for mass development, because of (1) the limited capacity to service the general population,

(2) The limited technology capability to cover large areas,

(3) The large size of the mobile device, and

(4) The high prices of mobile devices and tariffs [V-VI].

In the 1970s, countries were still focused on building nation-wide landline communications network rather than mobile networks for a few customers. At least in developed countries, mobile service providers that were government-owned PTT (Post, Telegraphy, and Telephony) bureaus or monopoly companies like AT&T developed or adopted any available technologies to provide mobile services during 1960s and 1970s without considering technology standardization for potential future markets. Therefore, the existing self-organized configuration of the industry before the 1G was fragmented and dominated by monopoly PTTs or companies that had close relationships with governments (See Figure below) [VII].

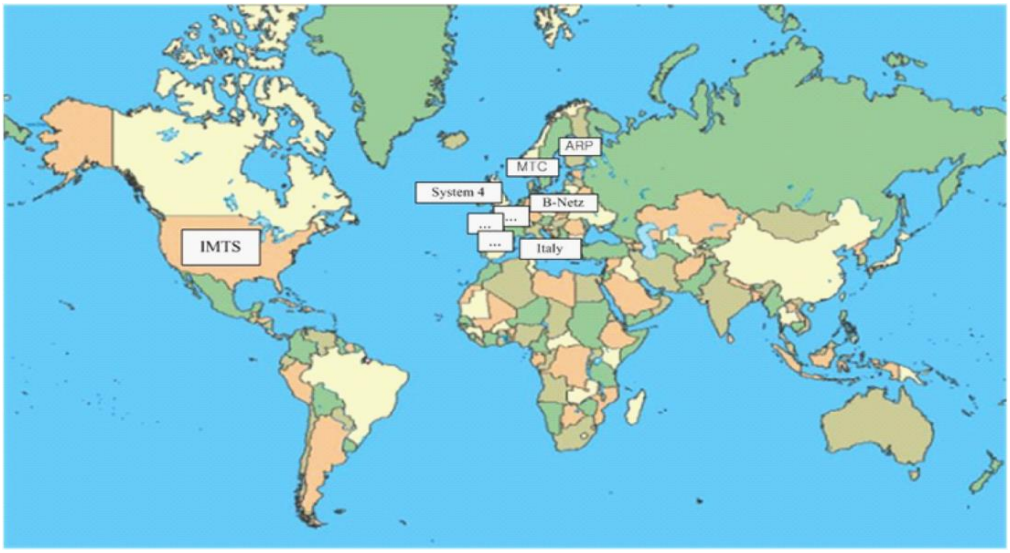


Fig.2. The Configuration before the 1G Technologies Standardizations [VII]

II. i. ETACS

European Total Access Communication systems (ETACS) was developed in mid-1980's and is virtually identical to AMPS except it is scaled to fit in 25 KHz channels used throughout Europe. Another difference between AMPS and ETAC is how the telephone number of each subscriber (called the mobile identification number or MIN) is formatted, due to the need to accommodate different country codes [VIII].

Fig.2.ii. Nokia 650 1G Technology Phone [VIII]

III. Review of 2nd Generation Technology 2 G:

2G technologies can be divided into Time Division Multiple Access (TDMA)-based and Code Division Multiple Access (CDMA)-based standards depending on the type of multiplexing used. The main 2G standards are:

- GSM (TDMA-based), originally from Europe but used in almost all countries on all six inhabited continents. Today accounts for over 80% of all subscribers around the world. Over 60 GSM operators are also usingCDMA2000 in the 450 MHz frequency band (CDMA450).
- IS-95 *aka* CDMA One (CDMA-based, commonly referred as simply CDMA in the US), used in the Americas and parts of Asia. Today accounts for about 17% of all subscribers globally. Over a dozen CDMA operators have migrated to GSM including operators in Mexico, India, Australia and South Korea.
- PDC (TDMA-based), used exclusively in Japan
- iDEN (TDMA-based), proprietary network used by Nextel in the United States and TELUS Mobility in Canada
- IS-136 a.k.a. D-AMPS (TDMA-based, commonly referred as simply 'TDMA' in the US), was once prevalent in the Americas but most have migrated to GSM.

2G services are frequently referred as Personal Communications Service, or PCS, in the United States.

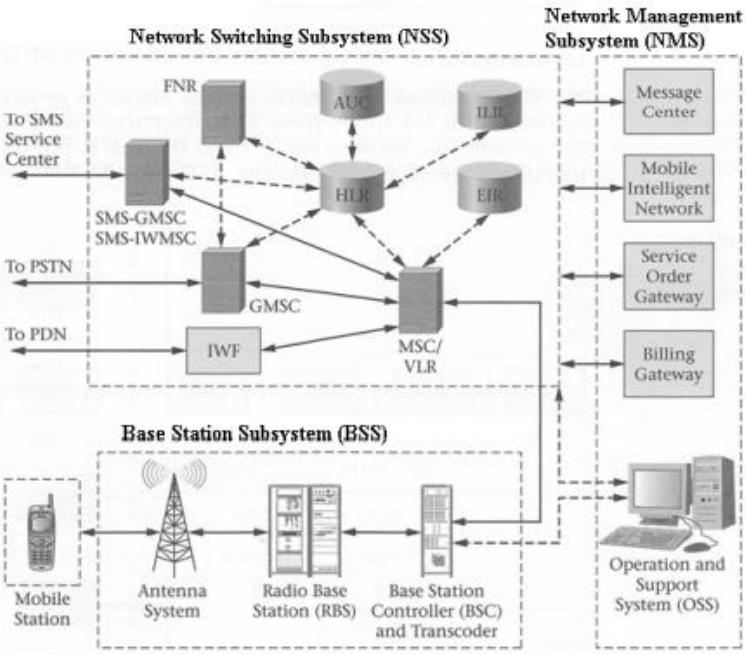
GSM and EDGE (Enhanced Data rates in GSM Environment): With both voice and data traffic moving on the system, the need was felt to increase the data rate. This was done by using more sophisticated coding methods over the internet and thus increasing the data rate up to 384 kbps. Implementing EDGE was relatively painless and required relatively small changes to network hardware and software as it uses the same TDMA (Time Division Multiple Access) frame structure, logic channel and 200 kHz carrier bandwidth as today's GSM networks. As EDGE progresses to coexistence with 3G WCDMA, data rates of up to ATM-like speeds of 2 Mbps could be available

[IX]. Nowadays, second-generation digital cellular systems still dominate the mobile industry throughout the whole world [III].

Fig. 3.i. 2 G Technology Cell Phone [IX]

III.i. GSM Network Infrastructure

The following figure depicts a typical GSM network (called, Public Land Mobile Network or PLMN) infrastructure.



Ref: Wireless Communications Systems and Networks, By Mullett, Thomson Publisher
Note: The solid lines are for user traffic plus control signalling, if any. The dotted lines represent control/management signalling/messaging only.

Fig. 3.ii. GSM Body [X]

AUC Authentication Center
BSC Base Station Controller
BSS Base Station Subsystem
BTS Base Transceiver System (Antenna System + Radio Base Station)
EIR Equipment Identification Register (for IMEI verification)
IMEI International Mobile Equipment Identity
FNR Flexible Numbering Register (for number portability)
GMSC Gateway MSC
HLR Home Location Register
ISDN Integrated Services Digital Network
IWF Interworking Function
ILR Interworking Location Register (for roaming between AMPS and GSM system)
IWMSC Interworking MSC
MS Mobile Station
MSC Mobile Switching Center
NSS Network Switching Subsystem
OSS Operation and Support System
PDN Public Data Network
PSTN Public Switched Telephone Network
SMS Short Message Service
VLR Visitor Location Register

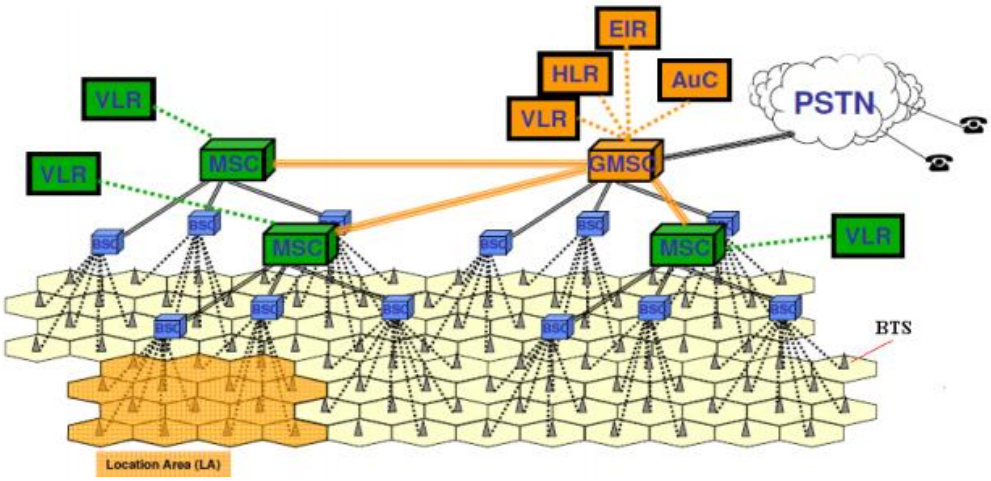


Fig. 3.iii. Architecture of GSM [XI]

IV. Review of 3th Generation Technology 3 G:

The third generation mobile technology based on wide band wireless network fulfilling the International Mobile Telecommunications-2000 (IMT-2000) specifications by the International Telecommunication Union. As per the IMT-2000 standards, a system is required to provide peak data rates of at least 200 Kbit/s. 3G

functions in the range of 2100 Hz and bandwidth 15-20 MHz The communication provides enhanced clarity and perfection like the real conversation. Recent 3G releases provide mobile broadband access of several M bit/s to smart phones and mobile modems in laptop computers. The first release of (Third Generation Partnership Project) 3GPP Long Term Evolution (LTE) standard completely fulfil the (International Telecommunications Union) ITU 4G requirements called the IMT-Advanced. 4G or 3.9G technology is the first release LTE. Its evolution LTE Advanced is a 4G technology. 3G offers a vertically- integrated, top-down, service-provider approach to delivering wireless Internet access. 3G is a technology for mobile service providers. Mobile services are provided by service providers that own and operate their own wireless networks and sell mobile services to end-users, usually on a monthly subscription basis. Mobile service providers use licensed spectrum to provide wireless telephone coverage over some relatively large contiguous geographic serving area [XII-XIII].

Historically, this might have included a metropolitan area. Today it may include the entire country. From a user's perspective, the key feature of mobile service is that it offers (near) ubiquitous and continuous coverage that is, a consumer can carry on a telephone conversation while driving along a highway at 100Km/hour. To support this service, mobile operators maintain a network of interconnected and overlapping mobile base stations that hand-off customers as those customers move among adjacent cells. Each mobile base station may support users up to several kilometers away. The cell towers are connected to each other by a backhaul network that also provides interconnection to the wire line Public Switched Telecommunications Network (PSTN) and other services. The mobile system operator owns the end-to-end network from the base stations to the backhaul network to the point of interconnection to the PSTN (and, perhaps, parts thereof). These can support data rates of from 384Kbps up to 2Mbps, although most commercial deployments are expected to offer data rates closer to 100Kbps in practice. While this is substantially below the rates supported by the current generation of wire line broadband access services such as DSL or cable modems, it is expected that future upgrades to the3G or the transition to 4G mobile services will offer substantially higher bandwidths. Although wire line systems are likely to always exceed the capacity of wireless ones, it remains unclear precisely how much bandwidth will be demanded by the typical consumer and whether 3G services will offer enough to meet the needs of most consumers. Auctions for 3G spectrum licenses occurred in a number of countries in 2000 and the first commercial offerings of 3G services began in Japan in October 2001. More recently, Verizon Wireless has announced "3G" service in portions of its serving territory (though this is not true-3G service). 3G offers much narrower bandwidth but over a wider calling area and with more support for rapid movement between base stations[XIV].

The IMT-2000 framework sets the following goals for the so called 3G wireless systems:

- Global standards to allow for low cost and worldwide roaming.
- High Quality of Service (QoS) especially for voice.

- Support for advanced services: Multimedia, Bandwidth on Demand, High speed data.
- Multi environment capabilities
- Compatibility of service with fixed network
- In building/private system integration

Fig. 4. 3G Technology Phone [XIV]

V. Review of 4th Generation Technology 4 G

4G short for fourth generation, is the fourth generation of mobile telecommunications technology, succeeding 3G and preceding 5G. A 4G system, in addition to the usual voice and other services of 3G, provides mobile ultra-broadband Internet access, for example to laptops with USB wireless modems, to smartphones, and to other mobile devices. Conceivable applications include amended mobile web access, IP telephony, gaming services, high-definition mobile TV, video conferencing, 3D television, and cloud computing.

Two 4G candidate systems are commercially deployed: the Mobile WiMAX standard (first used in South Korea in 2007), and the first-release Long Term Evolution (LTE) standard (in Oslo, Norway and Stockholm, Sweden since 2009). It has however been debated if these first-release versions should be considered to be 4G or not, as discussed in the technical definition section below [XV].

In the United States, Sprint (previously Clear wire) has deployed Mobile WiMAX networks since 2008, while Metro-PCS became the first operator to offer LTE service in 2010. USB wireless modems were among the first devices able to access these networks, with WiMAX smartphones becoming available during 2010, and LTE smartphones arriving in 2011. The consumer should note that 3G and 4G equipment made for other continents are not always compatible, because of different frequency bands. Mobile WiMAX is currently (April 2012) not available for the European market [XV].

V.i. Imt-Advanced Requirements

This article uses 4G to refer to IMT-Advanced (International Mobile Telecommunications Advanced), as defined by ITU-R. An IMT-Advanced cellular system must fulfill the following requirements: [XV]

- Be based on an all-IP packet switched network.
- Have peak data rates of up to approximately 100 Mbit/s for high mobility such as mobile access and up to approximately 1 Gbit/s for low mobility such as nomadic/local wireless access.
- Be able to dynamically share and use the network resources to support more simultaneous users per cell.
- Using scalable channel bandwidths of 5–20 MHz, optionally up to 40 MHz.
- Have peak link spectral efficiency of 15 bit/s/Hz in the downlink, and 6.75 bit/s/Hz in the uplink (meaning that 1 Gbit/s in the downlink should be possible over less than 67 MHz bandwidth).
- System spectral efficiency is, in indoor case, 3 bit/s/Hz/cell in downlink and 2.25 bit/s/Hz/cell in uplink.
- Smooth handovers across heterogeneous networks.
- The ability to offer high quality of service for next generation multimedia support.

Table 1. 1G to 4G [15]

Generation	Requirements	Comments
1G	No official requirements. Analog technology.	Deployed in the 1980s.
2G	No official requirements. Digital Technology.	First digital systems. Deployed in the 1990s. New services such as SMS and low-rate data. Primary technologies include IS-95 CDMA and GSM.
3G	ITU's IMT-2000 required 144 kbps mobile, 384 kbps pedestrian, 2 Mbps indoors	Primary technologies include CDMA2000 1X/ EVDO and UMTS-HSPA. WiMAX now an official 3G technology.
4G	ITU's IMT-Advanced requirements include ability to operate in up to 40 MHz radio channels and with very high spectral efficiency.	No technology meets requirements today. IEEE 802.16m and LTE-Advanced being designed to meet requirements.

The 4G network will encompass all systems from various networks, public to private; operator-driven broadband networks to personal areas; and ad hoc networks. The 4G systems will interoperate with 2G and 3G systems, as well as with digital (broadband) broadcasting systems. In addition, 4G systems will be fully IP-based wireless Internet which will provide access to wide range of telecommunication services, including advanced mobile services, supported by mobile and fixed networks, which are increasingly packet based, along with a support for low to high mobility applications and wide range of data rates, in accordance with service demands in multiuser environment (see fig.4). This paper provides a comprehensive overview of the evolution of Mobile Wireless Communication Networks from 1G to 4G [XII].

The fourth generation mobile communication system is developed after the third generation (3G) mobile phone standards. A fourth generation system (4G) provides various features which are not involved in Third generation standards or any other generation before 3G (i.e. first generation and second generation). The features included in 4G are Video conferencing, gaming services, IP telephony, high definition (HD) mobile TV. It also provides Internet access facility at a very rapid speed which is known as mobile ultra-broadband internet access.

The fourth generation mobile systems uses orthogonal frequency division multiplexing (OFDM), Multiple input multiple output (MIMO), software defined radio (SDR) technologies. The OFDM technology is similar technology as FDM (Frequency division multiplexing) technology but a technological difference is that in OFDM the subcarriers are orthogonally spaced to each other to reduce the interference. It also reduces the Frequency selective fading which affects severely the transmitted signal at a channel. Due to the orthogonal arrangement of subcarriers the cross-talk between sub channels is eliminated. One advantages of OFDM is that intercarriers guard bands are not necessary.

OFDM also improves the spectral efficiency. The OFDM technology uses a fast Fourier transform (FFT) to convert the time domain signal in to frequency domain signal. The use of FFT algorithm reduces the computational time and also increases the overall efficiency of the system .The second technology used in fourth generation standard is Multiple input multiple output (MIMO). In this system the number of multiple antennas is used at transmitter and the number of multiple antennas is used at receiver to improve the bit error rate (BER) and data rate so as to maintain the system capacity. This technology provides a reliable communication. To reduce the problems of global roaming the software defined radio (SDR) is developed. The software defined radio technology implements the radio functionality as a software module running on a generic hardware platform. This technology is advantageous because of its flexibility, interoperability, connectivity and re-configurability [XIII]. Along with this advantage it also faces some drawbacks such that it increases complexity and physical size of terminal. The second disadvantage is that the ADC's (analog to digital converters) are insufficient.

The fourth generation standards mobile system provides data rates greater than 200 Mbps. While, third generation mobile systems provide the data rates up to 2 Mbps. Thus, fourth generation systems promises the users for to provide better data rates. Due to the higher data rate a speedy communication is possible which makes users

lives easier. By implementing the fourth generation technology the high date speed networks connects simultaneously which offers the faultless handoffs around all over the geographical regions. The faultless handoffs provide efficient communication over a wireless link. The cognitive radio network technology guarantees the secure connection.

The innovations in fourth generation mobile technology includes following: [XIV]

- The mobile communications comprises two levels: a) access to the mobile network and b) access to the mobile services.

Table 2. Results [XV]

Technology	1G	2G	3G	4G
Design Began	1970	1980	1990	2000
Implementation	1981	1991	2001	2010
Services	Analog voice	Digital voice, short message	Higher capacity, data rates up to 2 Mbps	Higher capacity, completely IP-oriented,multimedia,data to hundreds of megabits
Standards	AMPS, ETACS, NMT etc.	TDMA,CDMA,GSM	WCDMA, CDMA-2000	Single standard
Data Rate	NA	14.4 kbps	2 Mbps	>200 Mbps
Multiplexing	FDMA	TDMA, CDMA	CDMA	OFDM
Core Network	PSTN	PSTN	Packet network	Internet

VI. Conclusion:

The last few years have witnessed a phenomenal growth in the wireless industry. The ever increasing demands of users have triggered researchers and industries to come up with a comprehensive manifestation of the up-coming fourth generation (4G) mobile communication system. As the history of mobile communications shows, attempts have been made to reduce a number of Technologies to a single global standard. The first generation (1G) has fulfilled the

basic mobile voice, while the second generation (2G) has introduced capacity and coverage. This is followed by the third generation (3G), which has quest for data at higher speeds to open the gates for truly "mobile broadband" experience, which will be further realized by the fourth generation (4G).

Conflict of Interest:

There was no relevant conflict of interest regarding this paper.

References

I. Amit Kumar, Dr. Yunfei Liu ,Dr. Jyotsna Sengupta, Divya, "Evolution of Mobile Wireless Communication Networks 1G to 4G", International Journal of Electronics & Communication Technology, IJECT Vol. 1, Issue 1, Dece- mber 2010.

II. F. Williams, Ericsson, "Fourth generation mobile," in *ACTS Mobile Summit99*, Sorrento, Italy, June 1999.

III. Fumiyuki Adachi, "Wireless past and Future: Evolving Mobile Communication Systems". IEICE Trans. Findamental, Vol. E84-A, No.1, January 2001.

IV. H. Huomo, Nokia, "Fourth generation mobile," in *ACTS Mobile Summit99*, Sorrento, Italy, June 1999.

V. Jamil.M." 4G: The Future Mobile Technology" , in TENCON 2008 IEEE Region 10 Confererence, 19-21 Nov. 2008

VI. Jun-Zhao Sun, Jaakko Sauvola, and Douglas Howie, "Features in Future: 4G Visions From a Technical Perspective,"in IEEE, 2001.

VII. Kamarularifin Abd Jalil, Mohd Hanafi Abd. Latif, Mohamad Noorman Masrek, "Looking Into The 4G Features", MASAUM Journal of Basic and Applied Sciences Vol.1, No. 2 September 2009.

VIII. Kamarularifin Abd Jalil, Mohd Hanafi Abd. Latif, Mohamad Noorman Masrek, "Looking Into The 4G Features", MASAUM Journal of Basic and Applied Sciences Vol.1, No. 2 September 2009

IX. Mobile Technology: Evolution from 1G to 4G, Electronics for You, June 2003.

X. Mishra, Ajay K. "Fundamentals of Cellular Network Planning and Optimization, 2G/2.5G/3G…Evolution of 4G", John Wiley and Sons, 2004

XI. Mishra, Ajay K. "Fundamentals of Cellular Network Planning and Optimization, 2G/2.5G/3G…Evolution of 4G", John Wiley and Sons, 2004.

XII. Nabeel ur Rehman, Asad Asif,Junaid Iqbal, "3G Mobile Communication Networks" in Explore Summer 2006.

XIII. Pereira, Vasco & Sousa, Tiago. "Evolution of Mobile Communications: from 1G to 4G", Department of Informatics Engineering of the University of Coimbra, Portugal 2004.

XIV. "Transition to 4G: 3GPP Broadband Evolution to IMT-Advanced", Rysavy Research/3G Americas. [Online] Available: www.rysavy.com/PR/3GA_ PR_2010_09.pdf

XV. Third Generation (3G) Wireless White Paper, Trillium Digital Systems, Inc. March 2000.