Wireless Evolution with 4G Technologies and comparison between 3G and 4G

Md. Nazrul Islam, A.O.M Asaduzzaman

***Abstract*— The word wide revolution in mobile is changing our lives in term of the way we work, learn and interact. A long way in a remarkably short time has been achieved in the history of wireless. Evolution of wireless access technologies is about to reach its fourth generation (4G).In the past few decades, mobile wireless technologies have experience 4 or 5 generations of technology revolution and evolution, namely from 0G to 4G. 4G seems to be the solution for the growing user requirements of wireless broadband access and the limitations of the existing wireless communication system. The Fourth generation (4G) 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. In this paper, we review evolution of 4G mobile technology and comparison between Fourth generation (4G) and Third generation (3G) mobile technology vis-à-vis in terms of their portals, performance, advantages and disadvantages. The paper throws light on the evolution and development of 4G mobile wireless technologies along with its speed, connected devices, components and related protocols.**

***Index Terms*— Internet protocol, OFDM, Mobile Wireless Communication Networks, 1G, 2G, 3G, 4G, CDMA, FDMA, GPRS, GSM, TDMA, Trillium Solution, Mobile Broadband**

ANSI = American National Standards Institute	**HIPERLAN** = High Performance Local Area Network (an ETSI standard)
API = Application Programming Interface	**HTML** = Hypertext Markup Language
BRAN = Broadband Radio Access Network	**ITU** = International Telecommunications Union
CAC = Connection Admission Control	**IMT-2000**= International Mobile Telecommunicate 2000 (the 3G ITU standard)
CDMA = Code Division Multiple Access	**LAC** = Link Access Control
DAB = Digital Audio Broadcasting (a standard)	**MAC** = Medium Access Control
DVB = Digital Video Broadcasting (a standard)	**MAP** = Mobile Applications Protocol
EDGE = Enhanced Data rates for GSM Evolution	**OFDM** = Orthogonal Frequency Division M
ETSI = European Telecommunications Standards Institute	**PAN** = Personal Access Network
FDD = Frequency Division Duplex	**QoS** = Quality of Service
GPRS = General Packet Radio Services	**SMS** = Short Message Service
GSM = Global System for Mobile Communications	**TDD** = Time Division Duplex
HAN = Home Area Network	**UMTS** = Universal Mobile Telecommunication System (the 3G ETSI standard)
HAPS = High Altitude Platform Stations	**UTRA** = UMTS Terrestrial Radio Access
W-CDMA = Wideband Code Division Multiple A	**VAN** = Vehicle Area Network
WLAN =Wireless Local Area Network	**VHE** = Virtual Home Environment
WML = Wireless Markup Language	**WAP** = Wireless Area Protocol
	XDSL = X (various) Digital Subscriber Line

Table1: Abbreviations

I. INTRODUCTION

A great deal of attention is currently being paid to the 2G, 2.5G, 3G, and 3G+ (4G) cellular networks Generation. Each generation has been a giant stride which revolutionized the field of mobile communication. As discussed in paper [2], era of telecommunication started with 1G in 1980 where all the systems where based on analog radio signal technology. Voice was considered to be the main traffic. Various 1G standards defined were Advance Mobile Phone System

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(AMPS), Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA). In 1990, 1G was replaced by 2G which provided rich set of services such as high voice quality and global mobility based on the digital radio signal technology. 2G includes standards such as Global System For Mobile Communications (GSM), General Packet Radio System (GPRS). Both 1G and 2G are based on circuit-switched technology for data communication at low speed. 2G was a huge success. 2G was followed by 2.5G which is an intermittent between 2G and 3G. It is based on both circuit switched and packet switched technologies providing high data rate with low power consumption. It uses the infrastructure of Global System for Mobile communications (GSM) and Code division multiple access (CDMA) to provide its services. In the present generation, 2.5G is replaced by 3G which includes standards from 2.5G and also some other technologies such as WiMAX (Worldwide Interoperability for Microwave Access). It is totally based on the packet switching technology providing broad range of high quality services to the end user to meet the demand of high data rate and increasing rate of network users Before 3G was deployed all over the world, the idea of technology beyond 3G started evolving. This idea was beyond the imagination of ordinary mobile user promising "connect anytime, anyhow, anywhere"[3]. This ubiquitous network access will be achieved by seamlessly integrating the available and new networks using a core IP based network layer. This vision is called as the 4th generation of communication (4G).

II. WIRELESS EVOLUTION

Mobile Cellular Network evolution has been categorized in to 'Generations' as shown in Fig. 1 [5].Each wireless generation are mention below along with Fourth generation wireless technology .

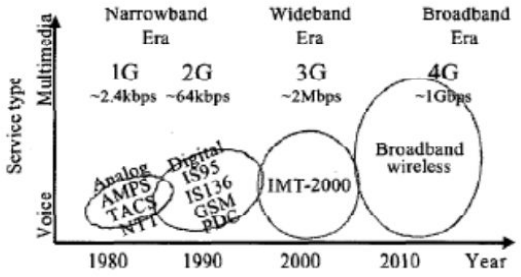

Figure 1: Evolution of Mobile Cellular Network[17]

2.1 First generation

The First Generation of wireless mobile communications was based on analog signaling. In 1980 the mobile cellular era had started, and since then mobile communications have undergone significant changes and experienced enormous growth. Fig. 1 shows the evolution
of the mobile networks. First-generation mobile systems used analog transmission for speech services. In 1979, the first cellular system in the world became operational by Nippon
Telephone and Telegraph (NTT) in Tokyo, Japan.. The two most popular analogue systems were Nordic Mobile Telephones (NMT) and Total Access Communication Systems (TACS). Other than NMT and TACS, some other analog systems were also introduced in 1980s across the Europe. In India First Generation mobile service were initially launched in 1995 in which only voice service were available. The service cost factor was also very high.

2.2 Second Generation (2G)

The second generation of digital mobile phones appeared about eleven years later to First Generation mobile phones, along with the first digital mobile networks.
The second generation (2G) of the wireless mobile network was based on low-band digital data signaling. Compared to first-generation systems, second-generation (2G) systems use digital multiple access technology, such as TDMA (time division multiple access) and CDMA (code division multiple access). The most popular 2G wireless technology is known as Global Systems for Mobile Communications (GSM). GSM systems, first implemented in 1991, are now operating in about 140 countries and territories around the world .Global System for Mobile Communications, or GSM, uses TDMA technology to support multiple users During development over more than 20 years, GSM technology has been continuously improved to offer better services in the market. The first GSM systems used a 25MHz frequency spectrum in the 900MHz band. FDMA is used to divide the available 25MHz of bandwidth into 124 carrier frequencies of 200 kHz each. Each frequency is then divided using a TDMA scheme into eight timeslots.
Today, GSM systems operate in the 900MHz and 1.8 GHz bands throughout the world with
the exception of the Americas where they operate in the 1.9 GHz band. While GSM technology was developed in Europe, Code Division Multiple Access (CDMA) technology was developed in North America. CDMA uses spread spectrum technology to break up speech into small,
digitized segments and encodes them to identify each call.

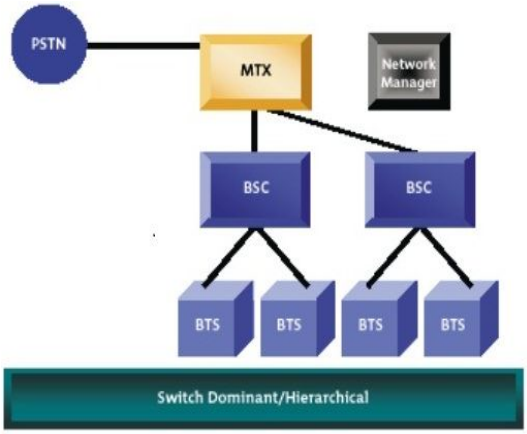

Figure 2: 2G Wireless Infrastructures

2G wireless networks are digital and expand the range of applications to more advanced voice services, such as Called Line Identification. 2G wireless technology can handle some data capabilities such as fax and short message service at the data rate of up to 9.6 kbps, but it is not suitable for web browsing and multimedia applications. This GSM network also has an extension to the fixed telephony network. A new design was introduced into the mobile switching center of second-generation systems. In particular, the use of base station controllers (BSCs) lightens the load placed on the MSC (mobile switching center) found in first-generation

systems. This design allows the interface between the MSC and BSC to be standardized. But all of these users need more facilities such as Email and fast internet access, Wireless purchasing, Global roaming, etc. To meet these demands, network operators and wireless equipment manufacturers alike were turning toward a third generation (3G) of wireless systems that deliver higher data rates based on packet transmission and new modulation formats.

2.3 Second Generation (2G+) Wireless Networks

The virtual explosion of Internet usage has had a tremendous impact on the demand for advanced wireless data communication services. For supply on demand GSM, PDC and other TDMA -based mobile system providers and carriers developed 2G+ technology which was packet-based and increases the data communication speeds to as high as 384kbps. The move into the 2.5G world began with General Packet Radio Service (GPRS). These 2G+ systems are based on the following technologies: High Speed Circuit-Switched Data (HSCSD), General Packet Radio Service (GPRS) and Enhanced Data Rates for Global Evolution (EDGE) technologies. This circuit-switched technology improves the data rates up to 57.6kbps by introducing 14.4 kbps data coding and by aggregating 4 radio channels timeslots of 14.4 kbps. GPRS is the most significant step towards 3G. 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 [7, 6]. Nowadays, second-generation digital cellular systems still dominate the mobile industry throughout the whole world.

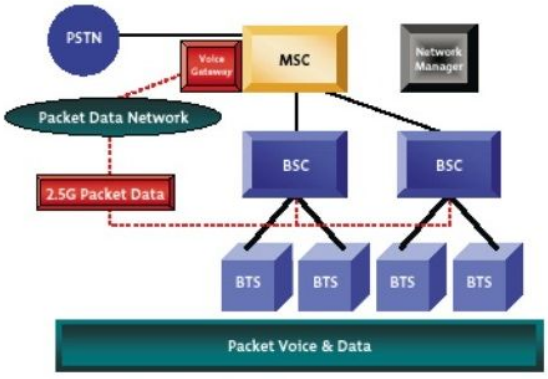

Figure 3: 2.5 G Wireless Infrastructures

2.4 The Third-Generation (WCDMA in UMTS, CDMA2000 &TD-SCDMA)

3G [8][9] is the third generation of mobile phone standards and technology. 3G technologies have enabled faster data transmission speeds, greater network capacity and more advanced network services. In May 2001, NTT DoCoMo (Japan) launched the first pre-commercial 3G network –branded as FOMA. Following the first pre-commercial launch, NTT DoCoMo again made history on October 1, 2001, with the first commercial launch of 3G in Japan. UMTS-HSPA is the world's leading 3G technology.

2.4.1 Third Generation (3G) Wireless Networks Architecture

3G wireless technology represents the convergence of various 2G wireless telecommunications systems into a single global system that includes both terrestrial and satellite components. One of the most important aspects of 3G wireless technologies is its ability to unify existing cellular standards, such as CDMA, GSM, and TDMA, less than one umbrella. The following three air interface modes accomplish this result: wideband CDMA, CDMA2000 and the Universal Wireless Communication (UWC-136) interfaces. Wide band CDMA (W-CDMA) is compatible with the current 2G GSM networks prevalent in Europe and parts of Asia. W-CDMA will require bandwidth of between 5Mhz and 10 MHz, making it a suitable platform for higher capacity applications. It can be overlaid onto existing GSM, TDMA (IS-36) and IS95 networks. Subscribers are likely to access 3G wireless services initially via dual band terminal devices. W-CDMA networks will be used for high-capacity applications and 2G digital wireless systems will be used for voice calls. The second radio interface is CDMA2000, which is backward compatible with the second generation CDMA IS-95 standard predominantly used in US. The third radio interface, Universal Wireless Communications – UWC-136, also called IS-136HS, was proposed by the TIA and designed to comply with ANSI-136, the North American TDMA standard. 3G wireless networks consist of a Radio Access Network (RAN) and a core network. The core network consists of a packet-switched domain, which includes 3G SGSNs and GGSNs, which provide the same functionality that they provide in a GPRS system, and a circuit-switched domain, which includes 3G MSC for switching of voice calls. Charging for services and access is done through the Charging Gateway Function (CGF), which is also part of the core network. RAN functionality is independent from the core network functionality. The access network provides a core network technology independent access for mobile terminals to different types of core networks and network services. Either core network domain can access any appropriate RAN service; e.g. it should be possible to access a "speech" radio access bearer from the packet switched domain. The Radio Access Network consists of new network elements, known as Node B and Radio Network Controllers (RNCs). Node B is comparable to the Base Transceiver Station in 2G wireless networks. RNC replaces the Base Station Controller. It provides the radio resource management, handover control and support for the connections to circuit-switched and packet-switched domains. The interconnection of the network elements in RAN and between RAN and core network is over Iub, Iur and Iu interfaces based on ATM as a layer 2 switching technology. Data services run from the terminal device over IP, which in turn uses ATM as a reliable transport with QoS. Voice is embedded into ATM from the edge of the network (Node B) and is transported over ATM out of the RNC. The Iu interface is split into 2 parts: circuit switched and packet-switched. The Iu interface is based on ATM with voice traffic embedded on virtual circuits using AAL2 technology and IP-over-ATM for data traffic using AAL5 technology.

These traffic types are switched independently to either 3G SGSN for data or 3G MSC for voice.

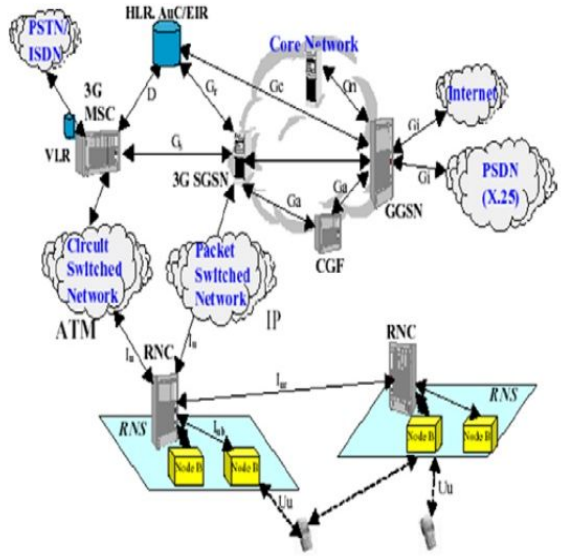

Figure 4: 3G Wireless Network Architecture[10]

2.4.2 Features of 3G

3G telecommunications, is a generation of standards for mobile phones and mobile
Telecommunication services fulfilling the International Mobile Telecommunications-2000 (IMT-2000) specified by the International Telecommunication Union. Application services include wide-area wireless voice telephone, mobile Internet access, video calls and mobile TV, all in a mobile environment. To meet the IMT-2000 standards, a system is required to provide peak data rates of at least 200 Kbit/s. Recent 3G releases, often denoted 3.5Gand 3.75G, also provide mobile broadband access of several Mbit/s to smart phones and mobile modems in laptop computers.

The following standards are typically

Branded 3G:

• the UMTS system, first offered in 2001, standardized by 3GPP, used primarily in Europe, Japan, China (however with a different radio interface) and other regions predominated by GSM 2G system infrastructure. The cell phones are typically UMTS and GSM hybrids.

Several radio interfaces are offered, sharing the same infrastructure:

- The original and most widespread radio interface is called W-CDMA.
- The TD-SCDMA radio interface, was commercialized in 2009 and is only offered in China.
- The latest UMTS release, HSPA+, can provide peak data rates up to 56 Mbit/s in the downlink in theory (28 Mbit/s in existing services) and 22 Mbit/s in the uplink.

2.4.3 What's new in 3G?

- A wide range of market-focused applications
- Long-term market-driven creativity, an innovative value chain and real user benefits, driving genuine market demand
- Advanced, lightweight, easy-to-use terminals with intuitive interfaces · Instant, real-time multimedia communications
- Global mobility and roaming
- A wide range of vendors and operators, offering choice, competition and affordability High-speed e-mail and Internet access

2.4.4 The Speed

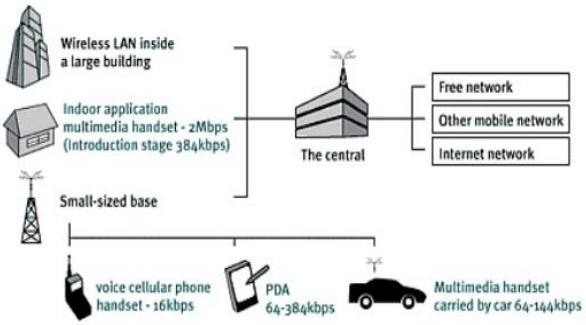

Figure 5: Speed of 3G Network

3G enabled users to transmit voice, data, and even moving images. In order to realize these services, 3G improves the data transmission speed up to 144Kbps in a high-speed moving environment, 384Kbps in a low-speed moving environment, and 2Mbps in a stationary environment. 3G provides services like Internet connection, transmission of large-scale data and moving contents photographed by digital cameras and videos, and software downloading.

2.5 Fourth Generation Wireless Systems

4G stand for Fourth Generation wireless network .In simplest terms; 4G is the next generation of wireless networks that will replace 3G networks sometimes in future. In another context, 4G is simply an initiative by academic R&D labs to move beyond the limitations and problems of 3G which is having trouble getting deployed and meeting its promised performance and throughput. In reality, as of first half of 2002, 4G is a conceptual framework for o r a discussion point to address future needs of a universal high speed wireless network that will interface with wire line backbone network seamlessly. 4G is also represents the hope and ideas of a group of researchers in Motorola, Qualcomm, Nokia, Ericsson, Sun, HP, NTT DoCoMo and other infrastructure vendors who must respond to the needs of MMS, multimedia and video applications if 3G never materializes in its full glory.

2.5.1 Reasons to have 4G:

1. Support interactive multimedia services: Teleconferencing, wireless internet etc.
2. Wider bandwidths, higher bit rates.
3. Global mobility and service portability.
4. Low cost.
5. Scalability of mobile networks.

2.5.2 New in 4G:

1. Entirely packet-switched networks.
2. All network elements are digital.

3. Higher bandwidths to provide multimedia services at lower cost (up to 100Mbps).
4. Tight network security.
5. Adaptive array technology.
6. Ultra wide band technology.
7. Simulation and analysis of advanced adaptive modulations/coding schemes.
8. Reconfigurable radio systems.
9. Self-organizing networks end-to-end mobile IP and adaptive QoS (Quality of Service)

2.5.3 Opportunities in 4G:

1. It is expected and predicted that consumers will continue to replace handsets with newer technology at a fast rate.
2. Desirable higher data capacity rates, the growth opportunity for 4G is very bright and hopeful.

2.5.4 Applications:

1. Location application 4G location application will be based on visualized, virtual navigation scheme that will support a remote database containing graphical representation of streets, buildings and other physical characteristics of a large metropolitan area.
2. Virtual navigation and telegeoprocessing. You will be able to see internal layout of a building during an emergency rescue. This type of application is referred to as 'telegeoprocessing'.
3. Telemedicine

2.5.5 Technique used in 4G:-

- OFDM
- USB (Ultra Wide Band)
- Millimeter wireless.
- Smart Antennas
- Long term power prediction.
- Scheduling among users.
- Adaptive modulation and power control.

2.5.6 4G Network Architecture

Figure 1shows the widely accepted 4G network structure with IP as the core network used for communication; integrating the 2G, 3G and 4G technologies using a convergence layer [3].

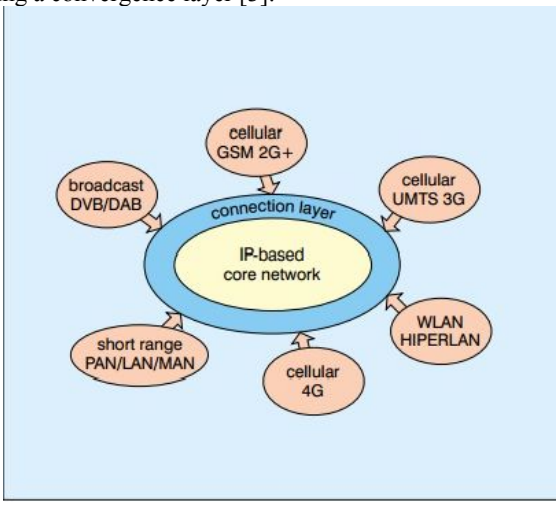

Figure 6: 4G Network Structure

Figure 7 shows the proposed layered/level Architecture of 4G network elucidated in [14]. This architecture fulfills the basic requirement of servicing the standalone and mobile subscribers on an "anytime, anywhere, anyhow" basis in dynamic network conditions. The architecture is based on Internet Protocol version 6 (IPV6) which operates at the transport layer enabling seamless communication across various heterogeneous networks and based on the key factors such as mobility, Quality of Service (QoS) and efficient resource management schemes.

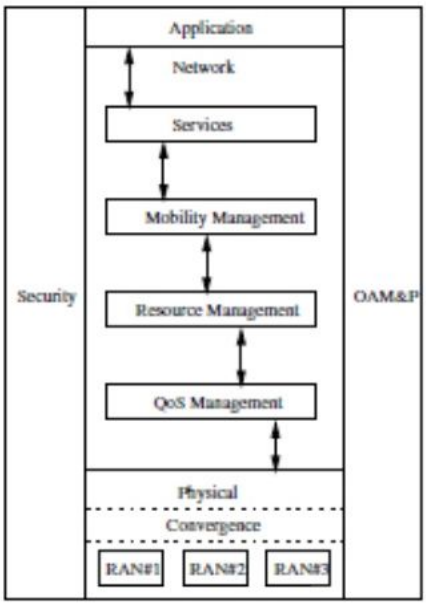

Figure 7: Layered 4G Architecture

2.5.7 Advantages and Disadvantages of 4G:-

Advantages:-

- Support for interactive multimedia voice, streaming video, internet & other broadband services.
- IP based mobile system.
- High speed, high capacity & low cost per bit.
- Global access, service portability & scalable mobile services.
- Better scheduling and call admission control technique.
- Ad-hoc & multi-hop network.
- Better spectral efficiency.
- Seamless network of multiple protocols & air interfaces.

Disadvantages:-

- Expensive
- Battery uses are harder to implement
- Need complicated hardware.

III. COMPARISON OF 3G WIRELESS NETWORKS AND 4G WIRELESS NETWORKS:

3G:

3rd generation of mobile telecommunications technology also called Tri-Band 3G.It is the successor to 2G technology.

It has various release versions like 3.5G, 3.75G.The technologies under it are CDMA 2000, UMTS, EDGE, 1XRTT, EVDO. It based on high capacity broadband data. It has data bandwidth of 2Mbps. It has bandwidth of 5-10 Mbps. The spectral efficiency ranges from 1-5 Mhz. Costly in implementation. The data throughput is up to 3.1Mbps.It has a peak upload rate of 5 Mbps. The peak download rate is 100 Mbps. It supports packet switching. Its network architecture is wide area cell based. It uses turbo codes for error correction. It has frequency band of 1.8-2.5 GHz. It provides video access to the user. No virtual presence. It provides digital navigation.

4G:

4G is the fourth generation of mobile phone mobile communication technology standards. It is the successor to 3G technology. It do not have its own release versions whereas it has release versions of technologies under it. The technologies under it are WiMAX, Lte. It is completely based on Internet Protocol. It has data bandwidth of 200Mbps. Flexible bandwidth. The spectral efficiency could be 20 Mhz. Low cost than 3G. The data throughput practically is 3-5Mbps and potentially it is 100-300 Mbps. It has a peak upload rate of 500 Mbps. The peak download rate is 1 Gbps. It supports packet as well as message switching. Its network architecture is integration of wireless LAN and wide area network. It uses concatenated codes for error correction. It has frequency band of 2-8 GHz. It provides HD video access to the users. Virtual presence is also possible. It provides virtual navigation.

A comparison Table between 3G and 4G is given below:

Specifications	**3G**	**4G**
Frequency Band	1.8 – 2.5 GHz	2 – 8 GHz
Bandwidth	5-20 MHz	5-20 MHz
Data rate	Up to 2Mbps	20 Mbps or more
Access	Wideband CDMA	Multi-carrier – CDMA or OFDM(TDMA)
FEC	Turbo-codes	Concatenated codes
Switching	Circuit/Packet	Packet
Data Throughput:	Up to 3.1mbps	3to5mbps but potential estimated at a range of 10 to300 mbps.
Peak Upload Rate:	50 Mbit/s	50 Mbit/s
Peak Download Rate:	100Mbit/ s	1Gbit/s
Switching Technique:	packet switching /circuit switch	packet switching, message switching
Network Architecture:	Wide Area Cell Based	Integration of wireless LAN and Wide area.
Services And Applications:	CDMA 2000, UMTS, EDGE etc.	Wimax2 and LTE-Advance
Forward error correction (FEC):	3G uses Turbo codes for error correction	Concatenated codes are used for error correctionsin4G
Frequency Band:	1.8 – 2.5GHz	2 – 8GHz

Table 2: A Brief comparison between 3G and 4G[18]

IV. FUTURE

Cellular networks however may see an improvement in implementing this technology.

4G mobile phone technology promises faster communication Speeds (100 Mbps to 1 Gbps), capacity and diverse usage formats. These formats would provide richer content and support for other public networks such as optical fiber and wireless local area networks.

CONCLUSION

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).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. This paper provides a comprehensive overview of the evolution of Mobile Wireless Communication Networks 4G and a comparison between 3G and 4G.

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