WIRELESS COMMUNICATION NETWORKS: ADVANCEMENT TO 4G

Pranavi Macharla, Jagadish Nayak
Department of Electronics and Communication
Engineering, BITS Pilani Dubai Campus, Dubai, UAE

ABSTRACT
The objective of this paper is comprehensive study related to Fourth Generation (4G) technology of mobile communication. In 4G, researches are related to the development of Long Term Evolution (LTE)-Advanced technology. LTE-Advanced is not a new technology; it is an evolutionary step in continuing the development of Long Term Evolution (LTE). The most important technologies for 4G are Multiple Input Multiple Output (MIMO) & Orthogonal Frequency Division Multiplexing (OFDM). Third Generation (3G) cellular systems provide high data rates for mobile broadband services which are further followed by 4G. 4G cellular systems provide wide range of services which are increasingly packet based supported by both mobile and fixed networks and also provide data rates at higher speeds. This paper provides an overview of the evolution of mobile wireless communication networks from third generation (3G) to fourth generation (4G).

KEYWORDS: *3G, 4G, Long Term Evolution, 3GPP, OFDM*

I. INTRODUCTION

Mobile wireless technology has evolved from an analog system which can send only speech signals to digital system which can send any kind of information like voice, data etc. with very high speeds efficiently. It had experienced many changes in its growth and evolved into different generations like 1G, 2G, 3G and 4G. Current research on mobile wireless technology concentrates on advance implementation of 4G technology. 1G became available in 1980's that made the mobile wireless technology into large scale. Analog systems were replaced by digital systems in second generation. 2G improved the wireless communication quality by introducing messaging and data at lower speed [3].
3G technology is originally designed and developed for high speed data and internet access. 3G standard networks were different in different parts of the world. Hence a common network standard was developed globally which uses services independent of the technology platform. The International Telecommunications Union (ITU) has defined the demands for 3G networks with IMT-2000 standard [1]. 3GPP is an organisation that continued the work to full fill the IMT-2000 standard. 3GPP was established in 1998 with its main objective to come up with technical specifications that would be applicable for 3G networks globally. IMT-2000 delivers a system with high spectrum efficiency and capacity. Its standards are based on evolutionary and revolutionary 3G standards. Evolutionary standards are based on the evolution from the previous standards. There are two standards deployed from it. They are- CDMA2000 which is evolved from 2G CDMA standard IS-95 and the other standard is EDGE, evolved from 2G TDMA standard GSM. Revolutionary standards require a new spectrum allocation. One of the standards is WCDMA which requires channel bandwidth of 5MHz. TD-SCDMA and DECT are other standards which requires TDD frequency assignment. Third generation (3G) networks offer wide range of advanced services by achieving

network capacity through spectral efficiency. Services include- video calls, broadband wireless data, gaming services, etc. 3G technology uses TDMA and CDMA air interface techniques.

4G cellular systems are the emerging technology for the future wireless networks. From the past few years, researchers have been working on the projects which are efficient to wireless networks for enhanced telecommunication to provide quality and efficiency. International Telecommunications Union (ITU) has created a set of standards under IMT-Advanced that all networks must meet the requirements in order to be considered as a 4G technology. Initial versions of 4G networks did not meet the ITU standards. These almost 4G networks were called as 3.9G networks. 4G technology is an IP based and packet switched integrated system which is capable to provide speeds of 100Mbps and 1Gbps. It uses OFDMA multi carrier transmission technique instead of spread spectrum technology. 4G standards are LTE-Advanced and WiMAX technologies which meet the IMT-Advanced standards [8].

This paper is organized as follows. Section 2 provides a brief review of 3G technology, including its features and technologies. Proposed architecture for 4G, key features enabling 4G and its features are covered in section 3. Section 4 provides the comparative analysis of 3G and 4G. Section 5 briefs up the conclusion of the paper, future work is discussed in section 6 and section 7 enlists the references of the paper.

II. THIRD GENERATION (3G)

Third generation (3G) cellular systems are designed to offer future advances in wireless technology. Some of the features of 3G systems are- high speed capability up to 2Mbps, extensive bandwidth enhanced multimedia services, providing flexibility in routing.

1.1 UMTS

Universal Mobile Telephone Services (UMTS) is one of the 3GPP standard also called as WCDMA. It is backward compatible with 2G GSM system to support inter-mode (TDD to FDD or FDD to TDD) and inter-system (UMTS to GSM or UMTS to GPRS) handoffs. It is one of the leading and dominant standards for 3G worldwide. It supports both packet and circuit switching services. UMTS consists of three main subsystems-

- UE (User Equipment) which interfaces with the users
- UTRAN (Universal Terrestrial Radio Access Network) which handles all radio related functionalities
- CN (Core Network) which is responsible for transport functions such as routing, switching calls and data, tracking users.

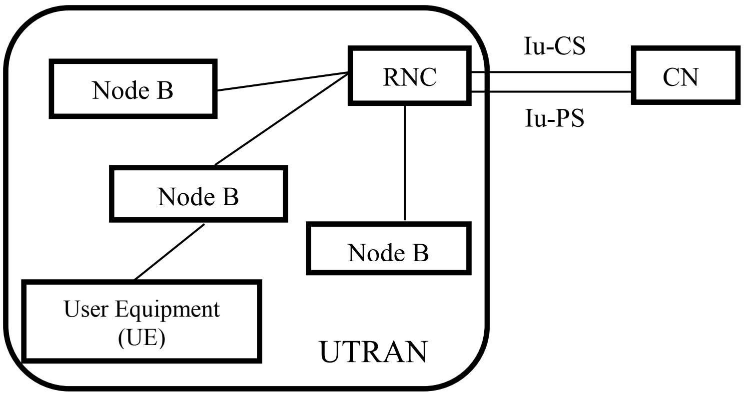

Figure 1: UMTS Architecture

UTRAN and CN are connected by an open interface called as Iu interface. Interfacing for a circuit switched network is called Iu-CS interface and for a packet switched network it is Iu-PS interface. UTRAN consists of Node B and RNC. Node B is a base station transceiver. RNC (Radio Network

Controller) is similar to base station controller whose functions are call establishment, soft handoff and power controlling.

WCDMA is a wideband direct sequence spread spectrum technique which uses channels whose bandwidth is much greater than the data to be transferred. It is used as a variable orthogonal spreading for multiple accesses. There are three types of interfaces used-

- FDD- It consists of separate uplink or downlink frequency bands with constant frequency offset between them.
- TDD- It consists of uplink or downlink in same band but time shares transmission in each direction.
- Dual Mode- It supports both FDD and TDD.

Bandwidth of WCDMA is 5MHz in which each service provider can deploy multiple 5MHz carriers at same cell site. Characteristics of WCDMA are fast power control in both uplink and downlink and the ability to vary the bit rate. Advantages of WCDMA are soft handoff, better quality in multipath environment.

1.2 CDMA2000

CDMA2000 is also called as 3X or CDMA three competes with WCDMA up to 2Mbps. This technique is backward compatible to 2G CDMA/IS-95 technologies. CDMA2000RTT (Radio Transmission Technology) includes enhancements that effectively double the CDMA IS-95 spectral efficiency and also the number of simultaneous voice calls the system can handle. It uses FDD and TDD duplexing methods. It can support multiple carrier bandwidths and frequency bands. Bandwidth which is deployed of 1.25MHz one of the versions of CDMA also called as CDMA20001XRTT. Other version of CDMA2000 technology is called CDMA2000-3X which uses 5MHz bandwidth. Hence it is classified together with UMTS in WCDMA. It delivers peak data rates of up to 144Kbps for mobile and 2Mbps for stationary applications. CDMA2000 standard has developed a data optimised version called CDMA2000 1XEV-DO (Data Only) which supports data rates of up to 2457.6Kbps uplink and 153.6Kbps data rate downlink. Packet data is only supported by this technology. It is designed to accommodate high speed data users which require more bandwidth in downlink for downloading information [14].

1.3 HSPA

High Speed Packet Data Access (HSPA) is an upgrade version of WCDMA technology which is used to increase the packet data performance. It is a combination of HSDPA and HSUPA.

HSDPA: HSDPA was introduced for higher bit rates and lower delays. The improved support for data services was increased since UMTS was introduced by 3GPP. HSDPA has one transmitter per cell that is NodeB. Hence the physical channels are orthogonal at least at the point of transmission. The data is carried on a shared channel to different UE's. The radio interface used in HSDPA is NodeB. The maximum channel rate for HSDPA is 14.4 Mbps with peak user data rate of 13.4Mbps.

HSUPA: High Speed Uplink Packet Data Access (HSUPA) is also known as Enhanced UL. It has many transmitters with each user equipment (UE) having an active uplink which moves and sends information independently. It is not possible to have physical channels orthogonal to each other since the UE's are independent. The data is carried from different users on a dedicated channel known as Enhanced Dedicated Channel-Dedicated Physical Data Channel (E-DPDCH). More than one E-DPDCH will be used for more data rates.

1.4 HSPA+

The evolved version HSPA to increase the bitrates is referred as HSPA+ where new functions like higher order modulation schemes (64QAM AND 16QAM) and Multiple Input Multiple Output (MIMO) are added. Other functions of HSPA+ are Dual Carrier-HSDPA where carrier aggregation of two adjacent 5MHz bands is used to increase the performance.

III. FOURTH GENERATION (4G)

3.1 LTE – Long Term Evolution

LTE is not a new standard but it is an evolved version of UMTS standard with all the modifications and extensions. The aim of LTE is to improve the UMTS mobile standard to cope up with future requirements. LTE is becoming the dominant global standard for fourth generation (4G) cellular systems. 3GPP has specified LTE as very high flexible interface standard. LTE was deployed in the end of 2009 with its first release providing data rates up to 300Mbps, increasing spectrum efficiency, flexible in frequency and bandwidth and different architecture designed to reduce the cost. It supports FDD and TDD to operate in any bandwidths in the allocated spectrum [9]. The key parameters of the LTE technology are given below.

Table I: Key features of LTE technology

Frequency Range	FDD and TDD bands
Channel bandwidth	1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz, 20MHz
Modulation schemes	Uplink : QPSK, 16QAM, 64QAM Downlink : QPSK, 16QAM, 64QAM(optional)
Multiple access schemes	Uplink : SC-FDMA (Single Carrier Frequency Division Multiple Access) Downlink : OFDMA (Orthogonal Frequency Division Multiple Access)
Antenna technology	MIMO (Multiple Input Multiple Output)
Peak data rate	Uplink : 75Mbps (20MHz) Downlink: 150Mbps (2x2 MIMO), 300Mbps (4x4 MIMO)

3.1.1 LTE Architecture

LTE consists of an access part called E-UTRAN (Evolved Universal Terrestrial Radio Access Network), and a core part EPC (Evolved packet core) both combined together called EPS (Evolved Packet System) which is purely IP based. Real time services and data services are carried by the IP protocol. The LTE access network (E-UTRAN) consists of base stations called evolved-NodeB (e-NB), which are inter connected via X2 interface and the core network by S1 interface. Evolved-NodeB's support OFDMA antenna techniques and each e-NB has an IP address, it is part of all-IP network. They are connected to each other to reduce the time required for hand over and speed up the connection set up. EPC is responsible to provide IP connection between an external packet data network by using E-UTRAN and UE (User Equipment) [6].

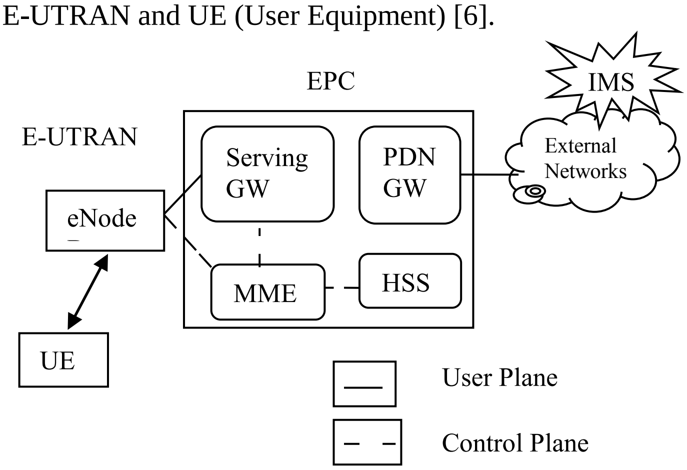

Figure 2: LTE Architecture

Multimedia services which are packet oriented are deployed and delivered efficiently by the all-IP core network through IP Multimedia Subsystem (IMS). This results in lower costs and rapid deployment of new services for networks operators [15].

(i) E-UTRAN: The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) is an access network for LTE which consists of e-NodeB base stations and user equipment (UE). eNodeB provides air interface between the control plane protocol and the user plane towards the user equipment. All the eNodeB's are interconnected to each other by an interface called X2 interface. Each eNodeB is connected to MME/GW (Mobility Management Entity/Gateway) which is a part of EPC by an S1 interface. The interfaces of the network are built on IP protocols. The main difference between UTRAN and E-UTRAN is the absence of centralised radio network controller [4]. The functions of eNodeB include –

- Scheduling and allocation of uplink and downlink radio resources
- Radio Resource Management
- Coordination handover with the neighbouring eNodeB's
- IP header compression and user data encryption.
- eNodeB's can communicate with multiple gateways for load sharing and redundancy.

(ii) EPC: Evolved Packet Core is the packet domain of LTE. It is a flat architecture with all-IP system. EPC is composed of four elements: Serving GW, PDN GW, MME and HSS. EPC is connected to the external networks such as IMS.

- HSS: Home Subscriber Server is a database which contains subscriber related information which supports call setup, user authentication and mobility management functions.
- Serving GW (SGW): Serving gateway is the point of inter connection between the PDN-GW and eNodeB. The main function of SGW is to route packets of data between PDN-GW and E-UTRAN. It is responsible for anchoring the user plane for inter eNodeB handover and between LTE and 3GPP accesses.
- PDN GW: Packet Data Network gateway is the point of inter connect between the EPC and the external IP networks. The function of PDN GW is to route the data packets between the UE and external IP networks and also allocate IP address or IP prefix. It anchors the user plane for mobility between 3GPP access systems and non 3GPP access systems.
- MME: Mobility Management Entity handles signalling related to security and mobility for E-UTRAN access. It is responsible for tracking and paging of the idle mode of UE, manages mobiles and controls the establishment of EPS bearer in the selected gateways.

(iii) IMS: The IP Multimedia Subsystem (IMS) function is to deliver Internet Protocol multimedia services. It provides a framework of subscriber databases, gateways and application servers.

3.2 OFDM – Orthogonal Frequency Division Multiplexing

OFDM technology has become an emerging path to many wireless standards like LTE, WiMAX, DVB, etc. due its high data rates. In this technology, a channel is divided into many narrowband channels at different frequencies, each of them is modulated with data and multiplexed to form an OFDM carrier. These narrowband channels are called OFDM subcarriers which are orthogonal to each other to reduce interference [2]. The orthogonal property can be maintained by adding a cyclic prefix which prevents inter-carrier interference (ICI). Cyclic prefix is used with modulation to prevent the effect due to multipath. Due to orthogonal property the system becomes more robust towards multipath. These subcarriers are multiplexed using techniques like FDM. OFDM is a special form of multiple-carrier multiplexing. This system uses FFT/IFFT for better implementation which converts time domain to frequency domain. OFDM uses differential or adaptive modulation schemes and coding schemes. The different modulation and coding schemes are assigned based on the distance from the subscriber to the cell site. For example, if the subscriber in close to the cell site, higher order modulation schemes like QAM is assigned whereas the subscriber at the edge of the cell is assigned with lower order modulation schemes such as QPSK. To improve BER in OFDM system, channel coding or decoding and interleaving techniques are used. The advantages of OFDM technology are- high spectral efficiency, reduces frequency selective fading at the transmitter, it does not require inter-carrier guard bands, it does not require channel equalisers.

3.3 MIMO – Multiple Input Multiple Output

MIMO is a wireless cellular technology which is utilized in various wireless systems like WLANs, 3G and 4G systems. This is a special class of wireless technology which uses multiple antennas at the transmitter and the receiver to transmit more data streams in less time. A signal takes many paths between the transmitter and receiver. These paths occur as a result of number of objects that appear between the transmitter and receiver. These multiple paths are introduced as interference previously, but using MIMO technology this becomes one of the advantages. These multiple paths are used to provide robustness to the channels by increasing the data capacity [7]. The two main formats of MIMO are spatial multiplexing which utilises different paths to carry additional information i.e. by increasing the data throughput capability and spatial diversity which refers to transmit and receive diversities which are used to improve SNR and improve the reliability of the system with respect to fading. The throughput of the channel can be increased by adding the increasing number of transmitter and receiver antennas to the system. Multiple antenna technology is used for internet, multimedia services and 4G mobile services. This technology provides high data capacities, increases range and reliability, diversity due to fading, and employed for diversity gain as there are multiple antennas. MIMO technology is one of the techniques that use available bandwidth efficiently as this is the most valuable product for wireless communication systems.

3.4 LTE-Advanced

LTE-Advanced focuses on higher capacity, to further develop LTE towards LTE-Advance, to provide higher bit rates and to full fill the IMT-Advanced requirements proposed by 3GPP. IMT-Advanced uses various bands of spectrum which are also applied in LTE along with the future bands of IMT-Advanced. The new functions introduced in LTE-Advanced are Carrier Aggregation (CA), Enhanced-MIMO, Coordinated Multipoint (CoMP) and Relay Nodes (RN) [12]. Some of the features of LTE-Advanced are-

- Peak data rates – downlink: 1Gbps, uplink: 500Mbps
- Spectrum efficiency – downlink: 30bps/Hz, uplink: 15bps/Hz
- Latency – less than 5ms
- Access technology – OFDMA/SC-FDMA

3.5 Carrier Aggregation

LTE-Advanced uses carrier aggregation to increase the bit rates compared to LTE. In this process carriers are combined together to increase the bandwidth and capacity. Each aggregated carrier is called as component carrier which can have bandwidth of 1.4, 3, 5, 10, 15 or 20MHz. Maximum of five carriers can be aggregated i.e. maximum bandwidth of 100MHz. There are two methods of carrier aggregation- contiguous and non-contiguous [10]. Intra-band contiguous is the simplest way of aggregation by using contiguous carrier components within the same frequency band which is not always possible due to frequency allocations. Non-contiguous component carriers which operate in same frequency band separated by a gap are called non-contiguous intra band carrier aggregation whereas carrier components which operate in different frequency bands are called non-contiguous inter band carrier aggregation. Aggregating multiple carriers together enables improved efficiency, increase in data rates and latency is reduced.

3.6 Evolved-MIMO

MIMO is used to transmit data through two or more antennas in both frequency and time and to receive data by two or more antennas to increase the bit rate. This technique is used for high signal to noise ratio conditions. In LTE-Advanced, 8x8 MIMO is supported in downlink and 4x4 MIMO in uplink. The features of Evolved-MIMO for LTE-Advanced are improved system performance, increased data rates and support various transmission schemes [11].

3.7 CoMP

Coordinated Multi Point (CoMP) is introduced by 3GPP to improve network performance at the cell edges. It provides coordinated transmission and reception in downlink and uplink through transmitter and receiver antennas in the same sector. Coordination can be done for both homogeneous and heterogeneous networks. The transmitter and receiver antennas can belong to same or different eNodeB’s and also located at same or different sectors. The coordinated transmission and reception can be of two types- joint and dynamic. Joint transmission takes place when the data from two or more transmission points is transmitted in the same frequency and at the same time. Similarly when the data is received at two or more receive points from a single UE and the received data is combined to improve quality is called joint reception. Dynamic point selection is the process where the data is transmitted only from one transmitter point even though there are many transmitter points available for data transmission. Advantages of CoMP are- it reduces interference, increases received power, utilises the network for better transmission of data and enhanced reception performance.

IV. PERFORMANCE COMPARISON OF 3G AND 4G

Third Generation (3G) is the next step after 2G technology. In the near future, 4G is the technology which switches 3G to 4G. The basic difference between 3G and 4G is the speed [5]. The detail comparison of both the technologies is as follows [13].

Table II: Comparison performance of 3G and 4G

Key Parameters	Third Generation (3G)	Fourth Generation (4G)
Data Throughput	Up to 3.1Mbps (with average speed between 0.5 to 1.5 Mbps)	2 to 12 Mbps (estimated speed of 100 to 300 Mbps)
Peak download (downlink) rate	100 Mbps	1Gbps
Peak upload (uplink) rate	5 Mbps	500 Mbps
Bandwidth	1.8 – 2.5GHz	2 – 8 GHz
Switching technique	Both circuit and packet switching	Packet switching
Access technologies	WCDMA and CDMA2000	OFDM/OFDMA
Network architecture	Cell-Based Wide Area (WAN)	Integration of wireless LAN and WAN
Forward error correction	uses turbo codes for error correction	Concatenated codes are used for error correction
Internet protocol	Air link protocols	IPv4, IPv6

V. CONCLUSION

Wireless cellular technology has evolved into many generations. First generation satisfied with speech signals, second generation introduced digital systems with capacity and coverage. Third generation has fulfilled with high speed data which opened the gate for mobile broadband experience. Now, 4G is evolving to provide more data capacity by delivering faster and better mobile broadband experiences. It will change the world of wireless systems with its extraordinary features.

4G systems are purely IP based which provides many services which are packet based. The main technologies of 4G are OFDM and MIMO. 4G systems will change the wireless technology with its extraordinary features. LTE and LTE-Advanced provides higher data rates. LTE-Advanced is a progressive system, additional improvements to it achieve spectrum accessibility and progressive multi-antenna methods. This paper provides a review study of 3G and 4G technologies, characteristics, evolution and the performances of 3G and 4G are also compared.

VI. FUTURE WORK

4G technology is expected to be concluded within two years. 5G is the next step in the evolution of mobile communication. 5G will therefore not only be about mobile connectivity for people. Rather, the aim of 5G is to provide ubiquitous connectivity for any kind of device and any kind of application that may benefit from being connected. Key technology components include extension to higher frequency bands, advanced multi-antenna transmission, lean design, user/control separation, flexible spectrum usage, complementary device-to-device communication, and backhaul/access integration.

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AUTHORS

Pranavi Macharla is currently pursuing her B.E.Hons degree from Birla Institute of Technology and Sciences Pilani, Dubai Campus in Electronics and Communication Engineering. As a Communication Engineer, her research interests are Mobile Telecom Networks, Wireless Communication and Communication Networks.

Jagadish Nayak is an Assistant Professor in EEE Department, Birla Institute of Technology and Sciences Pilani, Dubai Campus. He has a PhD (2009) from NITK Surathkal, India and Masters (2001) from Manipal University, Manipal, India. His area of research is Image Processing, Digital Signal Processing, Digital Electronics, and Communication Systems.