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Evolution of Wireless Networks Technologies, History and Emerging Technology of 5G Wireless Network: A Review

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Abstract

The huge demand for wireless data transmission is never met. Many generation of mobile communication systems have been stepped over and some of the main challenges that need to be address are yet unsolved. Increasing demand for large area coverage, over one Trillion of mobile user equipments (UEs) capacity, high data rate, low latency, high quality of service and low energy consumption are the target for the future technology. This paper presents overview of previous wireless technologies and today wireless communication network. And due to exponential increase in the demand of present UEs there is needed to move beyond 4G as the theoretical 4G specifications have been reached. The paper addressed challenges that will be encountered by future wireless communication, proposed techniques and the promising imaginations of the future 5G for 2020 and beyond.

Keywords: Wireless technologies; LTE; Wi-max; OFDM; 5G

Introduction

The evolving fifth generation (5G) cellular wireless networks are envisioned to provide large coverage area, higher data rate, higher capacity and high quality of service (QoS), high performance and spectrum efficiency increased. The Increasing Internet data traffic has driven the capacity demands from the Old generation technology such as 1st generation (1G) to the incoming future generation (5G) by 2020. This used either circuit switching and or packet switching with additional licensed spectrum and unlicensed spectrum like WiFi, Bluetooth and WiMAX [1]. The paper presents the trend in wireless network technologies and challenges towards 5G.

Evolution of Wireless Technologies

0G technology

In the early 20 centaury, car base telephone system was first tested in 1946 this is called 0G which is mobile radio telephone. It is analogue telecommunication which required the use of push-pull techniques to connect calls. In 1950, push-to-talk system was invented where user push button when transmitted and when received. In 1960, in order to allow user to talk and receive at the same time, an improved mobile phone system was developed that used two channels, one for transmission and one to receive called duplexing [2].

As far back as late 1970, individual countries started developing their own communication systems such as analogue mobile phone system (AMPS) in America, total access communication system (TACS) and Nordic mobile telephone (NMIT) used in part of Europe, Japanese-total access communication system (J-TACS) used in Japan and Hong Kong [3].

1G technology

In 1981, bell lab introduced the first generation telecommunication technology called advance mobile phone system (AMPS) which support 5 to 10 times more users in IMTS (Improved Mobile Telephone System), this is a new deployment called first generation (1G) wireless telecommunication. 1G has technology which includes Nordic Mobile Telephone (NMT), NMP -NETDAC Mobile telephony, TACS: Total Access Communication System, e-TACS European total access communication system. It was only used for voice call [4]. It is simplest type of wireless data, variations in the signal-disrupts over long distance because It used an analogue signal i.e. analogue telecommunication with a bite rate of 4.8 kbps-9.6 kbps.

However, it has a lot of disadvantages, the distance covered is not wide and prone to noise and attenuation. Others include weak security on air interface, full analogue mode of communication, small capacity, poor voice quality, poor battery life, phone size too big, limited channel capacity, poor handoff reliability, frequent call drop and no roaming [5]. In other to solve some of the disadvantages, all radio communication organisations were working together leading to formation of European telecommunications standard institute (ETSI) and this lead to movement from analogue signals to digital signals.

2G technology

The first digital telecommunication technology was deployed 1992 called second generation (2G) telecommunication. Digital signals are able to cover up long distance and less prone to noise compare to analogue signals. Other superiorities of 2G include the battery last longer due to the radio signals having low power, systems were considerably superior on the spectrum permitting extreme larger mobile penetration levels and introduced information services for mobile, gap with SMS text and MMS messages [6]. The technology converts analogue signal to digital signal and vice versa in both transmitting and receiving end respectively. It has a data rate of 14-64 kbps.The technology used include code division multiple access (CDMA), Groupie Special Modio

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and after it was globally accepted it was renamed Global System for Mobile (GSM) communication, digital AMPS (D-AMPS) and personal digital communication (PDC) [7]. However, it was only used for voice signals communication though it provides voice and limited data services and uses digital modulation for improved audio quality but the demand for fax, short message and data transmission was growing rapidly. 2G digital technologies can be divided into two standards; first, time division multiple access (TDMA) which technology includes GSM originally from Europe but used worldwide, IDEN proprietary network used by Nextel in US and PDC used exclusively in japan; and second, code division multiple access (CDMA) which used technology includes IS-95 commonly referred as CDMA and used in US and part of Asia [8]. It has a data rate of about 96 kbps. It has advantages of digitally encrypted which reduce noise, more efficient on spectrum, greater mobile phone penetration and introduction of data services for mobile (SMS) [9].

2.5G technology

Later the years, 1997, a new technology called 2.5G telecommunication called General Package Radio Service (GPRS). It was deployed to clarify 2G-systems that used packet-switched domain additionally to the circuit-switched GSM network. On telecommunication device, the network displaced 'G' and able to communicate both voice signal and text message. The data rate is 56-164 kbps less and there is need to access internet service, this leads to a new generation technology [10]. In 1998, 2.5G pro was introduced due to increase in network devices and internet.

2.7G technology

In 1997, 2.7G was introduced. This used the technology called Enhance Data-rate for GSM Evolution (EDGE) and on telecommunication device, the network displace 'E'. It introduced 8PSK modulation scheme of CDMA and can deliver data rate is around 144 kbps and a few more to be able to access internet using the same GPRS Infra radio service [11]. However, the major drawback are need for improvement in transmission quality, spotty coverage, unable to support complex data such as video, low system capacity, cell tower has a limited coverage area, abrupt dropped calls and many more [12].

3G technology

In the year 1999, due to evolution increase in data rate, a new technology was developed called 3rd generation (3G) technology. It used wideband code division multiple access (WCDMA). Initial the data rate up to 170-500 kbps. In 2001, it used Universal Mobile terrestrial/telecommunication system (UMTS) which has data rate of 384 kbps for mobile system and up to 2 Mbps for stationary or walking users, increase spectrum efficiency: 5 MHz, a greater number of users that can be simultaneously supported by a radio frequency bandwidth, high speed mobile access to services based on internet protocol (IP). It used FDMA and TDMA techniques that provide the ability to transfer voice data and non-voice data, less complexity, larger capacity, broadband, high data rate at lower incremental cost than 2G global roaming and due to this increase in data rate, it leads to video calling using smart phone, music download, e-mails and instant messaging over the same network simultaneously [13]. The technology also used CDMA 2000 evolution data optimized (EVDO) and the idea behind is to have a single network standard instead of the different type adopted in US, Europe and Asia. New organisations were formed such as China (CCSA), Japan (ARIB and TTC), USA (ATIS) and Korea (TTA). All the body form ITU-T, ITU-T, ITU TELECOM governed by ITU-R. ITU-R manages the international radio frequency spectrum, ensure the effective use of spectrum, and define technology families and allocation, proposed requirement for radio technology.

3.5G technology

In 2001, 3.5G called High speed downlink/download package access (HSDPA) was released this provide efficient uses of IP. In 2002, high speed uplink/upload package access (HSUPA) was also released this reduces the delay in downlink package and provided a data rate of 2 Mbps [14]. The technology used are GSM and 3rd generation partnership project (3GPP) using packet switching. It is used for integrated high quality audio, video and speed data. The main network used GSM time division multiple access (TDMA) with horizontal hand off. Transmitting frequency is between 1.6-2.5 GHz. However, there is a problem of poor QoS at the uplink due to increasing UEs.

3.75G technology

2004, 3.75G called high speed package access increase (HSPS+) which only deal with uplink data rate and provide mobile access of higher data rates of several Mbps to Smartphone's and mobile modems in laptop computers [15]. The uplink data rate of about 5 Mbps reduces the latency or delay. Long-Term Evolution technology (LTE) and Fixed Worldwide Interoperability for Microwave Access (WIMAX) is the future of mobile data services [16]. LTE and Fixed WIMAX has the potential to supplement the capacity of the network and provides a substantial number of users the facility to access a broad range of high speed services like on demand video, peer to peer file sharing and composite Web services [17]. The technology used CDMA of 1x EVDO with packet switching. Used for high speed internet and multimedia. However, the downlink data rate is low.

3.9G technology

In 2007, 3.9G called long term evolution (LTE) also called 4G LTE. It makes used 3GPP standard including MIMO and Higher order modulation upto 64 QAM. Evolution of 3GPP started from GPRS to edge to UMTS to HSDPA to HSUPA to LTE. Either MIMO or 64 QAM can be used at a time [18]. The downlink data rate up to 30 Mbps and uplink data rate of about 11 Mbps [19]. The goals of 3.9G technology are to provide high QoS, high data rate, high coverage area and low fee services. The only limitations of 3.9G are high bandwidth requirement, high spectrum licensing fees and huge capital. The broadband signal is between 1-5.8 GHz [20].

Today 4G Technologies

Every 10 years a new technology always emerged and since the advent of 3G and its series, mobile users have developed tendency of using the internet on the fly. In the year 2010, due to users increase not only in voice and SMS only but inclusion of multimedia services [21]. The work started in Rel-10 by the 3GPP and is presently standardizing Long Term Evolution (LTE) Advanced as forthcoming 4G standard along Wi-Max. It had the initial objective of meeting the International Mobile Telecommunications-Advanced (IMT-Advanced) requirements set by the International Telecommunications Union (ITU) which truly defined 4th generation (4G) systems. The 4G wireless systems were designed to fulfill the requirements of International Mobile Telecommunications-Advanced (IMT-A) using IP for all Services [22]. 4G has about 1 Gbps for stationary users and 100 Mbps for high mobile users. This is used for high mobility like train, speed car, etc. and it is global mobility support [23]. It create a faster speed, reduce delay for both connection establishment and transmission latency, increase user data rate throughput between 20-100 mbps, increase cell-edge bit-rate, reduce cost per bit, implying improved spectral efficiency,

simplified network architecture, seamless mobility including between difference radio-access technology, reasonable power consumption for the mobile devices, mobile multimedia, video streaming, TV broadcast, video calls, news, music, sport enhanced gaming, chat, location service GPS, life saving-telemedicine connection anywhere, anytime with anyone suitable for high resolution movies, integrated wireless solution and customized personal services [24]. 4G provides higher bandwidth enables a range of new applications, lower cost than previous generations, faster and more reliable. According to the statistics of Global TD-LTE Initiative (GTI), 364 LTE commercial networks have been launched by the third quarter of 2015 [25].

4G Technology architecture

High-speed packet access (HSPA) and long-term evolution (LTE) have been launched as a segment of the advancement of current wireless based technologies. The first commercial deployment was in northern Europe in 2009 which uses multiple services such as multi-cell HSDPA, HetNet, Coordinate multipoint, carrier aggregation, massive memo, etc. [26]. The first phase of 4G LTE includes OFDM, MC-CDMA, LAS-CDMA and community-LMDS. It has minimum speed ranging from 10 Mbps to a theoretical 100 Mbps for downlink and up to 50 mbps for uplink later technology technologies. The second phase is 4G-WiMAX (worldwide interoperability for microwave access) include OFDM, MC-CDMA, LAS-CDMA and network-LMDS) [27]. It has up to 128 mbps in downlink and 56 mbps for uplink. Unlike 3G which has circuit switching for voice communication, packet switching for data communication, 4G has fully IP based infrastructure. IP multimedia system (IMS) is used to bridge the gap between voice calls and telephony network [28]. This deployed used of multiple carrier, MIMO [29] application of packet switching on radio interface.

Challenges of 4G

However, current predictions for future systems point out tremendous challenges far beyond what the ITU initially established for 4G. Because of increase in telecommunication device, as more users come online 4G networks has reaching their limit of what it is capable of handling and by 2020, over 9 billion users will be connected [30]. This will result to low speed, and users need more data rate from their smart phone devices. In order to move from single service to multiservice network by the year 2020, 5G is to be commercialised [31]. The main goals of 5G is to addresses the challenges that are not effectively addressed by 4G,i.e increasing the capacity, data rate, reducing latency, massive device connectivity, reduced cost and consistent Quality of Experience provisioning. The target goals for 5G are 1000 times higher mobile data volume per area, 10 to 100 times higher typical user data rate, 10 to 100 times higher number of connected devices, 10 times longer battery life for low power devices and 5 times reduced end-to-end latency.

The Future 5G Technology

The Mobile and Wireless Communications Enablers for the Twenty-Twenty Information Society (METIS) project of European Union started research work of 5G at the end of 2012 to achieve future development of mobile communication techniques [32]. In China, IMT-2020 promotion group was founded in April of 2013 to serve as a platform to promote the 5G study. Its goal is to organize domestic forces to actively carry out international cooperation and to jointly promote the international development of 5G. In Korea, Samsung tested and verified the technical feasibility of millimeter wave in the bands of about 28 GHz [33]. Other possible candidate technologies such as massive MIMO [34] novel multiple access [35], and new channel coding [36-38] have attracted more and more interest. The International Telecommunication Union (ITU) has also started its study on the International Mobile Telecommunication system towards 2020 (IMT-2020) since 2013, (ITU, 2015). 3GPP will start its study and standardization work on IMT-2020 from March 2016 [39,40]. The data is to have high throughput with 5 Gbps data rate, wider area coverage. It will be able to handle a 1000x more traffic than today network and 10x faster than 4G LTE using packet switched wireless system [41]. The applications include downloading and HD movie within a few seconds, autonomous driving, photo reality, machine-machine communication, artificial intelligence etc. the techniques include pervasive network where user can currently be connected to wireless access technologies, group cooperative relay make available high data rate for users over wide range of the cell, cognitive radio technology which make the user to locate radio landscape and user decided to choose between optimum radio access network, modulation scheme and other parameters to configures itself to gain the best connection network access to have the optimum performance; smart antenna which make it possible to alter beam direction to able more direct communication and limited interference and also increase cell capacity [42].

5G Technology architecture

The Architectures of 5G are all-IP based model for wireless and mobile networks interoperability. It make used of an advanced access technology named Beam Division Multiple Access (BDMA) and Non- and quasi-orthogonal or Filter Bank multi carrier (FBMC) multiple access [43]. The system consists of various UEs and a number of independent, autonomous radio access technologies include millimetre wave to increase the no of UEs connected and capacity [44], small cells to increase area coverage and throughput especially at the hotspot and blind spot, [45] massive memo to reduced the penetration loss through the walls of the building, beam forming and full duplex as shown in Figure 1. It make used of 6-300 Ghz radio frequency signal. Within each of the terminals, each of the radio access technologies is seen as the IP link to the outside Internet world. This will open more bandwidth for every UE to be allocated which leads to increase in speed, high quality video and multimedia contents. There is different radio interface for each Radio Access Technology (RAT) in the mobile terminal. Each IP interface in the terminal is characterized by its IP address and net mask and parameters associated with the routing of IP packets across the network [46].

Conclusion

There are two views of 5G systems: (1) Evolutionary where the system will have capacity of supporting "wwww" allowing a highly flexible network such as a Dynamic Adhoc Wireless Network (DAWN) and advanced technologies including intelligent antenna and flexible modulation are keys to optimize the adhoc wireless networks.

(2) Revolutionary where an intelligent technology capable of interconnecting the entire world without limits. It will provide pervasive network where user can easy connected to several wireless technologies and can move between them. They proposed that Present wireless based technologies, like 3GPP, 3GPP2, IEE, LTE technology, HSPA and Wi-Fi via OFDM, MC-CDMA, LAS-CDMA, UWB, community-LMDS and IPv6, will be incorporating new technology components that will be helping to meet the needs. The evolution of IEE started from 802.16 fixed WiMAX, 802.16 mobile WiMAX to 802.56 m. With the introduction of IEEE 802.11ac, 802.11ad and 802.11af standards are very helpful in the road toward achievement of 5G.

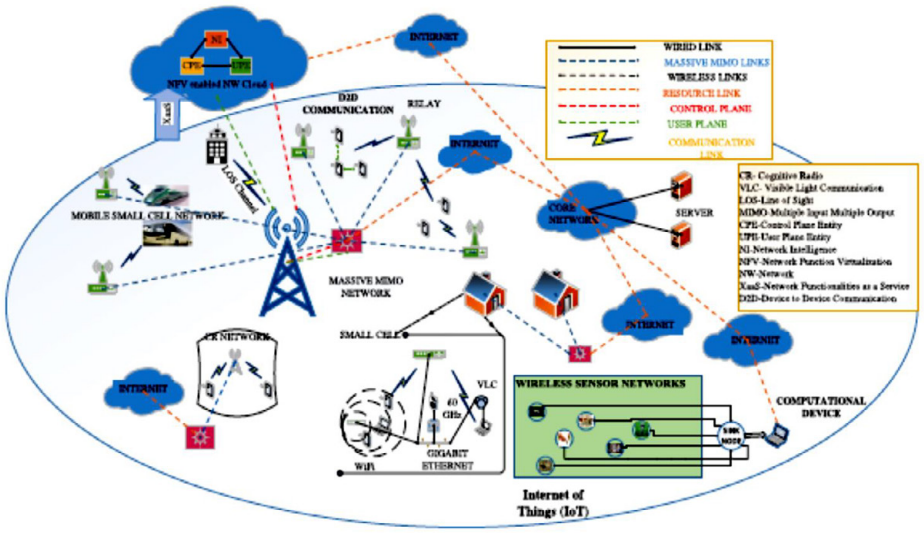

Figure 1: Architecture of 5G wireless Network [17].

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