EVOLUTION OF MOBILE WIRELESS COMMUNICATION

Yathiendra Vunnam¹, Pavani T², Kondala Rao Vunnam³
¹,²Dept. of ECE, Gokaraju Rangaraju Institute of Engineering & Technology,³Dept. of Physics, Andhra University

Abstract—The advancements in wireless communication have been huge since it being introduced in the early 1960's. The evolution of mobile systems started with 1G, which has been followed up with 2G, 3G, 4G and 5G being the next and upcoming generation. In this paper, we attempt to see and analyses the changes experienced in the field of mobile communications since its inception. We also aim to get some basic insight on how the fore coming 5th generation of mobile systems work and analyses the problems it will face to be implemented. This paper discusses the advancements and the problems faced by the respective generations while being implemented, and how the next technology was able to overcome at least few of them.

Keywords: Telecom, Wireless, Mobile Communication, Connected devices, 5G

I. INTRODUCTION

Over the past few years, we have seen a radical change in the field of communication especially in terms of mobile communication. Every few years, we have seen more sophisticated and complicated networks evolve. These networks not only improved the way people communicated, but also made the world move a step ahead in terms of connectivity. With the next generation of wireless communication right around the corner, it would be helpful to analyze how far we have evolved from our earliest mode of wireless communication, that is 1G or 1st Generation wireless networks.

Fig. 1 : Evolution of 1G to 5G(www.meee-services.com)
1ST GENERATION
The first commercial implementation of cellular mobile system was in the year 1979 with Japan's NTT. This technology used Analog standards. They utilized analog technology, usually frequency modulated radio signals with a digital signaling channel. 1G had various standards in different geographical locations. Few of the most popular include NMT (Nordic Mobile Telephony) used in Baltic and Nordic countries and Advanced Mobile Phone System (AMPS) used in Australia and North America.

Major attributes of this technology are
• Frequency Band: 150 - 900MHz
• Bandwidth: Analog telecommunication
• Carrier Frequency: 30KHz
• Key Characteristic: Voice only communication
• The technology used: Analog cellular
• Data rate capacity: 2.4 to 14.4 kbps

1G wireless communication had a lot of disadvantages and few of them are
• Poor voice quality
• Poor battery
• Big cellular phones
• No security
• Very slow speed
• Signal interference

These limitations were tended to in the next Generation of wireless technology that is, the second generation of wireless technology ‘2G’.

2ND GENERATION
With the need for a secure and more accessible network still at large, CEPT (European Conference of Postal and Telecommunications Administrations) had started research to build a better technology which is pan-European. In the year 1991, we were able to get the second generation of wireless communication technology successfully deployed. This technology had features which were tremendously better than its precursor.

Few of its characteristics include:
• Frequency Band: 900 - 1.8MHz (Narrow Band)
• Bandwidth: 900MHz
• Key Characteristic: Digital Transmission
• The technology used: Digital cellular
• Data rate capacity: 64Kbps

This generation introduced many new features which were unexpected and novel to its users. It included many advanced applications such as SMS (Short Message Service) for storing and forwarding textual information. It also introduced global roaming i.e. availability of communication services away from the home country. The most noted and famous standards was GSM- (Global System for Mobile communications) which is currently still available and in use in more than 200 countries. Other standards that were deployed include PDC (Personal Digital Cellular used in Japan), Eden (developed by Motorola), IS-95. The digital transmission was employed using TDMA (Time Divi-
sion Multiple Access) method and used switching technology to achieve better efficiency. Even CDMA (Code Division Multiple Access) was deployed, it was used in IS-95 standard. One of the main reasons for 2G to become such a big hit was that it provided security, it used digital encryption to keep the network secure. Few of the many advantages which 2G provided include better voice calling, better network capacity, less power usage, better voice clarity and noise cancellation. It was also quite environmentally friendly compared to its forerunner.

It also had its fair share of disadvantages which include:
- Requiring strong signal as digital signals are weak.
- Inability to handle complex data, such as videos.
- Inefficient usage of Bandwidth and Infrastructure.
- Reduced range of Sound.

In India, the first cellular call made was on July 31st, 1995 over Modi Telstra’s MobileNet GSM network of Kolkata. The bandwidth with which most of the telecom companies which used GSM technology operate are between 900 MHz and 1800 MHz. While Airtel, Idea, Vodafone, Aircel, BSNL are the major operators. Whereas CDMA operators used Frequencies under 850Mhz with, BSNL, Reliance, Tata are the major players.

2.5TH GENERATION

The transition from 2G to 3G took a long time. To the common eye, there was no improvement between but in contrary, there were advancements with 2.5G and 2.75G. 2.5G is commonly described as 2G with GPRS technology. It had interim standards which linked the gap between the 2G standards and the 3G standards. It was introduced around the year 2001, it provided increased data speeds and various features dealing with complex data forms. The most important service introduced with this upgrade was WAP (Wireless Application Protocol) which provided the ability for users to browse the internet while using mobile phones. Another important feature which was introduced was MMS (Multimedia Messaging service). This feature provided the users to send complex data, such as photos and videos as messages. The main difference between 2G technologies and 2.5G is that 2.5G uses packet-switching where as 2G used circuit switching. Packet-switching is efficient and complex switching technology which results in high data speed.

Few of its features are:
- Key Characteristic: Packet-switching
- Receive/Send e-mails (Electronic Mails)
- Web browsing
- Data rate capacity: 64-144 kbps
- During 2.5G Camera phones were introduced
- There was a boost in the speed from 9.6kbps in 2G to 64 kbps in 2.5G
- Always-on connectivity.
- Small attachments + instant messaging.
- No need for new infrastructure, Infrastructure could be used with modifications to the previous generation

The main standards implementing 2.5 were GPRS (General Packet Radio Service) and EIA-95. Were extensions of GSM and IS-95 respectively.
The disadvantages were:
- Did not really provide adequate speed like true 3G does
- Not a major leap for the industry
- Had similar problems like 2G

2.75G was the stepping stone for EDGE (Enhanced Data Rates for Global Evolution) which involved using EGPRS (Enhanced GPRS). It was deployed AT&T in the year 2003. It used 8PSK additionally for transmitting and encoding data. It was able to transmit data at a speed of almost 3 times that of 2G. This technology was used to migrate from 2G to 3G.

Its features include:
- Data is enhanced for GSM Environment.
- Bandwidth of GPRS technology is increased.
- EDGE resulted in the increase of bandwidth of GSM from 144 Kbps to 384 Kbps.
- Evolution towards 3G standards started.

Its disadvantages would be:
- Its protocol is asymmetrical (only one action can accommodate high speed).
- It worked only for GSM networks.

3rd Generation
The 3rd Generation of Wireless Technology was developed by the ITU (International Telecommunication Union). The research was started in the early 1980's and it nearly took 15 years to develop this technology. The first non-commercial implementation was in the year 1998 whereas the first commercial implementation was in the year 2001 by NTT DoCoMo of Japan. It took about 5 years for Japan to get a complete transition from 2G to 3G. GPRS and EDGE technologies helped in bridging the gap and facilitating the transition from 2G to 3G. The main motivation for the upgrade was due to the small capacity of 2G networks. ITU had developed few standards known as IMT -2000 (International Mobile Telecommunication) standards to ease growth, assist diverse applications and increase bandwidth.

The main features of 3G technology are:
- Key Characteristic: Digital broadband, increased speed
- Frequency Band: 1.6 – 2.0 GHz (Wide band)
- Bandwidth: 100MHz
- Technology: CDMA, UMTS, EDGE
- Data rate capacity: 144kbps – 2Mbps
- Facilitates greater data, voice capacity and transmits high speed data at feasible costs
- 3G mobiles work on both 3G as well as 2G technologies
- Provides local services for accessing weather and traffic notifications
- Video conferences and video calls are another important feature in 3G mobile technology

The location and bandwidth information available to 3G devices give the rise of applications which were not previously available to cellular mobile phone users. Some of the applications are Video on demand, GPS (Global Positioning System), Video Conferencing, Mobile TV, Location-based services.
Even though there are various advantages associated with 3G technology, there are certain drawbacks like:

- The cost to upgrade the cellular infrastructure and base station to 3G is very high.
- Service providers had to pay excessive amounts for 3G agreements and licensing.
- Issue with the cost of handsets and their availability in few regions.
- Exorbitant power consumption

In 2008, the Indian Government owned BSNL and MTNL launched 3G in India. Whereas other private companies such as Airtel, Idea and Vodafone launched their services in 2010. The frequency bands used in India are between 2100 MHz and 900MHz.

**4TH GENERATION**

4G is the wireless technology that super-ceded 3G. It was built upon the existing 3G network. The first publicly available 4G network has been in the Scandinavian capitals Stockholm and Oslo. It basically does everything that 3G offers but more efficiently and at a better speed. The carriers used OFDM (Orthogonal Frequency-Division Multiplexing) instead of CDMA or TDMA. Two of the most popular standards are LTE and WIMAX.

The features and capabilities of 4G include:

- Better Security Features
- High Data Capacity
- Cost Per bit is economical
- Frequency Band: 2 – 8 GHz
- Bandwidth: 100MHz
- Key Characteristic: High speed, all Internet Protocol based.
- Capacity (data rate): 100Mbps – 1Gbps

The main game changers for 4G were the ability for a better quality of service, better speed and data capacity with higher security. The drawbacks of 4G include:

- Higher Battery usage
- Harder to implement
- Requirement for complicated hardware
- Equipment is really expensive to implement the next generation network.

The major competitors in India are Reliance Jio, Idea Vodafone, Airtel. In India there are basically 3 bands and Reliance Jio operates in all 3 of them, whereas the other three operate in only two other bands. Reliance Jio operates in Band 3, Band 40 and Band 5 which is 1800 MHz, 2300 MHz, and 850 MHz in terms of MHz. The other operators use only band 40 and band 3. To enhance the competition Idea and Vodafone have started using 2500 MHz (popular china Frequency band) to give a better service.

**5TH GENERATION**

5G is the upcoming generation of cellular wireless technology. It has significant changes over the currently used 4G networks. 5G has been created to meet the data requirements and large growth in connectivity of today’s society, help facilitate the connected devices in the internet of things, and to support tomorrow’s innovations. 5G will initially work simultaneously with prevailing 4G networks before upgrading to fully standalone networks with coverage expansions and subsequent releases.

Table 1. Shows 5G specifications defined by the ITU as part of IMT 2020.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Suggested performance</th>
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<tbody>
<tr>
<td>Peak data rate</td>
<td>At least 20 Gbps down link and 10 Gbps uplink per mobile base station. This represents a 20 fold increase in downlink over LTE</td>
</tr>
<tr>
<td>5G connection density</td>
<td>At least 1 million connected devices per square kilometer (to enable it support)</td>
</tr>
<tr>
<td>5G Mobility</td>
<td>0 km/h to “500 km/h high speed vehicular: access”</td>
</tr>
<tr>
<td>5G Energy efficiency</td>
<td>The 5G spec. call for radio interfaces that are energy efficient when under load, but also drop into a low energy mode quickly not in use.</td>
</tr>
<tr>
<td>5G spectral efficiency</td>
<td>30 bits/Hz downlink and 15 bits/Hx uplink. This assumes 8x4 MIMO (8 spatial layers up, 4 spatial layers down)</td>
</tr>
<tr>
<td>5G real world data rate</td>
<td>The spec “only” calls for user download speed of 100 Mbps and upload speed of 50 Mbps</td>
</tr>
<tr>
<td>5G Latency</td>
<td>Under ideal circumstances, 5G networks should offer users a maximum latency of just 4ms (compared to 20ms in LTE).</td>
</tr>
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The 5G mobile cellular system will bring a major change the way mobile communication networks work. To attain this, we require a totally novel radio access network and a novel core network to provide the necessary execution.

5G networks are made of two essential components a core network and a radio access network (RAN).

**5G New Radio, 5G NR:** The name given to the 5G radio access network is 5G new radio. It composes of various components required for the new radio access network. It uses a lot better adjustable technology, the system responds to the varying and unique requirements of cellphone users, whether they are a high data user, or small IoT node, mobile or stationary.

**5G NextGen Core Network:** Though the early deployments of 5G will utilize the core network of LTE or perhaps even 3G networks, the eventual purpose is to have an original network that is able to manage the much greater data volume while still being able to supply a somewhat lower level of latency.
The RAN consists of all types of resources that are required to connect Cellphone users to the core network. Small cells are going to a major and important factor in the development of millimeter wave frequencies where the connection is brief. To facilitate continuous connection to the user’s cells will be spread in clusters based upon the user requirement which will enhance the macro network so that it provides a wide area coverage. The macro calls will use MIMO antennas that are multiple inputs multiple outputs. Due to which we can simultaneously receive and send more data. The major advantage is that number of users can concurrently connect to the network and still maintain high throughput. These antennas are physically smaller than the antennas of the previous technologies. The core network manages all the network functions such as managing data, internet and voice connections. To integrate it with cloud and internet services the 5g network is being redesigned. It also has distributed servers which in turn reduces latency. Most of the new features include network function virtualization (network functions can be instantiated in real time) and network slicing (segmenting network for each domain) for diverse services and applications these will be controlled by the core network.

5G is developing at a rapid pace and has met some challenging timelines. The first deployments are expected in 2020 as trial deployments have already occurred. As effective communications enable economic growth and are seen as an essential element of modern-day life and industry many countries are rushing to deeply 5G .

II PROBLEMS FACED TO IMPLEMENT 5G

Frequency bands: Even though 4G operated on frequency bands established below 6GHz. 5G requires bands up to 300GHz. This means that wireless carriers will have to build for these bands as they build and roll out their 5G networks.

Deployment and coverage: Though 5G offer a substantial amount of increase in terms of bandwidth and speed. It has a limited range which requires it to have more infrastructure. This will require to keep extra repeaters around densely populated cities and will be a task like spreading out 4G to rural areas.
Cost: The cost to build and buy networks is going to be high as we require better frequency bands and more infrastructure.

Device Support: As 4G compatible phones were only able to access 4G networks. It is expected that 5G networks will require the user to have better devices to be able to use the network.

5G Signals could jam satellites: There have been new reports suggesting the radio frequencies 5G networks will use could contaminate critical observations made by weather satellites.

Though 5G has not yet come into the market. The TRAI (Telecom Regulatory Authority of India) has proposed frequency bands 3.4GHz – 3.6GHz as well as 26-28GHz for utilization.

III CONCLUSION
In only half a century, we have progressed from no connection to fully connect. For an individual to be living in our society, it is important and essential to be connected. This can only be done these days by using mobile phones. This paper has been able to review the journey of how we were able to create new and sophisticated technologies to meet our demands and requirements. With the year 2020 fast approaching it will be interesting to see how 5G will change the way we communicate and what new features and technologies will it be able to generate.
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