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Mobiles: A Journey from then to Now

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Abstract
The "Journey of Mobiles" is an intriguing exploration into the evolution, innovation, and transformative impact of mobile devices on human life. Spanning several decades, this journey reflects the relentless pursuit of technological advancement, shaping the way we communicate, work, and interact with the world around us. From the humble beginnings of mobile communication to the sophisticated and multifaceted devices of today, the trajectory of mobiles encapsulates a remarkable odyssey marked by rapid development, paradigm shifts, and a continuous quest for greater connectivity and convenience. As we delve into the history and progression of mobiles, through this paper we uncover a narrative that mirrors the relentless march of progress and the profound influence of these pocket-sized marvels on the fabric of modern society. This is a captivating voyage through the realms of innovation, design, and societal impact as we unravel the fascinating story of the "Journey of Mobiles."

Keywords: 1G, 2G, 5G.

1. Introduction

In the ever-evolving landscape of technology, the journey of mobiles stands as a captivating narrative that has transformed the way we connect, communicate, and navigate our daily lives. From humble beginnings as bulky communication devices to sleek, multifunctional companions, mobile phones have undergone a remarkable metamorphosis over the decades. This journey not only reflects the relentless pursuit of innovation but also mirrors the societal shifts and global advancements that have shaped the digital era. Join us as we embark on a fascinating exploration of the "Journey of Mobiles," tracing the evolution of these pocket-sized marvels and their profound impact on our interconnected world.

2. First Generation

The advent of the first generation of mobiles marked a groundbreaking era in the history of telecommunications. Emerging in the late 1970s and extending into the 1980s, these early mobile devices laid the foundation for what would become an indispensable aspect of modern life. In the infancy of mobile communication, the primary objective was to provide users with the ability to make voice calls wirelessly, liberating them from the constraints of wired connections.

These pioneering mobiles were characterized by their bulky and cumbersome designs, often resembling portable radios more than the sleek and compact smartphones of today. The technology powering these devices relied on analog transmission, and the networks were limited in capacity, accommodating only a fraction of the users we see today. The first-generation mobiles operated on the Advanced Mobile Phone System (AMPS), a standard that allowed for the establishment of cellular networks. One of the most iconic symbols of this era was the Motorola DynaTAC 8000x, commercially launched in 1983. Weighing in at nearly two pounds and featuring a retractable antenna, the DynaTAC became the first commercially available handheld mobile phone. Despite its size and limited functionality by contemporary standards, it represented a revolutionary leap forward in communication technology.

The first-generation mobiles, with their primitive functionalities and size constraints, might seem archaic compared to the sleek devices we carry today. However, their introduction paved the way for subsequent generations of mobile technology, each building upon the foundations laid by its predecessor. The first generation may have been characterized by its limitations, but it set the stage for the wireless revolution that continues to shape the way we connect, communicate, and experience the world around us.

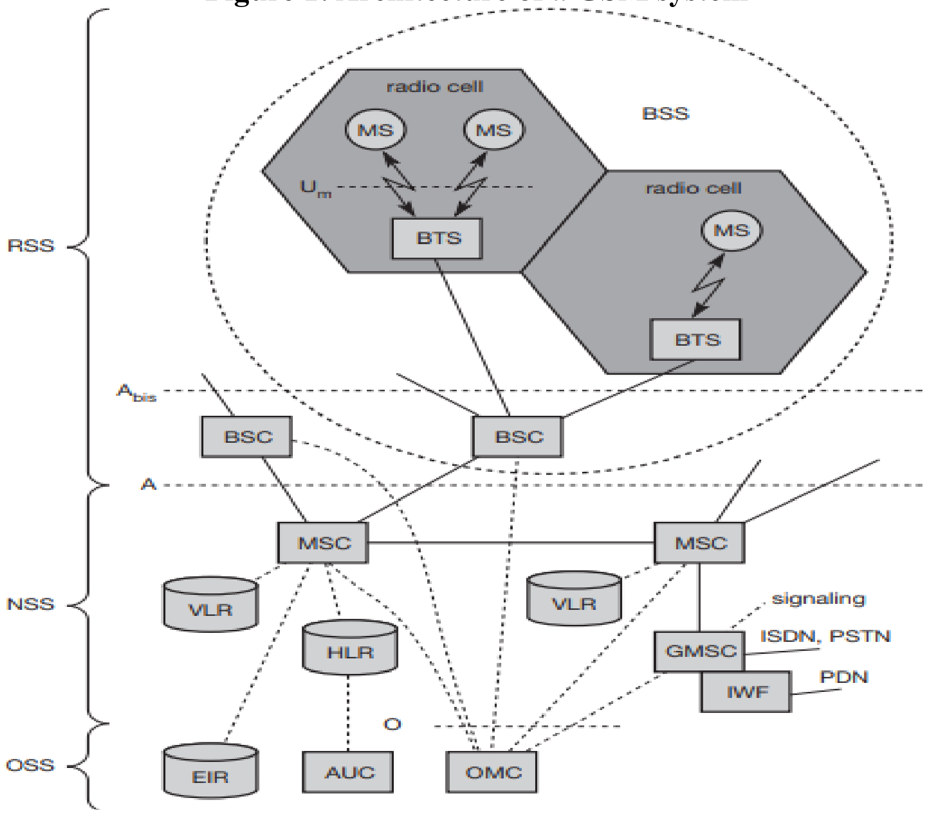
Morse developed the telegraph system, and which is one of the very early communication systems. History of wireless communication goes back to 1865 when Maxwell's equations were developed. Then came Hertz who demonstrated the existence of electromagnetic waves. First experiment of wireless communication was done in 1894-95 when JC Bose ignited gunpowder and rang bell at a distance. Marconi was responsible for long distance wireless telephony in 1896 and Nicola Tesla in 1898 used wireless lightening. Claude Shannon laid the foundation of Information Theory. Work of Nyquist was proved by Shannon on 1949. Thereafter was the age where instead of individual contributions they were more of a holistic or system level of group level contributions. First generation systems were completely analog. Examples include AMPS and TACS in United States, NMT in Europe.

3. Second Generation: 2G

This era marked a significant advancement from the first generation (1G) of mobile technology, bringing about improved communication capabilities and paving the way for the modern mobile landscape. Here are some key aspects of the second generation of mobiles.

- The European Conference on Post and Telecommunication Administration(CEPT) founded the Group Speciale Mobile.
- Objectives was better and efficient wireless communication than analog.
- Used GMSK
- Smooth phase transition was there.
- Relaxed requirement on Power amplifier.
- Enhanced battery life for handheld equipment.
- Required complex equalizers.
- The bandwidth of occupancy is around 200 kilohertz.

Figure 1: Architecture of a GSM system



4. Third Generation: 3G(IMT 2000)

The advent of 3G (Third Generation) mobile technology marked a significant leap forward in the evolution of wireless communication systems. Introduced in the early 2000s, 3G represented a substantial enhancement over its predecessor, 2G, and brought about several key advancements. The key features of third generation are:

- Offered voice and non-voice telecommunication services to mobile and roaming users
- Accommodate a variety of mobile terminals:
  - Small: carried on person
  - Are mounted in vehicles
- Account for road traffic management and control systems
- Support emergency services as user id and location information.
- The main objective was to allow extension of cell sizes in rural or remote areas.
- Include a mobile satellite component.
- Transmission quality was improved.
- Blocking probability of voice calls was reduced.

Standards of 3G

- Universal Mobile Telecommunication System (UMTS)
- UMTS Terrestrial Radio Access (UTRA)
- China Wireless Telecommunication Standard
- TDD systems
- TIA(South Korea) CDMA 2000
- IMT 200 Multi carrier

Technologies in 3G++

- Variable Data Rate
- ✓ multiple code word assignment-variable SF
- ✓ modulation- BPSK,QPSK
- Coverage/Improvement
- ✓ Turbo Codes
- ✓ Hybrid ARQ
- ✓ Link Adaptation
- Capacity Improvement
- ✓ Multi antenna transmission
- ✓ Multi user scheduling
- Modes in 3G
- ✓ Multicarrier modes
- ✓ Direct Spread
- ✓ TDD
- ✓ Chip Rate 3.84Mcps
- ✓ Channel Bandwidth: 5 MHz
- Channel Coding
- ✓ Convolution codes, Turbo Codes
- ✓ SF 4-256 (Uplink) , 4-512(Downlink)

WCDMA was used. The frequency reuse factor in WCDMA was 1, still the quality improvement was there because it used codes that were designed in such a way that they could cancel cochannel interference so that one could get back to use the same frequency in the neighboring base stations.

Frequency Borrowing: Frequency could be borrowed from the neighboring cells, used and then can be returned. This is done if more traffic is there in 1 cell and other cells have less traffic. For example, a sports event or a political event. For Multipath diversity in WCDMA, we can have a frequency selective channel. RAKE fingers can collect the signal from different paths, combine them together and thereby achieve multipath diversity. Signals are combined in different bands.

Table 1: Comparison of WCDMA and GSM

	WCDMA	**GSM**
Bandwidth	5 MHz	200 KHz
Frequency Reuse Factor	1	1-18
Power Control	1.5 KHz for both uplink and downlink	Lower
Frequency Diversity	Multipath Diversity	Frequency Hopping
Packet Data	Packet Scheduling	Slot based with GPRS

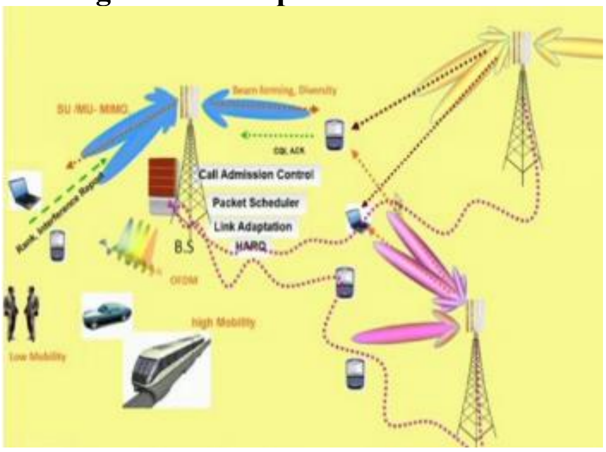
5. Fourth Generation: 4G (IMT Advanced)

The advent of 4G (Fourth Generation) mobile technology represented a significant milestone in the evolution of wireless communication systems, building upon the foundations laid by its predecessors. Introduced in the late 2000s, 4G brought about several key advancements that revolutionized mobile connectivity.

IMT Advanced systems are the 4G systems, beyond IMT 2000. Its advantages include:

- Supports low to high mobility applications.
- Wide range of data rates.
- High quality multimedia applications.
- Worldwide roaming.
- Peak data rates: 100Mbps for high and 1Gbps for low mobility.

Figure 2: Multipoint Transmission



Important Parameters:

Cell Spectral Efficiency

It is defined differently for different environments as classified from indoor to micro cellular to the base coverage urban area, this is rather the urban area, which is more important, and high mobility scenarios.
It is different for uplink and downlink.
Measured in bits per second per hertz of bandwidth per unit of cell.

Peak Spectral Efficiency

It is defined as the highest theoretical data rate normalized by the bandwidth that means, bits per second per hertz, which is the received bits assuming error-free condition assignable to a single mobile station, when all available resources for the corresponding link direction are utilized, that is excluding radio resources that are used for physical layer synchronization and all those things.
Minimum requirement of PSE
Downlink : 15b/s/Hz
Uplink: 6.75b/s/Hz

Bandwidth

Scalable bandwidth is available or is the ability of the candidate radio interface technology to operate with different bandwidth allocation.
Systems or the equipment should be capable of accessing different bandwidths as per allocation or as per the situation or controlled by the access point or the base station or the entire network.
Scalable bandwidth up to and including 40MHz up to 100MHz

Cell edge user efficiency

It is defined as the 5 percent of the cumulative distribution of the normalized user throughput. So, 5 percent means, the 5 percentile point.

If we are taking users in different locations, and if suppose the base station is located in the center, so then the user which is close to the base station is going to experience a better SINR compared to the user at the cell edge. So, if we collect the spectral efficiencies of all the points, and we plot the cumulative distribution function, then the 5 percentile points performance is basically the cell edge spectral efficiency.

Control Plane Latency

Control plane also referred to as the C-plane latency is typically measured as transmission time from different connection modes that is from idle to active state. A transition time excluding downlink paging delay and wire-line network signaling delay of less than 100 millisecond shall be achievable from idle state to active state in such a way that user plane is established.

User Plane Latency

The user plane latency also known as the transport delay is defined as the one-way transmit time between the SDU packet being available at the IP layer in the user terminal or the base station.

Mobility

Stationary – 0km/hr – indoor
Pedestrian > 0km/hr-10km/hr- Microcellular
Vehicular – 10 – 120km/hr- Base coverage urban
High speed vehicular – 120-350km/hr –High speed

Handover

When it comes to mobility, handover again naturally comes into play.

The intra-frequency handover is defined as around 27.5 milliseconds, and the inter-frequency handover is defined within the spectrum and is 40 and between spectrum bands is 60.

These are the numbers, which have to be met and these specific situations have to be tested for.

VoIP Capacity

4G systems do not have the provision for circuit switched voice, which was there for earlier generations. It has packet switched data. All the real time traffic is available as packet data.

Mobility is also a big factor, which comes into play over here. So, when you combine the mobility which brings in a huge amount of uncertainty because, of the Doppler effects along with the stochastic nature of packet scheduling, then supporting real time traffic such as voice or VoIP is a critical challenge.

Main components of 4G systems

1. OFDM Systems: Increased spectral efficiency
2. Higher QAM: 16QAM, 64QAM, 256QAM. Increase Spectral efficiency
3. MAC Optimization: Packet scheduling and radio resource allocation increases spectral efficiency
4. MIMO: Increases spectral efficiency N times
5. Carrier Aggregation: Huge improvement in data rate
6. Hybrid ARQ

7. Link adaptation

6. Fifth Generation: 5G (IMT 2020)

Rapid adoption of smart phones and mobile applications

- ✓ cause a tremendous increase in the volume of the mobile data traffic.
- Number of devices accessing the network are expected to increase due to
- ✓ Poliferation of Internet of Things(IoT)
- Mobile Communication is intricately tied to the socio-economic fabric of the modern generation of the human beings
- The tight coupling between mobile communication systems and socio-technical trends are expected to go beyond 2020.
- Also it is forseen that, there will be
- ✓ More traffic volume.
- ✓ More devices with diverse service requirements.
- ✓ Better quality of user experience.
- ✓ Better affordability.

IMT systems should support emerging new use cases, requiring:

- A very high data communication.
- A very large number of connected devices.
- Ultra low latency.
- High reliability applications.

Users expect instantaneous connectivity: Applications need to exhibit flash behavior without waiting time.

Flash behavior is

- a key factor for cloud services.
- virtual reality.
- augmented reality applications.

Features of 5G

1. Beamforming and M-MIMO: are aligned with higher frequencies.
2. Wide contiguous bandwidth: enhance data delivery efficiency and ease of hardware implementation.
3. Reduced cell size (order of few tens of meters): provide larger-area-traffic capacity in dense areas
4. Very high data rate communication
5. Large number of connected devices
6. Ultra low latency eg: E-health, safety, office, entertainment.
7. High reliability applications eg: remote surgery, where you require a very high reliability; autonomous vehicles and things like that.

Figure 3: According to International Telecommunications Union (ITU), the 4 billion mobile subscriber mark was reached in 2008.

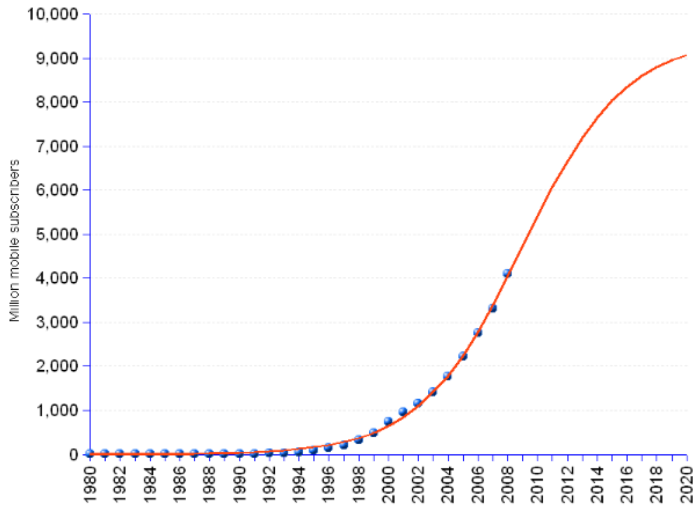
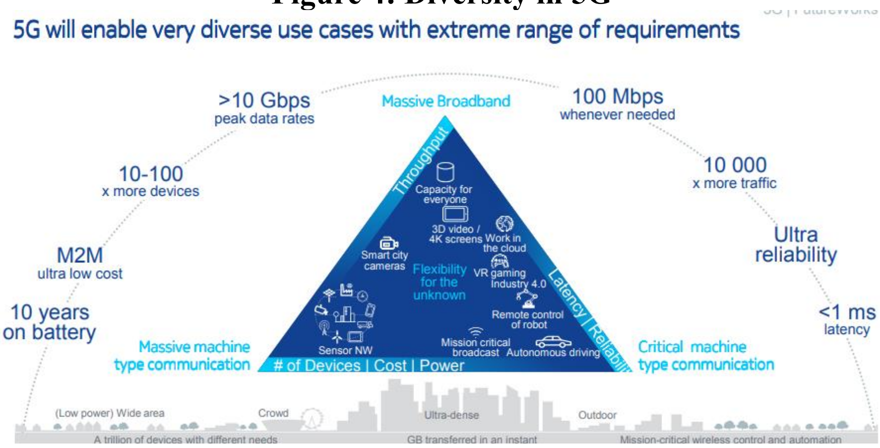


Table 2: Comparison of different generations				
Generation	**Year**	**Type**	**Principle used**	**Rate**
1G	1970-80	Analog Voice	FDMA	Very low rate
2G	1980-90	Digital Voice	TDMA/CDMA	Few Kbps
3G	1990-2000	Digital Voice+ Data	WCDMA	10s of Mbps
4G	2000-2010	Wireless Broadband	OFDMA	100s of Mbps
5G	2020	Smaller cells + MM waves	MMIMO	10Gbps
6G	2022			

Figure 4: Diversity in 5G



Present day communication are designed with the human **user in mind**.
Design is to consider **machine to machine** (M2M) communication. Examples are:

- Driverless Cars, Enhanced mobile cloud services.
- Real time traffic control optimization
- Emergency and disaster response
- Smart grid
- E-health
- Efficient industrial applications

Higher User Density

- Another very critical thing.
- Shopping malls stadiums, open air festivals: there will be a lot of other users who will be using them in traffic jams probably or in public transit. So, these are a lot of scenarios which are expected.

High Quality at High Mobility
Maintaining high quality at high mobility will

✓ help successful deployment of applications on user equipment located inside cars or high speed trains.

Enhanced multimedia services are driven by

✓ Increasing demand for mobile high definition multimedia in entertainment, medical treatment, safety and security areas.

Further user will get devices with

✓ Ultra-High Definition display, multi-view High Definition display
✓ Mobile 3D projections, immersive video-conferencing and
✓ Augmented reality and mixed reality display and interface.

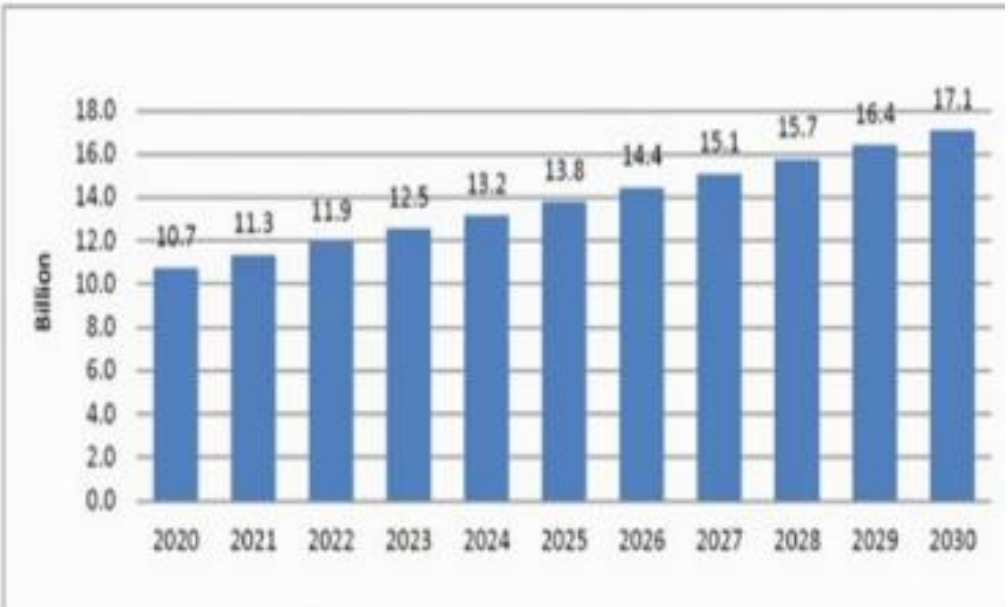
Internet of Things: Driver for different requirements
Number of connected things will exceed the number of human user devices
Connected things can be:

✓ Smart phones, sensors, actuators, cameras, vehicles atc.
✓ Energy consumption
✓ Transmission power
✓ Latency requirements
✓ Cost

Application areas

✓ Smart energy distribution grid systems
✓ Agriculture
✓ Health care
✓ Vehicle-to-Vehicle and Vehicle-to-road infrastructure communication.

Figure 5: Estimated traffic by 2030



7. Conclusion

Mobile have travelled a long journey before reaching the stage where they are today. The estimated traffic by 2030 will be more than 17 billion subscribers. The paper attempts to highlight and compare various generations of mobile communication.

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