A comparative overview of modern communication systems and standards

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A comparative overview of modern communication systems and standards

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ABSTRACT

With the dynamic changes in technological advancements, wireless communication technologies has made a tremendous progress from simple to complex systems that are able to communicate across multiple networks platform. As these systems continue to prove their proficiency and benefits, it is strongly asserted that wireless technologies will continue to play an even more critical and vital role compared to wired connections in the future. The most relevant question now regarding the future of wireless technologies is whether it going to dominate the wireline transmission or be a complementary to wireline where it’s difficult for any reason to have wireline like wireless backhaul. With today’s wireless data rate speeds it would be difficult to imagine it replacing wireline in the near future, but technically speaking it is feasible to achieve those data rates with use of wider spectrum.

Moreover, wireless communication technologies particularly that of wireless mobile phone technology, is continuously more preferred in communication today, making it the first priority of modern day lifestyle. Modern communication system standards have therefore been subjected to evaluation and analysis to establish a more profound understanding of these various technologies.

The proposed study presents an overview of various wireless communication systems such as: Global system for mobile communications (GSM), high-speed packet access (HSPA), long-term evolution (LTE), mobile WiMAX, ultra wideband (UWB) technology, ultra mobile broadband (UMB), wireless local area network (WLAN), Bluetooth wireless technology, and, Wi-Fi.
On the whole a relative study is to be conducted here which permits the reader to compare modern wireless technologies and modulation technique used by them, and the standards used to address the current growing demand of wireless services.

**ACRONYMS**

2G- Second Generation  
3G-Third Generation  
3GPP-Third Generation Partnership Project  
3GPP2- Third Generation Partnership Project 2  
4G- Fourth Generation  
AP- Access Point  
APD- Adaptive Power Distribution  
ARP- Address Resolution Protocol  
ASN- Access Service Network  
CDMA- Code Division Multiple Access  
EPC- Evolved Packet Core  
EV-DO- Evolution Data Optimized  
FDD- Frequency-Division Duplex  
FDM- Frequency Division Multiplexing  
GPRS- General Packet Radio Service  
GPS- Global Positioning System
GSM- Global System for Mobile Communications
HSDPA- High Speed Data Packet Access
HSPA- High Speed Packet Access
ICI- Inter Carrier Interference
ITU- International Telecommunications Union
Kbps- kilobits per second
LAN- Local Area Network
LTE- Long Term Evolution
MAC- Media Access Control
MAN- Metropolitan Area Network
Mbps- Megabits per second
MIMO- Multiple Input Multiple Output
MPEG- Moving Picture Experts Group
MS- Mobile Station
NCMS- Network Control and Management System
OFDMA- Orthogonal Frequency Division Multiple Access
OFDM- Orthogonal Frequency Division Multiplexing
PHY- Physical Layer
PSTN- Public Switched Telephone Network
PDCP- Packet data convergence protocol
QoS- Quality of Service
RLC- Radio link control
RF- Radio frequency
SAE - System Architecture Evolution
SISO - Single Input Single Output
TDD - Time Division Duplex
TDM - Time Division Multiplexing
TDMA - Time Division Multiple Access
UMTS - Universal Mobile Telecommunications System
VoIP - Voice over Internet Protocol
WiMAX - Worldwide Interoperability for Microwave Access
Wi-Fi - Wireless Fidelity
UTRA - universal terrestrial radio access (evolved).
UWB - Ultra wideband technology
UMB - Ultra mobile broadband
WPAN - Wireless Personal Area Network

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1. CHAPTER 1

Introduction to Study

Chapter one Presents an introduction of the chief subject matter of this study including problem discussion, goals and objectives, significance of study, delimitations of the study, and the structure of the thesis.

1.1 Introduction

Mobility and Access is what wireless technologies is all about. Mobility is the ability to move freely while been able to hold a continuous communication and access is the services provided regardless of the type of connection. The most important reason behind mobile broadband development was the productivity growth that resulted from being connected to a cellular network. With landline operators providing speeds of 100 to 1000 Mbps it is almost a necessity for wireless systems to compete with these rates in order to stay attractive to users. Achieving these rates from a technical point of view is possible but only if a large part of spectrum is available and we are willing to decrease the cell sizes.
In technical terms the major issues we are concerned with are:

1- Spectral efficiency........bps/Hz
2- Data throughput......... kbps
3- Coverage......................m²

During last few decades we have had great progress in these three fields with growth in the range of 20% to 50% annually. One of the best known postulates of the computer world is the Moore’s Law [30]. It states that number of transistors on an integrated circuit (IC) doubles every two years means that computational power of IC’s grow at an exponential rate. This progress follows by decreasing the size and cost’s of electronic circuits and devices is very essential in planning for future developments.

With technological advancements in wireless technology, wide ranges of techniques have been applied by which information exchange has become possible through utilization of high capacity wireless links. Many systems, e.g., computers, phones, printers, television sets, cameras, and even airplanes and satellites have eventually been designed to adapt and apply wireless technologies. Thus, with such development of wireless technologies, an increase in more promising and useful applications and systems has been widely observed at an international scale and level. Wireless standards and systems for wireless communication have therefore been evolving at high rates to ensure a reliable and upscale system performance. The significant implementation of wireless techniques has brought the greatest impact ever occurred on modern communication. Radio broadcasting, cellular telephony and wireless internet access has made wireless communication more accessible by making use of its various technologies. Though the purpose of information exchange has not yet changed, there has evolved new methods of communication that have significantly reduced the cost and the size of system and equipments while ensuring that the
communication range and speed increase as well as the number of users. In addition, wireless communications became a central point of the development of the telecommunications industry for its capabilities to connect people.

1.2 Problem Definition

To provide an overview of different wireless communication technologies and specifically discuss systems and standards used by such technologies.

1.3 Goals and Objectives

Following are the goals and objectives of the study:

1. To provide a comprehensive overview of existing wireless technologies.
2. To compare different wireless technologies and systems like Bluetooth, WLAN, Wi-Fi, GSM, LTE, HSPA, UWB, UMB, OFDMA and WiMAX based system for communication.
3. To find out the characteristic of various wireless technologies in terms of their data throughput, and range.

1.4 Review Questions

With reference to the stated goals and objectives of the study, the following questions were initiated in order to allow the readers to get an understanding of different wireless technology standards.

1. What are the capabilities of current wireless technology and systems such as 4G (LTE), WiMAX, 802.11 (WLAN), Bluetooth, and different UWB based systems and how did they develop and evolve over the years?
2. What are the similarities between existing wireless technologies in terms of applications?
1.5 Significance of Study

Understanding wireless communication technologies and systems according to various technical specifications and to review existing wireless standards and systems like Bluetooth wireless technology, WLAN, WiMAX, UWB, GSM Mobile, Wi-Fi, HSPA, LTE, UMB and OFDMA based system for communication which provides an additional insight in learning.

1.6 Limitations

This study is specifically aimed to get a review of wireless technology standards. However, like any other work, this study is subjected to a series of limitations that encloses this study only within a set of predetermined parameters. Firstly, the study is limited to the following wireless standards: Bluetooth, Wi-Fi, Infrared Technology, WiMAX, UMB, HSPA, and 802.11 (WLAN), GSM, 4G (LTE) and UWB based wireless systems. Secondly, only a comparative overview of existing wireless standards, its access, and application, will be conducted in the study. Such mentioned details constitute the parameters or limitations of this study. Any information not included within the range of these given framework shall not be considered as relevant or pertinent to the goals and objectives of this study.

1.7 Thesis Structure

Below is an outline form of the thesis structure:

1. CHAPTER I: Introduction
   1.1- General Introduction
   1.2- Problem Definition
1.3- Goals and Objectives
1.4- Review Questions
1.5- Significance of the Study
1.6- Limitation
1.7- Thesis Structure

2. CHAPTER II: Literature Review
   2.1- Literature Review
   2.2- Wireless Technologies
   2.3- Issues
   2.4- Overview of Different Wireless Technologies and Systems

3. CHAPTER III: Results and Discussion

4. CHAPTER IV: Conclusions and Recommendations

2. CHAPTER 2

Literature Review

Chapter two starts with a literature review of various wireless technologies, and is further divided into categories and concepts which are deemed helpful and necessary to the study.
2.1 Literature review

The following literature review reflects the technical specifications and services offered by various wireless standards. Their advantages and disadvantages are also extracted, by keeping in view the goals and objectives of the study.

2.2 Wireless Technologies

In the current dynamic and advanced technological environment users wants to have reliable and high speed access to the internet, or the Cloud, at anytime and anywhere on the planet. Therefore, wireless access, its reliability and greater data through-put along with application capabilities of wireless devices has been in great demand. Before going in to detail of each wireless standard, there are some general issues which are discussed below.

2.3 Issues:

Since wireless devices need to be small and wireless networks is bandwidth limited, some of the key challenges in wireless networks are [6]:

- Data rate enhancements
- Spectral efficiency
- Interference
- System Interoperability
• Power management
• Security

• Data Rate Enhancements

Increased data throughput can be achieved through improvement in hardware and software systems. Achieving better data compression, modulation techniques and power management are addressed by software improvement while achieving more compact and more powerful transceivers and power efficient devices are addressed as hardware improvement. The growing demands for applications on electronic devices require a higher data transfer rates while the data rate in wired transmission is bound by the mediums capacity in the wireless transmission higher data rates are more challenging and requires both software and hardware designs plus dealing with interference, noise and mobility in mobile devices. One way to achieve greater data rates is to have better data compression. Data compression is playing an important role in the quality of, e.g., audio-video links. There are different data compression standards such as MPEG-2/4 which are among the more effective compression standards. Other parameters that can affect data throughput are multipath and interference. Multipath channel issues have been strongly alleviated by introduction of MIMO advanced antenna systems while interference can be dealt with through different approaches depending on the nature of the noise.
Spectral efficiency

Bandwidth is a very valuable commodity and should be used efficiently. Spectral efficiency is measured in bps/Hz and it is an indicator for how efficient data bits transmit over a given bandwidth. It is a measure of how effective the modulation technique or air interface techniques are to transmitting data bits over the air or it can be used to predict the number of users or services that could be supported by a given bandwidth. Different level of evolution in mobile technology history can be distinguished by how high spectral efficiency they have achieved.
Spectral efficiency of different cellular technology

<table>
<thead>
<tr>
<th>Generation</th>
<th>Standard</th>
<th>year</th>
<th>Bandwidth MHz</th>
<th>Spectral Efficiency Bit/s/Hz</th>
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</thead>
<tbody>
<tr>
<td>1G</td>
<td>NMT</td>
<td>1981</td>
<td>0.025</td>
<td>0.064</td>
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<tr>
<td>2G</td>
<td>GSM</td>
<td>1991</td>
<td>0.2</td>
<td>0.17</td>
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<tr>
<td>2.5G</td>
<td>GSM/EDGE</td>
<td>2003</td>
<td>0.2</td>
<td>0.33</td>
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<tr>
<td>3G</td>
<td>WCDMA</td>
<td>2001</td>
<td>5</td>
<td>0.51</td>
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<td>IEEE802.16d</td>
<td>2004</td>
<td>1.75, 3.5, 7, 20</td>
<td>1.2</td>
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<tr>
<td>3.5G</td>
<td>HSDPA</td>
<td>2007</td>
<td>5</td>
<td>8.44</td>
</tr>
<tr>
<td>4G</td>
<td>LTE</td>
<td>2009</td>
<td>20</td>
<td>16.32</td>
</tr>
<tr>
<td>4G</td>
<td>LTE advanced</td>
<td>2012</td>
<td>40</td>
<td>30</td>
</tr>
</tbody>
</table>

- **Interference**

Signals with identical frequencies may cause interference with each other and degrade the data throughput of the network, e.g., the frequency band at 2.4GHz, widely used by different electronic devices such as cordless phone, microwave ovens and car alarms, is the same frequency at which Wi-Fi and 802.11b/g/n/ac operate. Other frequencies such as 5 GHz band have been introduced to wireless communication to avoid the interference problem at the congested frequencies such as 2.4 GHz.

It should be noted that compressed data is more vulnerable to interference which necessitates the use of proper error checking/correction to insure the authenticity of received data. Along with that a variation of transfer protocol to adapt to time-varying network and traffic characteristics are may be a good idea to enhance the data rates.
• **System Interoperability**

As for any communication devices, interoperability between different product brands and compatibility in the same line of products, are the main issues. These problems may arise due to use of different protocols and interfaces by electronic devices. In wireless technology in order to resolve interoperability issues, IEEE has given respective preferences for designing compatible path for exchange of information with respect to frequency and signals, bandwidth and radio system coverage for wireless technologies and has adopted/developed standards like 802.11 among others to enhance interoperability.

• **Power management**

The battery power constraint of mobile devices has placed a restriction on the range and throughput of the system. With the size of mobile devices shrinking needs for low power electronic circuit designs and more powerful batteries are more acute. The power consumption of mobile devices varies depending, e.g., on what modulation scheme has been used as some modulation are requiring more power than others, as well as the range of transmitting signals.

• **Security Issues**

Growing number of wireless devices increase demands for more sophisticated wireless network security. Wireless security concerns stems from the nature of this technology which provides coverage even beyond physical boundaries such as walls. Wireless network can be broadly classified in two main categories by the way they are connected to the internet and interconnected
together: ad-hoc (peer to peer) and infra structure (access point). In ad-hoc networks, several computers/nodes are connected together and sharing their resources without any need of administration while in infrastructure the computers/nodes access the internet through an access point, network administration, which in turn is connected to wired internet. Security concerns regarding ad-hoc network are far greater than infra structure network as there is no control over the network.

To provide Wireless networks with password or network key for accessing the network is one way to protect the network but there are other more sophisticated ways such as software and hardware firewalls to increase the security in wireless networks.

- Software firewalls are installed on a server or a computer and it confine programs for getting access to the network, file sharing, and additional user defined variables.
- Hardware firewalls are installed on standalone devices and wireless routers. These firewalls permit access only for authentic user accounts.

Data encryption and authentication techniques such as IEEE 801.11 standard has offered Wired Equivalent Privacy (WEP) which describes a method to decode information and offer security and privacy for authorized users or the encryption method of Wi-Fi Protected Access (WPA), which supports 256-bit or 128-bit decoding. There are few various kinds of WPA, such as: WPA-AES, WPA-TKIP, WPA2 and WPA-PSK.

There are other approaches to meet the security constraints and the requirement of reliable network access where the most appropriate solution is to set up a Virtual Private Network (VPN). VPN is a technology that uses internet or other intermediate networks for connecting remote sites or computers together. VPN makes sure the route is isolated from other users and the data are secured
by encryption it works by establishing a virtual point-to-point connection, tunnelling the traffic, and employs encryption techniques to protect the transmitted data through the tunnel.

**Overview of modern Wireless Technologies and Systems**

Wireless systems have been organized in two groups of fixed and mobile wireless standards with each group arranged in increasing range. WiMAX standard exists in both groups since there are both fixed and mobile WiMAX. In an orderly fashion the standards discussed are as follows:

1. WLAN, Bluetooth, Infrared, Wi-Fi, Fixed WiMAX
2. GSM, Mobile WIMAX, HSPA, HSPA+, LTE, UMB, UWB

### Wireless standards

![Diagram showing wireless standards](image)

**2.4 Wireless Local Area Network (WLAN)**

WLAN is a wireless application that uses Wi-Fi or WiMAX service in a network. This network is built when a device, Access Point (AP) and Network Adapters forms the foundation for
wireless network where AP detects and broadcast wireless signals and at the back-end devices must be integrated with wireless network adapters, is attached to a wired network edge and a client communicates with access point through a wireless adapter. This enables users to be mobile within a local coverage area and still be connected to the network. Most modern WLANs are based on IEEE 802.11 using modulation techniques like spread-spectrum or OFDM. Spread spectrum technologies like DSSS and FHSS are common modulation techniques used to implementing the WLAN where DSSS implementation is more power hungry than FHSS.

Wireless Local Area Network allow exchange of information between computers, printers and mobile phones primarily using a frequency band at 2.4GHz with a bandwidth of 20 MHz for 802.11 a-g protocol and 20/40 MHz for 802.11 n-ac protocols. Medium access control (MAC) support different data rates. It operates in Direct Sequence Spread Spectrum (DSSS) or Orthogonal Frequency Division Multiplexing (OFDM). WLAN combine user mobility with data connectivity. WLAN can be used to access shared information without using cables. Some of characteristics of wireless LANs are:

- The services availability are only confined or limited by the range of WLAN.
- Convenience and simplicity in installation and configuration of the system.
- Installation and running cost of Wireless LAN is lower than wired LAN in the long run plus that there are more freedom in reshaping the nodes compare to Wired LAN.
- WLAN can be configured to meet different installation requirement or to extend its’ coverage by adding more access point or repeaters or by a change to a peer-to-peer configuration.
2.4.1 Advantages of WLAN:

- Mobility & connectivity: It is not restricted to any physical barrier or terminal
- Availability in places where normally wired connection are impossible

2.4.2 Disadvantages:

- The bandwidth offered by WLAN is much slow as compared to the standard cable bandwidths
- Less secure due to interference with other wireless networks or other radio signals which can result in loss of signal
- Limited number of users allowed on the network.

2.5 Bluetooth

Bluetooth offers a short range wireless connectivity and provides wireless connection between Internet and other different devices. Normally it operates at a data rate of 1Mbps and effectively within the range of 5-10m for a so called class 2 Bluetooth devices which has a maximum permitted power of 2.5 mW and it uses the FHSS modulation technology. Frequency hopping spread spectrum (FHSS) use a pseudo random sequence known to both the receiver and the transmitter to switch the carrier frequency between different frequency channels. Synchronization at the receiver end with the transmitters’ hopping sequence is the most important challenge of this technology. This technology is highly efficient against narrow band interference which makes it capable to share the frequency channel with other transmitters and has a very high level of security against deliberate jamming. Several Bluetooth compatible devices can be connected together include cell phones, PDA’s and wireless headsets. Due to the range limitation
it’s hard to create a network with devices using Bluetooth technology. Bluetooth is an inexpensive technology and is cheaper to implement which ultimately results in lower cost for the users. It offers a high level of compatibility among devices such as headsets, hands free kits, and are able to connect with other devices even if they are not of the same model or brand. Bluetooth devices often avoid interference with other wireless devices, e.g., Wi-Fi because of its’ frequency hopping and dynamic error handling. Hence increasing levels of interference is predominantly confined to slowing down the data rate as more packets need to be resent. An advantage of Bluetooth devices are their very low power consumption.

Bluetooth supports both sharing of data and voice communication for mobile phones and headsets. We can connect up to seven Bluetooth devices with each other a PAN (Personal Area Network) within a range of 10m for a so called class 2 Bluetooth devices or a range of 100 m for a so called class 1 Bluetooth device which has a maximum power of 100 mW. The frequency range assigned to Bluetooth in United States and Europe is from 2402 MHz to 2480 MHz. Bluetooth make use of three different kinds of modulation techniques depending on bit rate and information:

1. **Gaussian Frequency Shift Keying (GFSK)**
   
   Use for basic rate, 1 Mbps, as well as for the packet header and access code.

2. **Differential Encoded Quaternary Phase Shift Keying**
   
   Use for a 2 Mbps bit rate Bluetooth and is abbreviated as π/4-DQPSK.

3. **Differential Phase Shift Keying**
   
   Use for a 3 Mbps bit rate of data and is abbreviated as 8DPSK.

### 2.5.1 Advantages
• Very suitable for quick and short range wireless technology
• Facilitate both voice and data interaction
• Devices locate one another and initiate a conversation without any user input.
• Provides synchronization between all connected personal devices.

2.5.2 Disadvantages
• Data transfer rate is relatively low compare to infrared.
• There is possibility of interference and degradation of data transfer speed between Bluetooth and Wi-Fi signals, as they use the same frequency band, depending on the strength of both signals.
• Not secure for sharing sensitive type of information.

2.6 Infrared technology

Infrared is next to visible light at electromagnetic spectrum starting from frequency band of 405 THz to 300 GHz. Infrared uses Pulse Position Modulation (PPM) which is an orthogonal modulation scheme used primarily in optical communication with little or no interference around such as in fiber optic or IR remote controls. It uses short pulses with two different delays between pulses which represents the logical data. Like light, infrared cannot penetrate objects that are opaque. A majority of the Infrared connections use direct line of sight and create a point-to-point connections between two devices. Directed systems give limited range about 1 m and are typically used in personal area networks but sometimes they have been applied in particular wireless LAN applications. IR technology is not practical for mobile technology with the exception for
reflective/broadcast IR which is limited to a very short range in the scale of 5 to 10 m. Some common applications of infrared technology are locking systems for cars, security response systems, headphones, navigation systems, TV’s, CD players, telephones, computers parts like keyboards, printers, mouse, floppy disk drives, and controlled environmental systems including doors, lights, radios, and windows [3]. Infrared technology used in LAN is categorized into three different types [13]:

1. IrDA-SIR (slow speed) infrared supporting data rates up to 115 Kbps
2. IrDA-MIR (medium speed) infrared supporting data rates up to 1.15 Mbps
3. IrDA-FIR (fast speed) infrared supporting data rates up to 4 Mbps
4. IrDA-VFIR for data rates of up to 16 Mbps and range of up to 10 m
5. IrDA-UFIR for data rates of up to 96 Mbps and range of up to 10 m
6. IrDA-Giga-IR for data rates of up to 512,1000 Mbps and range of up to 10 m

2.6.1 Advantages

- Simple circuitry
- High interference immunity and high security as the beams’ directionality makes it a line of sight technology
- Low power requirement

2.6.2 Disadvantages:

- Blocked by physical objects like walls
- Short range
- Normally require direct line of sight
• Sensitivity to light and condition of its’ transmission medium as direct sun light or rain and fog disturb the signal

2.7 Wi-Fi

According to some researchers, the term Wi-Fi referred to “Wireless Fidelity”, however, few of them have suggested that Wi-Fi is a standardized trademark term that means IEEE 802.11x. Wi-Fi or Wireless Fidelity technology is aimed to provide high data transfer rate for LAN environment. Modulation Techniques used in Wi-Fi technology are Single Carrier Direct Sequence Spread Spectrum (DSSS)/Direct Sequence-code division multiple access (DS-CDMA) and Multicarrier OFDM. Wi-Fi streams information into small pieces and allocate each stream of the information across frequency channels in the spectrum. There are six different wireless standards being setup by the Institute of Electrical and Electronic Engineers (IEEE) namely:

1. 802.11a
2. 802.11b
3. 802.11g
4. 802.11n
5. 802.11ac
6. 802.11 ad

802.11a: 802.11a was the first introduced standard in the line of IEEE standards but due to its’ higher cost have never gained popularity for public use but instead used in business
network. It’s been operating at 5 GHz band and a 20 MHz bandwidth with a data transfer rate of up to 54 Mbps. This standard has used orthogonal frequency division multiplexing (OFDM) scheme for its’ signal modulation. Loosely speaking OFDM is squeezing multiple transmissions in one channel. In this scheme instead of a single carrier a large number of subcarriers, usually a power of 2, e.g., 256 or 1024, which are spaced in equal distance to each other, are being modulated with a higher order of quadrature amplitude modulation, e.g., 64QAM. QAM is a technology that uses two 90 degree out of phase sinusoidal carrier to transmit data. Since the two carriers share the same frequency band but have a 90 degree phase shift they can be modulated independently and transmitted. This technique enhances the data transmission bit rate over a given bandwidth of QAM to twice of the pulse amplitude modulation (PAM) for obvious reason. Higher order QAM gives even further improvement in data transmission bit rate. Combination of higher order modulation like 64QAM and large number of subcarriers in OFDM enables more bits of data to be modulated on the subcarriers which increase further the data throughput. Large number of subcarriers increases the data throughput as well as reducing the effect of interference and multipath fading on the signal.

**802.11 b/g:** The most commonly used standards are 802.11b and 802.11g which are of comparatively low cost and provide wireless connectivity in railways, airports, restaurants, other public areas or at home. But there are variations with respect to speed between the two standards. They are using direct sequence spread spectrum (DSSS) and a combination of DSSS & OFDM modulation respectively. DSSS modulation is about mixing the signal with a pseudo noise code and spread it over a wider bandwidth than the original signals’ bandwidth. The resulted signal would not be any different than white noise unless it is correlated again with the same noise sequence.
Longer noise sequences enhance signal to noise ratio (SNR) for the signal. This technique allows multiple transmitters to share the same channel provided the pseudo noise sequences are not cross correlated. This modulation has very good characteristic in interference rejection capabilities against narrow band interference. The reason behind it is that the pseudo noise (PN) sequence of 1 and -1 values, working as a spread factor and multiplication by the PN sequence spread the signal like white noise and twice multiplication of the signal by the same sequence code (property of PN sequence: $1 \times 1 = 1$, and $-1 \times -1 = 1$) dispersing the signal and reproduce the original data while the interference that only multiplied once, uncorrelated with PN, spreads further and decrease more in power density.

**802.11n:** The 802.11n is an improvement of earlier standards by adding multiple-input multiple-output antennas (MIMO) features operating on dual bands of 2.4 / 5 GHz with two channels of 20 and 40 MHz allowing a data rates of 600 Mbps in (4x4) MIMO. The 802.11n is the most widely used standard compared to its’ predecessors due to enhanced range and data rates. The predominant modulation scheme for the 802.11/n and later standards are OFDM.

**802.11ac:** The 802.11ac is a fifth generation Wi-Fi standard operating at 5 GHZ band using 20, 40, 80 and 160 MHZ channels with a theoretical maximum speed of up to 1.3 Gbps which is much faster and even more power efficient than its predecessor 802.11n with a beam forming capability which could drastically extend its range and its’ power efficiency. The 5 GHz band offers wider channel availability in comparison with 2.4 GHz band.
**802.11ad:** The 802.11ad is a tri band standard with frequency bands of 2.4 / 5 / 60 GHz. It uses spectrum in the 60GHz band where there is more bandwidth than in 2.4 or 5 GHz band available which allows higher data transfer speed of up to 7Gbps. 802.11ad has a much shorter range compared to 2.4 or 5 GHz band due to the signals higher frequency properties which limits penetration via obstacles and faster attenuation. With a range at around 10 m it is definitely going to make Bluetooth an obsolete technology.

Wi-Fi performs its functionality by deploying unlicensed spectrum in the 2.4GHz band and can be coupled with other wireless technologies to provide access over greater distances. For instance, Motorola supports the Canopy radio system that can offer multi-point links of up to 16 Km and point-to-point links of up to 56 Km [4].

Wi-Fi has become an integral part of offices and companies and public places such as airports, libraries, café or at home.

### 2.7.1 Advantages

- Mobility
- Accessibility throughout the Wi-Fi Networks range.
- Simplicity and convenience of installation and utilization.

### 2.7.2 Disadvantages

- Interference in 2.4 GHz band from, e.g., microwaves or cordless phones cause degradation in performance.
- In order to obtain additional range, repeaters or additional access points need to be purchased which further add up cost.
• The spectrum assignments and operational aspects are not reliable worldwide.
• The use of Access points can endanger personal and private information transmitted from Wi-Fi.
• There are great security concerns for wireless network as the most commonly used security and encryption methods are with flaws and vulnerable to hackers. Encryption method such as WPA, WPA2, or WPS in Wi-Fi are known to have drawbacks like WPS having a flaw that allows it to be hacked and the router's WPA or WPA2 password could be retrieved [7].

2.8 Fixed WiMAX 802.16d

Worldwide Interoperability for Microwave Access (WiMAX) is an IP based fourth generation 4G wireless broadband communication technology that delivers high speed internet access to vast geographical area either from an access point to the base station or from the base station to the main wired network backhaul. That is where the name “last mile broadband” comes from. Although WiMAX is very similar to Wi-Fi only on a very larger scale and faster speed, its’ capability of seamless interworking with Wi-Fi or 3GPP makes it very competitive to other technologies. It was intended to provide a bit rate of up to 40Mbps in its 2005 revision and up to 1Gbps in its 2011 revision. The range of this technology exceed by far the range of the conventional Wi-Fi LAN and offer coverage within a radius of more than 50KM. WiMAX creation was a response to worldwide demand for a more powerful wireless system in terms of range and user coverage. WiMAX should enable delivery of wireless broadband access where DSL and
Cables are not capable to reach users and using the existing infrastructure and platform in order to keeping the costs of equipment and investment for new systems down. WiMAX technology enables delivery of the wireless broadband signals for both mobile and fixed users and portable users (Portable as limited mobility but not as fast as mobile). In 2006, the Korean Telecom company had started using 2.3GHz mobile WiMAX version called WiBRO to ensure that there was high performance for video and data services.

Wireless standards that were developed within the IEEE 802 ranged from short range Personal area network (PAN) standard in 802.15 to wide area network (WAN) 802.20. WiMAX Standard has been introduced by IEEE as wireless metropolitan area network (WMAN) and marketed as WiMAX. The first version is formed to operate for fixed mobile broadband access using 10-66GHz band. The spectral efficiency of WiMAX for both downlink and uplink are in excess of 15bps/Hz and 6.75bps/Hz when using 4 × 4 (MIMO) and 2 × 4 (MIMO) antenna configurations respectively. It has air-link access latencies of not more than 10ms, intra-frequency and inter-frequency handover of interruption time of 27.5ms and 40-60ms respectively. WiMAX employs the OFDM (Orthogonal Frequency Division Multiplexing) modulation technique for its high spectrum efficiency and ability to deal with multipath interference.

WiMAX and Wi-Fi are not very much different except for the longer range of the WiMAX but nevertheless data rate dramatically decrease at the cell edges of WiMAX which counteract this advantage.

Long Term Evolution (LTE), compared to WiMAX, has the advantage of being more compatible to the existing technologies like 3G which makes it more competitive. Both of these wireless technologies are playing an equally noteworthy contribution for the future of wireless networks. Both WiMAX and LTE possess identical goals for facilitating worldwide wireless data network
connectivity for laptops, mobile phones, and other computing devices and offer higher speed and higher capacity as compared to former 3G and wireless broadband network standards. WiMAX is supporting a perfect backhaul technology for 4G networks whereas the international market seems to be switching towards LTE as the global solution for accessing mobile information.

The improvement of cellular phones through years can be categorized in different generations depending on the level of underlying technology. The categories are not standardized based on some special characteristics or on the general performances.

The first generation (1G) cellular technology was analog wireless access system. It could merely handle voice traffic, couldn’t handle static noise and offered no security against eavesdropping. First generation analog cellular network was not able to handle the growing demand for more capacity and incompatibility towards digital network with regards to, e.g., roaming. The disadvantages of analog technology in comparison to the strengths of digital technology had paved away for second generation (2G) cellular technology, aka, GSM.

The digital technology was by far surpassing analog as it was much easier and cheaper to work with digitized data and to use advanced signal processing techniques which was feasible through the nature of digitization of data. Cheaper digital signal processors (DSP), than analog devices, paved away for more powerful cellular technologies and handheld devices.
2.9 GSM (Global System for Mobile Communications)

GSM, the first digital wireless mobile phone standard launched in 1991, is the most widely used cellular technology in the world with over 3 billion in subscribers and still increasing.

2G technology can be divided in two multiple access techniques:
1- CDMA- Code Division Multiple Access

2- TDMA- Time Division Multiple Access

The first technique was adopted in USA and called CDMAone. CDMA is a spread spectrum technology which allows each user to transmit over the entire bandwidth by using a distinct orthogonal code. That way it supports more users and it is more bandwidth efficient than GSM. CDMAtwo has offered data rates of 115.2 kbps.

The second technique was adopted in Europe and was called GSM. GSM used TDMA (Time Division Multiple Access) technology within FDMA (Frequency Division Multiple Access) technology which can accommodate many users at the same frequency but on different time slits. This way a 25 MHz frequency band can be divided using a FDMA scheme into 124 carrier frequencies with a spacing of 200 kHz. Each carrier frequency is then divided into 26 time frames.
which in turn are divided into 8 time bursts of 0.5777ms. Each user is allocated one burst as all the
communication in GSM is done in bursts.

GSM cellular technology arrived with the promises of delivering more capacity and compatibility
for the wireless mobile system. GSM success was indebted mostly to worldwide roaming ability in
GSM networks. GSM has introduced some very vital elements for the advancement of the cellular
technology such as:

• encryption of the communication to protect the privacy of communication
• Short message servicing (SMS)
• Subscriber Identity Module (SIM) that stored the users identity

SIM card allowed upgrade of the phone while keeping the same identity on the network. SIM card contain a unique secret authentication key for encrypting and decrypting the radio signal. It also provided the capability of storing other information such as the “phone book” and SMS. SIM cards allowed users to change phones without any need of reconfiguration which let the handset making market to boom. This in turn allowed mobile operator to more revenue by catering for more services available on more sophisticated handsets.

GSM network architecture can be grouped into four main areas:

• Mobile station (MS)
  Includes mobile equipments

• Base station subsystem (BSS)
  Handling communication with mobiles on the network

• Network and switching subsystem (NSS)
Providing control and interfacing for the network and it includes: mobile switching service centre (MSC), home location register (HLR), visitor location register (VLR) and authentication centre (AuC)

- Operation and support subsystem (OSS)

Control and monitoring the whole mobile network

Visitor Location Register (VLR) contains subscriber data for those subscriber’s who are registered in MSC. In every MSC there is a VLR in an integrated node. Home Location Registers (HLR) is the database that has every user’s subscription record along with the record of their last location. These databases are essential in the handover process for the obvious reason.

The modulation scheme used in GSM is Gaussian Minimum-Shift Keying (GMSK), which is a type of continuous-phase Frequency Shift Keying (FSK) that is a form of phase modulation. In GMSK, the signal to be modulated onto the carrier is initially levelled with a Gaussian low-pass filter before getting fed to a frequency modulator, which deeply diminishes the interference to its fellow channels (adjacent channel interference). It has benefits of being able to carry out digital modulation while maintaining the spectrum efficiently.

This modulation keeps the amplitude almost constant which allows more efficient power amplifiers in the transmitter that in turn is saving current consumption and thereby battery power. A very vital issue for any wireless device including cellular phones is the battery power management.

2G technologies were based on circuit switched approach in which two network nodes were connected through a dedicated channel even before they actually communicate and the full bandwidth of the channel was available throughout the session. That was a wasteful approach in terms of bandwidth efficiency and utilizing resources. The solution was IP based packet switched
system and the first step toward that was the introduction of GPRS (General Packet Radio Service) in GSM networks. Adding packet switching capability to GSM was the beginning of what it called 2.5G. GPRS could provide data rates up to 114 kbps. Introduction of Enhanced data rate for GSM evolution (EDGE) for GSM and CDMA2000 for CDMA brought these two system one step closer to 3G but they have been named 2.75G. Even though their data rates were greater than 114kbps required to be qualified as 3G technology, their data rate were far less than the actual 3G systems. EDGE supported data rates of 236.8 kbps while CDMA2000 were limited to 144kbps. The Figure shows a schematic of different wireless mobile systems [15] [16].

SAE: System architecture evolution
2.9.1 GSM Mobility

The most important part of a mobile wireless network from the mobility point of view is how the handover process from one cell or base station (BS) to another is done. With the reality of different standards existing side by side like 2G, GSM and 3G, UMTS/WCDMA/HSPA or even 4G, LTE the handover process can be very tricky and complicated as it involves two completely different techniques two communicate and handle the migration. With the world wide extent of GSM coverage often the best fallback network is the GSM.

Mobility management is the procedure that manages among others: location update of the user’s and roaming. The mobility management of GSM mainly depends on a centralized approach. GSM operator has the responsibility of providing data in the Home Location Register (HLR). HLR holds an indication as reference to Mobile Switching Center (MSC) with a concerning Visitor Location Register (VLR), where the mobile station is presently registered and the corresponding location information, i.e., the key/identifier of the location area is stored. When the location entry needs to update, the concerned HLR and VLR are updated. For every incoming request of call the HLR is cross examined first and on its request approval, the routing data dealing with the visited MSC/VLR is returned [8].

2.9.2 Advantages

- Widespread use of GSM throughout the world facilitate roaming
- GSMs worldwide coverage and subscribers forms a great market for handset makers, users and operators.
- GSM has the ability to use repeaters.
2.9.3 Disadvantages

- TDMA burst transmission interferes with some electronics such as pace maker.

- GSM technology is not capable of handling many callers on a cellular tower in comparison with other technologies such as 3G.

- Users share the same bandwidth which could lead to interference if many users are present and trying to make calls. Therefore newer technologies have changed to WCDMA in 3G or OFDMA in 4G.

- QoS problems, with missed and dropped calls are common with GSM technology.

2.10 Mobile WiMAX 802.16e

The 802.16e -2005 release known as mobile WiMAX in contrary to Wi-Fi has support for high speed mobility which is an important feature if WiMAX want to challenge LTE. Important WiMAX features that allow mobility support are as follows:

1- Adaptive modulation allows the system to adapt to different type of networks or channel conditions.

2- Data rate scalability where increased channel bandwidth allows achieving higher data rate.
WiMAX technology’s connection-oriented, establishing an end-to-end connection between devices before sending over any data, architecture allows a variety of applications such as voice and multimedia applications while its IP based architecture besides all the known services available for broadband allows a variety of services to be defined at later time.

OFDMA, the multiple access technique used in WiMAX, is the dominant choice of wireless broadband technologies. OFDMA has excellent ability against frequency selective channel fading and multi path channels by efficient use of frequency sub carriers plus that its’ transceiver structure is simple which allows implementation of complex antenna techniques like MIMO and BF(Beam Forming). These advanced antenna techniques allow WIMAX system to have a higher data throughput and greater coverage. Using MIMO technique allows almost double data rate compare to SISO resulting in up to 37 Mbps for downlink and 10 Mbps for uplink using a 10 MHz channel bandwidth. Beam forming technique, directing the downlink/uplink signal to terminals at the cell edge, is essential to WiMAX system in order to have a reliable communication and avoiding ICI (Inter Carrier interference). Frequency spectrum available to operators is limited and expensive therefore modern technologies such as WiMAX and LTE are designed to make the most use of the allocated spectrum by employing advanced technique such as ICIC, Inter-Cell Interference Coordination, available to achieve frequency reuse 1, adjacent cells using the same frequency band, in the network. Ability to supporting frequency reuse 1 can be achieved by

1- Controlling power and its directivity in different part of the cell, around centre and the edge

2- Support for low rate coding

3- Employing HARQ (hybrid ARQ), a combination of forward error-correcting code and ARQ error control, to ensure the transmission reliability
WiMAX system is an IP based technology which has support for both internet protocol formats IPV4 and IPV6. In WiMAX system, the base station allocate resources based on bandwidth request of terminals and QoS (Quality of service), providing sufficient bandwidth for the applications depending on the type of users connection, parameters. Security provided by mutual authentication of mobile and network in presence of data encryption with keys provided by the base station to add extra security to the system.

A major difference between LTE and WiMAX is that LTE will require the use of a SIM in order to operate. This will be convenient for cellular devices that are already compatible with a SIM, but not for laptops and other technological devices without SIM interfaces. WiMAX however, does not require a SIM or any other hardware token. Therefore, all authentication methods used to identify a customer’s device will be easily entered into several devices. The one WiMAX device can be configured to use one set of customer ID settings, enabling it to be easily used for multiple WiMAX networks in different locations, or within the same network but for different customer identities.

The difference between mobile WiMAX and fixed WiMAX besides the mobility support of mobile WiMAX, (Mobile WiMAX offering full mobility support as compared to fix WiMAX), is that mobile WiMAX is using a scalable OFDMA mode, while fix WiMAX is using an OFDM 256 mode. The two modes are not compatible with each other. The difference between the two modes is how they deal with the channel characteristics as channel in mobile environments are varying very rapidly [19].

### 2.10.1 Advantages

- High performance for both video and data services
- Wide coverage with maintaining of high data rate
- Reliable security with strong encryption
2.10.2 Disadvantages

- Operating at around 50Km radius increases the bit error rate resulting to lower signal strength.
- WiMAX is very power hungry
- High running and installation costs
- Lack of compatibility with other wireless mobile technologies, e.g., 3G or GSM

2.11 High Speed Packet Access (HSPA)

HSPA was the first step towards 4G capabilities of supporting voice and data with comparatively higher data transfer rate and low latency.
A substantial latency fall happens after the introduction of WCDMA through LTE which mostly indebted to smarter network architecture such as the new SAE technology in LTE, (system architecture evolution) which has distributed more intelligence and processing power at the lower level of the network such as base stations and by doing this many calls and data won’t be routed through the core network but instead take more faster routes to the destination in adjacent cells or base stations.

HSPA is an improvement of 3G UMTS technology. The improvement made by enhancing WCDMA (wideband code division multiple access) through introduction of HSDPA (High Speed Downlink Packet Access) for downlink which provides 3 times the capacity of 3G UMTS of up to 14 Mbps and then HSUPA (High Speed Upload Packet Access) for the uplink with data rate of up to 5.7 Mbps.

Despite HSPA using many similar technologies as mobile WiMAX to increase throughput and spectral efficiency never the less the cell size in HSPA compare to WiMAX are 2 to 4 times larger for the same performance.

HSPA is a packet switched based standard called even 3.5 G or transitional 3G for improving 3G UMTS further towards the 4G standard’s specification. HSPA achieved its high data rate and
spectral efficiency through utilizing new technologies such as higher order modulation, 16QAM for the down link and QPSK (Quadrature Phase Shift Keying) for the uplink, and variable coding [24] [17] [1].

2.11.1 Advantages

- Fast link adaptation, process of choosing and fast updating optimum modulation and coding rate.
- Fast scheduling to prioritize user with best instantaneous channel condition
- Using MIMO to enhance data rate and channel capacity
- It prepares the transition to all IP based systems such as LTE
- Cost efficient when upgrade from 3G to HSPA in many cases is only a software upgrade

2.11.2 Disadvantages

- HSPA service is not capable to share the identical carrier frequency resources efficiently. Due to this reason, a system band needs a switch in the system to increase its delay time.
- The bandwidth is limited to 5 MHz and is has not been able to utilize flexible spectrum allocation
2.12 HSPA+

HSPA+ is a further improvement of HSPA towards 4G standard by using radio technologies available through more powerful digital signal processors. Enhancing the HSPA would allow taking the full advantage of existing CDMA based radio interface which could considerably extent the life of existed hardware and infrastructure before migrating to an OFDM platform. This was possible because performances of CDMA and OFDMA, employed in LTE, techniques were very comparable in a reduced channel bandwidth of 5 MHz. Upgrading HSPA to HSPA+ was a step in the right direction in order to have a smooth transition to LTE with all operations for voice and data in only packet switched mode and to insure the backward compatibility of the system as well. HSPA+ is providing data rates of up to 168 Mbps in the down link and 22 Mbps in the uplink by employing 4x4 MIMO.

**HSPA+ peak data rates (Mbps)**

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>Upload Mbps</th>
<th>Download MBps</th>
</tr>
</thead>
<tbody>
<tr>
<td>5MHz</td>
<td>MIMO 4x4 68.988</td>
<td>MIMO 2x2 42.19</td>
</tr>
<tr>
<td>10MHz</td>
<td>MIMO 4x4 137.976</td>
<td>MIMO 4x4 168.76</td>
</tr>
<tr>
<td>20MHz</td>
<td>MIMO 4x4 275.972</td>
<td>MIMO 4x4 337.52</td>
</tr>
</tbody>
</table>

2.12.1 Advantages

- Shorter latency time compare to HSPA.
- Backward compatibility and easy transition to LTE
• Higher peak data rate, greater spectral efficiency, shorter delays and lower costs in data transmission compare to HSPA.

2.12.2 Disadvantages

• It is difficult to implement HSPA+ in a flat architecture for future compatibility with LTE

• Implementing multiple carriers require network synchronization

2.13 Long-Term Evolution (LTE)

3GPP (Third generation partnership project) is the standardization body behind GSM/UMTS/HSPA and evolved HSPA (HSPA+). Increasing demands for wireless services and applications required a faster network and faster radio interface and more cost efficient solutions in order to satisfy market demands. 3GPP organization has outlined the requirement for a new technology to achieve these goals. The new technology is using Evolved UMTS terrestrial radio access (E-UTRA) for its radio air interface and Evolved UMTS terrestrial radio access network (E-UTRAN) for its core network and it is called LTE (Long-term evolution) 4G also known as UMTS long term evolution or Evolved UTRA or Evolved UTRAN.

To achieve higher data rate a new standard called UMTS (universal mobile telecommunication system) based on W-CDMA (wideband code division multiple access) has been developed capable of both packet & circuit switching connections offering a data rate of 384 Kbps. UMTS was sort of a hybrid by using packet switched connections for data and circuit switched connections for real
time uses. Then out of demands for greater data capacity and more spectral efficiency and lower latency and lower user costs, LTE (Long Term Evolution) a purely IP based system based on OFDMA (Orthogonal frequency division multiple access) has been developed.

OFDMA more accurately is an OFDM technique adapted to multi users. OFDM is not a multiple access scheme but only allocate the channel/subcarrier at any time to only one user. There are techniques such as time division multiple access (TDMA) with separate time slots or frequency division multiple access (FDMA) with separate channels to allow OFDM for multiple users but none of the above are as spectrally efficient as OFDMA which accommodate more users on the same channel at the same time. The scheme allocates subcarriers to users so that all users can transmit and receive at the same time on the same channel.

These technologies stands for LTEs high data rate and its’ capability against interference. It employs 64 QAM (Quadrature Amplitude Modulation Technique) which combines both ASK (Amplitude Shift Keying) and PSK (Phase Shift Keying). This scheme allows a data transmission rate twice as faster as pulse amplitude modulation (PAM). LTE uses merely IP protocol for all of its connection services which makes it more compatible with WWW and services offers on the internet such as VOIP. LTE have taken the wireless communication to a different level with its high capacity and seamless mobility.

2.13.13GPP

3GPP or the 3rd generation partnership project was an agreement to standardize telecommunication standards for 3rd generation mobile systems based on evolved GSM network and UTRA (Universal Terrestrial Radio Access) by bringing major standard organizations to form a
partnership known as “Organizational Partners” in 1998. The LTE specifications in Release 8 and later documents does not satisfy the technical requirement of a 4G standard set by 3GPP but due to the advancement that LTE, WiMAX and HSPA+ have introduced compared to 3G standard, it was decided to be called 4G system while LTE-advanced and WiMAX-advanced are to be called “True 4G” systems. LTE advancement for radio access technology could not have been achieved without an equal advancement in the core network. The evolution in the core network side known as SAE (System Architecture Evolution) is about spreading more intelligence and processing power across the network by interconnecting base stations and giving them more autonomy to perform more functionality which will provide a lower latency and faster data routing to comply with LTE demands.
2.13.2 3GPP2

3GPP2 was introduced by the International Telecommunication Union's (ITU) International Mobile Telecommunications “IMT-2000” initiative. 3GPP, the organization that defined UMTS as the 3G upgrade of GSM and LTE as the 4G upgrade of UMTS, is like a sister project of 3GPP2, the organization that defined CDMA2000 which was the 3G upgrade of CDMA, which makes it possible to reach an agreement on interworking between the two standards to facilitate global roaming and effective network services which are independent of location. [3GPP] [24][25].

2.13.3 Advantages:

- LTE offers flexible channel bandwidth of 1.4, 3, 5, 10, 15 or 20 MHz plus offers an optimized capacity for travelling speeds of 15 km/h up to 500km/h.
- LTE delivers improvement in the end user experience by reducing latency which improves interactive and real time application experiences.
- The increased spectral flexibility and efficiency, increased capacity and simple network architecture offer effective cost proposition for LTE technology.
- 4G LTE employs security measures such as: Universal Integrated Circuit Card (UICC), Subscriber Identity Module (SIM), and symmetric key confirmation by means of 128-bit keys.

2.13.4 Disadvantages:
- Use of MIMO technology in LTE requires additional antennas at the base station and new handsets to benefit from the new technology.
- There is high start up cost as well as upgrading which requires new equipments that needs to be installed as well.

2.14 UWB (Ultra Wide Band)

UWB technology uses low power, very short pulses which results in high bandwidth, short range communication using a wide radio spectrum. UWB is a carrier less signal that transmit information over a wide bandwidth, i.e., more than 500MHz and operates at ranges 3.1 to 10.6 GHZ. UWB has a high channel capacity increasing linearly with the bandwidth according to Shannon’s formula $C = W \log_2 (1 + SNR)$ which makes UWB a very good technology for short range wireless devices such as wireless USB. UWB is one of the modern technologies that use both short and medium range communication with various throughputs. Because of the short pulse duration of the signal, it allows high accuracy in the estimated arrival time while the wideband characteristic of the signal makes it less vulnerable to multipath interference or jamming. Moreover low power consumption and low complexity of Ultra-Wideband transceiver makes it more cost effective and more suitable for autonomous systems/sensors with power constraints. Until recently UWB has been used in radar based application through its ability to see through obstacles and under surfaces but with advances in sensors, processors, and wireless devices some other applications such as Wireless Sensor Networks (WSN), a large group of sensor nodes with each sensor equipped with its own processor and radio transceiver for interconnection, has emerged. Combining wireless sensor with UWB location precision capabilities allows a variety of
applications for, e.g., in automatic control systems in factories or monitoring and measuring of some concerned values.

UWB signals resembles IR signals in using short duration pulses and it’s natural to use the same modulation technique called PPM or BPSK besides other modulation techniques such as OFDM or DSSS [12] [27] [31].

1.14.1 Advantages:

- UWB support high data throughput and provides multiple-access.
- Ultra short signal in nano-scale range has several advantages.
  1. They have capability of penetrating through obstacles.
  2. Fine precision ranging in the centimetre range
  3. Immune from multipath interference and jamming.
- UWB’s carrierless transmission allows for low complexity and small hardware

1.14.2 Disadvantages:

- UWB receivers have long synchronization time and need to be complex enough to deal with multipath channels natural to short pulse signals.
- UWB antennas are very complex to manufacture due to requirements of UWB system.
- Complex signal processing is required for multiplexing, beamforming, and recover data from noisy environment
• Wide bandwidth and low power make channel characterization a very difficult task

2.15 UMB (Ultra Mobile Broadband)

The 3GPP2 is the organization that defined CDMA2000 as the 3G upgrade of CDMAOne and the UMB as 4G upgrade of CDMA2000. Even though UMB was the natural upgrade for CDMA2000 standards but due to market favouring LTE it was abandoned even though the underlying technologies were similar. LTE is now responsible for backward compatibility towards CDMA2000. Both UMB and LTE are based on Internet TCP/IP technologies, OFDM, MIMO and using System Architecture Evolution (SAE) technologies and share many vital characteristics even though they are from different standards. Mobile communication using fourth generation technology has an objective of providing data and voice over the IP services which leaves only one solution for network design and that is packet-switched, IP-based network architecture.

UMB achieves very high data rates of around 275 Mbps for the downlink, and 75Mbps for the uplink with a scalable bandwidth between 1.25-20MHz using combined air interface techniques of CDMA, OFDM, TDM, FDD, SDMA and OFDMA.

2.15.1 Advantages:

• Low latency, seamless handoff, low overhead signalling to increase spectral efficiency and high cell capacity
• Low power consumption

2.15.2 Disadvantages:

• It has been abandoned by major companies in favour of LTE

3. CHAPTER 3

Chapter three presents the results and findings of the study with their corresponding discussions. These results are presented in logical manners with the help of tabular and graphical presentations.

3.1 Results and Discussion

In this study, the term “generations” was frequently used as a reference to different stages in cellular development. 1G, First generation technology commenced in 1980s and was analogue in
nature. 2G, Second generation, expanded subscribers’ capacity by deploying digital standards. CDMA systems and Global System for Mobile Communications (GSM) were the highly popular 2G standards. 3G, Third generation technology, brought more CDMA developments such as WCDMA/UMTS that enhanced data rate to 2 Mbps. 3G had greater data rates due to recent evolution such as EV-DO or HSDPA/HSUPA/HSPA+ standards capable of extending data rates from 14 Mbps in download in release 5 to 336 in download in release 11 of 3GPP with employing of 2X2 MIMO, 8 carriers, 40 MHz bandwidth and 64 QAM. 4G technologies have already been introduced to us in different standards followed by WiMAX, UMB, and LTE. UMB has abandoned in favour of LTE and WiMAX did not become very popular with network providers even though WiMAX, based on Wireless Metropolitan Area Networking (WMAN), provides very high data throughput over long distance in a point to multipoint. In addition, it can provide wireless services up to 20 or 30 miles away from the base station.

LTE has gained the requirements of fourth-generation mobile networks for both existing 3GPP/3GPP2 standards. Many wireless communication industries are focused on deploying the LTE systems, with respect to its features and capabilities. Firstly, LTE was found to be based on OFDMA modulation technique and deployed for accessing multiple subscribers in one channel. Secondly, LTE is flexible, that is, it can be configured so as to ensure its operation on different channel bandwidths. The common channel sizes were found to be 1.4, 3, 5, 10 and 20MHz. Number of sub carriers used by OFDM varies with the bandwidth. Sub carriers are modulated using QPSK, the 64QAM or 16QAM.

From the analysis, WiMAX was seen to be as good as LTE technology [9] [19]. Both technologies are based on Orthogonal Frequency Division Multiple Access (OFDMA) and both appear to have identical goals for enabling worldwide wireless data network connectivity for laptops, cell phones,
and other computing devices. The only difference is that WiMAX technology is designed specifically for broadband access. WiMAX standard was originally meant for wireless technology alternative to cable TV internet connection (DSL) [10]. IEEE had originally standardized WiMAX as 802.16 or fixed WiMAX. Later in 2005, a mobile version that was designated 802.16e became standardized.

UMB/LTE has certain advantages over WiMAX, UMB/LTE provides much greater mobility service in terms of seamless handoffs, robust frequency reuse and adaptive interference management as compared to mobile-WIMAX. UMB/LTE has about 2 times more data spectral efficiency over WIMAX. UMB/LTE, (4G) technologies have developed for mobile wireless services while WIMAX on the contrary was developed for fixed wireless access and much later mobility was added to it. In terms of technological comparisons for mobile applications, UMB/LTE poses a better solution than Mobile-WIMAX.

Bluetooth and Wi-Fi have various applications in today's homes, offices, which creates a set up for network connectivity, printing, or transferring of files. Wi-Fi is intended as a replacement for cabling in general local area network access with range much greater than Bluetooth. On the other hand Bluetooth and its application are outlined as WPAN, (Wireless Personal Area Network). Bluetooth is a replacement for cabling in a variety of personally carried applications in any environment.

When we compare 3G and Wi-Fi, these two technologies basically reflect different services and architectural design goals but both has attracted a lot of customers attention for providing broadband wireless access to the Internet. Wi-Fi refers to IEEE 802.11 wireless Ethernet standard to support wireless LANs whereas 3G refers to the collection of third generation mobile technologies which offer integrated data and voice across mobile networks. Capacity and quality in
3G networks have further improved with high speed access technologies like High Speed Downlink Packet Access (HSDPA).

Following table is the comparison table of wireless technologies we have discussed thus far. The table highlights some characteristics of these technologies such as, network coverage, data rate, and frequency.

## Wireless Technologies Comparison Table

<table>
<thead>
<tr>
<th>Technology</th>
<th>Standard</th>
<th>Frequency GHz</th>
<th>Speed Mbps</th>
<th>Range m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluetooth</td>
<td>802.15</td>
<td>2.45</td>
<td>0.72</td>
<td>10</td>
</tr>
<tr>
<td>Infrared</td>
<td>IrDa-(S/M/F)IR</td>
<td>10 - 18</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Wi-Fi</td>
<td>IEEE 802.11a</td>
<td>5</td>
<td>54</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>IEEE 802.11b</td>
<td>2.4</td>
<td>11</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>IEEE 802.11g</td>
<td>2.4</td>
<td>54</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>IEEE 802.11n</td>
<td>2.4 / 5</td>
<td>600</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>IEEE 802.11ac</td>
<td>5</td>
<td>Up to 1300</td>
<td>Up to 200</td>
</tr>
<tr>
<td></td>
<td>IEEE 802.11ad</td>
<td>2.4 / 5 / 60</td>
<td>Up to 7000</td>
<td>10</td>
</tr>
<tr>
<td>WIMAX</td>
<td>IEEE 802.16</td>
<td>2 - 66</td>
<td>365 up to 1000</td>
<td>50,000</td>
</tr>
<tr>
<td>GSM</td>
<td>2G</td>
<td>890-915 mobile 935-960 BS</td>
<td>0.010 - 0.384</td>
<td>550</td>
</tr>
<tr>
<td>HSPA+</td>
<td>3G</td>
<td>0.850 – 1.9, 0.9 - 2.1</td>
<td>336</td>
<td>440</td>
</tr>
<tr>
<td>LTE</td>
<td>3.5G</td>
<td>0.8, 0.9, 1.8, 2.1, 2.6, 3.5, 3.7</td>
<td>1,000</td>
<td>50,000</td>
</tr>
<tr>
<td>LTE advanced</td>
<td>4G</td>
<td>0.8, 0.9, 1.8, 2.1, 2.6, 3.5, 3.7</td>
<td>3,000</td>
<td>Up to 100,000</td>
</tr>
<tr>
<td>UWB</td>
<td>IEEE 802.15 3c</td>
<td>3.1 – 10.6</td>
<td>2000</td>
<td>10 - 20</td>
</tr>
<tr>
<td>UMB</td>
<td>4G</td>
<td>0.850</td>
<td>80 – 300</td>
<td>85,000 - 90,000</td>
</tr>
</tbody>
</table>
3.2 Implications

The standards and systems for wireless communication ranging from Bluetooth technology for moderate rate communication over a short range to the fourth generation (4G) LTE system for high data rates and long range communication between mobile devices were covered in this overview. This overview was done to identify modern communication systems and standards such as Bluetooth wireless technology, Wireless local area network (WLAN), GSM, High Speed Packet Access (HSPA), Long-Term Evolution (LTE), Mobile WiMAX, Ultra Wide Band (UWB) technology and Ultra Mobile Broadband (UMB). What was covered was just a part of all relevant literature relating to existing standards and systems for wireless communication.

Recommendation to industry to avoid spectral congestion is to move to higher frequencies where spectral space is not limited. Major benefit on high frequencies depend on the size of the antenna, which permits many elements of an antenna to form a common structure in order to create phased arrays that has very high gain and that can enhance receiving and transmitting power. IEEE 802.11ad standard using 60-GHz band, target commercial and consumer applications.

Due to the absence of clarity on some existing standards and systems for wireless communication this study recommends:

- Systems beyond IMT-2000 are required to be identified for packet-based network, commonly for 2G, 3G and 4G radio access. Using these mode operators may be able to rollout radio access as complement to deploy radio technologies and ensure that subscribers can get connected from anywhere at any time.
• Another area that needs a follow up is the performance of IEEE 802.11a WLAN standard, which acts over slow, frequency selective, and Ricean fading channels that uses Viterbi decoding algorithm.

• Find better modulation schemes to enhance the throughput and reduce interference and less power consumptions.

• There is also a need of putting more effort in harmonizing the existing standards to the wireless systems being developed.

• In order to meet the challenges of wireless networks, there should be compatibility in wireless technologies so the elements such as issues of interference, interoperability, power control and security etc may not persist and each of the technology can meet the IEEE standard.

• The wireless industry has been taking essential measures for offering Location Based Services (LBS), i.e., to provide information specific to location but, despite of several different wireless technologies, revenues from commercial LBS are less than expected. It is due to the performance limitations that do not allow wireless technologies to support some of the more demanding applications.
4. **CHAPTER 4**

Chapter four presents an overall summary of the study as well as the generalizations or conclusions that have been drawn from all the data gathered and interpreted.

### 4.1 Conclusion

Literature on some existing standards and systems for wireless communication was reviewed to provide an overview of these standards and systems for wireless communication. Two fundamental aspects which have raised demand for wireless communication are:

1. Faster and more reliable wireless system
2. Enhancing productivity.

Dominant wireless standard was found to be the Global System for Mobile Communications (GSM), which has more than 3.5 billion subscribers globally. GSM was the first digital wireless mobile system and soon became very popular for its enhanced capacity and reliability but still way too slow compared to wired internet network. The answer for more capacity and reliability comes in the form of enhanced GSM, 3.5G or HSPA, and LTE. LTE’s impact on wireless mobile was as big as GSM was on analog mobile wireless in comparison.

### 4.2 The Dissertation as a Learning Experience

By proper examination of the information in this dissertation, this study may address questions regarding existing standards and systems for wireless communication. From this study readers and
learners can easily get a proportional overview of each of the mentioned wireless technologies and systems which will give them an idea about which technology and system to look for according to their requirements, ease and reliability.
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