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4G WIRELESS COMMUNICATION TECHNOLOGY: AN INTROSPECTION

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Abstract:
4G wireless communication technology is fully IP based packet switched communication network which provides high speed internet access at anytime, anywhere and anyhow with seamless mobility to end-user. It is integrated wireless solution for IP based and non IP based devices. It provides 100Mbps and 1Gbps data rate respectively, in outdoor and indoor environment with high quality of service, high degree of security, affordable cost and one billing. This paper explores what 4G wireless communication technology is , along with some of the aspects in order to fully figure out the architecture, application, advantages , underlying technologies , security concerns and challenges of effectively implementing 4G wireless communication technology.

INTRODUCTION

We are living in the age of wireless technology. The use of mobile has touched almost every sphere of our life. The mobile handset has become integral part of our life. According to TRAI's monthly telecom subscription, India has total 996.66 million subscribers in September 2015. The Compound Annual Growth Rate (CGRA) for mobile subscription is nearly 10.2%.Figure1 shows the growth of mobile subscription in India from December- 2014 to August2015. The invention of wireless mobile technology has greatly revolutionized the telecommunication industries. The vast world has become just like small village.

After the much used 2G and 3G network technologies the 4G technology consists of all basic standard of both of these with advanced modification and changes with end user centric design approach. $g is generally described as MAGIC (Mobile Multimedia Any time anywhere Global mobility support, Integrated Wireless solution and Customised personal service). IEEE (Institute of Electrical and e\Electronics Engineers, USA) officially called 4G as B3G (Beyond 3G) According ITU (International Telecommunication Union) , the 4G system is capable of transmitting data with 100 Mbps speed in mobile phones and 1Gbps in stationary local networks. The emergent 4G technologies such as Wi-MAX(Wireless Interoperability for Microwave Access) and LTE (Long Term Evolution), LTE Advance are stronger enough to provide high QoS and vast coverage range than Wi-Fi.Bharati Airtel launched India's first 4 G service using TDLTE technology in Kolkota on April 10,2012.

Figure1: Growth of Indian Mobile subscription

THE EVOLUTION TO 4G

The cellular networks are evolving through several generations (figure 2). The first generation (1G) wireless mobile communication network was analog system which was used for public voice service with the speed up to 2.4kbps. The second generation (2G) is based on digital technology and network infrastructure. As compared to the first generation, the second generation can support text messaging. Its success and the growth of demand for online information via the internet prompted the development of cellular wireless system with improved data connectivity, which ultimately lead to the third generation systems (3G).

3G systems refer to the developing technology standards for the next generation of mobile communications systems. One of the main goals of the standardization efforts of 3G is to create a universal infrastructure that is able to support existing and future services. This requires that the infrastructure be designed so that it can evolve as technology changes, without compromising the existing services on the existing networks. Separation of access technology, transport technology, service technology and user application from each other make this demanding requirement possible.

The 4th Generation (4G) wireless technology is considered to be an extension of 3G technology. It integrate current existing 3G cellular networks (i.e., OFDM, CDMA2000, WCDMA and TD_SCDMA) and Wi-Fi (i.e. Wireless LAN) networks with fixed internet to support wireless mobile internet as the same quality of service as fixed internet.

The evolution 1G to 4G with their important features is schematically shown in figure2

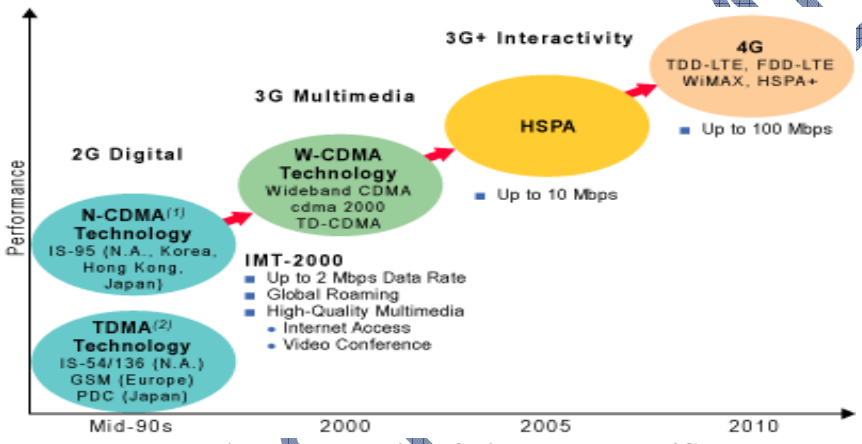

Figure 2: Evolution of wireless network 4G

The table 1 shows the comparison of 1G to 5G wireless technologies with reference to various parameters

Table1 : Comparison of 1G to 5G wireless technologies

Generation→ Features↓	1G	2G	3G	4G	5G
Deployment	1970 – 1980	1990 - 2001	2001-2010	2011	2015-20 onwards
Data Rates	2kbps	14.4-64kbps	2Mbps	200 Mbps to 1 Gbps	1Gbps and higher
Technology	Analog Cellular Technology	Digital Cellular Technology: Digital narrow band circuit data Packet data	Digital Broadband Packet data: CDMA 2000 EVDO UMTS EDGE	Digital Broadband Packet data: WiMax LTE Wi-Fi	wwww Unified IP seamless combination of broadband LAN PAN MAN WLAN
Service	Analog voice service No data service	Digital voice with higher clarity SMS, MMS Higher capacity packetized data	Enhanced audio video streaming video conferencing support Web browsing at higher speeds IPTV support	Enhanced audio, video streaming IP telephony HD mobile TV	Dynamic Information access, Wearable devices with AI Capabilities
Multiplexing Switching	FDMA	TDMA, CDMA	CDMA	CDMA	CDMA
Core Network	PSTN	PSTN	Packet N/W	Internet	Internet
Standards	MTS AMTS IMTS	2G:GSM 2.5:GPRS 2.75:EDGE	IMT-2000 3.5G-HSDPA 3.75G:HSUPA	Single unified standard LTE, WiMAX	Single unified standard
WEB Standard		www	www(IPv4)	www (IPv4)	wwww (IPv6)
Handoff	Horizontal only	Horizontal only	Horizontal & Vertical	Horizontal & Vertical	Horizontal & Vertical
Shortfalls	Low capacity, Unreliable handoff, Poor voice links, Less secure	Digital signals were reliant on location & proximity, required strong digital signals to help mobile phones	Need to accommodate higher network capacity	Being deployed	Yet to be implemented

OBJECTIVES AND APPROACHES OF 4G

4G is being developed to accommodate the quality of service (QoS) and rate, requirements set by forthcoming applications like wireless broadband access, Multimedia Messaging Service, video chat, mobile TV, High definition TV content, Digital Video Broadcasting (DVB), minimal service like voice and data, and other streaming services for anytime-anywhere". The4G working group has defined the following as objectives of the 4G wireless communication standard: A spectrally efficient system (in bits/s/Hz and bits/s/Hz/site) High network capacity: more simultaneous users per cell_ A nominal data rate of 100 Mbit/s while the client physically move sat high speeds relative to the station, and 1 Gbit/s while client and Station are in relatively fixed positions as defined by the ITU-R._ A data rate of at least 100 Mbit/s between any two points in the world

_ Smooth handover_ across heterogeneous networks

_ Seamless connectivity and global roaming across multiple networks

_ High quality of service for next generation multimedia support (real-time audio, high speed data, HDTV video content, mobile TV, etc.)_ Interoperability with existing wireless standards, and all IP, packet switched network

REASONS TO HAVE 4G

One of the major reason of 3G being unable to repeat the success story of 2G was provision of only few additional services over 2G.It was not encouraging enough for the customers to change their equipment's. User-centric approach for the design of 4G to avoid mismatch between user's expectations and services provided by 4G.The important features of 4G which caters to the end user's expectations are as follows:

1. Support interactive multimedia services: teleconferencing, wireless Internet, etc

2. The applications developed to avail the services are highly user friendly

3. By configuring the operational mode of their devices, the user can have flexibility to filter the data and services as per his preferences.

4. Wider bandwidths, higher down load speeds of about 1Gbps in LAN and 100 Mbps in WAN which is about 250 times greater than 3Gwireless network

5. Multiple standards of 3G restrict the user's mobility and interoperation across different networks. 4G targets at providing a unified global standard which will facilitate global mobility and service portability. In other words, end user can subscribe to different services from different service providers using the same mobile device.

6. Due to intelligent networking seamless hand-over from any network to any network take place easily.

7. Global mobility and service portability.

8. Low cost.-4G not require to develop completely new system rather built on the top of the existing network which makes 4G much cheaper than the 3G

9. Scalability of mobile networks i.e. the ability to handle the increasing number of users and services.4G uses IPv6 addressing scheme which will support large number of wireless devices eliminating the need for Network Address Translation (NAT)

10. Lower power consumption as compare to 2G and 3G

11. TV, internet, phone, radio, home environment sensors all reachable through one device | the cell phone.

12. High bandwidth and better response time which is 10 times better than 3G.

13. Less time required to build 4G system. It uses the same tower and optical fiber cable as 3G.They only have to upgrade the 3G tower with 4G components.

4G NETWORKARCHITECTURE (ELEMENTS OF THE LTE SYSTEM)

LTE encompasses the evolution of

- Radio access through E-UTRAN (e Node B)
- Non-radio aspects under the term System Architecture Evolution (SAE)

Entire system composed of LTE & SAE is called Evolved Packet System (EPS)

At a high level a LTE network is composed of

1. Access network comprised of E-UTRAN
2. Core Network called Evolved Packet Core (EPC)
3. UE – User Equipment used to connect to the EPS (Evolved Packet System). This is an LTE capable UE
4. The LTE network is comprised of Access Network and Core Network.

Fig.3 shows the LTE network elements.

ACCESS NETWORK:

ENB (e Node B) – The evolved RAN consists of single node, the e Node B that interfaces with UE. The e Node B hosts the PHY, MAC, RLC & RRC layers. It handles radio resource management & scheduling.

CORE NETWORK (EVOLVED PACKET CORE-EPC)

- MME (Mobility Management Entity) – Performs paging, chooses the SGW during UE attach
- S-GW (Serving Gateway) – routes & and forwards user data packets
  - P-GW (Packet Gateway) – provides connectivity between the UE and the external packet networks.

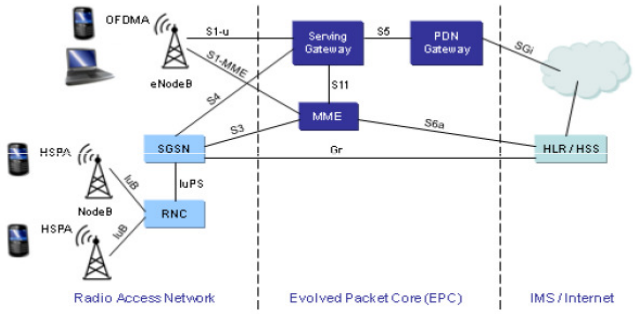

Figure3:LTE Network Elements

WIRELESS TECHNOLOGIES USED IN 4G

- OFDM /OFDMA
- UWB
- MILLIMETER WIRELES
- SMART ANTENNAS
- MIMO
- SDR
- IPv6 Support

ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

OFDM, a form of multicarrier modulation, works by dividing the data stream for transmission at a bandwidth B into N multiple and parallel bit streams, spaced B/N apart. Each of the parallel bit streams has a much lower bit rate than the original bit stream, but their summation can provide very high data rates. An OFDM transmitter accepts data from an IP network, converting and encoding the data prior to modulation. An IFFT (Inverse Fast Fourier Transform) transforms the OFDM signal into an IF analog signal, which is sent to RF trans-receiver. The receiver circuit reconstructs the data by reversing this process. With Orthogonal sub carriers, the receiver can separate and process each sub carrier without interference from other sub carriers. More impervious to fading and multi path delays than other wireless transmission techniques, OFDM provides better link and communication quality. OFDMA is the multiple access technique using OFDM, which is used for downlink transmission of symbols for achieving high spectra efficiency. Figure 4 shows how available bandwidth is divided into very many narrow bands and transmitted in parallel fashion.

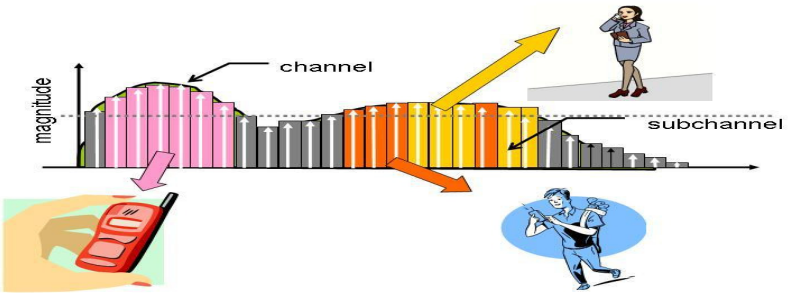

Figure4: OFDMA technique

MILLIMETER WIRELESS

Using the millimeter-wave band(above 4 GHz) for wireless service is particularly interesting, due to the availability in this region of bandwidth resources committed by the governments of some countries to unlicensed cellular and other wireless applications. If deployed in a 4G system, millimeter wireless would constitute only one of several frequency bands, with the 5GHz band most likely dominant.

ULTRA WIDE BAND (UWB)

A UWB transmitter spreads its signal over a wide portion of the RF spectrum, generally 1GHZ wide or more, above 3.1GHZ.The FCC has chosen UWB frequencies to minimize interference to other commonly used equipment, such as televisions and radios. This frequency range also puts UWB equipment above the 2.4GHZ range of microwave ovens and modern cordless phones, but below 802.11 a wireless Ethernet, which operates at 5 GHZ. Traditional RF equipment uses an RF carrier to transmit a modulated signal in the frequency domain, moving the signal from a base band to the carrier frequency the transmitter uses.UWB is "carrier free", since the technology works by modulating a pulse, on order of tens of microwatts, resulting in a waveform occupying a very wide frequency domain.

One distinct advantage of UWB is its immunity to multipath distortion and interference. Multi path propagation occurs when a transmitted signal takes different paths when propagating from source to destination. The various paths are caused by the signal bouncing off objects between the transmitter and receiver. One part of the signal may go directly to the receiver while another deflected part will encounter delay and take longer to reach the receiver. Multi path delay causes the information symbols in the signal to overlap, confusing the receiver this is known as inter symbol interference (ISI).

The short time span of UWB waveforms typically hundreds of picoseconds to a few nanoseconds means that delays caused by the transmitted signal bouncing off objects are much longer than the width of the original UWB pulse, virtually eliminating ISI form overlapping signals. This makes UWB technology partially useful for infrastructure and mobile communications applications, minimizing S/N reduction and bit errors.

SMART ANTENNAS

A smart antenna system comprises multiple antenna elements with single processing to automatically optimize the antennas radiation (Transmitter) and/reception (receiver)patterns in response to the signal environment. One smart antenna variation in particular, MIMO, shows promise in 4G systems, particularly since the antenna systems at both transmitter and receiver are usually a limiting factor when attempting to support increased data rates. Smart antenna allow the same radio frequency to be used for other user without worry of interference. It follows the user as they move as shown in the fig 5.

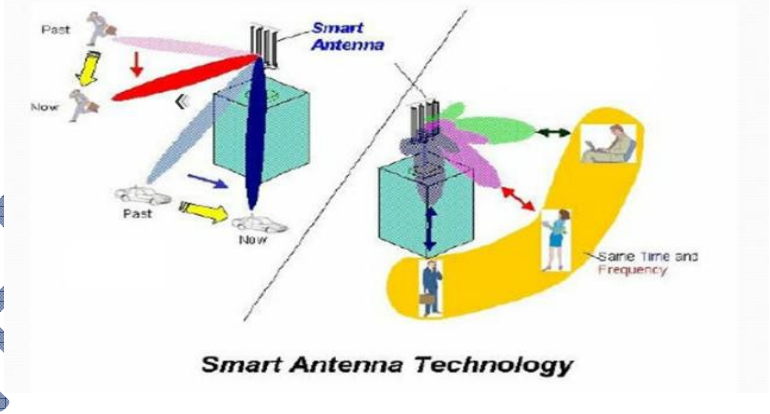

Figure 5: Smart antenna technology

MIMO (MULTI-INPUT MULTI-OUTPUT)

It is a smart antenna system where 'smartness' is considered at both transmitter and receiver. MIMO represents space-division multiplexing (SDM) – information signals are multiplexed on specially Separated N multiple antennas and received on M antennas. Field experiments by several organizations have shown that a MIMO system, combined with adaptive coding and modulation, interference cancellation, and beam-forming technologies, can boost useful channel capacity by at least an order of magnitude. MIMO antenna system is multiple antenna system used at both transmitter and receiver. To improve communication performance .it increases range, quality of received signal and spectrum efficiency.

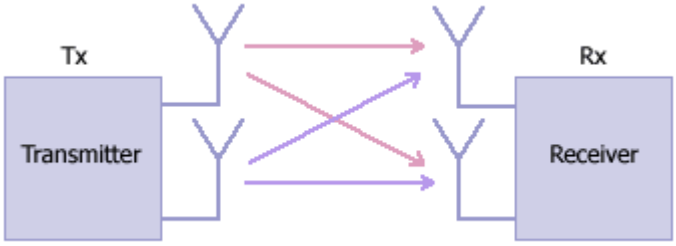

Figure 6: MIMO 2x2 systems

Multiple Input Multiple Output (MIMO), 2x2, two antennas at both the transmitter and the receiver is shown in the fig.6

SOFTWARE DEFINED RADIO (SDR)

SDR is a radio communication system implemented as software on the personal computer or embedded devices. It scans the available networks and then reconfigures itself for the selected network by downloading the software specific to that network. It is used for implementation of the multimodal, multi-band, multi-standard user terminals and base stations which allow accessibility across various wireless and wire line heterogeneous networks. There are several advantages of SDR such as flexibility in network expansion i.e. operator can expands its network infrastructure by adding few modems to base station transceiver system. It reduces the cost for development of multimodal, multiband and multi-standard user equipment's. This will benefit both the end users and the service providers. The current SDR technology is not capable of supporting the multiple networks. It should be enhanced to support multiple networks

INTERNET PROTOCOL VERSION 6 (IPV6)

It is the most recent version of the Internet Protocol (IP), the communications protocol that provides an identification and location system for computers on networks and routes traffic across the Internet. IPv6 was developed by the Internet Engineering Task Force (IETF) to deal with the long-anticipated problem of IPv4 address exhaustion. IPv6 is intended to replace IPv4. It includes 128 bits which is 4 times more than 32 bit IP address in IPv4.

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APPLICATION OF 4G TECHNOLOGY

- **Virtual presence :** For example always on connection to keep people on event.
- **Virtual navigation:** Remote data base contains the geographical representation of streets, buildings and physical characteristics of a large metropolis. Block of this database are transmitted in rapid sequence to vehicles.
- **Telegeo processing:** Queries dependent on location information of several users, in addition to temporal aspects have many applications for example GIS ,GPS. Online satellite mapping will be loaded instantly by 4G technology.
- **Crisis management:** Natural disaster can cause breakdown in communication system. In today's world it might take few weeks to restore the system but in 4G it is expected to restore such crisis issues in a few hours.
- **Telemedicine:** Remotely located patient is monitored and advised through streaming them related videos by medical consultant. Thus 4G supports remote health monitoring.
- **Multiuser video conferencing**: Subscriber can arrange multiuser video conferencing talk.
- **Ultra high speed internet access:** Internet surfing, email, video streaming, live gaming, and general web browsing is available.
- **HDTV:** HDTV channel is directly available on 4G enabled smart phone.
- **4G in normal life:** Traffic control, mobile phones, sensors on public vehicles.

CHALLENGES FACED IN MIGRATION TO 4G

The challenges faced in migration to 4G are

MULTIMODE END USER TERMINAL

The user terminal used in 4G has to interact with different access network. This may encounter several design issues such as limitation in the device size, cost, power consumption and backward compatibility to the systems. Availing 4G services require the multimode devices to discover and select the preferred wireless network. Services discovery in 4G is much more challenging than 3G. Use of SDR (Software Defined Radio) is the solution for this. SDR scans for the available network and

download the software required to interface with the selected networks. Fig 7 shows single multimode device with multiple interface accessing the different wireless network.

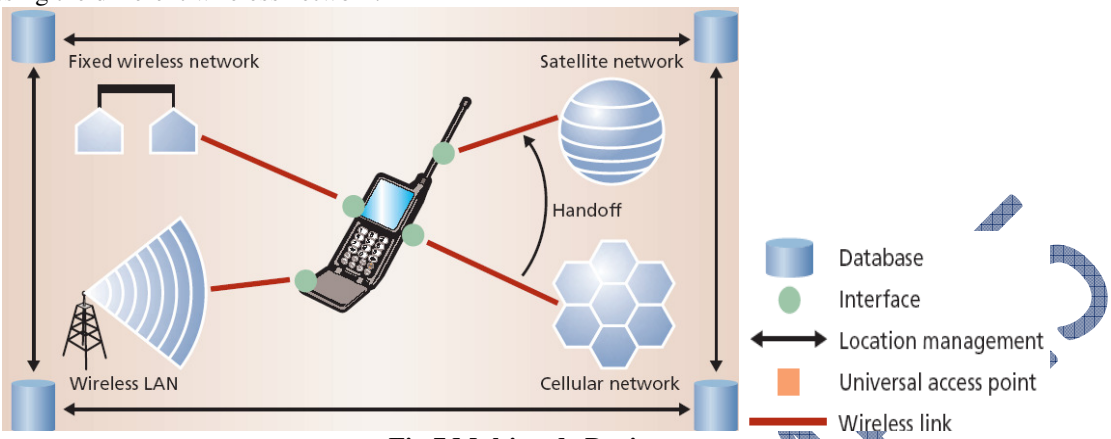

Fig 7 Multimode Device

SYSTEM DISCOVERY & SELECTION

The wireless device has the responsibility to select the wireless network which provides optimized performance and high QoS for a particular time, place and service. Due to heterogeneity of 4G networks, wireless device have to process the services, and connect to appropriate service providers. Various services provider have their own protocols which can be incompatible with each other, as well as with the user device.

Fig.8 shows a user accesses an overlay network consisting of several UAPs

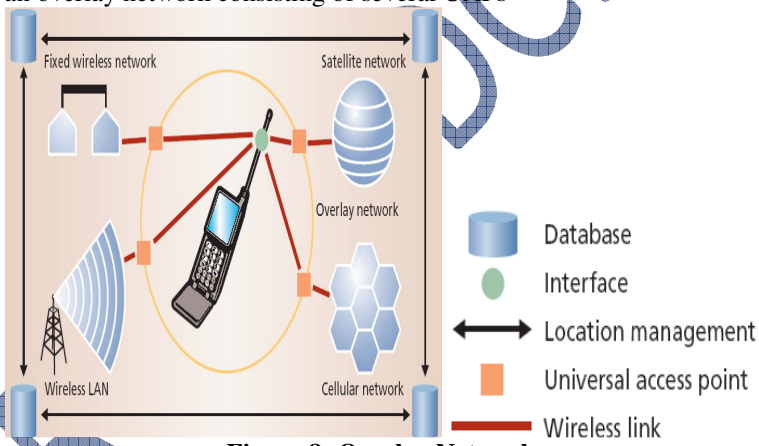

Figure 8: Overlay Network

SECURITY& PRIVACY

Data encryption and decryption method being used for 3G network are not suitable for 4G network as new devices and services are introduced for the first time in 4G networks. 4G provides very wide geographical area coverage with seamless service. The user device has to interact with different networks exchanging different types of data complicates the security and privacy issues. To overcome these security and privacy issues, the existing security & privacy method have to modify with great extent so that they will be applicable to heterogeneous 4G network.

QUALITY OF SERVICE WHILE INTEGRATING DIFFERENT DEVICES

The main challenge that 4G networks are facing is integration IP based and IP based devices, the same time maintaining very good quality of service.

SERVICE AND BILLING

Managing user accounts and billing then has become much more complicated with 4G networks and the mainly due to heterogeneity of 4G networks and the frequent interaction of service providers. The research team has addressed this concern and proposed several frameworks to handle the customers billing and user account information.

LOCATION AND HANDOFF MANAGEMENT

In 4G, user can roam across the whole geographical boundaries of wireless networks. Location management becomes critical which involves tracking the location of mobile user and maintaining information such as the authentication data, QoS capabilities, and original and current cell location. In Hand-off management it is essential to maintain ongoing communication when user moves from one cell to another within the same wireless system across different wireless systems (2G, 3G , WLAN). In doing so, hand off process faces several challenges like maintaining QoS and systems performance across the different wireless networks. Figure9 shows vertical and horizontal handoff management process.

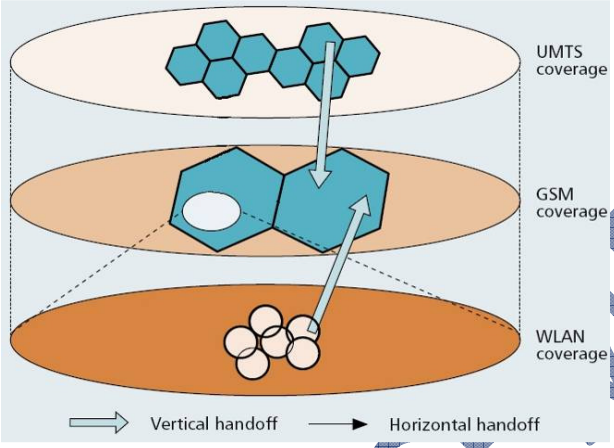

Fig 9: Handoff Management

LATENCY

Many 4G services are delay sensitive.

CONCERNING COMPLEXITY

4G networks is undoubtedly complex, as compared to 3G network. More research is required to make the network simpler.

Complex resources allocation

Management of the frequency and spatial resources in multi network, multiuser environment is complex process as compared to 3G.

INTERFERENCE

Multiple access interference control and mitigation in heterogeneous environment (co-existing air interfaces, varied terminal & services) is an issue.

POWER CONSUMPTION

By any measure power consumption in future multifunction, multi standard 4G terminals will sharply increase. Usability is seriously compromised, heat management becomes an issue.

Non compatibility of handset: It is impossible to make our current mobile handset to be compatible with 4G.

CONCLUSION

In a world going wireless the technologies with higher throughput get importance day by day.4G wireless networks not only enable more efficient, scalable, affordable, reliable wireless services but also provide wider variety of services. The advent of 4G has greatly revolutionized the field of telecommunication domain bringing the wireless experience to a completely new level. It would provide wealth of features and services making the world a smaller place to live.4G should also take lesson from the 3G's failure to capture the imagination of the end-users. Technology should not be developed for technology's sake rather it should target the end-user. Thus user-centric approach towards 4G's development is the key to its success. Though 4G is facing challenges, we believe that future research will overcome these challenges and integrate newly developed services to 4G networks, making them available to everyone, anytime, anywhere and anyhow with any wireless technology.

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