Abstract—Due to the increase in demand for speed, multimedia support and other resources, the wireless world is looking forward for a new generation technology to replace the third generation. This is where the fourth generation wireless communication comes into play. 4G wireless communication is expected to provide better speed, high capacity, lower cost and IP based services. The main aim of 4G wireless is to replace the current core technology with a single universal technology based on IP. Yet there are several challenges that inhibit the progress of 4G and researchers throughout the world are contributing their ideas to solve these challenges. This project deals with understanding the features and challenges, the proposed architectural frameworks, multimedia support and multiple access schemes for 4G.

I. INTRODUCTION

The wireless communication filed is a very fast growing area with the number of users and their demand for better resources increasing day by day. The R&D departments of many companies are working on a future technology that can meet these demands at a lower cost. 3G is necessary but not sufficient for the demands today. So the world is taking its leap towards the fourth generation wireless communication that promises to bring an end to most of the problems faced. 4G wireless is expected to be launched by 2010, but there are numerous challenges faced by researchers in achieving the desired features. Most of the ongoing researches are in the area of distributed computing, mobile agents, multimedia support etc. Some other research area is to improve the Quality of Service from the viewpoint of both the user and service providers. 4G wireless infrastructures are expected to be deployed in an environment where many other types of wireless and wired communication systems already exist. This paper is organized as follows. Section II provides a brief review of the previous generations, desired features and research challenges faced by 4G. Section III describes the core architectural framework and some architectural models proposed for 4G. Section IV provides some proposed solution for handoff mechanism for 4G. In Section V, the multiple access schemes for 4G are discussed. Section VI deal with multimedia support for 4G. Section VII gives some applications of 4G and finally section VIII gives the conclusion.

II. 4G VISION

A. Brief History of Generations

First Generation: 1G was based on analog technology and basically intended for analog phones. It was launched in the early 1980s. It introduced the first basic framework for mobile communications like the basic architecture, frequency multiplexing, roaming concept etc. Access technology used was AMPS (Advances Mobile Phone Service).

Second Generation: 2G was a revolution that marked the switching of mobile communication technology from analog to digital. It was introduced in the late 1980s and it adopted digital signal processing techniques. GSM was one of the main attractive sides of 2G and it introduced the concept of SIM (Subscriber Identity Module) cards. Main access technologies were CDMA (Code Division Multiple Access) and GSM (Global System for Mobile Communication).

2.5 Generation: 2.5 G was basically an extension of 2G with packet switching incorporated to 2G. It implemented hybrid communication which connected the internet to mobile communications.

Third Generation: The basic idea of 3G is to deploy new systems with new services instead of just provide higher bandwidth and data rate. Support for multimedia transmission is another striking feature of 3G. It employs both circuit switching and packet switching strategies. The main access technologies are CDMA (Code Division Multiple Access), WCDMA (Wideband CDMA), and TSSDMA (Time division Synchronous CDMA).

B. Limitations of 3G

Why do we need 4G? To answer this question we need to understand some of the major limitations of 3G. Some of the
reasons for a new generation of mobile communication are listed below

- Difficulty of CDMA to provide higher data rates
- Need for continuously increasing data rate and bandwidth to meet the multimedia requirements
- Limitation of spectrum and its allocation
- Inability to roam between different services
- To provide a seamless transport end-to-end mechanism
- To introduce a better system with reduced cost

C. Some main desired Features of 4G:

**High usability and global roaming:** The end user terminals should be compatible with any technology, at any time, anywhere in the world. The basic idea is that the user should be able to take his mobile to any place, for example, from a place that uses CDMA to another place that employs GSM.

**Multimedia support:** The user should be able to receive high data rate multimedia services. This demands higher bandwidth and higher data rate.

**Personalization:** This means that any type of person should be able to access the service. The service providers should be able to provide customized services to different types of users.

D. Main Challenges

To achieve the desired features listed above researches have to solve some of the main challenges that 4G is facing. The main challenges are described below

**Multimode user terminals:** In order to access different kinds of services and technologies, the user terminals should be able to configure themselves in different modes. This eliminates the need of multiple terminals. Adaptive techniques like smart antennas and software radio have been proposed for achieving terminal mobility.

**Wireless system discovery and selection:** The main idea behind this is the user terminal should be able to select the desired wireless system. The system could be LAN, GPS, GSM etc. One proposed solution for this is to use software radio approach where the terminal scans for the best available network and then it downloads the required software and configure themselves to access the particular network.

**Terminal Mobility:** This is one of the biggest issues the researchers are facing. Terminal mobility allows the user to roam across different geographical areas that uses different technologies. There are two important issues related to terminal mobility. One is location management where the system has to locate the position of the mobile for providing service. Another important issue is handoff management. In the traditional mobile systems only horizontal handoff has to be performed where as in 4G systems both horizontal and vertical handoff should be performed. As shown in figure 1, horizontal handoff is performed when a mobile moves from one cell to another and vertical handoff is performed when a mobile moves between two wireless systems. Some solutions for achieving vertical handoff have been discussed in section IV.

![Figure 1: Handoff mechanisms](image)

**Personal mobility:** Personal mobility deals with the mobility of the user rather than the user terminals. The idea behind this is, no matter where the user is located and what device he is using, he should be able to access his messages.

**Security and privacy:** The existing security measures for wireless systems are inadequate for 4G systems. The existing security systems are designed for specific services. This does not provide flexibility for the users and as flexibility is one of the main concerns for 4G, new security systems has to be introduced.

**Fault tolerance:** As we all know, fault tolerant systems are becoming more popular throughout the world. The existing wireless system structure has a tree like topology and hence if one of the components suffers damage the whole system goes down. This is not desirable in case of 4G. Hence one of the main issues is to design a fault tolerant system for 4G.

**Billing System:** 3G mostly follows a flat rate billing system based where the user is charged just by a single operator for his usage according to call duration, transferred data etc. But in 4G wireless systems, the user might switch between different service providers and may use different services. In this case, it is hard for both the users and service providers to deal with separate bills. Hence the operators have to design a billing architecture that provides a single bill to the user for all the services he has used. Moreover the bill should be fair to all kinds of users.
III. ARCHITECTURES

A. Architectural Core

4G wireless system is expected to be built on an IP-based core network for global routing along with more customized local area network that supports dynamic handoff mechanism and Ad-Hoc routing. Mobile IPv6 (MIPv6) is the standardized IP-based mobility protocol for IPv6. In 4G LANs will be installed everywhere like in trains, vehicles etc or might be formed in an Ad-Hoc basis by random collection of devices that happens to come in a specific radio range. New routing protocols have to be designed for such systems.

In 4G mobile systems, each terminal is assigned a home agent, which has a permanent home IP address. When terminal moves to another location it obtains a new temporary address called the care-of address. The user terminal regularly updates the home agent with its current care-of address. If the user is at home, another device can communicate with the user using its home IP address. When the user moves to some other location communication is carried out using another procedure. If a host wants to communicate with the user, it first sends a setup message to the user’s home agent (which the host knows). The home agent knows the care-of address of the user and it forwards the setup message to the user terminal. The home agent also forwards the care-of address of the user to the host so that future messages can be sent directly to the user.

B. Proposed Architectures

Multimode Devices: In this configuration, a single terminal employs multiple interfaces to access different wireless system. Figure 3(a) shows the framework of this architecture. The requirement for this scheme is that the device should incorporate the required hardware necessary to access the different technologies. The flaw with this is that it increases the complexity of the user device which might make it more expensive to the common user. One advantage of this architecture is that it does not require any network modification or internetworking devices. The QoS handling for this type of architecture still remains an open issue.

Overlay network: In this type of architecture, a user can access an overlay network which consists of several UAP (universal access points). The architectural model for this is shown in figure 3(b). The UAP selects an access point depending on user choice, availability and desired QoS. In this case the overlay network performs the major operations such as handoff, frequency translation, content adaptation etc, instead of the terminal performing it. So the overlay network will suffer an increase in complexity.

Common Access Protocol: This architecture can be used if a wireless network can support one or two different protocols. Figure 3(c) shows the framework for this.
architectural model. One solution to this is to use wireless ATM (Asynchronous Transfer Mode), which might need internetworking between different networks. To implement this all wireless networks must be capable of transmitting ATM cells with additional headers. This allows the user to communicate with different wireless networks using the same protocol.

IV. HAND OFF MECHANISMS

As cited in section II, performing vertical hand off is one of the most challenges faced by researchers working on 4G. Vertical hand off is the hand off performed when a user switches from one network to a totally different network. This section discusses some of the proposed schemes for performing vertical hand offs. One major issue in hand off is reducing the handover latency. Whenever a mobile node moves to a new location it takes some time to establish a care-of address and to inform the home agent it’s new care of address. This accounts for the handover latency which is undesirable.

A. Mobile IPv6

When a mobile moves from its home to another location, it obtains a new care-of address by contacting the subnet of that particular network. When a mobile node moves from one network to another, it detects the new subnet by analyzing the router advertisement that is periodically sent out by the access router. By using the subnet of the new network, which the mobile gets from the router advertisement, the mobile node configures itself a new care-of address. The mobile then needs to verify if there is any duplicate address in the same radio range. So it performs the DAD (Duplicate Address Detection) process and it scans the neighborhood for any duplicate addresses. If the mobile duplicate address, it has to reconfigure itself a new care-of address. Once a new care-of address is obtained, the mobile updates the home agent with its new care-of address.

The problem with this hand off scheme is that, to perform DAD the mobile take a lot of time. This increase the handover latency. One solution to this problem is the mobile should perform the DAD operation in parallel with its communication.

B. Hierarchical Mobile IPv6

The main idea behind this scheme is to reduce the signaling load between the mobile and the home agent there by reducing the hand off latency. The global internet is divided into regions defining local area mobility. These domains are generally managed by a unique administrative authority. Each domain is connected to the internet through a mobility anchor point. When a mobile first enters a domain it has to regionally register with that domain to advertise to its home agent its new localization. When the mobile moves across different access routers in the domain, it has to send a local registration to the mobility anchor point to update its localization. So the communication load between the mobile and the home agent is reduces since the mobility anchor point acts as the home agent.

Hierarchical MIPv6 operates in two modes. When a mobile enters a visited domain it must perform a home registration in which the mobile informs the mobility anchor point its home address. Then when the mobile moves within the cell, it switches between two modes, the basic mode and the extended mode. In basic mode, the mobile station has two
addresses, a regional care of address based on the mobility anchor point prefix and an on-link care-of address based on the current access router prefix. Here the mobility anchor point acts as the home agent. It takes the packets destined for the regional care of address and tunnels them to the on-link care-of address. These operations are totally transparent to the home agent. But not every mobile may be able to obtain a regional care-of address. In this case, it works in extended mode where the regional address may any one of the mobility anchor point addresses. The mobility anchor point stores a table of the current care-of address and the home address of the mobiles. When it receives a packet destined to a mobile, it de-tunnels and then re-tunnels it to the current care-of address.

V. MULTIPLE ACCESS TECHNIQUES

3G wireless multiple access techniques were widely based on CDMA and WCDMA. But 4G demands a better multiple access technique for reducing the MAI (Multiple Access Interference) and ISI (Inter Symbol Interference) and thus improve the bit error rate performance. MC-CDMA is the best candidate that would satisfy the demands of 4G wireless systems. Moreover adaptive modulation techniques have been proposed for 4G, where the modulation scheme is changed dynamically based on the current channel estimates. MC-CDMA is the hybrid combination of OFDM (Orthogonal Frequency Division Multiplexing) and CDMA. MC-CDMA with adaptive modulation promises to meet the demands of 4G regarding high data rate with a lower BER (Bit Error Rate).

OFDM has the capability to cancel multi-path distortion in a spectrally efficient manner. Rapid variation in channel characteristics are caused by multi-path and Doppler spread (due to the different speeds of mobile). Sometimes these time varying channels are characterized by very good SNR (Signal to Noise Ratio), but worse SNR at other times. So a fixed modulation technique cannot achieve the best spectral efficiency as the system has to be built with a modulation scheme considering the worst case scenario. Hence during good channel conditions the system would not be able to obtain the best possible spectral efficiency. This is where adaptive modulation shows its role. Adaptive modulation techniques takes advantage of the time varying channel characteristics and adjust the transmission power, data rate, coding and modulation scheme for the best spectral efficiency.

A. MC-CDMA

The basic idea of CDMA is to maintain a sense of orthogonality among the users in order to eliminate the MAI. This is done by employing orthogonal spreading codes to spread the data sequence. In MC-CDMA these spreading codes are defined in the frequency domain. Pseudo orthogonal codes can be used instead of orthogonal codes, thus increasing the number of users that can be accommodated. But pseudo orthogonal codes can increase MAI since the spreading codes are not fully orthogonal.

![Figure 6: MC-CDMA Transmitter](image)

Figure 6 shows the configuration of an MC-CDMA transmitter for user j. It takes the input data stream and converts in to parallel data sequences each parallel data sequence is multiplied with the spreading code. A guard interval in inserted between the symbols to eliminate ISI caused by multi-path fading.

![Figure 7: MC-CDMA receiver](image)

In MC-CDMA receiver the received data is first coherently detected and then multiplied with the gain to combine the energy of the received signal scattered in the frequency domain.

The system model for adaptive MC-CDMA is shown in figure 8. There is a channel estimator which estimates the characteristics of the channel using pilot symbols (QPSK symbols) and updates the modulation selector which in turn selects the optimal modulation scheme.
VI. MULTIMEDIA – VIDEO SERVICES

4G wireless systems are expected to deliver efficient multimedia services at very high data rates. Basically there are two types of video services: bursting and streaming video services. Streaming is performed when a user requires real time video services, in which the server delivers data continuously at a playback rate. Streaming has little memory requirement as compared to bursting. The drawback of streaming video is that it does not take advantage of available bandwidth. Even if the entire system bandwidth is available for the user, streaming video service will transmit data only at a particular playback rate. Bursting is basically file downloading using a buffer and this is done at the highest data rate taking advantage of the whole available bandwidth. The flaw with this type of transmission is that it demands a large memory requirement. So work is being done to come up with a new scheme that limits the memory requirements and can exploit the available bandwidth of the system. The simulation details and comparison of streaming and bursting video transmission have been discussed in [11].

VII. APPLICATIONS OF 4G

Virtual Presence: This means that 4G provides user services at all times, even if the user is off-site.

Virtual navigation: 4G provides users with virtual navigation through which a user can access a database of the streets, buildings etc of large cities. This requires high speed data transmission.

Table 1: Comparison of different generations

<table>
<thead>
<tr>
<th>Generation</th>
<th>Technology</th>
<th>Features</th>
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<tbody>
<tr>
<td>1G wireless</td>
<td>• Advanced Mobile Phone Service AMPS</td>
<td>• Analog voice service</td>
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<tr>
<td></td>
<td></td>
<td>• No data service</td>
</tr>
<tr>
<td>2G wireless</td>
<td>• Code Division Multiple Access (CDMA)</td>
<td>• Digital voice service</td>
</tr>
<tr>
<td></td>
<td>• Global System for Mobile Communication (GSM)</td>
<td>9.6K to 14.4K bit/sec.</td>
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<tr>
<td></td>
<td>• Personal digital cellular (PDC)</td>
<td>• CDMA, TDMA and PDC offer one-way data transmissions only</td>
</tr>
<tr>
<td></td>
<td>• Wide-band Code Division Multiple Access (WCDMA)</td>
<td>• Enhanced calling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Features like caller ID</td>
</tr>
<tr>
<td>3G wireless</td>
<td>• Based on the Interim Standard-95 CDMA standard (CDMA 2000)</td>
<td>• No always-on data connection.</td>
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<tr>
<td></td>
<td>• Time-division synchronous code division multiple access (TD-SDM)</td>
<td></td>
</tr>
<tr>
<td>4G wireless</td>
<td>• Orthogonal Frequency Division Multiplexing (OFDM) &amp; (WOFDM)</td>
<td>• Superior voice quality and data always add on</td>
</tr>
<tr>
<td></td>
<td>• Multi Carrier CDMA (MC-CDMA)</td>
<td>• Up to 2M bit/sec. always-on data</td>
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<td></td>
<td>• LAS-CDMA</td>
<td>• Broadband data services like video and multimedia</td>
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<tr>
<td></td>
<td></td>
<td>• Enhanced roaming</td>
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<tr>
<td></td>
<td></td>
<td>• Circuit and packet switched networks</td>
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<td></td>
<td></td>
<td>• Entirely packet switched Networks.</td>
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<tr>
<td></td>
<td></td>
<td>• All network elements are digital.</td>
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<tr>
<td></td>
<td></td>
<td>• Higher bandwidth to provide multimedia services at lower cost</td>
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<tr>
<td></td>
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<td>(up to 100Mbits/sec).</td>
</tr>
</tbody>
</table>

Tele-Medicine: 4G will support remote health monitoring of patients. A user need not go to the hospital and can get videoconference assistance for a doctor at anytime and anywhere.

Tele-geoprocessing applications: This is a combination of GIS (Geographical Information System) and GPS (Global Positioning System) in which a user can get the location by querying.

Crisis management: Natural disasters can cause break down in communication systems. In today’s world it might take days or
weeks to restore the system. But in 4G it is expected to restore such crisis issues in a few hours.

Education: For people who are interested in life long education, 4G provides a good opportunity. People anywhere in the world can continue their education online in a cost effective manner.

VIII. CONCLUSION

4G seems to be a very promising generation of wireless communication that will change the people’s life in the wireless world. There are many striking attractive features proposed for 4G which ensures a very high data rate, global roaming etc. Table 1 shows the features and comparison between the different generations. New ideas are being introduced by researchers throughout the world, but new ideas introduce new challenges. There are several issues yet to be solved like incorporating the mobile world to the IP based core network, efficient billing system, smooth hand off mechanisms etc. 4G is expected to be launched by 2010 and the world is looking forward for the most intelligent technology that would connect the entire globe.

REFERENCES