CHAPTER 1

INTRODUCTION

1.1 HETEROGENEOUS MOBILE WIRELESS NETWORK

A heterogeneous wireless network (HWN) is a composite made of two or more wireless access technologies, each with its own characteristics in terms of coverage, quality of service (QoS) assurance, radio resources and an implementation. Nowadays many different types of networks communicate among themselves to form heterogeneous wireless networks (HWN).

A mobile multiple mode device, which provides a service through a Land Mobile Radio network and its able to maintain the service when switching to a cellular network is called as heterogeneous mobile wireless network in this thesis.

Field based emergency personnel and other authorities such as disaster responder and disaster commanders are heavily secured in portable radio communications called as Public Safety Land Mobile Radios in order to save people life.

The 3G Cellular network and 4G cellular network support packet switched broadband services with a variety of multimedia applications, which include higher data rates, voice, video and web browsing.
The considerable differences in terms of services and data rates between these two kinds of Land Mobile Radio and cellular network are largely due to market forces, requirements, spectrum policy and other parameters.

In the interoperable cellular and LMR networks, disaster responders access services in cellular networks that are not available in public safety LMR network which is used to increase the service availability.

Besides, when a disaster responder moves out of the coverage of public safety LMR networks with an ongoing communication session, the session should be handoff to cellular networks instead of being dropped for providing service continuity.

This section briefly explains the public safety Land Mobile Radio and cellular network

1.1.1 Cellular Network

1.1.1.1 Introduction

Cellular communication is experienced explosive growth in the past two decades. Today millions of people around the world use cellular phones. Cellular phones allow a person to make or receive a call from almost anywhere. Likewise, a person is allowed to continue the phone conversation while on the move. Cellular communications are supported by an infrastructure called a cellular network, which integrates cellular phones into the public switched telephone network.
The cellular network has gone through four generations.

- **First Generation (1G):** The first generation of cellular networks is analog in nature.

- **Second Generation (2G):** To accommodate more cellular phone subscribers for increasing the network capacity, digital TDMA (time division multiple access) and CDMA (code division multiple access) technologies are used in the 2G. With digital technologies, digitized voice can be coded and encrypted. Therefore, the 2G cellular network is also more secure.

- **Third Generation (3G):** The 3G integrates cellular phones into the Internet world by providing high speed packet switching data transmission and circuit switching voice transmission.

- **Fourth Generation (4G):** The 4G cellular network is based on OFDMA transmission and is designed to support mobile Internet.

![Figure 1.1 Multiple access schemes](image-url)
Figure 1.1 shows the multiple access schemes used from the first generation to the fourth generation. Figure 1.2 shows the transmission bands and technology used in the last three decades.

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<thead>
<tr>
<th>1G</th>
<th>2G</th>
<th>3G</th>
<th>4G</th>
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<td>25-30 KHz</td>
<td>200 KHz</td>
<td>5 KHz</td>
<td>1.4-20 KHz</td>
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<td>1980 AMPS</td>
<td>1990 GSM</td>
<td>2000 WCDMA</td>
<td>2010 LTE</td>
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**Figure 1.2 Transmission Bands**

A cellular network provides cell phones or mobile stations (MS) with wireless access to the public switched telephone network (PSTN). The service coverage area of a cellular network is divided into many smaller areas, referred to as cells, each of which is served by a base station (BS).

**Figure 1.3 Typical Cellular Network**
The BS is fixed, and it is connected to the mobile telephone switching office (MTSO), also known as the mobile switching center. The MSC is a telephone exchange configured specifically for mobile applications, and it is sometimes called a Mobile Telephone Switching Office (MTSO). Since it is responsible for connecting all mobile stations to the PSTN in a cellular system with the wireless link between the BS and MS. MSs such as cell phones are able to communicate with wire line phones in the PSTN. Both BSs and MSs are equipped with a transceiver. Figure 1.3 and 1.4 illustrate a typical cellular network, in which a cell is represented by a hexagon and a BS is represented by a triangle.

A cellular system accommodates a large number of users over a large geographical area, within a limited frequency spectrum. High capacity is achieved by limiting the coverage of each base station transmitter to a small geographical area called a cell. Here, the same radio channels are reused by another base station (BS) located some distance away.

Figure 1.4: An Illustration of Cellular Network
Figure 1.5: Cellular structure of the metropolitan area

The Figure 1.5 shows one big area is divided into three cells with three base stations. A sophisticated switching technique called a handoff enables a call to proceed uninterrupted when the user moves from one cell to another. A mobile unit communicates via wireless channel with its own BS and may be handed off to other base stations throughout the duration of a call. There are many cellular systems and main differences among them are in their use of the frequency spectrum and the spacing between the channels.

1.1.1.2 Multiple Access Technologies

In any cellular system or cellular technology, it is necessary to have a scheme that enables several multiple users to gain access to it and use it simultaneously. Cellular technology has progressed different multiple access schemes have been used. They form the very core of the way in which the radio technology of the cellular system works.

There are four main multiple access schemes that are used in cellular systems ranging from the very first analogue cellular technologies to those cellular technologies that are being developed for use in the future. The multiple access schemes are known as FDMA, TDMA, CDMA and OFDMA.
In any cellular system, it is necessary to have a scheme whereby it handles multiple users at any given time. There are many ways of doing this process, and as cellular technology has advanced, different techniques have been used.

There are a number of requirements that any multiple access scheme must be able to meet:

- Ability to handle several users without mutual interference.
- Ability to maximize the spectrum efficiency
- It is robust and enables ease of handover between cells.

**Frequency Division Multiple Access (FDMA):** FDMA is the most straightforward of the multiple access schemes that have been used. As a subscriber comes onto the system, or swaps from one cell to the next, the network allocates a channel or frequency to each one. In this way, the different subscribers are allocated a different slot and access to the network. As different frequencies are used, the system is naturally termed as Frequency Division Multiple Access. This scheme was used by all analogue systems.

**Time Division Multiple Access (TDMA):** The second system came with the transition to digital schemes for cellular technology. Here, digital data could split up in time and sent as bursts when required. As the speech was digitized it could be sent in short data bursts, any small delay caused by sending the data in bursts would be short, and it is not noticed. In this way, it became possible to organize the system so that a given number of slots were available on a transmission. Each subscriber is allocated to a different time slot in which they could transmit or receive data. The different time slots are used for each subscriber to gain access to the system and it
is known as time division multiple accesses. Obviously, it allows a certain number of users to access the system. Beyond this, another channel is used, so that the systems use TDMA to have elements of FDMA operation as well.

**Code Division Multiple Access (CDMA):** CDMA uses one of the aspects associated with the use of direct sequence spread spectrum. It can be seen from the article in the cellular telecoms area of the site, when extracting the required data from a DSSS signal. It is necessary to have the correct spreading or chip code, and all other data from sources using different orthogonal chip codes would be rejected. Therefore it is possible to allocate different users different codes, and use this as the means by which different users are given access to the system.

The scheme has been likened in a room filled with people who are speaking different languages. Even though, the noise level is very high, it is still possible to understand someone speaking in your own language. With CDMA, different spreading or chip codes are used. When generating a direct sequence spread spectrum, the data to be transmitted is multiplied with spreading or chip code. This widens the spectrum of the signal, but it can only be decided in the receiver if it is again multiplied with the same spreading code. All the signals that use different spreading codes are not seen and are discarded in the process. In the presence of a variety of signals, it is possible to receive only the required one.

The base station allocates different codes to different users and when it receives the signal it will use one code to receive the signal from one mobile, and another spreading code to receive the signal from a second mobile. The same frequency channel is used to serve a number of different mobiles.
Orthogonal Frequency Division Multiple Access (OFDMA):
OFDMA is the form of multiple access scheme that is considered for the fourth generation cellular technologies along with the evolutions for the third generation cellular systems (LTE for UMTS / W-CDMA and UMB for CDMA2000). As the name implies, OFDMA is based around OFDM. This is a technology that utilizes a large number of close spaced carriers.

To utilize OFDM as a multiple access scheme for cellular technology, two different methods are used, one for the uplink and other for the downlink. In the downlink, the mobile receives the whole signal transmitted by the base station and extracts the data destined for the particular mobile. In the uplink, one or more carriers are allocated to each handset dependent upon the data to be transmitted. The cellular network is able to control, how the data are sent and received.

1.1.2 Land Mobile Radio Network

1.1.2.1 Introduction

The term public safety land mobile radio refers to wireless systems used by public safety agencies for coordinating teams and providing rapid emergency response. Land Mobile Radio (LMR) system is a collection of portable and mobile radio units designed to communicate with each other over predefined frequencies. They are deployed wherever organizations need to have instant communication between geographically dispersed and mobile personnel. Typical LMR system users include public safety organizations such as police departments, fire departments, and medical personnel. However, LMR systems also find use in the private sector for activities like construction, building maintenance, and site security.
In typical LMR systems, a central dispatch console or base station controls communications to the disparate handheld or mobile units in the field. The systems might also employ repeaters to extend the range of communications for the mobile users. LMR systems can be as simple as two handheld units communicating between themselves and a base station over preset channels. It is quite complex, consisting of hundreds of remote units, multiple dispatch consoles, dynamic channel allocation, and other elements.

Currently, public safety land mobile radio is used by public safety agencies for coordinating teams and providing rapid emergency response. Most public safety mobile wireless networks currently being developed throughout the world are based on two digital narrowband LMR technologies. The two digital narrowband LMR technologies are the following:

- APCO Project 25
- TETRA

These technologies satisfy a broad range of specialized wireless communications requirements particularly applicable to public safety including the following:

- Promoting the notion of tactical wireless communications networks including digital voice and digital multimedia data.
- Establishing a common tactical wireless communication networks, common network backbone infrastructure, and separate command and control multiagency scenarios permitting the maintenance of agency autonomy while promoting cooperative system usage.
- Supporting both infrastructure and non infrastructure based communication usages.
1.1.2.2 APCO Project 25

Land mobile radio is a growing field of communications. Association of Public Safety Communication Official (APCO) Project 25, standardized by the Telecommunication Industry Association (TIA) and Electronic Industries Alliance (EIA). Apart from Project 25, there are many other related technologies are available.

Project 25, also known by its short name P25 or APCO-25 is a digital radio system used for land mobile applications, especially by the federal, state or province and local public safety agencies. P25 radio is most widely used in North America and can often be thought of as being equivalent to TETRA radio, although it does not interoperate with it. Project 25, APCO-25 or P25 radio is a set of standards that defines the radio system.

Project 25, P25 radio has been defined under the auspices of APCO - Association of Public-Safety Communications Officials. APCO International is an organization of public safety communications professionals. It aims to serve the needs of public safety communications users and hence provide for the welfare of the general public as a whole. APCO provides expertise, professional development, technical assistance, advocacy and outreach.

APCO promotes many projects. These are given project numbers, and hence the project develops a standard for digital radio communications for the emergency services was given a project number (Project 25). The name Project 25 or P25 radio has remained with the technology. The standards themselves are held under the auspices of the TIA, Telecommunications Industry Association.
Project 25, or P25 radio is a standard that defines a form of interoperable digital two-way wireless communications products. The P25 radio system was developed in North America with state, local and federal representatives and Telecommunications Industry Association (TIA) governance. The P25 radio standards are administered by the TIA (Mobile and Personal Private Radio Standards Committee TR-8). P25 radio technology uses digital techniques for the transmission of voice and data.

The P25 radio technology is being developed in three phases:

- **P25 Phase 1:** The phase 1 Project 25 radios can operate in 12.5 KHz analogue, digital, or a mixed mode format. The Phase 1 radios use a form of modulation known as Continuous 4 level FM, C4FM. Phase 1 P25 compliant systems are backward compatible and interoperable with legacy FM systems. In addition to this, the P25 standards provide an open interface to the RF Subsystem to facilitate interlinking of different vendors' systems.

- **P25 Phase 2:** Phase 2 P25 radio systems are based around a 6.25 KHz channel bandwidth within this they achieve one voice channel or a minimum 4800 bps data channel. P25 Phase 2 uses frequency division multiple access (FDMA) and the modulation format is CQPSK. An alternative 2 slot TDMA solution is currently under development. Phase 2 implementation achieves the goal of improved spectrum utilization. Also being stressed are such features as interoperability with legacy equipment, interfacing between repeaters and other subsystems, roaming capacity and spectral efficiency/channel reuse.
P25 Phase 3: With the growing need for high speed data in many areas, Phase 3 of the P25 radio standards addresses the requirement. Additional features are aimed at providing functionality for a new aeronautical and terrestrial wireless digital wideband/broadband public safety radio standard that can be used to transmit and receive voice, video and high-speed data in wide-area, multiple-agency networks.

APCO Project 25 is a digital trunking standard for the US public safety market and is based on frequency division multiple access (FDMA) technology. APCO Project 25 Phase 2 use TDMA technology.

Different forms of modulation of the RF carrier are used between Phase 1 and Phase 2 of P25. These different forms of modulation help to enable the system to meet the different requirements between these two phases. C4FM are used for Phase 1 and CQPSK is used for Phase 2.

C4FM: C4FM is form of frequency modulation where the carrier is shifted in frequency at a particular rate to a particular location around a centre frequency - there are four positions, hence the name. This allows for each of the 4 "states" to represent a binary number. Each state is a known as a "Symbol" which contains two bits of information.

C4FM modulation is viewed as a type of Differential Quadrature Phase Shift Keying, DQPSK. Each symbol is shifted in phase by 45° from the previous symbol. Although the phase and hence the frequency is modulated for C4FM, the amplitude of the carrier is constant, generating a constant envelope frequency modulated waveform. This is of particular interest in preserving battery power.
For constant envelope modulation schemes are able to use non-linear power amplifiers which are more efficient, converting more power to usable RF energy for a given DC input.

- **CQPSK**: CQPSK modulates the phase and simultaneously modulates the carrier amplitude to minimize the width of the emitted spectrum which generates an amplitude modulated waveform.

### 1.1.2.3 TETRA

Terrestrial Trunked Radio (TETRA), standardized by European Telecommunications Standards Institute (ETSI). TETRA is used by considerable number of public safety agencies across the globe. TETRA is a modern standard for digital Private Mobile Radio (PMR) and Public Access Mobile Radio (PAMR). It offers many advantages including flexibility, security, and ease of use and offers fast call set-up times. This makes it an ideal choice for many business radio communications requirements. TETRA is aimed at a variety of mobile radio communications users including the police, ambulance and fire services. It is equally applicable for utilities, public access, fleet management, transport services, and many other users. TETRA uses time division multiple access (TDMA). The typical TETRA cell radius is 3.8 to 17.5 km for interference limited system.

**TETRA Radio Features**: TETRA radio offers many new and valuable features and in this way it is a major step forwards over previous private mobile radio communications systems. These include a fast call set-up time, which is a particularly important requirement for the emergency services. It also has an excellent group communication support, direct mode operation between individual radios, packet data and circuit data transfer
services, better economy of the frequency spectrum use than the previous PMR radio systems. It also provides advanced security features. The system also supports a number of other features including call hold, call barring, call diversion, and ambience listening.

The TETRA radio standard has undergone an evolutionary development to ensure that it is able to keep up with the needs of the users. There have been two releases of the TETRA radio standard.

- **TETRA Release 1**: As would be envisaged this was the first release of the TETRA radio standard which occurred

- **TETRA Release 2**: This release of the TETRA radio standard occurred in 2005 as a result of work dating back to 1999. It introduced a number of new features into the TETRA radio standard:
  - TETRA Enhanced Data Service (TEDS)
  - Mixed Excitation Liner Predictive, enhanced (MELPe) Voice Codec
  - Adaptive Multiple Rate (AMR) Voice Codec
  - Trunked Mode Operation (TMO) Range Extension

The TETRA radio system offers many features that enable it to have more flexibility than many other systems. The TETRA 1 radio systems provide the major features, and although further development to TETRA 2 and TEDS has enabled further facilities to be added, they still retain the TETRA 1 capabilities and are backward compatible. In this way, TETRA 1 forms the basis for all TETRA radio systems.
There are three different modes in which TETRA radio systems can be run:

- Voice plus Data (V+D)
- Direct Mode Operation (DMO)
- Packet Data Optimized (PDO)

The most commonly used mode is V+D. This mode allows switching between speech and data transmissions, and can even carry both by using different slots in the same channel. Full duplex is supported with a base station and mobile radio unit frequencies normally being offset by about 10 MHz to enable interference levels between the transmitter and receiver in the station to be reduced to an acceptable level.

DMO is used for direct communication between two mobile units and supports both voice and data. However, a full duplex is not supported in this mode. Only simplex is used. This is particularly useful as it allows the mobile stations to communicate with each other even when they are outside the range of the base station.

The third mode, PDO is optimized for data only transmissions. It has been devised with the idea that much higher volumes of data is needed in the future, and it is anticipated that further developments will be built upon the TETRA mobile radio communications standard.

TETRA radio uses TDMA techniques. This enables much greater spectrum efficiency than was possible with previous PMR systems because it allows several users to share a single frequency. As the speech is digitized, both voice and data are transmitted digitally and multiplexed into the four slots on each channel. Digitization of the speech is accomplished using a
system that enables the data to be transmitted at a rate of only 4.567 Kbits/second.

This lower data rate is achieved because the process that is used takes into account the fact that the waveform is human speech rather than any varying waveform. The digitization process also has the advantage that it renders the transmission secure from casual listeners. For greater levels of security that might be required by the police or other similar organizations, it is possible to encrypt the data. This would be achieved by using an additional security or encryption module.

One important feature of TETRA is that the call set up time is short. It occurs in less than 300 ms and can be as little as 150 ms when operating in DMO. This is much shorter than the time it takes for a standard cellular telecommunications system to connect. This is very important for the emergency services, where a time delay is very critical.

**TETRA radio frequencies and air interface:** For emergency services in Europe the frequency bands 380-383 MHz and 390-393 MHz have been allocated. These bands are expanded to cover all or part of the spectrum from 383-395 MHz and 393-395 MHz should be needed. For civil systems in Europe the frequency bands 410-430 MHz, 870-876 MHz / 915-921 MHz, 450-470 MHz, 385-390 MHz / 395-399 MHz, have been allocated.

TETRA radio trunk facility provides a pooling of all radio channels that are then allocated on demand to individual users, in both voice and data modes. By the provision of national and multi-national networks, national and international roaming is supported, the user being in constant communication. TETRA supports point-to-point and point-to-multipoint communications both by the use of the TETRA infrastructure and by the use of Direct Mode without infrastructure.
In addition to this, it is possible for TETRA radio to operate in a secure format. The digital data is encrypted before transmissions, making the system inherently secure. It is required for some covert operations or for the police services.

The TETRA radio system uses Time Division Multiple Access (TDMA) technology with 4 user channels on one radio carrier and 25 KHz spacing between carriers. It makes inherently more efficient than its predecessors in the way that it uses the frequency spectrum. The Data is transmitted at 7.2 Kbits per second for a single channel. It is increased fourfold to 28.8 Kbits per second when the multi-slot operation is employed.

1.2 EMERGENCY COMMUNICATION

1.2.1 Disaster Response and Recovery

A reliable, robust communication technology is necessary to transmit information at all stages of an emergency situation for efficiently handle the disaster. This includes disaster mitigation, preparation, response, and recovery. Emergency response and recovery have a more specific need for quick deployment and easy reconfiguration of a communication infrastructure. These are more time sensitive applications while mitigation and preparation allows a longer planning time.

When a large scale disaster strikes, first responders are sent to the site immediately. Once the most pressing needs of the disaster are addressed, the next step is to establish a command and control center. To accommodate this need, a communication infrastructure is required to provide decision makers with data and information from the site to receive digital maps, data, and feedback from personnel in the field in a timely manner. Also, it is able to provide a reliable connection with enough resources for a distributed command and control center.
The common requirements for all communications during emergency response are the following:

- Service Availability
- Service Continuity

The other needs such as confidentiality and different quality of service depend upon the nature of disaster and the specific application. It is a challenge to design a system that accommodates all of these needs.

Interoperability of heterogeneous systems is required to enable collaboration among different organizations and across various departments of the same organization. At a disaster site, different response organizations come up with a variety of devices using different technologies. Since there is not only single standard communication technology with application for emergency response and different organizations use different available technologies, we need to plan and provision interoperability among different devices in a heterogeneous environment. This has been addressed by the Interoperable Land Mobile Radio and Cellular Network, where a wide variety of benefits offered to disaster responders, including new multimedia services, increased data rates and fast response.

1.3 HANDOFF

1.3.1 ‘Handoff’ Definition

The term ‘Handoff’ refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another network. ‘Handoff’ is often known as handover, and it is a process that allows mobile station moves from one cell to another without interruption in the call/session.
1.3.2 Classification of Handoff

In principle, each mobile terminal (node), within range of at least one network access point (AP) is also known as a base station (BS). The area serviced by each base station is identified by the cell. The dimensions and profile of every cell depend on the network type, size of the base stations, and transmission and reception power of each base station. Usually, cells of the same network type are adjacent to each other and overlap in such a way that, for the majority of time, any mobile device is within the coverage area of more than one base station. Cells of heterogeneous networks, on the other hand, are overlaid within each other. Therefore, the key issue for a mobile host is to reach a decision from time to time as to which base station of which network will handle the signal transmissions to and from a specific host and handoff the signal transmission if necessary.

![Handoff classification tree](image)

Figure 1.6 Handoff classification tree
Handoff classification is based on several factors as shown in Figure 1.6. The network type is not only the handoff classification factor. Many more factors constitute categorization of handoffs including the administrative domains involved, number of connections and frequencies engaged.

The following are categorization factors along with the handoff classifications:

1. **First Factor: Network Types Involved**

   This is the most common classification factor. Handoffs can be classified as either horizontal or vertical. This depends on whether a handoff takes place between single types of network interface or a variety of different network interfaces. Figure 1.7 shows the horizontal and vertical handoff.

![Figure 1.7 Horizontal and Vertical Handoff](image)
Horizontal handoff: The handoff process of a mobile terminal between the access points (AP) supports the same network technology. For example, the changeover of signal transmission (as the mobile terminal moves around) from an LMR base station to a geographically neighboring LMR base station. It is considered as a horizontal handoff process.

Vertical handoff: The handoff process of a mobile terminal among the access points (AP) support different network technologies. For example, the changeover of signal transmission from a Land Mobile Radio base station to an overlaid cellular network is considered as a vertical handoff process.

2. Second Factor: Frequencies Engaged

Intrafrequency handoff: The handoff process of a mobile terminal across the access points operates on the same frequency. This type of handoff is present in the code division multiple access (CDMA) networks with frequency-division duplex (FDD).

Interfrequency handoff: The handoff process of a mobile terminal across the access points operating on different frequencies. This type of handoff is present in the CDMA networks with time-division duplex (TDD) and is the handoff type supported in GSM cellular systems.

3. Third Factor: Number Of Connections Involved

Handoffs can be classified as hard, soft, or softer.

Hard handoff: In a hard handoff, the radio link to the old base station is released at the same time a radio link to the new base station is established. In other words, using hard handoff,
a mobile node is allowed to maintain a connection with one base station at the given time.

**Soft handoff**: Contrary to hard handoffs, in a soft handoff a mobile node maintains a radio connection with not less than two base stations in an overlapping handoff region and does not release any of the signals until it drops below a specified threshold value. Soft handoffs are possible in situations where the mobile node is moving between cells and operates in the same frequency.

**Softer handoff**: A softer handoff is very similar to a soft handoff, except the mobile terminal switches the connection over radio links that belong to the same access point.

4. **Fourth Factor: Administrative Domains Involved**

An administrative domain is a group of systems and networks operates in a single organization of administrative authority. Administrative domains play a significant role in 4G wireless networks as different networks, each controlled by different administrative authorities, become available. Consequently, the classification of handoffs in terms of administrative domains is a crucial issue.

**Intra-administrative handoff**: A handoff process is a process, where the mobile terminal transfers between the different types of networks (supporting the same or different types of network interfaces) and managed by the same administrative domain.

**Inter-administrative handoff**: A handoff process is a process, where the mobile terminal transfers between different
networks (supporting the same or different types of network interfaces) and managed by different administrative domains.

5. **Fifth Factor: Necessity Of Handoff**

Handoffs are classified based upon its essential.

**Obligatory handoff:** In some situations, it is necessary for the mobile terminal to transfer the connection to another access point in order to avoid the disconnection.

**Voluntary handoff:** In other situations, transfer of connection is optional and it improves the quality of service or else not.

6. **Sixth Factor: User Control Allowance**

Handoffs can be classified as proactive or passive.

**Proactive handoff:** In a proactive handoff, the mobile terminal’s user is allowed to decide when to handoff. The handoff decision is based on a set of preferences specified by the user. Proactive handoff is expected to be one of the radical features of 4G wireless systems.

**Passive handoff:** The user has no control over the handoff process. This type of handoff is the most common in first, second and third generation wireless systems.

1.3.3 **Handoff Consideration**

The necessity for a handoff is indicated whenever the averaged signal to noise ratio or signal to interference ratio at the mobile station or base station falls below a threshold value. This threshold is usually determined by the systems operating specifications. The average number of handoff during a typical length of a call depends on the vehicular speed and cell size. The handoff initialization procedure starts when the parameter determines the
handoff found to be below the threshold level. If the handoff decision is delayed, then the link quality will be affected and probability call drop increased.

Several handoff approaches are based on parameters such as the signal to interference ratio, traffic volume, availability of channel. However, signal strength is most widely used in the handoff process. The parameter is measured by either the base station or the mobile station. When the base station measures the parameter, the handoff is known as Network Controlled Handoff (NCHO). When the mobile station measures the parameter and network takes the decision, it is known as Mobile Assisted Handoff (MAHO). When the mobile station is the sole controller of the handoff process is known as Mobile controlled Handoff (MCHO).

The Quality of handoff technique is measured by one or more several possible metrics. The metrics are call dropping probability, call blocking probability, number of unnecessary handoff and delay in execution of handoff.

1.4 RADIO RESOURCE MANAGEMENT

Radio resource management (RRM) is the system level control of co-channel interference and other radio transmission characteristics in wireless communication systems such as cellular networks, wireless networks and broadcasting systems. The rapid increase is the size of the wireless mobile community and its demands for high-speed multimedia communications stands in clear contrast to the rather limited spectrum resources, which have been allocated in international agreements.
Efficient spectrum or radio resource management (RRM) is the paramount importance in these increasing demands. RRM involves strategies and algorithms for controlling the parameters such as transmit power, channel allocation, data rates, handover criteria, modulation scheme, error coding scheme. The objective is to utilize the limited radio spectrum resources and radio network infrastructure as efficiently as possible.

RRM concerns multi-user and multi-cell network capacity issues, rather than point-to-point channel capacity. Traditional telecommunications research and education often dwell upon the channel coding and source coding with a single user. Although it is not possible to achieve the maximum channel capacity when several users and adjacent base stations share the same frequency channels.

Efficient dynamic RRM schemes may increase the system capacity in order of magnitude, which is often considerable more than what is possible by introducing advanced channel coding and source coding schemes. RRM is especially important in systems limited by co-channel interference rather than by noise. Cellular systems and broadcast networks homogeneously covers large areas, and wireless networks consisting of many adjacent access points that may reuse the same channel frequencies.

The cost for deploying a wireless network is normally dominated by the base station sites (real estate costs, planning, maintenance, distribution network, energy) and sometimes also by the frequency license fees. The objective of radio resource management is therefore typically to maximize the system spectral efficiency in bit/s/Hz/base station site or Erlang/MHz/site, under constraint that the grade of service should be above a certain level.
The latter involves covering a certain area and avoiding outage due to co-channel interference, noise, attenuation caused by the long distances, fading caused by the shadowing and multipath, Doppler shift and other forms of distortion. The grade of service is also affected by blocking due to admission control, scheduling starvation or inability to guarantees the quality of service that is requested by the users.

1.5 MOTIVATION

Over the last two decades, the heterogeneous network has become tremendously popular for its inter-operability. The inter-operability has been achieved by bridging the two different networks. This way of bridging two different networks is said to be heterogeneous network.

Public safety agencies are using Land Mobile Radio in the disaster environment for their emergency communication. It is very crucial during the emergency communication between disaster responder and disaster commander due to the lower data rates, less service accessibility and fewer multimedia services whereas commercial cellular network provides higher data rates, higher service availability and more multimedia services.

The mobile node in the Land Mobile Radio uses the finer services of cellular network, when it handoffs to a cellular network. The disaster responder cannot save the people life in the disaster environment; if the Land Mobile Radio networks of disaster responder has not been in good communication with disaster commander.

The efficient communication has been achieved between the disaster responder and commander, when the disaster responder handoff from Land Mobile Radio network coverage to the cellular network coverage. It gives higher data rates, service availability and more multimedia services. The
evidence indicates that the handoff delay should be reduced for the service continuity.

In addition, the evidence indicates that the radio resource utilization should be improved for the service availability. The service availability and service continuity are achieved by reducing the handoff delay and maximizing the radio resource utilization. It is helpful to fast up the disaster response and recovery in the disaster environment. The description of the above forms the foundation of the work presented here.

1.6 RESEARCH AIMS AND OBJECTIVES

The main objective of this research is to study the reducing of application layer handoff delay, using seamless approach; this will be done in the following steps:

- Study network layer, transport layer and application layer protocols such as Mobile IP, mSCTP, H.323 and SIP delay reduction approaches in heterogeneous wireless network.
- Obtain the advantages and disadvantages of Application layer protocol such as H.323 and SIP.
- Simulate the SIP protocol and the Seamless SIP with optimal radio resource management framework using Network Simulator (NS2) in interworking public safety LMR and cellular network.
- Simulate the Session schedule manager based scheme in heterogeneous mobile wireless network to study the public safety LMR and cellular network performance when number of session’s occurred from a number of cells.
The simulation will study the following performance metrics (the handoff delay, radio resource utilization, service availability and service continuity).

Compare the simulation results for SIP protocol and S-SIP with optimal radio resource management framework.

Evaluate the Seamless SIP with optimal radio resource utilization, in terms of handoff delay, radio resource utilization, service availability and service continuity as well, compared to the standard SIP.

1.7 ORGANIZATION OF THE THESIS

The main work of this research is to reduce the handoff delay and increase the radio resource utilization for seamless communication in order to speed up the disaster response and recovery in the disaster environment.

Chapter 1 explains the overall introduction to heterogeneous mobile wireless network.

Chapter 2 sketches the historical prospective discussed in the available literatures pertaining to the handoff schemes and radio resource management schemes in heterogeneous wireless network. Further, the disadvantages in the literature are identified based on which the objective of this research is framed.

Chapter 3 describes a broad overview of existing Session Initiation Protocol, which is an application layer of signaling protocol.

Chapter 4 deals with the existing network layer, transport layer, application layer handoff schemes such as Mobile IP, mSCTP, H.323 and Session Initiation Protocol in different heterogeneous network environment.
Chapter 5 introduces new optimization techniques to seamless communication in interworking public safety LMR and cellular network for fast disaster response and recovery.

Chapter 6 discuss briefly about the experimental environment and the result of this research work.

Chapter 7 summarizes the conclusions of this research work. The future scope of this work is also presented in this chapter.