CHAPTER 1
INTRODUCTION

Mobility is the most important feature of a wireless cellular communication system. Usually, continuous service is achieved by supporting handoff (or handover) from one cell to another. Handoff is the process of changing the channel (frequency, time slot, spreading code, or combination of them) associated with the current connection while a call is in progress. It is often initiated either by crossing a cell boundary or by deterioration of the signal in the current channel. Handoff is divided into two broad categories—hard and soft handoffs. They are also characterized by “break before make” and “make before break.” In hard handoffs, current resources are released before new resources are used. In soft handoffs, both existing and new resources are used during the handoff process. Poorly designed handoff schemes tend to generate very heavy signaling traffic and thereby a dramatic decrease in quality of service (QoS).

The reason why handoffs are critical in cellular communication systems is that neighbouring cells are always using a disjoint subset of frequency bands, so negotiations must take place between the mobile station (MS), the current serving base station (BS), and the next potential BS. Other related issues, such as decision making and priority strategies during overloading, might influence the overall performance.

1.1 Introduction to Cellular Networks

The cellular network consists of several cells with each cell covering a certain geographic area. In each cell one base station is present. The cell area is determined by the signal strength within the region, which in turn depends on many factors such as height of the transmitting antenna, presence of hills, valleys and tall buildings, and
atmospheric conditions. Therefore, the actual shape of the cell may be in the form of zizzag shape. However, the cell is approximated as hexagon. Because the hexagon is a good approximation of the circular region and it allows a larger region to be divided into no overlapping hexagonal sub regions of equal size [34]. All mobile users in the cell are served by this base station (BS). These base stations allocate frequency channels to the mobile station (MS) or users for communication when a call is made. The mobile user is blocked when there the base station cannot allocate a free channel to it. When a mobile user using a frequency channel of that particular base station reaches the boundary of the cell and moving to another cell, it needs to free the current channel and should acquire a channel from the neighbouring cell to maintain connection. This procedure is called handoff or handover. These base stations are again linked to the base station controller (BSC). The set of base station controllers are connected to mobile switching center (MSC) which is responsible for controlling the calls and acting as a gateway to other networks. This cellular network scenario is shown in Fig. 1.1

The major elements present in the cellular mobile radio system are frequency reuse, co-channel interference reduction factor, carrier-to-interference ratio and cell splitting.

1.1.1 Frequency Reuse

Frequency reuse refers to the use of the same frequency channel in different areas that are distant enough so that the interference caused by the use of the same channel is not a problem. The users in different geographic locations may simultaneously use the same frequency channel. It improves the spectrum efficiency, but if the system is not properly designed serious problems may occur like interferences due to the common use of the same channel known as co-channel
interference. So, the cells which are using the same set of frequency channels called as co-channel cells should be at enough distance which is known as co-channel reuse distance or frequency reuse distance [34, 35].

Fig. 1.1 Cellular Network Scenario

1.1.2 Co-Channel Interference

Reusing the same frequency channel in different cells is limited by co-channel interference between cells, and the co-channel interference can be a major problem. As
long as the cell size is fixed, co-channel interference is independent of the transmitted power of each cell [34]. Carrier to interference ratio (C/I) is used to measure the amount of interference over a specific carrier.

1.1.3 Cell Splitting

When the traffic density increases and the frequency channels $F_i$ in each cell $C_i$ cannot provide enough mobile calls, the original cell can be split into smaller cells. Normally the new radius is one-half the original radius and the new area is one fourth of the old cell area. This implies an additional base stations needed to be established at the center of each new cell that has been added so that the higher density of calls can be handled effectively. As the coverage is smaller, the transmitting power levels are low and help in reducing co-channel interference [34].

1.2 Introduction to Channel Allocation

Channel allocation implies that a given radio spectrum is to be divided into a set of disjoint channels, which can be used simultaneously while minimizing interference in adjacent channels via good channel separation [34]. In order to divide a given radio spectrum into such channels many techniques such as frequency division, time division or code division can be used. In frequency domain, the spectrum is divided into disjoint frequency bands, whereas in the time division the channel separation is achieved by dividing the usage of the channel into disjoint time periods called time slots. In code division, the channel separation is achieved by using different modulation codes. About these three multiplexing schemes are shoned in the Fig.1.2.
Fig. 1.2 Different Generations of Mobile Telecommunication Systems

The Fig. 1.2 shows several development and migration paths for different mobile telecommunications systems. The Diagram is divided into three main multiplexing schemes, FDMA, TDMA, and CDMA. The first generation comprises analog systems, which typically rely on FDMA. The first 2G systems hit the market in the early nineties. In the US D-AMPS was a digital successor of AMPS, in Europe GSM was developed as a replacement for several versions of NMT, and PDC was introduced in Japan. All these 2G systems introduced a TDMA mechanism in addition to FDMA, which is still used for channel separation. With cdmaOne the first CDMA technology was available in the US as a competitor to the TDMA technologies.

GPRS introduced a packet-oriented service and higher data rates to GSM, EDGE proposes a new modulation scheme, and cdmaOne was enhanced to cdma2000 1x offering higher data rates. These systems are often called 2.5G systems. Most, but not all, systems added CDMA technology to become 3G systems. Cordless telephone systems started with CT0 and CT1 became digital with CT2 and ended in Europe in the fully digital standard DECT. This standard has even been chosen as one of the
candidates for a 3G system (IMT-FT). Most network providers offering GSM service today will deploy UMTS, while cdmaOne users will choose cdma2000 for simpler migration. The reasons for this are quite simple. With the introduction of GPRS in GSM networks, the core of the network was already enhanced in a way that it can be directly used for UMTS with the radio technologies UTRA FDD and UTRA TDD. A similar path for evolution exists for TD-SCDMA, the Chinese proposal for a 3G system (which has been integrated into UTRA TDD). With some simplification it can be said that UMTS mainly adds a new radio interface but relies in its initial phase on the same core network as GSM/GPRS. Also for cdmaOne the evolution to cdma2000 technologies is quite natural, as the new standard is backward compatible and can reuse frequencies. Cdma2000 1x still uses the same 1.25 MHz channels as cdmaOne does, but offers data rates of up to 153 Kbit/s. The cdma2000 3x standard uses three 1.25 MHz channels to fit into ITU’s frequency scheme for 3G.

GSM:

GSM is the most successful digital mobile telecommunication system in the world today. In the early 1980s, Europe had numerous coexisting analog mobile phone systems, which were often based on similar standards, but ran on slightly different carrier frequencies. To avoid this situation for a second generation fully digital system, the groupe spéciale mobile (GSM) was founded in 1982. This system was soon named the global system for mobile communications (GSM). In the context of UMTS and the creation of 3GPP (Third generation partnership project, 3GPP, 2002a) the whole development process of GSM was transferred to 3GPP and further development is combined with 3G development. 3GPP assigned new numbers to all GSM standards. The primary goal of GSM was to provide a mobile phone system that allows users to roam throughout Europe and provides voice services compatible to ISDN and other
PSTN systems. Readers familiar with the ISDN reference model will recognize many similar acronyms, reference points, and interfaces.

GSM standardization aims at adopting as much as possible. GSM is a typical second generation system, replacing the first generation analog systems, but not offering the high worldwide data rates that the third generation systems, such as UMTS, are promising. GSM has initially been deployed in Europe using 890–915 MHz for uplinks and 935–960 MHz for downlinks – this system is now also called GSM 900 to distinguish it from the later versions. These versions comprise GSM at 1800 MHz (1710–1785 MHz uplink, 1805–1880 MHz downlink), also called DCS (digital cellular system) 1800, and the GSM system mainly used in the US at 1900 MHz (1850–1910 MHz uplink, 1930–1990 MHz downlink), also called PCS (personal communications service) 1900. Two more versions of GSM exist. GSM 400 is a proposal to deploy GSM at 450.4–457.6/478.8–486 MHz for uplinks and 460.4–467.6/488.8–496 MHz for downlinks. This system could replace analog systems in sparsely populated areas. Special features of this system are, e.g., emergency calls with acknowledgements, voice group call service (VGCS), voice broadcast service (VBS). Furthermore, more elaborate techniques can be designed to divide a radio spectrum into a set of disjoint channels based on combining the above techniques.

The frequency channels should be reused in an efficient way to support many users. The frequency reuse factor of a cellular system is given by 1/N. Since each cell within a cluster is only assigned 1/N of the total available channels in the system. To connect without gaps between adjacent cells, the geometry of hexagons is such that the number of cells per cluster, N can only have values which satisfy equation

\[ N = i^2 + ij + j^2 \]

Where i and j are non negative integers.
The same frequency band or channel used in a cell can be reused in another cell as long as the cells are far apart and signal strength do not interfere with each other. The signal-to-interference ration (S/I or SIR) for a mobile receiver which monitors a forward channel can be expressed as

\[
\frac{S}{I} = \frac{S}{\sum_{i=1}^{I_i} I_i}
\]

Where \( S \) is desired signal power from the desired base station, \( I_i \) is the interference power caused by the \( i^{th} \) interfering co-channel cell base station. Because of the frequency channels are a scarce resource in a cellular mobile system, various channel allocation schemes, have been proposed like fixed channel assignment [30-32], dynamic channel assignment [25, 27, 28, 29], hybrid channel assignment [26, 30].

1.2.1 Fixed Channel Allocation Scheme [30-32]

In fixed channel assignment the number of channels is fixed for a particular cell. If the total number of available channels in the system is divided into sets, the minimum number of channel sets required to serve the entire coverage area is related to the frequency reuse distance \( D \) and radius \( R \) of each cell as follows [34]. The drawback here is, when the number of calls is increased beyond the limited number of channels for a cell, excess are rejected. Extensions to this allocation technique are borrowing schemes.

1.2.2 Simple Borrowing Scheme [30, 33]

A simple borrowing scheme implies that if all channels allocated to a cell are being used, then additional channels can be borrowed from any cell that has some free unused channels. Such a cell is called a donor cell. It can select a donor from among adjacent cells that has the largest number of free channels. This is known as borrowing from the richest [30]. After that it has to return the borrowed channel to the donor if a
channel becomes available in the cell that initially borrowed a channel. Another technique is to select the first free channel found for borrowing when the search follows a predefined sequence known as borrow first available scheme.

**1.2.3 Complex Borrowing Scheme [30, 34]**

In this scheme, the channels are divided into two groups. One group is assigned to each cell permanently and the second group kept reserved as donors to be borrowed by neighbouring cells. The ratio between the two groups of channels is determined a priori and can be based on estimated traffic in the system. Another technique is borrowing with channel ordering, is to assign priorities to all channels of each cell, with highest priority channels being used in sequential order for local calls in the cell while channel borrowing is done starting from lowest priority channels.

But there are relative advantages and disadvantages of this scheme in terms of total channel utilization, total carried traffic and allocation complexity and decisions are made based on traffic behavior. In order to alleviate the above problems, dynamic channel allocation schemes are developed.

**1.2.4 Dynamic Channel Allocation Schemes [25, 29]**

In this scheme, there is no pre assignment of frequency channels to the cells of the cellular network. All frequency channels are kept in a central pool. When there is a channel request in one base station, the mobile switching center chooses the appropriate frequency channel that gives maximum channel efficiency taking into account all the signal interference constraints. The channels are assigned for the duration of a call, after the call has finished, the channel is returned to the central pool or reallocated to a mobile user inside the same cell site that was controlling the channel before [34]. There are two types of dynamic channel allocation schemes. They
are distributed dynamic channel allocation technique and centralized dynamic channel allocation technique.

**Centralized Dynamic Channel Allocation Scheme [30, 34]**

In this scheme, a channel is selected for a new call from a central pool of free channels, and a specific characterizing function is used to select one among candidate free channels. The simplest scheme is to select the first available free channel that can satisfy the reuse distance. Another scheme is to pick a free channel that can minimize the future blocking probability in the neighbourhood of the cell that needs an additional channel known as locally optimized dynamic assignment [30, 34]. The disadvantage of this scheme is, if the mobile switching center which is acting as central pool of free channels fails the whole system will be affected and also burden or load on it increases. So to avoid these problems distributed dynamic channel allocation schemes are developed.

**Distributed Dynamic Channel Allocation Scheme [26-28, 30]**

In this scheme all the channels available are distributed across the network. The channels are distributed among several base stations. The base stations will communicate each other for acquiring the free channel available. Since the channels are distributed, even if one base station failures only these channels the base station is having will be affected, the other set of channels at other base stations will continue functioning and helps in providing channels.

These schemes are primarily based on one of the three parameters: co-channel distance, signal strength measurement and signal-to-noise interference ratio. In a cell based distributed scheme, a table indicates if other co channel cells in the neighbourhood are not using one or more channels and selects one of the free channels for the requesting cell. In an adjacent channel interference constraint scheme, in
addition to co channel interference, adjacent channel interference is taken into account while choosing a new channel [34]. The disadvantage of this scheme is the communication between several base stations in acquiring the free channel increases message complexity.

1.2.5 Hybrid Channel Allocation Scheme [26, 30, 34]

Hybrid channel allocation scheme is a combination of fixed and dynamic channel allocation scheme, with the channels divided into fixed and dynamic sets. This means that each cell is given a fixed number of channels that is exclusively used by the cell. Request for a channel from the dynamic set is initiated only when a cell has exhausted using all its channels in the fixed set [34]. The channel from the dynamic set can be selected by employing any of the dynamic channel allocation schemes.

1.2.6 Flexible Channel Allocation Schemes [33, 34]

In the flexible channel allocation scheme the set of available channels is divided into fixed and flexible sets. Each cell is assigned a set of fixed channels that typically sufficed under a light traffic load. The flexible channels are assigned to those cells whose channels have become inadequate under increasing traffic loads. The assignment of these emergency channels among the cells is done in either a scheduled or predictive manner. In the scheduled basis, it is assumed that the variation of traffic, such as the movement of traffic peaks in time and space, are estimated a priori. The change in assignment of flexible channels is then made at the predetermined peaks of traffic change. In the predictive strategy, the traffic intensity and the blocking probability is constantly measured at every cell site so that the reallocation of the flexible channels can be carried out at any point of time.
1.3 Introduction to Handoff

In cellular mobile communication systems, the number of channels available is limited. Hence, it is very important to effectively allocate channels. There are various schemes to assign channel frequencies to the base stations. Those schemes are divided into three categories i.e., fixed, dynamic and hybrid assignments [34]. Here we assume that there are fixed number of channels in each cell. So, here fixed assignment scheme is used to assign channel for initial and handoff calls.

When a mobile station wants to communicate with the other base station, channel should be free to be allocated to MS. If no channel is available before waiting time, the call is blocked. If channel is assigned, MS is connected to a base station. Because adjacent cells have some overlapped area, called handoff area, MS can use channels in either of adjacent cells [34]. When MS moves beyond the coverage area of the BS, to which it is newly connected is assigned. This process is called as handoff, handover or automatic link transfer. If there is no channel available in the new BS, the call is disconnected. This is called forced termination.

Mobility is the most important feature of a wireless cellular communication system. Usually, continuous service is obtained by supporting handoff (or handover) from one cell to another. Handoff is the process of changing the channel (frequency, time slot, spreading code or combination of them) associated with the current connection while a call is in progress. It is often initiated either by crossing a cell boundary or by deterioration in quality of the signal in the current channel.

1.3.1 Types of Handoff

Handoff is divided into 2 categories, hard and soft handoffs. They are also characterized by “break before make” and “make before break” respectively [36], i.e., in hard handoff, existing resources are released before new resources are utilized.
Usually, the hard handoff can be further divided into two different types – intra and inter cell handoff [39]. Hard handoff procedure is shown in Fig. 1.3. In soft handoff, both existing and new resources are used. The smaller the size of the cells and variable propagation of signals causes much frequent handoffs.

![Fig. 1.3 Hard Handoff](image)

The soft handoff can also be divided into two different types – multi way soft handoffs and softer handoffs. Soft handoff procedure is shown in Fig. 1.4. Poorly designed handoff schemes tend to generate very heavy signaling traffic and thereby a dramatic decrease in quality of service (QoS). The reason why handoffs are critical in cellular communication systems is that neighbouring cells are always using a disjoint subset of frequency bands, so negotiations must take place between the mobile station
(MS), the current serving base station (BS), and the next potential BS. Other related issues, such as decision making and priority strategies during overloading, might influence the overall performance [37].

![Fig. 1.4 Soft Handoff](image)

**1.3.2 Types of Services**

There are two different types of services, real time (such as audio and video transmission) and non-real time service (such as data transmission). There are several parameters in measuring cellular systems. Some of those are blocking probability for new calls originated in a cell, forced termination probability of on-going calls, queue length, average length of requests and average transmission delay for data users [38]. The design of a good handoff scheme requires that the blocking probability for new calls must be minimized and also reduce transmission delay of non-real time service calls and maximize channel utilization.
1.3.3 Handoff Initiation

The performance evaluation of a handoff is based on various initiation criteria. It is assumed that the signal is averaged over time, so that rapid fluctuations due to the multi-path nature of the radio environment can be eliminated [39]. If MS is moving from BS1 to BS2, the mean signal strength of BS1 decreases as the MS moves away from it. Similarly, the mean signal strength of BS2 increases as the MS approaches it. The Fig. 1.5 is used to explain various approaches described in the following subsection.

![Fig. 1.5 Signal strength between two adjacent BS’s for potential Handoff](image)

**Relative Signal Strength**

This method selects the strongest received BS at all times. The decision is based on a mean measurement of the received signal. In Fig. 1.4, the handoff would occur at position A.

**Relative Signal Strength with Threshold**

This method allows a MS to handoff only if the current signal is sufficiently weak (less than threshold) and the other is the stronger of the two. The effect of the threshold depends on its relative value as compared to the signal strengths of the two
BS’s at the point at which they are equal. If the threshold is higher than this value, say $T_1$ in Fig. 1.5, this scheme performs exactly like the relative signal strength scheme, so the handoff occurs at position A. If the threshold is lower than this value, say $T_2$ in Fig. 1.5, the MS would delay handoff until the current signal level crosses the threshold at position B. In the case of $T_3$, the delay may be so long that the MS drifts too far into the new cell. This reduces the quality of the communication link from BS1 and may result in a dropped call.

**Relative Signal Strength with Hysteresis**

This scheme allows a user to handoff only if the new BS is sufficiently stronger (by a hysteresis margin, $h$ in Fig. 1.5) than the current one. In this case, the handoff would occur at point C. This technique prevents the so-called ping-pong effect; the repeated handoff between two BS’s caused by rapid fluctuations in the received signal strengths from both BS’s.

**Relative Signal Strength with Hysteresis and Threshold**

This scheme hands a MS over to new BS only if the current signal level drops below a threshold and the target BS is stronger than the current one by a given hysteresis margin. In Fig. 1.5, the handoff would occur at point D if the threshold is $T_3$.

**Prediction Techniques**

Prediction techniques base the handoff decision on the expected future value of the received signal strength. A technique has been proposed and simulated to indicate better results, in terms of reduction in the number of unnecessary handoffs, than the relative signal strength, both without and with hysteresis, and threshold methods.
1.3.4 Handoff Decision [39]

The decision-making process of handoff may be centralized or decentralized (i.e., the handoff decision may be made at the MS or network). There are three different kinds of handoff decisions.

**Network-Controlled Handoff**

In a network-controlled handoff protocol, the network makes a handoff decision based on the measurements of the MS’s at a number of BS’s. In general, the handoff process (including data transmission, channel switching and network switching) takes 100-200ms. Network-controlled handoff is used in first generation analog systems such as AMPS (Advanced Mobile Phone System), TACS (Total Access Communication System), and NMT (Nordic Mobile Telephone).

**Mobile-Assisted Handoff**

In a mobile assisted handoff process, the MS makes measurements and the network makes the decision. In the circuit-switched GSM (Global System Mobile), the BS controller (BSC) is in charge of the radio interface management. This mainly means allocation and release of radio channels and handoff management. The handoff time between handoff decision and execution in such a circuit-switched GSM is approximately 1 second.

**Mobile-Controlled Handoff**

In mobile-controlled handoff, each MS is completely in control of the handoff process. This type of handoff has a short reaction time (in the order of 0.1 second). MS measures the signal strengths from surrounding BS’s and interference levels on all channels. A handoff can be initiated if the signal strength of the serving BS is lower than that of another BS by a certain threshold.
1.4 Motivation

As the growth of mobile users increasing in the present scenario and there is limited bandwidth available, there is a need to efficiently use the bandwidth available. In the past many channel allocation schemes proposed for the efficient utilization of bandwidth or channels. But very few algorithms have addressed quality of service guarantee in channel allocation. For providing better quality of service and improving system capacity we should minimize the call blocking probability as well as call dropping probability. We can minimize this quality of service parameters by efficient bandwidth reservation. If more bandwidth is reserved call blocking probability increases, if less bandwidth is reserved call dropping probability increases. The channel allocation scheme has to allocate channels to cells or mobiles in such a way as to minimize call blocking or call dropping probabilities, and also to maximize the quality of service.

Many bandwidth reservation channel allocation algorithms are proposed based on the user mobility and traffic in cellular networks. But predicting the user mobility is very crucial one in making decisions on bandwidth reservation. The user can move in any directions like straight, right, left or backwards. So if you can predict user mobility and according to that if you can make bandwidth reservation, performance can be increased. So this project proposes a distributed dynamic channel allocation scheme with small amount of bandwidth reservation initially and excess bandwidth reservation is done to a specified amount by considering user mobility and hot cells where number of handoffs will be more and cold cells where number of handoffs will be less.
1.5 Thesis Statement

With the enormous growth of mobile users, effective utilization of bandwidth is very much essential. In this point of view, this thesis proposes optimized channel allocation algorithm which uses cross layer architecture to efficiently utilize the bandwidth and time and priority based reservation scheme is also discussed. These procedures are used to reduce the call blocking probability, call dropping probability, end-to-end delay and thereby increasing the performance of the system by increasing the throughput of the complete system.

1.6 Objectives

Main objective of this thesis is to maximize the quality of service by the efficient utilization of bandwidth reservation. To have a channel allocation scheme which reduces the blocking of new calls and also efficiently handles handoff calls without dropping them.

The thesis aims to provide better performance in bandwidth reservation and channel allocation procedures. The main objectives of this research are listed below:

- To propose optimal channel allocation algorithm with efficient bandwidth reservation for cellular networks
- To propose time and priority based bandwidth reservation scheme for cellular networks.
- This thesis utilizes the cross layer architecture to reduce the end-to-end delay in packet delivery and to increase the throughput of the system.

1.7 Scope of the Thesis

In addition to this introductory chapter, the dissertation is organized into five chapters that present in detail about various algorithms that improve the performance of system in terms of the QoS parameters like call blocking probability, call dropping
probability, end-to-end delay of packet transmission and throughput. The following are the descriptions of various chapters of this thesis.

Chapter 2

In this chapter a brief study on the related work was carried out in this area. The different procedures and the ways the channel are allocated, bandwidth utilization, priority allocation procedures of the different authors are discussed.

Chapter 3

In this chapter the framework of this thesis is presented. The cross layer network is discussed which is used to reserve the bandwidth for handoff flows and helps in minimizing the dropping and blocking probabilities. The basis of this thesis work is presented in this chapter.

Chapter 4

In this chapter cross-layer system which is based on bandwidth reservation is proposed, which first reserves a certain amount of bandwidth to transfer flows. Then later, the bandwidth can be increased for handoff flows by the base station based on user mobility. The user is free to move in any direction. This chapter examines the possible movement of the user and reserves bandwidth accordingly. Therefore making the base stations dynamically increase the bandwidth reserved for handoffs when the bandwidth originally booked is insufficient reduces the possibility of call dropping and increases system throughput. The performance of the proposed system is compared with existing systems and better performance is proved.

Chapter 5

In this chapter thesis proposes a scheduling algorithm that uses bandwidth efficiently and thereby increasing system throughput. The flows are represented as originating and transfer flows. Applications related to these flows are represented as
voice, video, data, etc. Priority is given depending on the speed and different types of applications. In addition, priority is also based on time. Bandwidth is reserved based on the priority given to a particular stream. System performance is evaluated in terms of probability of blocking the call and the probability of call dropping and is proven to be better compared to older systems.

Chapter 6

In this chapter we shows all the results carried out and the related discussions on the outputs through the graphs

Chapter 7

This chapter deals with the conclusions of overall thesis. Further each chapter discussed the simulation results of the proposed novel methods carried out. A brief conclusion is also included at the end of each chapter.