Chapter 1

Introduction

1.1 Mobile Communications - a Historical Evolution

For the past two decades there has been a considerable growth in the field of wireless mobile communications and services. This unprecedented growth has been possible due to continuous improvements in technologies such as signal compression, bandwidth efficient modulations, improved error correcting codes and better multiple access techniques. The advances in computer and digital signal processing (DSP) technologies have resulted in compact size of the mobile terminals as well as in faster resource management using intelligent networks. Mobile systems have seen two generations giving voice and limited data services. This success has created a demand for higher data rate multimedia communication services and as a result activities on the development of third generation mobile systems (3G) [1] have been in full swing. Upcoming 3G systems employ code division multiple access (CDMA) techniques in addition to time division multiple access (TDMA). Full deployment of 3G systems may take little longer time than planned. However, capabilities of 2G systems are being enhanced towards 3G and being referred to

2.5G systems.

Looking at the history, one finds that wireless communication has seen sea changes over the last six decades, starting with services like 'Improved Mobile Telephone Services' (IMTS) [2] which provided limited coverage to a limited number of users in the 1940's to the enhanced digital mobile systems of today. However, the growth of mobile systems got an impetus after the introduction of cellular concept by Bell Labs to increase the coverage area as well as the capacity of the systems. First generation mobile systems (eg. AMPS) based on the cellular concept were pressed into service in 1970's, which employs analog communication techniques [3]. Subsequently, digital techniques were introduced to overcome most of the deficiencies in analog cellular systems. The mobile systems based on digital technology are popularly known as second generation or 2G systems. Some 2G systems also employ Code division multiple access (CDMA) technique [4] apart from the usual TDMA and FDMA techniques. Both the 2G and 3G systems employ advanced digital technologies to provide improved quality of service (QoS).

The key to the success of cellular mobile communications is an efficient handoff as the mobile moves from one cell to another. In fact, the primary concern for desired QoS is due to the proper handoff. Thus handoff management is very important in cellular mobile communications and is briefly discussed in the next section.

1.2 Handoff Management

Handoff management is an essential operation in any cellular mobile system to maintain a mobile user's connection with a base station. It is the process of changing radio connection of the mobile station (MS) from one base station (BS) to another BS as it moves from one cell to another. A typical inter cell handoff sce-

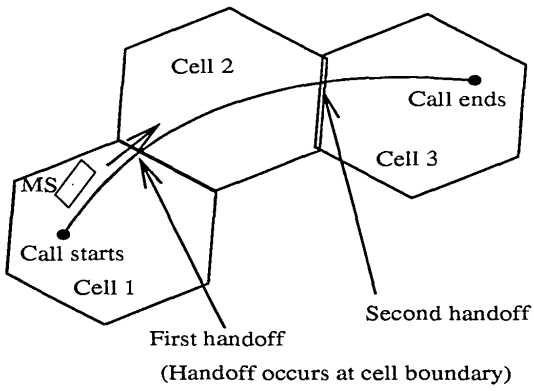

Figure 1.1: A typical inter cell handoff

nario is depicted in Fig.1.1. Handoff is termed as hard handoff when the connection to a new BS is established after breaking its connection to old BS, whereas it is termed as soft handoff when the connection to old BS is broken after establishing the connection to new BS [5]. Handoff should occur near the cell boundaries to avoid loss of link as the signal received from the serving BS deteriorates. The handoff process consists of a few operations like handoff detection and execution. They are indicated in Fig.1.2. For understanding the requirement of handoff and its successful execution, it is necessary to know the characteristics of the propagation environment. The mobile communications channel is known to be a fading channel. The randomness of the fading channel results in various problems in the operation of handoff. Before the handoff can be executed, its requirement is to be detected and unfortunately fading makes it difficult. Fading may also result in failure of the handoff. These problems have forced people to take up research in the area of handoff. Efficient handoff algorithms are needed for detecting the need for handoff and then executing the process of handoff. It may be pointed out that for effecting the handoff, resources like channels must be available. Further, the resources should be managed well to give the best performance in terms of their

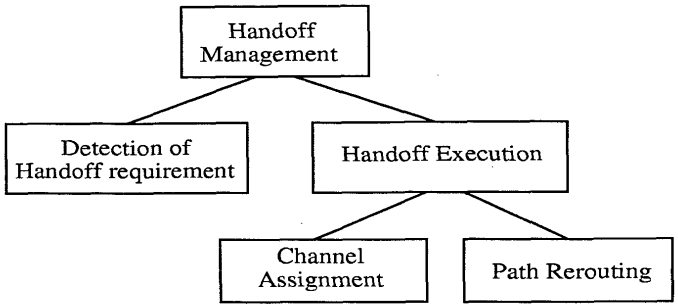

Figure 1.2: Handoff management operations in a cellular mobile system

utilization. Lack of resources and/or their inefficient handling may result in call dropping which is extremely undesirable. Once again a through study is essential to develop suitable channel assignment and management schemes.

For successful execution of handoff, channel resources should be available to establish a new connection between the MS and the mobile network. A call requesting handoff will be dropped if it does not get a channel to continue the call. To avoid such call dropping and to make handoff successful, an effective channel assignment scheme giving priority to handoff calls is needed. Several handoff and channel assignment procedures and algorithms have been proposed to overcome most of these and other difficulties for efficient service [6][7].

It may be pointed out that the cellular mobile communication was primarily developed and still used for voice applications and as such are circuit switched. Over the last few years and in time to come mobile data communications have also become a necessity. While the circuit switched network can also support data services, it may be desirable to have packet switching in mobile communications. Further, the emphasis is shifting from voice to multimedia applications which requires greater bandwidth. Based on these considerations mobile wireless ATM (WATM) is catching the attention of researchers recently. It may be pointed out

that ATM being a connection oriented packet service will require path rerouting when used in mobile communication networks [8].

In view of the above discussion we found the topic of handoff management quite interesting for our study. The issues of need for detection of handoff and channel assignments have been taken up for investigation. In addition, considering the trend, we have also taken up handoff management issues for the emerging mobile WATM networks. The next section highlights our research objectives.

1.3 Research Objectives

Handoff management in cellular mobile systems is the focus of our study. Objective of our research work is to

(i) understand the handoff mechanism
(ii) evaluate the performance of existing algorithms
(iii) develop and design new schemes to achieve improved and desired performance
(iv) study priority handoff channel assignment schemes and work out new ones and
(v) investigate issues and schemes of handoff rerouting for WATM systems.

Specifically the following studies have been taken up:

- Extensive survey of published literature and review of handoff management schemes.
- Performance evaluation of many existing hard handoff detection algorithms.
- Development and evaluation of a new handoff detection scheme.

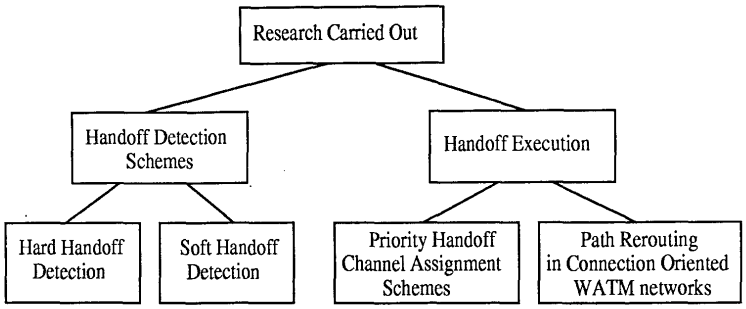

Figure 1.3: Research work carried out

- Performance analysis of two different soft handoff algorithms.
- Study of an existing priority based channel assignment scheme.
- Development and performance evaluation of a new channel assignment scheme giving priority.
- Study of a new generalized scheme for priority channel assignment scheme.
- Study of rerouting techniques for mobile WATM networks.
- Study of a new proposed rerouting scheme.

Our study includes a critical comparison of the alternative schemes under each category. Fig.1.3 reflects our research work presented in this thesis. The next section describes the approach to our study and work.

1.4 Approach to Work

The problem of handoff has been handled by analysis as well as simulation in general. In our case, we have taken up simulation for most of our studies such as

handoff detection algorithms and channel assignment schemes giving priority to handoff. Our preference for simulation has been to get a better practical insight to the problem. In fact this has helped us to come up with modifications and new ideas which have led to new algorithms with a potential of desired performance. However, we have also studied some of the handoff management schemes like the soft handoff and the rerouting problem in mobile WATM through analysis. Suitable parameters have been assumed for evaluation as explained in relevant sections in the thesis. At times we have defined some additional performance metrics which give a better picture of the scheme.

In our work, performance of hard handoff detection algorithms have been evaluated through simulation. Considerable time has been spent to develop a simulation model through C programming. The simulation includes generation of power-law path loss propagation model and log-normal (shadow) fading, implementation of filters for introducing spatial correlation in the generated shadow fading samples and for averaging out larger variations in the received signal. The developed simulation model has been verified by comparing the results obtained with the results published in literature.

Performance of soft handoff algorithms has been evaluated through an analytical model. The model has been evaluated using MATLAB.

Performance of the priority handoff channel assignment schemes has been evaluated through simulation. The simulation model includes generation of call arrival times, call duration times, velocity and direction of mobiles in the cellular service area, channel assignments, etc.

Performance of handoff rerouting schemes for mobile WATM networks has been evaluated through analysis and numerical computation. For various performance metrics reflecting the efficacy of the rerouting schemes, analytical expressions have

been derived and evaluated.

We have carried out our investigation to fulfill the objectives as highlighted here and reporting the work in this thesis whose organization is shown in the next section.

1.5 Thesis Organization

Besides this introduction chapter this thesis has seven chapters containing two review chapters and four contributory chapters. The last chapter viz. Chapter 8 contains major conclusions. About eighty references have been cited and listed in the thesis.

In addition to the brief description of the basics of cellular mobile communications, the hard and soft handoff detection algorithms have been reviewed in the second chapter. A qualitative comparison of the handoff detection algorithms have been made.

Since priority based channel assignment and rerouting in mobile WATM networks are our topics of research, they have been thoroughly reviewed in the third chapter. For convenience the third chapter consists of two parts; Part A deals with the review of channel assignment schemes and Part B is devoted to rerouting schemes which are useful for mobile WATM.

The fourth chapter describes a new hard handoff detection algorithm RSS-HT_{new} developed by us and its performance. Based on a network model and assuming the relevant parameters the performance of four existing hard handoff detection algorithms and also the proposed scheme have been evaluated. The results are reported in this chapter.

Soft handoff algorithms have been investigated analytically and reported in the

fifth chapter. Two soft handoff schemes which are signal strength based have been studied. It may be noted that our study of handoff detection is primarily based on signal strength.

Chapter 6 deals with the important issues of channel assignment in the process of handoff. Introduction of priority in assignment of channels helps in reducing the dropping of handoff requested calls. In addition to studying the known guard channel based priority handoff scheme, performance of our proposed 'Timer based priority handoff' scheme also has been investigated. A study on our development of a new 'Call duration based priority handoff' scheme has also been included in this chapter.

As mentioned earlier, mobile multimedia broadband communication services are drawing the attention of researchers over the past few years. Our studies on handoff issues in mobile WATM have been discussed in the seventh chapter. The primary issue of rerouting has been investigated by evaluating the performance of four existing schemes and one new scheme proposed by us.

The last chapter presents a brief summary and the major conclusions of our work.

1.6 Scope of the Thesis

Handoff management plays a vital role in cellular mobile communications. Properly designed handoff algorithms for detection and execution are critical for the overall functioning of a cellular radio system. A thorough review of the above handoff management mechanisms gives us a good understanding and insight of the issues involved in handoff. Various problems related to handoff detection and execution have been identified. This will be of help in devising new solutions and

techniques for efficient handoff management. A detailed comparative performance evaluation of most of the handoff algorithms and schemes has been made through simulation and in some cases by analytical investigation. This gives us first hand experience of the problems underlying handoff and the choice of handoff algorithms for better performance.