Performance Analysis of Handover In Cellular Network With Small Scale Radio Network.

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It is hereby declared that this project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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DEDICATION

I dedicate this project to the almighty Lord.

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List of Abbreviations of Technical Symbols and Terms

AMRIS-Ad hoc Multicast Routing Protocol Utilizing Increasing Id-numbers

AM Route-Ad hoc Multicast Routing

ANDA-Ad hoc Network Design Algorithm

AODV-Ad hoc On-demand Distance Vector Routing

AP-Access Point

ARS-Ad hoc Relaying Station

ASK-Amplitude Shift Keying

ATCP-Ad hoc TCP

ATM-Asynchronous Transfer Mode

ATP-Ad hoc Transport Protocol

BAAR-Base-Assisted Ad hoc Routing

BTS-Base Transceiver Station

BS-Base Station

CA-Certifying Authority

CDMA-Code Division Multiple Access

CDPD-Cellular Digital Packet Data

EDGE-Enhanced Data Rates for GSE Evolution

FDD-Frequency Division Duplex

FDDI-Fiber Distributed Data Interface

HIPERLAN-High-Performance Radio LAN

HLR-Home Location Register

HOD-Handover Dropping

HWN-Hybrid Wireless Network

iCAR-Integrated Cellular Ad hoc Relaying System

MCN-Multi Hop Cellular Network

SOPRANO-Self-Organizing Packet Radio Networks with Overlay

SSRN-Small Scale Radio Network

TWiLL-Throughput Enhanced Wireless in Local Loop

UCAN-Unified Cellular and Ad hoc Network

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Abstract

Integration of ad hoc mode into cellular system has enhanced the cellular communication in many ways. But for network designers, many challenges has aroused due to this merging of two types of networks. As ad hoc link is used, multi-hop handover is inevitable. There are many challenges in Multi-hop handover. Generally handover latency, call dropping and call blocking increases in many cases of multi-hop handover scenarios. The complexity of handover process, load sharing and resource management are also very critical issues. And most of these issues are not well addressed so far. If link selection is not correct then it leads to untimely termination of calls or frequent handoffs. If the reservation for handover call is more, the blocking of new calls will be more. In the case where reservation for handover call is less handover dropping will be more. So, to keep the call dropping rate within a tolerable range, there must be a scheme for reserving feasible minimum bandwidth for handover calls. There is no such scheme where the issue of selecting a destination node for handover is addressed. Moreover we must make reservations in such a way that it should be good enough to meet certain handover dropping (HOD) requirement and certain call blocking threshold. In this project we propose a scheme to assist handover in cellular network. To achieve our aforementioned goal we propose a small scale radio network. This network uses the self organizing feature of the ad hoc mode. Ad hoc mode is an additive component to the cellular system which does not impair the conventional system but creates extra opportunities to be connected with the base station. The scheme provides an auxiliary way to complete handover in cellular system. Moreover, this scheme enables each base station to find the feasible minimum bandwidth reservation for handoff calls based on the knowledge of adjacent cells' traffic information. Due to the use of multi-hop connections, our scheme can apparently alleviate the reservation requirement and lower the call blocking rate while retaining higher spectrum efficiency. We further provide a framework for information exchange among adjacent cells, which can dynamically balance the load among cells. Through this study, we demonstrate how we can utilize ad hoc mode in cellular systems to significantly improve the handoff performance. This scheme can reduce handover latency, handover call dropping and call blocking. Thus, better handoff performance compared to the single hop cellular system can be achieved.

CHAPTER 1

Introduction

1.1 Motivation

The conventional cellular system i.e. single hop cellular system is deeply commercialized and in the vogue for many years. On the other hand the pure ad-hoc wireless network has a limited area of use such as in the remote forests for sensing smoke prior to a fire break out, in the war field as temporary communication, in natural disaster affected zones where cellular network is uprooted and may be in few more areas. The merging of the both types of network can bring about a revolution in communication technology. This new type of network is known as hybrid wireless network. The capacity (maximum throughput) of a cellular network can be increased if the network incorporates the properties of multi-hop relaying along with the support of existing fixed infrastructure. MCNs combine the reliability and support of fixed base stations of cellular networks with flexibility and multi-hop relaying of ad hoc wireless networks.

Multi hop cellular network can increase the cell capacity as it uses additional ad hoc links to accommodate more number of calls. This reduces transmission power and interference as the transmission distance is shorter. But the challenges of MCN such as how to reduce the call dropping rate, how to simplify the multi-hop handoff processes, and how to take more advantage of ad hoc mode for better resource management, and most of these issues have not been well addressed yet. Of course there are attempts to solve these issues in many ways but the most appealing feature of ad hoc network, the self organizing feature was not utilized. In the next section we have provided a review of the existing models and designs. In this project we address the following issues

- Handover latency
- Feasible minimum reservation for handover calls
- Handover call dropping
- Call blocking

1.2 Related Works

The integration of multi-hop ad hoc mode into cellular systems has been conceived in late 1990s and early 2000s. However, one of the first thoughts of integration is to introduce relaying systems into cellular systems. Hsu and Lin might be the first presenting the potential idea called Multi-hop Cellular Networks (MCNs) [10]. In this project, the authors suggested to use multi-hop communications from mobiles to a base station via possibly multiple hops with lower transmission power so that more simultaneous communications can be accommodated. Different hands over scenarios are also presented in this work. The relay nodes participate in the handover process. When there is handover between two Base stations then it is the regular one same with Single hop cellular Network. But complexity is more for scenarios where the relay nodes and BTS both participate in the process. As the relay nodes do not form any kind of network and also do not use the self organizing features of ad hoc network so the latency of handover is more. This latency has to be reduced otherwise it may result in deterioration of seamless service for mobile users. In iCAR (Integrated

Cellular and Ad Hoc Relaying Systems), Wu et al. proposed to proactively deploy a new set of relaying nodes in areas where traffic congestion start forming and use these relaying nodes, called ad hoc relaying stations(ARSs), to relay the traffic from the congested cell to the non-congested cells where traffic can be served [5]. If works wells then this model can alleviate the load of a congested area and transfer the extra traffic to the cell where there is less traffic. Whenever there is a public event such as gaming tournaments, carnivals etc then that particular area may be congested with extra burden of the traffic. This may result in call blocking up to a severe level. To investigate how much ad hoc relaying could enhance the system capacity in MCNs, Law et al. studied the capacity by assuming that a cell is divided into two co-centered areas where direct communications are carried out within the near range between mobiles and the base station while multihop communications will be carried out only when mobiles are outside the near range [11] and found that for certain scenarios, the system capacity can indeed be increased. The system capacity increases due to the use ad hoc links. The ad hoc link is an extra link which the users use as opportunistically. Generally, the cellular link is used but when it is unavailable due the non existence of a direct link multi hop link is used. To take more advantages of relaying capability and by harvesting potential out band resource, Luo et al. proposed a unified cellular and ad-hoc network architecture (UCAN) based on 1xEV-DO (HDR) and 802.11b [8]. This work was motivated by the observation that a higher downlink data rate may be needed for many applications. By allowing wireless clients to relay the downlink traffic in this scheme, the system can achieve better throughput performance. The authors developed the discovery algorithm of wireless proxy (relay clients), which plays very important role in implementing their proposed architecture. In case where higher downlink data is less than uplink data the scheme may not perform well. In view of the potential gain in using ad hoc mode, future generation wireless cellular standards have also considered this issue and proposed ODMA (Opportunity Driven Multiple Access) protocol [12], which is a similar scheme to UCAN [8], but focuses on the improvement of data rate by allowing relaying. There are many proposals on ad-hoc/cellular integration architecture in the literature which address different aspects of various integrated networks. This trend carries many fold benefits to the cellular system. Cavalcanti et al. provided a survey of all these integrated networks [13]. Some of the features of the related works are compared. Le and Hossain have also given a survey on the existing MCNs [14], which focuses more on resource management. Cho et al. dealt with handoff issues of various types in MCNs [6]. In [15], Bhargava et al. took a different approach and intended to use cellular networks to help the management of ad hoc networks by utilizing the benefit of coverage offered by cellular systems. For achieving high data rate and better indoor coverage and fulfill capacity demand femtocell network is a good option [20]. The conventional algorithm used in macro cell for handover needs some modification to implement in the environment where seamless service is required while moving to and from macro cell. A hybrid handover management is proposed here by the authors with call admission control policy which takes care of seamless communication between integrated femtocell macro cell networks. G.H Lv et al has proposed an analytical model which is PH-renewal process. A matrix analytic approach and PH-renewal process both are used analyze the performance measure of the drop and block probability in the MCN.

As we can observe, most integration research works are based on cellular systems, we focus more on enhancing the performance of cellular systems because cellular systems are deeply commercialized and they can provide seamless coverage and mobility service

1.3 Objectives with Specific Aims:

The objective of this project is to improve handoff performance in cellular networks by using a small scale network. Hand off performance is measured by latency, call dropping and call blocking rate. There may be few other parameters. This scheme can easily accommodate those in future.
To achieve this objective, we have identified the following specific aims:

- To develop a scheme using small scale radio network which uses self-organizing mode of ad hoc networks to decrease handover latency.

- To find feasible minimum bandwidth reservations.

- To choose a node among available nodes as handover destinations.

- To compare the existing reservation schemes in conventional cellular system with this proposed scheme.

1.4 Outline of this Project Report:

- In Chapter 2 and 3, the modern trend of integrating ad-hoc and cellular network is discussed along with the challenges of multi-hop cellular networks (MCN).

- In chapter 4, we discussed how to reduce handoff latency. Analysis is given to find tradeoff between handover dropping (HOD) and Reservation, i.e., finding feasible minimum bandwidth reservation. A small scale radio network (SSRN) is proposed using relatively stationary nodes such as Automatic Relay Stations (ARS) which follows IEEE 802.11 standards. Architecture and role of each node is defined. The handoff process is also described in this particular model. Basic idea and mathematical representation is presented. An algorithm is formulated to find minimum reservation.

- In chapter 5, performance of the proposed algorithm is simulated using MATLAB simulation in terms of handover dropping rate, call blocking rate and bandwidth reservation. Conclusion and possible future works are presented in the last chapter of this report.

CHAPTER 2

Integration of Ad-Hoc and Cellular Networks

2.1 Fundamentals of Cellular Networks

A cellular network or mobile network, as depicted in figure 2.1, is a communication network where the last link is cellular. The network is distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a cell site or base station. This base station provides the cell with the network coverage which can be used for transmission of voice, data and others. A cell might use a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed service quality within each cell.

When joined together, these cells provide radio coverage over a wide geographic area. This enables a large number of portable transceivers (e.g., mobile, pagers, etc.) to communicate with each other and with fixed transceivers and telephones anywhere in the network, via base transceiver stations/system(BTS), even if some of the transceivers are moving through more than one cell during transmission.

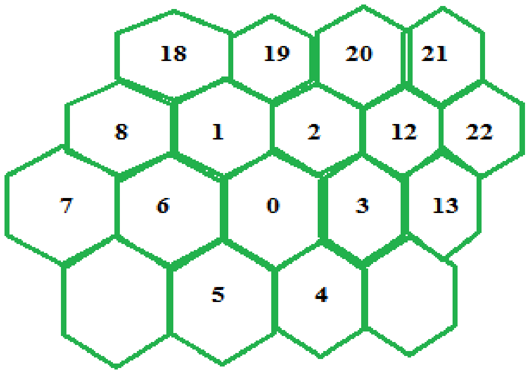


Fig 2.1 Cellular network

2.2 Integration of Ad-Hoc and Cellular Networks

This is the combination of conventional cellular and ad hoc network. This is the most recent trend. This gives reliability of cellular network and feasibility of ad hoc network. The intersection of two networks as shown in figure 2.2 is hybrid network. This Integration is emerging to be a potential field of research. So, we are giving a synopsis study.

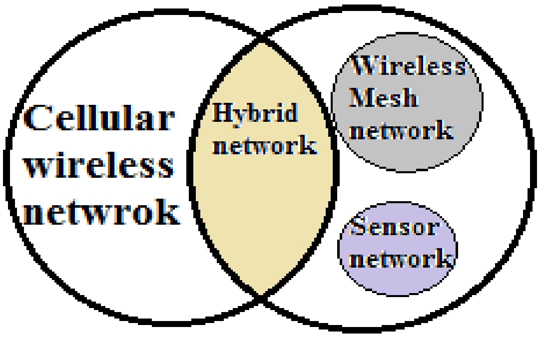


Fig 2.2 Integration of Ad-Hoc and Cellular Networks [21]

The major differences between cellular networks and ad hoc wireless networks are summarized in Table 2.1. The presence of base stations simplifies routing and resource management in a cellular network as the routing decisions are made in a centralized manner with more information about the destination node. But in an ad hoc wireless network, the routing and resource management are done in a distributed manner in which all nodes coordinate to enable communication among them. This requires each node to be more intelligent so that it can function both as a network host for transmitting and receiving data and as a network router for routing packets from other nodes. Hence, the mobile nodes in ad hoc wireless networks are more complex than their counterparts in cellular networks.

Table 2.1: Differences between Cellular and Ad Hoc network

Cellular Network	**Ad Hoc network**
Dependent on Infrastructure	Infrastructure less
Extension cost is higher than Ad Hoc Networks	Low cost of extending
Not as flexible as ad hoc networks	Flexible
Deeply commercialized	Not deeply commercialized
Used everywhere and every time in general	Mostly used in emergency time periods
Mounted in a place	Not fixed
Widely used and deployed in all over the world	Several issues are yet to be solved to deploy it

2.2.1 Capacity Enhancement

Each cellular service provider is allotted a certain band of frequencies. Considering the interference constraints, this restricts the number of channels that can be allotted to each cell. So, handover have been devised to enhance the capacity of cellular networks. It has been observed that the main reasons for reduction of cellular network capacity are off-center placement of antennas in the cell, limited frequency reuse imposed by a strict clustering scheme, and inhomogeneous propagation conditions. The nearest base station is not always the best for a mobile station, due to shadowing, reflections, and other propagation-based features. The simplistic model of cellular networks has to be modified to account for these variations. A few methods used to improve the capacity of cellular networks are discussed.

2.2.1.1 Cell-Splitting

Non-uniform traffic demand patterns create hotspot regions in cellular networks, which are small pockets with very high demand for channel access. In order to satisfy QoS constraints, the blocking probability in a hotspot region must not be allowed to shoot up. This gave rise to the concept of cell-splitting. A different layer of cells which are smaller in size, and support users with lower mobility rates, is overlaid on the existing (macro-cells) cellular network. These are called micro-cells as shown in figure 2.3. While macro-cells typically span across tens of kilometers, micro-cells are usually less than 1 Km in radius. Very small cells called pico-cells, of a few meters' radius, are also in use to cover indoor areas.

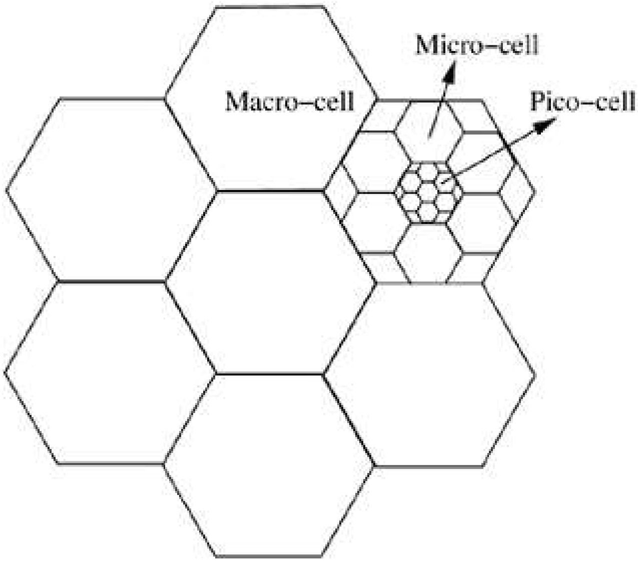


Fig 2.3: Cell-Splitting [16]

This is shown in Fig -2.3. Depending on the demands in traffic at a given point of time, channels can be allocated explicitly for the micro-cellular layer, or a sharing algorithm can be envisaged with the macro-cellular layer, by which channels can be allotted to the micro-cells as the demand arises. Users with lower rates of mobility are handled by the layer of smaller cell size. If a highly mobile user is handled by the microcellular layer, there is an overhead of too many handoffs. In fact, the handoffs may not be fast enough to let the call continue uninterrupted.

The introduction of a micro- or pico-cellular layer increases the available number of channels in hotspot regions and enables better frequency planning, so that the whole network does not have to be designed to handle the worst-case demand. This flexibility in frequency management leads to capacity enhancement.

2.2.1.2 Sectorization

This concept uses space division multiple access (SDMA) to let more channels be reused within a shorter distance. Antennas are modified from omnidirectional to sectorized, so that their signals are beamed only in a particular sector, instead of being transmitted symmetrically all around. This greatly reduces the downlink interference. A cell is normally partitioned into three 120-degree sectors or six 60-degree sectors. Further, the antennas can be down-tilted to reduce co-channel interference even more.

2.3 Handoffs

An important concept that is essential for the functioning of cellular networks is handoffs, also called handovers. When a user moves from the coverage area of one Base station to the adjacent one, a handoff has to be executed to continue the call. There are two main parts to the handoff procedure: the first is to find an uplink-downlink channel pair from the new cell to carry on the call, and the second is to drop the link from the first base station.

Electromagnetic radio waves are used for communication (exchange of information). In the following sections, the various characteristics of radio propagation are first discussed. Some of the important signal modulation mechanisms, multiple access techniques, and error control mechanisms are then described. A familiarity with all these fundamental aspects of cellular transmission is essential for understanding the issues involved in the design of cellular networks.

2.4 The Electromagnetic Spectrum

Cellular communication is based on the principle of broadcast and reception of electromagnetic waves. These waves can be characterized by their frequency (*f*)or their wavelength (λ). Frequency is the number of cycles (oscillations) per second of the wave and is measured in Hertz (Hz), in honor of Heinrich Hertz, the German physicist who discovered radio, and wavelength is the distance between two consecutive maxima or minima in the wave. The speed of propagation of these waves (*c*) varies from medium to medium, except in a vacuum where all electromagnetic waves travel at the same speed, the speed of light. The relation between the above parameters can be given as

$$\mathbf{c} = \lambda . f \qquad (1)$$

Where **c** is the speed of light ($3\times10^{8} m/s$), f is the frequency of the wave in Hz, and λ is its wavelength in meters.

2.5 Interference

Wireless transmissions have to counter interference from a wide variety of sources. Two main forms of interference are adjacent channel interference and co-channel interference. In the adjacent channel interference case, signals in nearby frequencies have components outside their allocated ranges, and these components may interfere with on-going transmissions in the adjacent frequencies. It can be avoided by carefully introducing guard bands between the allocated frequency ranges. Co-channel interference, sometimes also referred to as narrow-band interference, is due to other nearby systems (say, AM/FM broadcast) using the same transmission frequency. Narrow-band interference due to frequency reuse in cellular systems can be minimized with the use of multiuser detection mechanisms,3 directional antennas, and dynamic channel allocation methods. A guard band is a small frequency band used to separate two adjacent frequency bands in order to avoid interference between them. Multiuser detection is an effective approach used to combat the multiuser interference problems inherent in CDMA systems. Inter-symbol interference is another type of interference, where distortion in the received signal is caused by the temporal spreading and the consequent overlapping of individual pulses in the signal. When this temporal spreading of individual pulses (delay spread) goes above a certain limit (symbol detection time), the receiver becomes unable to reliably distinguish between changes of state in the signal, that is, the bit pattern interpreted by the receiver is not the same as that sent by the sender. Adaptive equalization is a commonly used technique for combating inter-symbol interference. Adaptive equalization involves mechanisms for gathering the dispersed symbol energy into its original time interval. Complex digital processing algorithms are used in the equalization process. The main principle behind adaptive equalization is the estimation of the channel pulse response to periodically transmitted well-known bit patterns, known as training sequences. This would enable a receiver to determine the time dispersion of the channel and compensate accordingly.

The Doppler shift is defined as the change/shift in the frequency of the received signal when the transmitter and the receiver are mobile with respect to each other. If they are moving toward each other, then the frequency of the received signal will be higher than that of the transmitted signal, and if they are moving away from each other, the frequency of the signal at the receiver will be lower than that at the transmitter.

2.6 Generations of Cellular System

2.6.1 The First-Generation Cellular Systems

After the basic concepts common to most cellular networks, the specific generations of cellular networks and the standards of each generation are discussed in the following sections. The first implementations of the cellular concept constitute the first-generation (1G) systems. These systems, such as the advanced mobile phone system (AMPS) in the United States and Nordic mobile telephony (NMT) deployed in several European countries, are analog-based (*i.e.*, they employ analog modulation and send information as a continuously varying waveform).

Advanced Mobile Phone System

AMPS divides the 800 MHz part of the frequency spectrum into several channels, each 30 KHz wide. The cellular structure uses a cluster size of seven, and each cell is roughly10-20 Km across. The AMPS system uses 832 full-duplex channels, with FDM to separate the uplink and downlink channels. The channels are classified into four main categories: downlink *control channels* for system management, downlink paging channels for paging a Mobile Terminal (MT), locating an MT in the network and alerting it when it receives a call), bidirectional *access channels* for call setup and channel assignment, and bidirectional data channels to carry user voice/data. AMPS provides a maximum data transmission rate of 10 Kbps When the MT(Mobile Terminal) is powered on, it scans for the most powerful control channel and broadcasts its 32-bit serial number and 10-digit telephone number on it. The base station which hears this broadcast registers the MT (Mobile terminal) with the mobile switching office (MSO), and informs the HLR (Home Location Register)) of the MT of its present location. The MT updates its position once every 15 minutes. To make a call, the MT sends the number to be called through an access channel. The base station sends this request to the MSO, which assigns a duplex channel for the call. MTs are alerted to incoming calls through the paging channel. The call is routed through the home to its current location. Once the MT is located, it takes up the call on the allotted voice channel. In order to conserve the battery power of the handset, the MT goes into a "sleep state" when it is idle. The designed sleep time is 46.3 ms in the AMPS system. The MT periodically wakes up to scan the paging channel and check if there is any call addressed to it. The service of a mobile network has similar measures of performance like that of a wired network. The concept of trucking, used in all communication networks, exploits the statistical behavior of users to enable a fixed number of channels to be shared by a much larger number of users. The grade of service (GoS) of a trunked network is a measure of accessibility of the network during its peak traffic time. GoS is specified as the probability of a call being blocked, or experiencing a queuing delays greater than a threshold value. The AMPS system was designed for GoS of 2% blocking.

2.6.2 The Second-Generation Cellular Systems

As mentioned earlier, 1G systems are analog which leads to the following problems:

(i) No use of encryption (1G systems do not encrypt traffic to provide privacy and security, as analog signals do not permit efficient encryption schemes, and thus voice calls are subject to eavesdropping).

(ii) Inferior call quality (This is due to analog traffic which is degraded by interference. In contrast to digital traffic stream, no coding or error correction is applied to combat interference).

(iii) Spectrum inefficiency This is because at any given time a channel is allocated to only one user, regardless of whether the user is active (speaking) or not. With digital traffic it is possible to share a channel by many users (which implies multiple conversations on a single channel) using TDMA or CDMA, and further, digital signals allow compression, which reduces the amount of capacity needed to send data by looking for repeated patterns.

The second-generation (2G) systems, the successors of 1G systems, are digital [*i.e.*, they convert speech into digital code (a series of pulses) which results in a clearer signal] and thus they overcome the deficiencies of 1G systems mentioned above. It may be noted that the user traffic (computer data which is inherently digital or digitized voice) must be converted into radio waves (analog signals) before it can be sent (between Mobile Terminal and base station). A 2G system is called personal communications services (PCS) in the marketing literature. There are several 2G standards followed in various parts of the world. Some of them are global system for mobile communications (GSM) in Europe, digital-AMPS (DAMPS) in United States, and personal digital cellular (PDC) in Japan.

Global System for Mobile Communications

GSM1 is an extremely popular 2G system, which is fully digital, used across over 100 countries. GSM originally stood for Grouped Special Mobile, the name of the working group that designed it.

There are four variants of GSM:

- Operating around 900 MHz [This first variant reuses the spectrum intended for Europe's analog total access communication system (TACS)]
- Operating around 1,800 MHz [licensed in Europe specifically for GSM. This variant is sometimes called digital communications network (DCN)]
- Operating around 1,900 MHz (used in United States for several different digital networks)
- Operating around 450 MHz (latest variant for replacing aging analog networks based on Nordic MT system)

Apart from voice service, GSM also offers a variety of data services. The modulation scheme used in GSM is Gaussian minimum shift keying (GMSK). GSM uses frequency duplex communication, and each call is allotted a duplex channel. The duplex channels are separated by 45 MHz Every channel is of 200 KHz bandwidth. Thus, GSM uses FDM to separate the channels. The downlink (base station-MT) channels are allotted 935-960 MHz, and the uplink (MT-base station) channels are on 890-915 MHz as shown in Fig 2.4. The uplink "frame" of eight slots is shifted by a delay of three slots from the downlink frame, so that the MT does not have to send and receive at the same time. A procedure called *adaptive frame alignment* is used to account for propagation delay. An MT which is far away from the base station starts its frame transmission slightly ahead of the actual slot commencement time, so that the reception at the base station is synchronized to the frame structure. The exact advancement is instructed by the base station to the MT, with MTs that are farther away from the base station requiring a greater advancement.

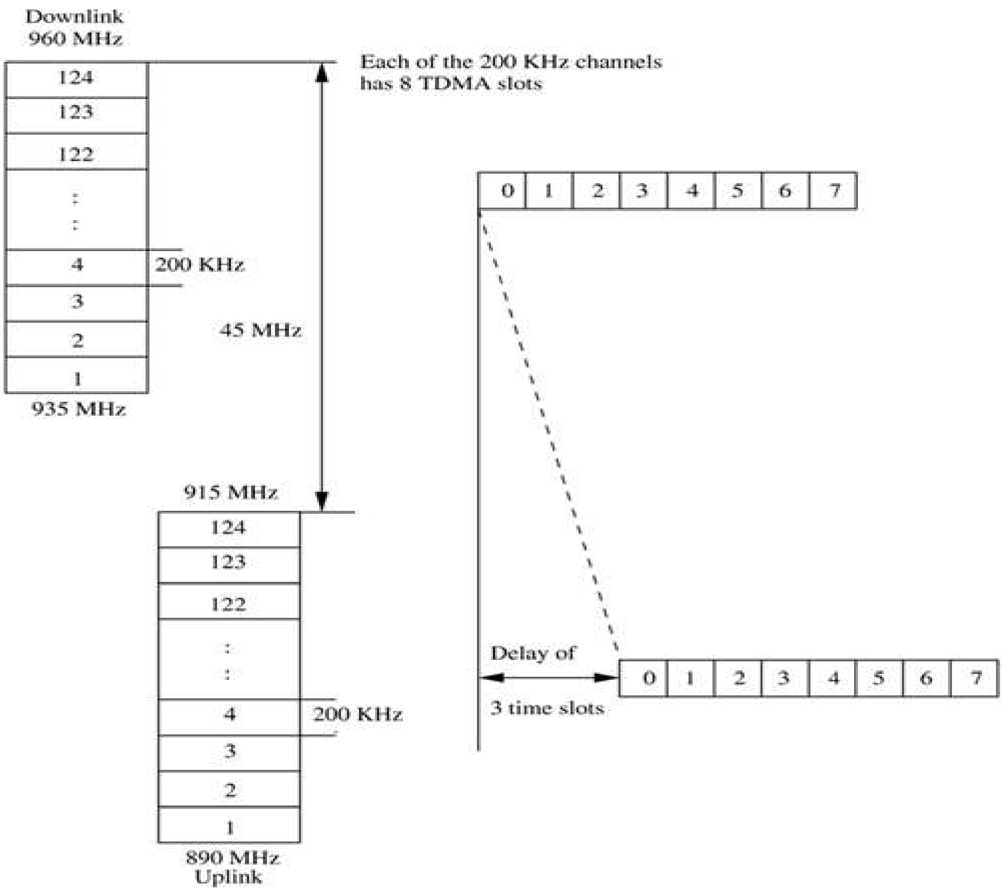


Fig 2.4 GSM frequency bands and TDMA frame

2.6.3 The Third-Generation Cellular Systems

The aim of the third-generation (3G) cellular system is to provide a *virtual home environment*, formally defined as a uniform and continuous presentation of services, independent of location and access. This means that the user must be able to access the services that he/she has subscribed to, from anywhere in the world, irrespective of his/her handover dropping (HOD) of access, as if he/she were still at home. This requires very stringent QoS adherence, and highly effective and optimized architectures, algorithms, and operations of the network elements. The use of "intelligent network architecture" is foreseen here [6], [7], [8]. The networks should contain advanced algorithms to handle

3G Standards

An evolution plan has been charted out to upgrade 2G technologies into their 3G
Counter parts. Table 2.2 lists some existing 2G systems and their corresponding 3G versions

Table 2.2 Evolution plan to 3G standards

Europe	GSM	W-CDMA(UMTS)
Japan	**PDC**	**W-CDMA(DoCoMo)**
USA	**IS-95/CDMA**	**CDMA 2000**
USA	**IS-136**	**UWC-136**

In 1992, the International Telecommunications Union (ITU) initiated the standardization of 3G systems, and the outcome of this effort was called international mobile telecommunications-2000 (IMT-2000). Table 2.3 shows IMT 2000 service types. The number 2000 stood for three things: (i) the system would become available in the year 2000, (ii) it has data rates of 2,000 Kbps, and (iii) it was supposed to operate in the 2,000 MHz region, which ITU wanted to make globally available for the new technology, so that users could roam seamlessly from country to country. None of these three things came to pass, but the name has remained.

Table 2.3 IMT-2000 service types

Service	Upstream	Downstream	Example	Switching
Interactive Multimedia	**256 kbps**	**256 kbps**	**Video conference**	**Circuit**
High Multimedia	**20 kbps**	**2 Mbps**	**TV**	**packet**
Medium Multimedia	**19.2 kbps**	**768 kbps**	**Web surfing**	**Packet**
Switched Data	**43.2 kbps**	**43.2 kbps**	**Fax**	**Circuit**
Simple Messaging	**28.8 kbps**	**28.8 kbps**	**E-mail**	**packet**
Speech	**28.8 kbps**	**28.8 kbps**	**Telephony**	**Circuit**

1.3.1 The Problems with 3G Systems

3G systems fundamentally need greater bandwidth and lower interference to be able to meet QoS requirements for data and multimedia services. Field tests have indicated that CDMA is an attractive

option for mobile cellular networks, as it can operate in the presence of interference, and can theoretically support very large bandwidth [5]. The performance of 3G systems is further improved by the use of smart antennas. This refers to the technology of controlling a directional antenna array with an advanced digital signal processing capability to optimize its radiation and/or reception pattern of signal. The claims and ground reality is shown in table 2.4.

Table 2.4 CDMA — The debate

Claims	Reality
Capacity of 20 times that of AMPS	**Only 3-4 times that of AMPS**
No more dropped calls	**40% call dropped when loaded**
No problem of interference	**Interference of existing AMPS**
Quality of speech promised at 8 kbps	**Had to change to 13 kbps**

Also, the software modules which implement new features/service can be downloaded over the air onto the handsets.

1.3.1.1 Wireless in local loop

In cellular systems, mobility was the most important factor influencing the design of the networks. Wireless in local loop (WLL architecture as shown figure 2.5) technology is, on the other hand, in the scenario of limited mobility. The circuit (loop) that provides the last hop connectivity between the subscriber and PSTN (Public Switched Telephone Network) is called the local loop. It has been conventionally implemented using common copper wiring. Optical fiber is not a popular local loop technology due to the high cost of deployment.WLL, also known as fixed wireless access (FWA) or radio in the local loop (RLL), is the use of wireless connectivity in the last hop between the subscriber and the telephone exchange (end office). existing network [5] WLL has many advantages for both the subscribers and the service providers. The deployment of WLL is much easier, and it can be extended.

2.8 Hybrid Wireless Networks

One of the major application areas of ad hoc wireless networks is in hybrid wireless architectures such as multi-hop cellular networks (MCNs) [5] and [3] and integrated cellular ad hoc relay(iCAR) networks [6]. The tremendous growth in the subscriber base of existing cellular networks has shrunk the cell size up to the pico-cell level. The primary concept behind cellular networks is geographical channel reuse. Several techniques such as cell sectoring, cell resizing, and multi tier cells have been proposed to increase the capacity of cellular networks. Most of these schemes also increase the equipment cost. The capacity (maximum throughput) of a cellular network can be increased if the network incorporates the properties of multi-hop relaying along with the support of existing fixed infrastructure. MCNs combine the reliability and support of fixed base stations of cellular networks with flexibility and multi-hop relaying of ad hoc wireless networks.
The MCN architecture is depicted in Fig 2.6. In this architecture, when two nodes (which are not in direct transmission range) in the same cell want to communicate with each other, the connection is

routed through multiple wireless hops over the intermediate nodes. The base station maintains the information about the topology of the network for efficient routing. The base station may or may not be involved in this multi-hop path. Suppose node A wants to communicate with node B. If all nodes

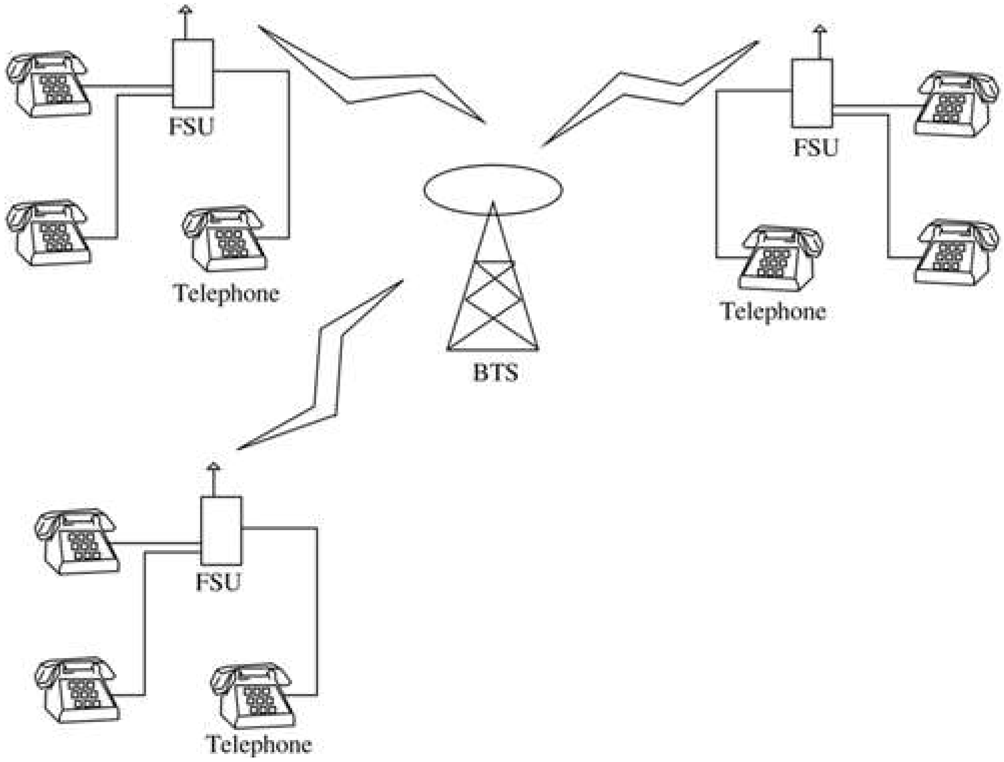


Fig 2.5: WLL architecture [21]

are capable of operating in MCN mode, node A can reach node B directly if the node B is within node A's transmission range. When node C wants to communicate with node E and both are in the same cell, node C can reach node E through node D, which acts as an intermediate relay node. Such hybrid wireless networks can provide high capacity resulting in lowering the cost of communication to less than that in single-hop cellular networks. The major advantages of hybrid wireless networks are as follows:

- Higher capacity than cellular networks obtained due to the better channel reuse provided by reduction of transmission power, as mobile nodes use a power range that is a fraction of the cell radius.
- Increased flexibility and reliability in routing. The flexibility is in terms of selecting the best suitable nodes for routing, which is done through multiple mobile nodes or through base stations, or by a combination of both. The increased reliability is in terms of resilience to failure of base stations, in which case a node can reach other nearby base stations using multi-hop paths.
- Better coverage and connectivity in holes (areas that are not covered due to transmission difficulties such as antenna coverage or the direction of antenna) of a cell can be provided by means of multiple hops through intermediate nodes in the cell.

2.9 Issues in Ad Hoc Wireless Networks

This section discusses the major issues and challenges that need to be considered when an ad hoc wireless system is to be designed. The deployment considerations for installation, operation, and maintenance of ad hoc wireless networks are also provided. The major issues that affect the design, deployment, and performance of an ad hoc wireless system are as follows:

- Medium access scheme
- Routing
- Multicasting
- Transport layer protocol
- Pricing scheme
- Quality of service provisioning
- Self-organization
- Security
- Energy management
- Addressing and service discovery
- Scalability
- Deployment considerations

Summary

A cellular network is a communication network where the last link is wireless. Each cell is served by one Base Station (BS). Ad-hoc network is infrastructure less network which is not commercialized as conventional cellular network. There are number of techniques to enhance cell capacity such as cell splitting, Sectorization etc. When a Mobile Terminal (MT) moves from one cell to another cell handover occurs. Cellular system has gone through evolutionary process. In beginning analog modulation was used in systems such as AMPS (USA), NMT (Europe). Later on it evolved to use digital modulation techniques. The latest trend is to integrate conventional cellular network with ad-hoc network to produce hybrid wireless network. In hybrid network area two major implementations are Multi-hop Cellular Network (MCN) and Integrated Cellular and Ad-hoc Relay (iCAR). There are number issues to be addressed in Ad-hoc networks such as medium access scheme, routing, security, self organization etc.

CHAPTER 3

Challenges of Multi-Hop Cellular Network

Recently, multihop or relay networks have been widely considered as supplementary technology in next-generation wireless systems such as fourth generation (4G), Third Generation Partnership Project Long-Term Evolution (3GPP LTE), and IEEE 802.16m to increase the cell radius or combat the shadowing effect, which is mainly caused by large obstacles between transceivers [1–5]. The application of the multihop concept to cellular networks, however, raises many technical issues, such as the best positions for the base station and relay stations (RSs); the number of RSs; spectrum allocation and multiplexing between the base station and Relay Stations, scheduling , and handover [1, 2]. Especially, the introduction of RS in cellular networks creates additional handover scenarios and increases the number of handovers. In conventional cellular systems, handover occurs only when a mobile station (MS) moves to different cells or different sectors of the same cell, whereas additional handovers occur in a multihop cellular network (MCN) between the base station and the RSs or between two different RSs. These additional MCN handovers can cause serious ping-pong problems and increase signaling overhead. Unfortunately, only a few research articles have studied handover issues in relay networks[6–8]. Reference [6] proposes a relay-assisted vertical handover scheme for hybrid cellular and wireless local area network (WLAN) systems. In this scheme, an active MS, which has an active connection, uses non-active MSs as relay stations in handover regions when a handover request is rejected or delayed for an unacceptable period of time. Reference [7] categorizes and evaluates the performance of different types of handovers in multihop radio-access networks (MRANs). In[7], the multihop handover schemes are categorized into forced handover and route optimization-
based handover, according to the handover initiation met handover dropping (HOD). In addition, the signaling mechanisms for these handover scenarios are proposed, and handover delay and signaling overhead are also investigated. Reference [8] proposes relay-assisted handover with geo-locating information in a hybrid ad hoc cellular system. An MS is assumed to be able to establish direct connections with nearby MSs to form a temporary wireless relay network, and the MS to- MS interface is based on a WLAN protocol like the integrated cellular and ad hoc relaying (i-CAR) system proposed in [2]. The relay-assisted handover in [8] uses relaying technology to avoid unnecessary handovers and call drop caused by abrupt channel degradation.

3.1 Architecture

The control messages for the unicast routing protocol (illustrated in Fig 3.1) are transmitted over the control channel. An on-demand approach is used in routing the best-effort traffic through the system. The routing protocol has a route discovery phase and a route maintenance phase. When a source A has a packet to send to a destination B to which a path is not known, it sends a *RouteRequest* packet to the base station over the control channel. The BASE STATION responds with a *RouteReply* packet containing the route, which is sent back to node A over the control channel. The route is computed by Dijkstra's shortest path search algorithm.

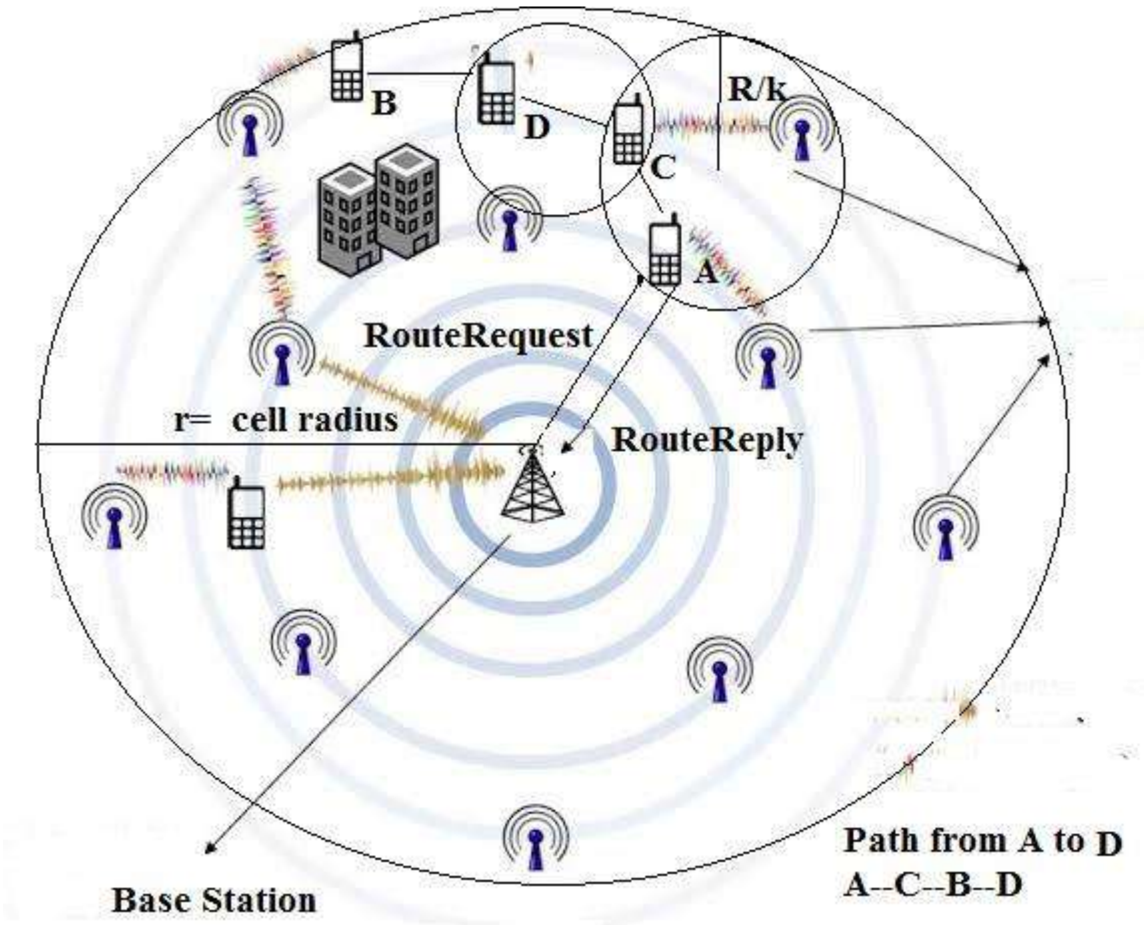


Fig 3.1 : MCN Architecture [9]

The source A, upon reception of the *RouteReply* packet, transmits the data packet with the entire route information contained in it, to the next node on the path, which in turn forwards it. This path is also cached in its local route cache (RC). Subsequent packets to the same destination are source-routed using the same path until the RC entry times out or a route break is detected. When anode C detects a break or an interference on the route from node A to node B,node C sends a packet similar to a *RouteRequest* packet to the base station, which sendsa new route to node A and node C.A real-time scheme for MCN is proposed in which the available bandwidth is split into one control channel and several data channels. These data channels are not clustered among the cells and hence can be used throughout the system area. While the transmission range on the data channels is kept at half of the cell radius, that on the control channel is equal to the cell radius. The base station also chooses the data channels to be used along each wireless hop in a route. The base station then broadcasts this information (the path and the channels to be used in every hop) over the control channel. Upon receiving this information, the sender, the intermediate nodes, and the destination become aware of the call setup. If the call cannot be established, the sender is appropriately informed by a unicast packet over the control channel. The channels for each hop in the wireless path obtained are allocated through a first-available-channel allocation policy. For each hop, the channels are checked in a predetermined order and the first channel that satisfies the constraints is used. At some point in the duration of the call, the wireless path may become unusable. This may happen because of either a path break or interference due to a channel collision. The MH that detects this sends a packet, similar to the *Route Request* packet, called '*RouteError'* packet to the base station, which computes a new route and broadcasts the information to all MHs in the cell. In order to reduce the chance of call dropping, some channels are reserved for rerouting calls, that is, of *Nch* channels, are reserved for handling route reconfiguration requests. The greater the value of reservation, the less the probability of dropping during handover.

3.2 Challenges

MCN networks pose certain design challenges due to the following reasons:

- MCN nodes are randomly deployed and hence do not fit into any regular topology. Once deployed, they usually do not require any human intervention. Hence, the setup and maintenance of the network should be entirely autonomous.

- MCN networks are infrastructure-less. Therefore, all routing and maintenance algorithms need to be distributed.

- An important bottleneck in the operation of MCN nodes is the available energy. MCNs usually rely only on their battery for power, which in many cases cannot be recharged or replaced. Hence, the available energy at the nodes should be considered as a major constraint while designing protocols. For instance, it is desirable to give the user an option to trade off network lifetime for fault tolerance or accuracy of results.

- Hardware design for MCN nodes should also consider energy efficiency as a primary requirement. The micro-controller, operating system, and application software should be designed to conserve power.

- MCN nodes should be able to synchronize with each other in a completely distributed manner, so that TDMA schedules can be imposed and temporal ordering of detected events can be performed without ambiguity.
- A MCN network should also be capable of adapting to changing connectivity due to the failure of nodes, or new nodes powering up. The routing protocols should be able to dynamically include or avoid MCN nodes in their paths.

- Real-time communication over MCN networks must be supported through provision of guarantees on maximum delay, minimum bandwidth, or other QoS parameters.

- Provisions must be made for secure communication over MCN networks, especially for military applications which carry sensitive data.

3.4 Handover Scenarios in MCNs

This section describes all possible handover scenarios in MCNs regardless of the relay station(RS) deployment structure. Handovers in MCNs can occur when an MS moves between different base stations, between different RSs, or between a base station and an RS. Fig 3.2 depicts diverse handover scenarios in MCNs. This section classifies each handover scenario into intra cell handover and intercell handover with the inter-sector or softer handover excluded. The detailed handover scenarios are explained in the following sections.

3.4.1 Intracell Handover

Scenario 1 (Intra cell Relay Station (RS)-Relay Station (RS) Handover*)* — In this scenario, an MS performs handover between two different RSs in the same cell. In Fig. 3.2, MS1 moving from RS1b to RS1a in cell 1 illustrates handover scenario 1. The base station easily can control the handover process because both the serving RS and the target RS are under their own control, and inter-base station information or signaling is not required. To prevent packet loss during the handover process, automatic retransmission request (ARQ) status should be consistent between a serving RS and a target RS. In this scenario, transfer of the ARQ status to the target RS is not required during handover if the ARQ function is located in the base station. In addition, the current layer 3 (L3) address can be used after the handover.

Scenario 2 (Intracell base station-relay station Handover) — In scenario 2, an MS changes its communication node from a base station to the RS of the same cell, or vice versa.

3.4.2 Inter Cell Handover

Scenario 3 (Intercell base station-base station Handover) —Scenario 3 is exactly the same as the inter-base station handover in the conventional cellular systems. The ARQ status should be transferred during the handover process if the ARQ is controlled by the base station, and the L3 address is also reassigned when the subnet is changed by the handover.

Scenario 4 (Intercell RS-RS Handover*)* — In scenario 4, an MS performs handover from anRS to the RS of different cells, which is the handover of MS4 in Fig. 3.2. This scenario can cause relatively larger signaling overhead than other scenarios because it requires inter-base station signaling and RS-base station signaling in both cells. In addition, the channel quality of the MS in this handover region can be seriously attenuated by the inter cell interference from the adjacent base stations and RSs. The ARQ status and the L3 address management are similar to those of scenario 3.

Scenario 5 (Intercell base station-RS Handover) — In scenario 5, an MS moves from a base station to the RS of different cells, or vice versa, which is the handover of MS5 in Fig. 3.2. Inter-base station signaling is also required in this scenario, and the ARQ status and the L3 address management are the same as scenario 3 except for additional signaling between the RS and the base station.

For Next Generation Networks an all IP feature is required and ad hoc mode is gaining more attention as an appealing addition to cellular networks. As a result, multi-hop handoffs become inevitable, which bring new challenges to network designers.

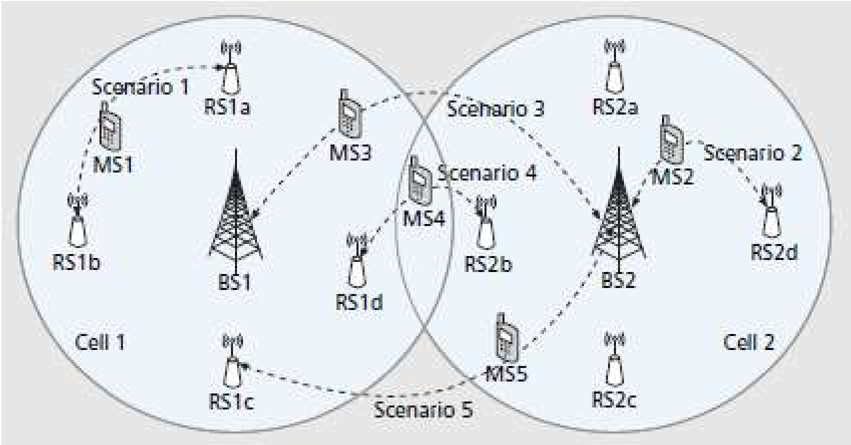


Fig 3.2 Handover scenarios [10]

Handover dropping (HOD) rate, bandwidth reservation for the required handover dropping (HOD) rate, complexity of handoff processes and utilization of resources are important metrics to evaluate the handoff performance. By introducing ad hoc mode into cellular systems, we can either achieve lower handover dropping (HOD) rate or reserve less bandwidth for the same required handover dropping (HOD)rate. In this project, we propose a small scale radio network which covers few cells and also an algorithm to find the minimum bandwidth reservation for each base station. Since its performance greatly depends on the access probability to the adjacent cells, we further propose to utilize the embedded ad hoc links to gather the traffic load information of neighboring cells. With such information, handoff calls can effectively select the best paths to the proper base stations. It has been demonstrated that our scheme can significantly improve the system performance. The network will also simplify the handover processes as the relay stations are positioned on the corners of cells.
Multi-hop cellular networks (MCNs) have received growing attention lately due to the intention that the next generation cellular networks can provide an all-IP platform, where new types of cellular networks, *e.g.*, WiFi and WiMAX, and traditional cellular networks can integrated seamlessly. 3GPP has been engaged in the study of this trend and the specification of the interworking between WCDMA networks and WLANs was standardized years ago. It is now well-known that these new cellular networks, usually operated in ad hoc mode, can be constructed more flexibly with much lower cost and higher data rate, though the coverage and mobility cannot be well supported. Consequently, it is expected that MCNs can take advantage of both traditional (single-hop) cellular networks and the new types of cellular networks. MCNs are commonly considered as cellular-based integration of cellular networks and ad hoc networks because ad hoc mode is an additive component to cellular systems, which does not impair the traditional cellular structure. This means that mobile users can access base stations through either direct (one-hop) connections or multi-hop connections. Cellular network is commercialized whereas ad-hoc network is not. Integration of both can improve the performance of cellular network in aspects such as increasing the capacity of cell by providing extra links. The hybrid network can also tradeoff between Handover dropping and call blocking in a way to satisfy customers. Apart from this ad-hoc network is rarely used in few applications such war field, remote forests as sensor networks etc. We thought of using the self organizing feature of Ad-hoc network to form an assisting network for better performance in traditional cellular system.

Summary

Multihop cellular Network (MCN) have been widely considered as supplementary technology in next generation wireless systems such as fourth generation (4G) and 3GPP LTE. In Multihop cellular Network extra links are created to enhance cell capacity. In addition to conventional cellular network this increases complexity in terms handover scenarios. There are a number of challenges in Multihop cellular Network (MCN) such as routing, maintenance, battery power etc. MCN gives birth to different types handover divided into two broad category intra cell handover and inter cell handover. Intra cell handover is further classified RS to RS (Relay Station) and BS (Base Station) to RS handover. Inter cell handover is further classified into 3 different scenarios-1.BS to BS, 2. RS to RS and 3. BS to RS. Due this kind of handover latency, call dropping may increase. So this issues has to be dealt carefully. We propose a scheme in next chapter to alleviate these anomalies.

CHAPTER 4
Proposed Scheme: Small Scale Radio Network

4.1 Handover Assisting Scheme with Small Scale Radio Network

Traditional cellular networks are typical one-hop wireless networks since only the last hop transmissions are wireless between mobile terminals and base stations. The existing infrastructures of cellular systems make seamless connections for mobile clients possible via handoff management.

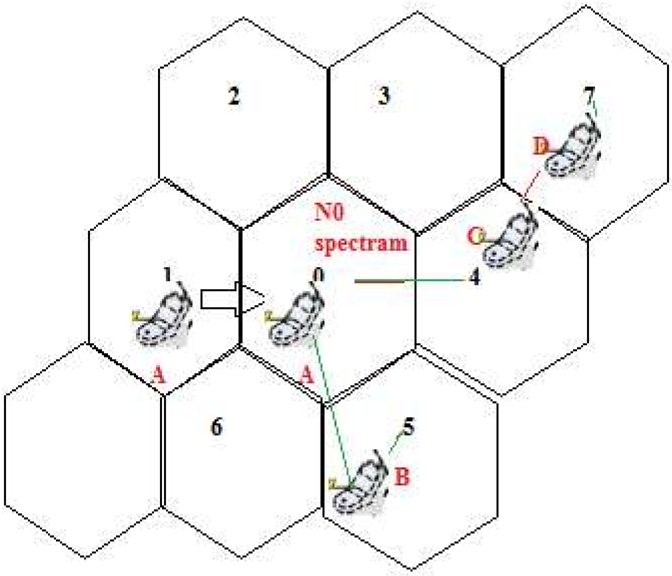
In the last few years, due to the intensive development in wireless ad hoc networks and the multi-interfaced mobile devices such as smart phones, multi-hop cellular networks (MCNs), the integration of ad hoc mode into cellular systems, have started to emerge. The origin of this new type of networks comes from the intention that the new cellular networks should provide an all-IP platform, where new types of wireless networks, e.g., WiFi and WiMAX, and the traditional cellular networks can interwork seamlessly with variety of services. 3GPP has been already engaged in the study of this trend [1] and the specification of the interworking between WCDMA networks and WLANs was standardized [2]. It is now well-known that these wireless ad hoc networks, usually operated in the ad hoc mode, can be confide more flexibly with much lower cost and potentially higher data rate due to much shorter transmission range, though the coverage and mobility may not be guaranteed. Consequently, it is expected that MCNs can take advantages of both traditional cellular networks and wireless ad hoc networks. An MCN is commonly considered as a cellular-based integration of a cellular network and ad hoc networks because ad hoc mode is treated as an additive component to cellular systems, which does not impair the traditional cellular infrastructure, which means that mobile users can access base stations through either direct (one-hop) connections or multi-hop connections. With the cellular-based MCNs under consideration, the first advantage over the traditional cellular systems we observe is the low cost of extending service coverage. Multi-hop wireless relaying can easily provide faraway wireless terminals with connections without building extra infrastructures (adding more base stations). Since the relay devices are usually much more portable than base stations, the flexibility in configuring more service connections is the second advantage we can expect. Moreover, this flexibility creates new ways, other than the traditional channel borrowing [3], to implement load balancing among different cells. Finally, with the ad hoc links bearing potentially higher data rate with extra spectrum, the system capacity can be expected to improve. Of course, we realize that the hidden assumption is that mobile terminals, in addition to the operator added ad hoc relaying stations, also participate in relaying and helping, which may not be practical if there is no incentive for the helping mobiles. Therefore, certain incentive protocols should be designed to stimulate mobile terminals to help the MCNs to operate. This topic will be investigated in a separate project. In this project, we focus on the benefits that the ad-hoc mode can bring to the handoff management. Handoff management is an important part of mobility management in Personal Communication Services (PCS) systems and any wireless cellular system in general in maintaining seamless connection [4]. Handoff dropping (handover dropping (HOD) rate is the major metric for assessing handoff performance and it usually requires the designed system to keep the handover dropping (HOD)lower than certain threshold in order to meet the customers' satisfaction. In wireless cellular networks, handover dropping (HOD)rate is usually guaranteed by bandwidth reservation for handoff calls in cells a mobile user most likely visits during its call connection. More bandwidth reservation can indeed meet the handover dropping (HOD)rate requirement, but at the price of blocking more new call connections because less resource is made available for new call connections. Thus, a good handoff management should not only keep the handover dropping (HOD)rate low, but also tie up less bandwidth. As a supplement to cellular systems, ad hoc links (links via relaying by using harvested either inband or outband resource opportunistically) create more opportunities for MNs to connect to base stations. Therefore, handover dropping (HOD)rate is expected to decrease with ad hoc mode introduced into the cellular systems. Moreover, since handoff calls may be connected to adjacent base stations and thus use adjacent cells' reservation, each cell can reserve relatively less bandwidth to achieve the same handover dropping (HOD)rate, and hence will accommodate more new calls. As we alluded earlier, the introduced ad hoc links create plenty opportunities for access to the cellular systems. By choosing good link connections, we can decrease the call dropping rate while inappropriate choice of links may lead to poor performance. Careless design of handoff decision process may increase the handoff frequency, increase the call dropping rate, or lead to the inefficiency of resource usage. How to design the handoff strategy in the MCNs becomes a more complicated task than purely comparing the received signal strength (RSS) because of the options offered by the multi-hop connections. This problem for MCNs has not been touched upon previously. Most previous works assume that the relaying is made by specific planted devices (relay stations) according to proper network planning [5, 6]. This assumption really limits the utilization of benefits offered by the self-organizing ad hoc networking and diminish the flexibility of the ad hoc mode introduced. In this project, we propose a new scheme, called SSRN (Small scale Radio Network Scheme), which utilizes the embedded, self-organized small-scale ad hoc networks to assist the handoffs. By exchanging information inside the embedded ad hoc networks, relay nodes can help handoff calls choose better handoff options and thus reduce the call dropping probability. Consequently, to meet a certain handover dropping (HOD)rate, base stations can reserve less bandwidth for handoff calls than before. We also design an algorithm to enable adjacent base stations to lower the bandwidth reservation according to the traffic information of their cells to loosen up more bandwidth for new calls while meeting the handover dropping (HOD)rate requirement. Furthermore, we have also proposed a framework for adjacent base station exchange information through which the load balancing among the surrounding cells can be implemented. Although there are some works on different issues in MCNs, such as cross-layer routing in [7], incentive schemes in [8], and the real-time traffic support in [9], they rarely address the handoff management and corresponding resource management by taking full advantage offered by the introduction of ad hoc mode.

4.2 System Model and Basic Idea

4.2.1 System Model

In the MCNs, there are two operational modes for a link. One is the traditional cellular operational mode using the cellular spectrum and following the cellular standard. The other we call the ad hoc mode may use outband spectrum and follows the ad hoc protocols such as IEEE802.11. The service coverage areas are divided into cells as in traditional cellular system while ad hoc links can cross the boundaries of adjacent cells when relaying traffic. Each base station is assumed to have the same transmission power as before which can cover the whole cell area. Since the focus of this project is the handoff issue in MCNs, in our model here, each MN (mobile node or mobile terminals or user equipment) is always bound to one certain base station, no matter whether via only cellular links or via multi-hop connections. We call the handoffs involving multi-hop connections as the multi-hop handoffs. When an MN(mobile node) moves from one cell to another and chooses the target base station as its serving base station, the handoff process is no different from that in the traditional cellular systems.

Only when a multi-hop connection exists either before or after an MNalters its connection, do the handoffs face the new type of network challenges. Fig4.1 illustrates the multi-hop handoffs in a multi-hop cellular system.



MN-Mobile Node

Fig 4.1 Multi hop Handover [10]

In Fig. 4.1, MN A moves from cell 1 to cell 0. Unfortunately, the base station in cell 0 has no spare spectrum. In the illustrated scenario, MN A has two options. It can either access the base station 5 through MN B or access base station 7 through MNC and MN D. Either option can enable MN A to access to the cellular system. Usually, a connection with more hops implies more potential disconnection vulnerability due to the mobility of intermediate nodes. There are also cases that the multi-hop connection may have high data rate due to less interference and shorter distance between nodes on the connection. How to choose between a single-hop connection and multi-hop connection is a challenging but important question. In this project, to simplify the analysis, we assume that each MN attempts the direct connection first before sinking multi-hop connection unless being redirected. When a direct connection is not available, a disconnected MN, or an MN looking for a handoff, searches for the nearby ad hoc spectrum to find the alternative connections. Some connected MNs broadcast their corresponding base stations' IDs and some other information via the ad hoc spectrum. For new calls, MNs search for all possible connections until they succeed. For handoff calls, due to the time limit of signaling process, MNs make several attempts to connect to different base stations until they succeed or the time limit is reached. The base stations' IDs are used to prevent repeated attempts. The connected MNs are responsible for relaying the connecting MNs' requests to the destination base station. The destination base station allocates cellular spectrum resource to the connecting MN in care of the last hop relay MNs. The base station keeps the information of the relay relationship of its serving MNs in order to deliver packets correctly. As a remark, the security may be a concern because the MNs on the connection may cause security leak. We will address the security issue elsewhere. In traditional analysis of cellular networks, it is assumed that the call droppings caused by link failure are usually ignored and only the call dropping is caused mainly by handoff failure. In fact, a connection can be disconnected due to wireless link failure, especially when the connection multi-hop. Thus call droppings caused by the failure of ad hoc links cannot be ignored in MCNs for our analysis. The call dropping rate can be expressed in such a formula as follows.

$$P(dropping)=1-(1-p(con\_fail))X(1-p(HOD) \quad (2)$$

Here, P(HOD) is the probability of call dropping due to handoff failures. P(con_fail) is the probability of call dropping caused by connection failures. Multi-hop connections is disconnected more easily due to the smaller transmission range, mobility of relay nodes and nature of multiple-hop. Obviously, the call dropping rate is related to the hop counts of the multi-hop connection and the mobility of relay nodes as well as the roaming nodes. To maintain a certain P((HOD) level, certain bandwidth should be reserved for handoff calls. If there is only one cell's resource under consideration, according to Markov Chain model, such as [16], the handover dropping (HOD)probability can be obtained when the traffic arrival and departure rate are given by

$$P_0 = f\,(n, ho, \mu, r) \ldots\ldots (3)$$

Here,
n= new calls,
ho=handover calls,
µ=call departure rate,
r=reserved channels,
We know that the transmission range of an MN is much smaller than that of a base station and many MNs are highly mobile. It seems ad hoc mode could not significantly help the cellular system due to much shorter span of certain links. However, there are still many relatively stationary MNs existing in the system because low mobility can achieve higher data rate or purely because of users' behaviors. Devices such as ARS in [5] can also be introduced to increase the stability of multi-hop connections. Therefore, due to the existence of plenty of potential relay nodes, we can rely on multi-hop connections to improve the performance of cellular systems.

4.2.2 Basic Idea

In MCNs, beside the base stations, the existing relay nodes can also assist the roaming MNs to complete handoff process via multi-hop connections. The multiple handoff options may connect the same roaming MN to different base stations, or to the same base station via different paths. Among multiple handoff options, how to find the best is very important but challenging. Connecting to inappropriate base stations through inappropriate relay nodes at inappropriate timing may not only increase the handoff frequency, increase the call dropping rate, but also lead to the inefficiency of resource. In order to make the right decision, it is important for roaming nodes to collect more information about the candidate choices. It is well known that self-organization is one of the major advantages of ad hoc networks, and thus relay nodes can easily exchange information in ad hoc mode. When the relay nodes form small-scale ad hoc networks, the resource information can be exchanged and maintained periodically within the networks, just as in some routing algorithms in IP networks. The roaming nodes can obtain the necessary information to enable the path selection for a connection with better QoS and lower the call dropping probability. Large-scale ad hoc networks are not suitable for this task because the information exchange will create too much signaling overhead.

The traditional way to control the handover dropping (HOD) rate in cellular networks is to adjust the bandwidth reservation for the handoff calls [17]. Higher reservation means lower handover dropping (HOD) rate. However, blindly increasing the bandwidth reservation also lead to the higher call blocking rate for new calls, thus decrease the spectrum efficiency. Therefore, searching for the optimal reservation which can also satisfy the constraint of the handover dropping (HOD) rate should be the goal for each base station. For MCNs, due to the existence of multi-hop handoffs and multiple handoff attempts, each base station can practically have a smaller bandwidth reservation. The knowledge of adjacent cells' traffic can help each base station making resource management more efficient, furthermore, balance the load among different base stations. Based on the insights above, in this project we propose two schemes to improve the handoff performance. In the first scheme, we let a part of the stationary MNs form small-scale ad hoc networks to exchange and maintain necessary information for the potential handoffs. When handoffs occur, the roaming MNs can utilize the present information to choose the best choice for handoffs. The utilization of self-organizing characteristic of ad hoc networks in MCNs is manifested through the use of multi-hop and offs. The second scheme deals with the bandwidth reservation at each base station. Each base station gathers the traffic information of its adjacent cells, takes the prospective multiple handoff attempts for roaming MNs into account and makes the least reservation. This mechanism is then further developed to a framework which can balance the load among different cells when traffic load is significantly unbalanced.

4.3 Small Scale Radio Network

4.3.1 Overview

Multi-hop connections can reduce the handover dropping (HOD)greatly in that more opportunities are provided than before. However, although potential paths exist in these nodes, it may not be easy to find the best choice. In MCNs, there are probably many connected MNs surrounding one disconnected MN. Among all these potentially connected nodes, some may have already been connected to the base stations that have no spare channels to accommodate new connections while others are highly mobile and not suitable for relaying. Although several attempts for a handoff process are generally acceptable, trial and error approach is not a good idea. Fortunately, as we all know, information can be effectively gathered and shared using the power of networking. To make information exchange more effective and more helpful to the handoffs, we may prefer to select stationary nodes to form mobile ad hoc networks (MANETs) to assist handoffs. Obviously, when the scale of these assisting networks becomes large, the coverage can be wider and the handoff can gather more help. On the other hand, the maintenance of the assisting networks will become more difficult and the information exchange will be less effective. Thus, we need to employ stationary, small-scale ad-hoc networks to more effectively assist the multi-hop handoffs in cellular systems. Based on this argument, we propose our scheme handling multi-hop handoffs, called ‘‘Small Scale Radio Network(SSRN)’’, in which we address how to select nodes for the relaying and how to form the handoff assisting networks. In this project, we focus on the handoff issues and simply assume that these networks can be formed by the instruction of operators.

4.4 Architecture and roles

We first describe the network architecture and roles of the assisting networks in Fig. 4.2 In this network architecture, each of these embedded ad hoc networks covers the area which may cover several adjacent cells. As Fig. 4.2 shows, several Mobile Nodes (MN) form one embedded small scale radio network in the cellular systems which spans across several cells. In fig.4. 2, the circled nodes are the backbone nodes and the solid lines between them stand for the relatively stationary links. The triangular nodes stand for the roaming nodes which are searching for base station connections with the help of the embedded ad hoc networks. We call these nodes ‘‘attaching nodes (ANs)’’. The nodes in the backbone connecting directly to the base stations are marked with ‘‘0’’ inside the circles. We call these nodes ‘‘portal nodes (PNs)’’ because they have portal capability of connecting to the backbone cellular system. Other nodes in the backbone not directly connected to base stations use the number inside the circles to stand for the hop counts to portal nodes

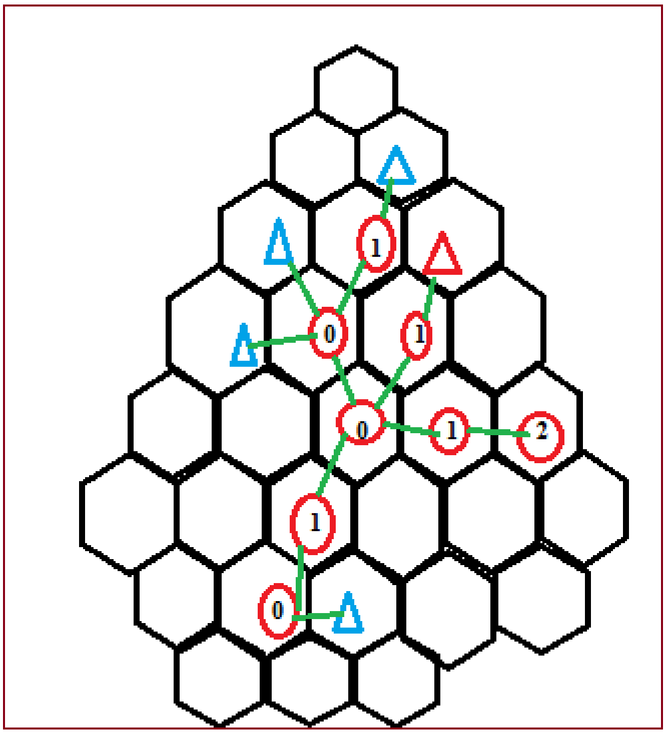


Fig 4.2: Small Scale Radio Network in Cellular System

We call them ‘‘relay nodes (RNs)’’. RNs and PNs form the backbone of the embedded ad hoc networks which assist multi-hop handoffs in the cellular system. The ANs which cannot have the direct connection to base stations use the Embedded Ad-hoc Nodes (EANs) to find alternative connections. The backbone node which have direct connection to the attaching nodes are their ‘‘dock nodes(DNs)’’. ANs’ DNs do not have to be PNs. Each PN should also know the corresponding ANs which connect to a base station through it via different DNs. These ANs are called the ‘subordinate nodes (SNs)’’ of this PN.

4.5 Information Maintenance in SSRN

PNID: Portal Nodes ID. This ID is kept for routing packets properly. It is also required whenever we are running node choosing algorithm.

BSID: ID of the base station. If the ID is saved then we may avoid repeated attempts by the mobile devices.

Table: 4.1 Portal Node's Information Table

PNID	The ID for the candidate of portal nodes
BSID	The ID of the BASE STATION which connects to the corresponding portal node
EstCellBW	Estimated available bandwidth of corresponding base station
HC	Hop counts to the corresponding portal node
PC	The available portal capacity to the corresponding BASE STATION

EstCellBW: Estimated bandwidth of corresponding base station

HC: Hop counts to the corresponding portal node

PC: Portal Capacity. This the measurement of available bandwidth. The available portal capacity to the corresponding base station

Table: 4.2 Attaching Node's Information Table

ANID	The ID of the attaching node
PNID	The ID of the attaching node's corresponding portal node
HC	Hop counts to the corresponding attaching node
OPC	The occupied portal capacity by the corresponding attaching

ANID: ID of the attaching node. This may serve to track the route the mobile device.
PNID: ID of the attaching node's corresponding portal node. This may help when base station changes.
HC : Hop counts to the corresponding attaching node.
OPC: Occupied portal capacity by the corresponding attaching

Table: 4.3 Subordinate Node's Information Table

SNID	The ID of the subordinate node
DNID	The ID of the subordinate node's corresponding dock node
HC	Hop counts to the corresponding docking node
OPC	The occupied portal capacity by the corresponding subordinate node

SNID: ID of the subordinate nodes are required when forming the network this particular nodes. This serve as destination of the routed packets.

DNID:ID of the subordinate node's corresponding dock node. Whenever the dock nodes are changing this has to informed through proper channel.

HC: Hop counts to the corresponding docking node. This gives the measurement of the vulnerability of the link. The more the count is the more the link is prone to break up.

OPC: Occupied portal capacity by the corresponding subordinate node

4.6 Handoffs via Small Scale Radio Network (SSRN)

Apparently, introducing the ad hoc mode gives handoff decision more flexibility in cellular systems. The first possible change of handoff procedures is that with the existence of EANs, handoffs might involve multiple nodes in the SSRNs. Previously the handoffs are always from one cell to another, with direct connections to base stations. With the existence of SSRNs, handoffs can also possibly take place from one EAN to another, from one SSRN to a direct connection or vice versa, or within the same SSRN. Procedures for these types of handoffs should be specified to avoid the possible resource waste and service interruption.

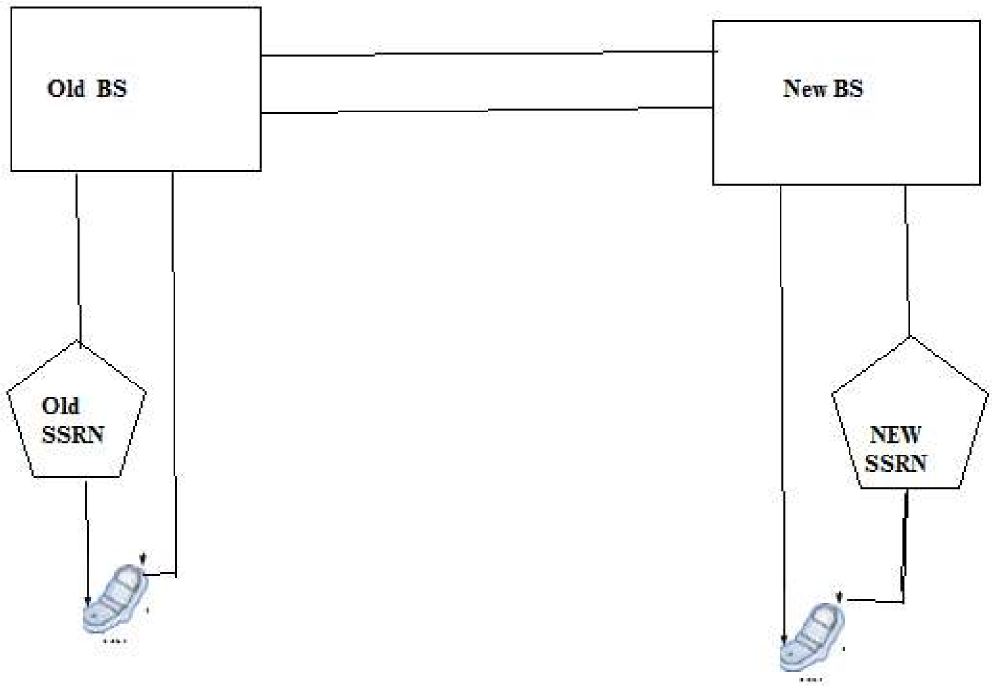


Fig 4.3 Hand off via SSRN

4.7 How to Choose Among The Probable Destinations For Handover.

1.

A) Estimation of P(HOD)

n= new calls,

ho=handover calls,

µ=call departure rate,

r=reserved channels,

P(BS_ HOD)= f (n, ho,µ,r) … (4)

f is function of n, ho,µ,r the derivation is given here. As we know

$$P(0)= \left(\sum_{k=0}^{c-r} \frac{(n+ho)^k}{k!\mu^k} + \sum_{c-r}^{c} \cdot \frac{(n+ho)^{c-r} ho^{k-c-r}}{k!\mu^k} \right)^{-1}$$

$$P_C = \frac{(n+ho)^{c-r}\ h^r}{c!\ \mu^c}$$

$$P(BS\_HOD) = \frac{(n+ho)^{c-r} ho^r}{c!\mu^c} . P(O) \quad \textbf{... (5)}$$

Where,

$$P(0)= \left(\sum_{k=0}^{c-r} \frac{(n+ho)^k}{k!\mu^k} + \sum_{c-r}^{c} \cdot \frac{(n+ho)^{c-r} ho^{k-c-r}}{k!\mu^k} \right)^{-1}$$

B) Estimation of Available Bandwidth, E_BW

E_BW=g(n,ho,µ,r)

$$E\_BW = \min(E\_BW, \frac{1}{4,hc}) \min_{i\epsilon}(L_i) \quad ...(6)$$

2. Estimation of hand off cost

P_K(One_HOD)=1-(1-P_K(BS_HOD) x P_K(PN_HOD) x P_K(DN_HOD)

Note that P_K(One_HOD)=0, if P_K(BS_HOD)=0 or, P_K(PN_(HOD))=0 and P_K(DN_HOD)=0 implies no handover has taken place.

3. Hop count

$P_K(Con\_fail)=1-(1-P_k(One\_hop\_fail))^{hop\_coount}$

The more the hop count is the connection more likely to break up.

4. Relative Position Of Destination BASE STATION To The MN's Movement

Given that the MN keeps the moving history, it can have the conditional probability for each candidate of the handoff destination(BS_i| BS_h) where BSi stands for the base station i and BS_hstands for the previously visited base stations. The extra handover dropping (HOD)probability can be expressed via the following equation.

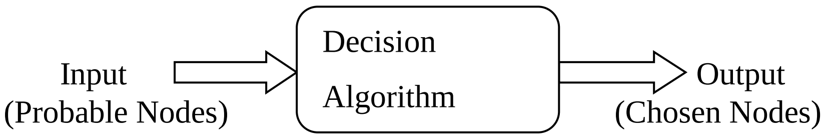
P_i(extra_HOD)=(1-P(BSi|BS_h)

P((HOD)$_{AVERAGE}$ denotes the averaged handover dropping (HOD)rate derived by averaging the overall chosen dropping rates of the MN's recent handoffs. Therefore, the overall handover dropping (HOD)rate for each candidate can be derived as below. The overall call dropping rate can be derived via formula:

$(P_{Dropping})_K$ = 1-(1-P(conection_fail))x(1-P(HOD)

Over all Call Dropping can be derived as follows-
$(P_{Dropping})_K$ = 1-(1-P(conection_fail))x(1-P_k (HOD)
Where,
P_k((HOD)=1-(1-P_K(One_HOD)x(1-P(extra_(HOD …(7)

4.8 Handover Decision Algorithm and Pseudo code



Algorithm

Step 1: Input probable candidate Nodes.
Step 2: Calculate handover dropping (HOD)probability for each node.
Step 3: Output chosen nodes based on least HANDOVER DROPPING (HOD).

Pseudo code

```
 H_O_D  <n,ho,μ,r,c,a,b,c1,d,x,z>
{
a=0;
b=0;
c1=n+ho;
d=c-r;
e=k-c-r;
for  x=1 to z      // z is number of candidates
{
for k=0 to d
             {
              a= pow(c1,k)/k*(k-1)*pow(μ,k);
             }
for k=d  to  c
            {
              b=pow(c1,d)*pow(ho,e)/k*(k-1)*pow(μ,k);
             }
P[x]=a+b;

          }

for  x=1 to z      // z is number of candidates
if (p[x]>p[x+1]) then      // Sorting the candidates
temp=P[x];
P[x]=P[x+1];
P[x+1]=temp;
```

}
}
Write (P[x]);

4.9 Finding Minimum Reservation

According to [16], handover dropping (HOD)rate in a cutoff prioritized reservation system can be modeled as a finite-state Markov chain.
In Fig-4.1 Si denotes the state of i channels being occupied. N and HO stand for the arrival rate of new calls and handoff calls, respectively. C is the total number of channels and R is the number of reserved channels. μ is the departure rate for both types of calls. In this model, handoff calls and new calls start to use the shared channels when there are still spare channels in the shared channel pool. When the shared channels are used up, only handoff call scan use the reserved channels.
We can write the state equations as the follows.

$P_0 = f$ (n, ho, μ, r).

$$P_0 = \frac{(n+ho)^{c-r} ho^r}{c!\mu^c} .. \left(\sum_{k=0}^{c-r} \frac{(n+ho)^k}{k!\mu^k} + \frac{(n+ho)^{c-r} ho^{k-c-r}}{k!\mu^k} \right)^{-1} \quad (1)$$

Where n and ho denotes arrival rate of new calls and handover calls respectively, departure rate is denoted by μ and r denotes number of reserved channels.
Each Base station calculates the overall handover dropping (HOD)according to the following equation-

$$(HOD)_{Total} = P_0..((1-q)^M + \sum_{i=1}^{M} (1-qi) \frac{pm}{M}. q \quad (2)$$

Where,
$(HOD)_{Total}$ = Overall Handover Dropping,
P_o = handover dropping (HOD)rate when only one cell's resource is considered,
q = accessibility,
M = total number of cells,
pm = measured one attempt handover dropping (HOD)for a cell.

$$P(i) = \begin{cases} \frac{n+ho}{i\mu}.P(i-1), & \text{for } i=1,2,3,\ldots\ldots c-r \\ \frac{ho}{i\mu} P(i-1), & \text{for } i=c-r+1, \ldots\ldots c \end{cases}$$

With normalized condition we can derive the probability of state 0 as follows:

$$P(0) = \left(\sum_{k=0}^{c-r} \frac{(n+ho)^k}{k!\mu^k} + \sum_{c-r}^{c} . \frac{(n+ho)^{c-r} ho^{k-c-r}}{k!\mu^k} \right)^{-1}$$

The handover dropping (HOD)happen when all the channels are occupied. Therefore, the handover dropping (HOD)rate is the probability of state C

$$P_C = \frac{(n+ho)^{c-r} \; h^r}{c! \, \mu^c}$$

As per the fig: 4.4,the call blocking probability is equal to the summation of probabilities that the states occupy state C - R to state C.

$$P_B = \sum_{K=C-R}^{C} P(K)$$

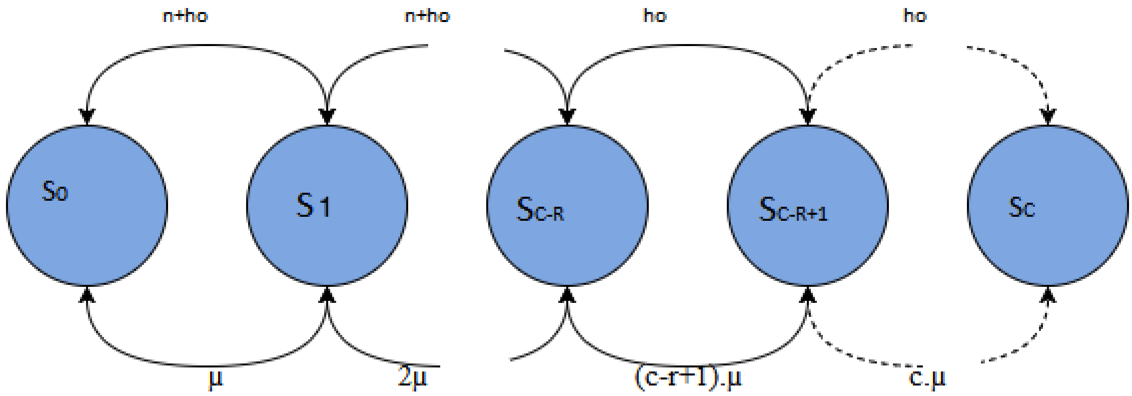


Fig 4.4: Markov Chain Model for handoff Reservation System

To maintain a certain level of handover dropping (HOD)rate, each BASE STATION should reserve certain amount of bandwidth for handoff calls. If the reservation is not enough, the expected handover dropping (HOD)rate will be exceeded. However, since the reserved resource is separated from the shared resource, if the reservation is unnecessarily high, the blocking rate for new calls will increase, leading to dissatisfaction in new call blocking

Therefore, the focus of resource management is to find the minimum resource reservation which meets the handover dropping (HOD)requirement. In MCNs, since we can make more than one attempt for handoff, we can expect lower handover dropping (HOD)rate than in one-hop cellular networks with the same traffic load and same reservation even though multi-hop connections bring in extra traffic from the adjacent cells.
Here ,
Input = A given handover dropping (HOD)rate denoted as P_r(HANDOVER DROPPING (HOD)),
Output =feasible minimum value of r.

We need to find minimum Reservation that is finding value of r. As we consider multiple cells around so we need also calculate the one attempt (HOD), P_k (HOD) for other cells as well.

Besides the handover dropping (HOD) rate of neighboring cells, each base station also needs to know the probability that multi-hop handoffs can access the adjacent cell. This access probability, corresponding to a surrounding base station i, denoted as qi, can be measured by dividing the number of calls in current cell (base station 0) which have access to base station i to the total number of calls in the current cell. Obviously, this measurement requires the handoff calls to report extra information to base station, the accessibility to other base stations.
With these broadcasted and measured P_k(HOD), we can find the expression of the final handover dropping (HOD)rate as in equation 8. While we take the required handover dropping (HOD)rate as Pr(HOD), we can derive the minimum reservation by incorporate formula f(n.ho,µ,r). We use N to denote the maximum number of attempts after the direct handoff attempt fails and M to denote the number of neighbors of the current cell.

So, the required handover dropping (HOD) is expressed as in the following equation

$$\Pr(HOD)=P_0.(\prod_{i=1}^{m}(1-q)\sum_{i=1}^{m}\frac{\mathrm{Pk((HOD))}}{\mathrm{m}} \text{ x } q+\sum_{i=1}^{m}.\sum_{j\neq i}^{m}\frac{\mathrm{Pk((HOD))XPj((HOD))}}{2!}.2+\ldots$$

$$\ldots\ldots+q.\prod_{i=i1,i2,..}^{m}(1-q) \quad \text{...(8)}$$

Summary:

Multihop cellular network (MCN) comes in the existence with a goal to establish an all-IP platform. MCN takes advantages of both conventional cellular network and Ad hoc network. To combat the challenges such as handover dropping, delay, load balancing etc one small scale radio network termed as SSRN is proposed. Here cellular link and ad hoc link both are used opportunistically. Obviously this increases the cell capacity. As SSRN may cover few cells when deployed in boundaries it gathers information about adjacent cell's traffic. For this reason reservation is optimum. Call blocking and Hand over dropping (HOD) is efficiently balanced to reach users satisfaction. Apart from Base stations in SSRN relay nodes (RN), attaching nodes (AN) are introduced. The backbone nodes directly connected with attaching nodes are their dock nodes termed as DN. The last tier nodes are portal nodes (PN). All the different types of nodes are identified with unique ID. To understand the real time scenario including connection vulnerability hop count is another important metrics. To choose among the available destination nodes following calculations are to done prior to handover:

I. Estimation of dropping probability owing to base station : P(BS_HOD)
II. Estimation of handover cost
III. Hop count
IV. Relative position of destination BS to the Mobile Nodes movement.

With all these considerations a decision algorithm is generated. The pseudo code can be developed into working program. To find minimum reservation the parameters such as number of new calls(n), handover calls (ho), departure rate of both n and ho (μ) and reserved channels (r) are taken into consideration. This is expressed as *f* (n, ho, μ, r). The stages are depicted using Markov Chain model.

We also formulate call dropping rate(Pr(HOD) at the different values of q (accessibility). The first component can be calculated by $P_0.(\prod_{i=1}^{m}(1-q)\sum_{i=1}^{m}\frac{\mathrm{Pk((HOD))}}{\mathrm{m}}$ x q,the second as $\sum_{i=1}^{m}.\sum_{j\neq i}^{m}\frac{\mathrm{Pk((HOD))XPj((HOD))}}{2!}.2$ and the final is $q.\prod_{i=i1,i2,..}^{m}(1-q)$. To check the impact of SSRN on handover results (call dropping and blocking) we need to simulate our equations at different values of accessibility. We have vividly dealt with this simulation work in next chapter.

CHAPTER 5
Comparison with Existing Single Cell Network

5.1 Performance Evaluation

In this Chapter, we study the benefits that multi-hop connections can bring to the cellular systems in terms of handoff performance. We are realizing these benefits by integrating Small scale radio network (SSRN) in conventional cellular system.
We have the following set up of the resource parameters for simulation:-

5.1.1 Simulation Set up 1

Total number of channels=30 and reservation is kept for 6 channels. So, we have kept a reservation percentage = 20% of total channels.

Table 5.1: Simulation set up 1

Number of Channels	**30**
Number of Reserved Channels	**6**
Average Number of Initial Calls	**25**
Average Number of Handoff Calls	**20-120**
Accessibility	**0-1**
Average Call Intensity per User	**0.1**erl

Firstly, we look into the handover dropping (HOD)(Handover Dropping) rate improvement when - reservation of each BASE STATION remains unchanged. We set a scenario of five adjacent cells with one cell in the center and four cells surrounding it. For the single cell handover dropping (HOD)rate, we calculate using formula

$P_0 = f(n, ho, \mu, r)$.

$$P_0 = \frac{(n+ho)^{c-r} ho^r}{c!\mu^c} . \left(\sum_{k=0}^{c-r} \frac{(n+ho)^k}{k!\mu^k} + \frac{(n+ho)^{c-r} ho^{k-c-r}}{k!\mu^k} \right)^{-1} \text{..................(9)}$$

Where n and ho denotes arrival rate of new calls and handover calls respectively, departure rate is denoted by μ and r denotes number of reserved channels.
Each Base station calculates the overall handover dropping (HOD)according to the following equation-

$$(HOD)_{Total} = P_0 .((1-q)^M + \sum_{i=1}^{M} (1-qi) \frac{pm}{M} . q \text{............................(10)}$$

Where,
$(HOD)_{Total}$ = Overall Handover Dropping,
P_o = handover dropping (HOD)rate when only one cell's resource is considered,
q = accessibility,
M = total number of cells,
pm = measured one attempt handover dropping (HOD)for a cell.

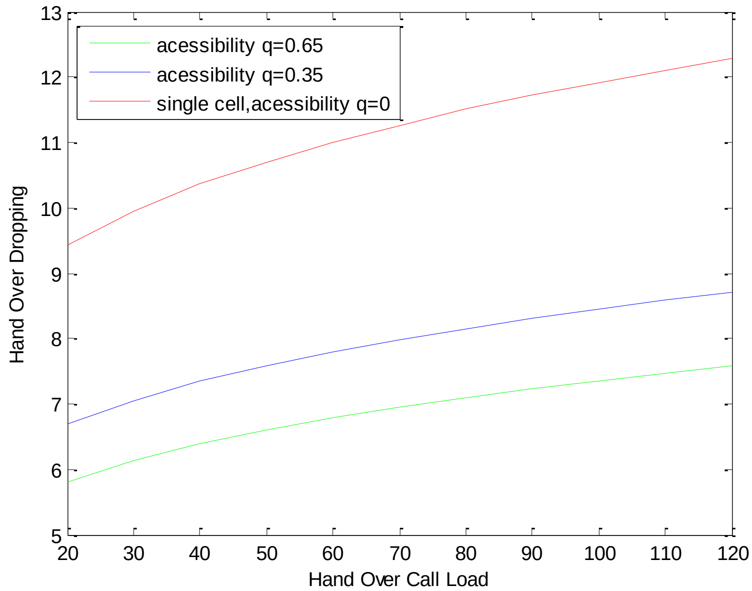


Fig 5.1 Handover Dropping in Single Cell and in SSRN

In this simulation the overall handover dropping (HOD)rate of the center cell has been shown. Fig 5.1 shows the relationship between traffic load and handover dropping (HOD)rate. From Fig 5.1 we can see that when traffic load increases, the handover dropping (HOD)rate increases accordingly.

Red line indicates call dropping of a single hop cellular network which does not use Small Scale Radio Network.

Blue line indicates call dropping when we use the proposed scheme with accessibility=0.35. With the help of adjacent cells, handover dropping (HOD)rate can be reduced greatly. From Fig 5.1, we can see that even with a small access probability, such as q = 0.35, the handover dropping (HOD)rate can be improved with 2.

Green line indicates call dropping when we use the scheme with accessibility=0.65.Here call dropping is even lesser.

At Handover call load=20, Single Hop Cellular Network has a drop more than 9 and the scheme reduces it by 2 and 1 when using accessibility 0.35 and 0.65 respectively.
We can also see from Fig 5.1, when traffic load increases to a certain level, the handover dropping (HOD)rate will deteriorate badly. The reason is that the current reservation cannot support the traffic load and the rejected traffic also forms a big burden on the adjacent cells.

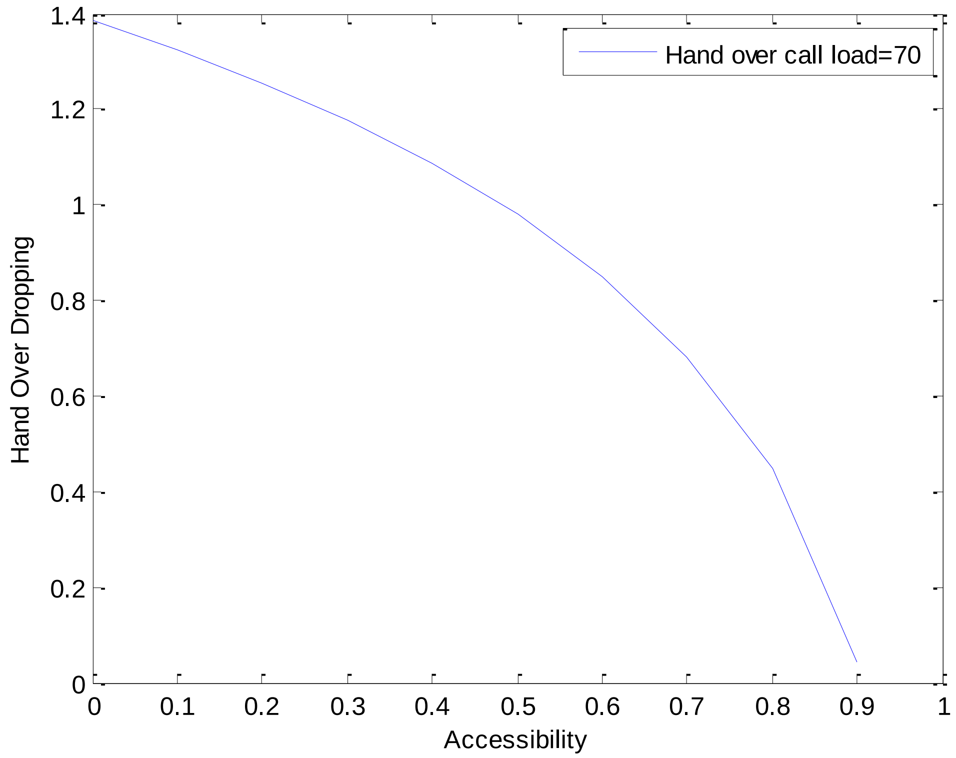


Fig 5.2 Impact of accessibility on Handover dropping

Fig 5.2 shows the relationship between handover dropping (HOD)rate and different access probabilities under a certain traffic load. Here traffic load is 70.

Call dropping is highest (more than 1.2) when q=0. This implies that when we use a single hop cellular network we have highest number of dropping.

But with increment of accessibility the dropping reduces. When we have q=0.8 the dropping is less than 0.5

Most important observation from this simulation is that when the access probability increases, the handover dropping (HOD)rate decreases dramatically when the accessibility is equal to 1 then we see Handover dropping is **nearly zero**. This implies when accessibility to other cells is nearly 1 we do not need any reservation or very small reservation to meet certain HANDOVER DROPPING (HOD)(nearly 0).

In Fig 5.3 the numbers of reserved channels are shown (along Y axis) with different traffic loads (along X axis)

Here we evaluate how the channel reservation is relieved with the help of adjacent cells. Lower reservation can also greatly reduce the call blocking rate of new calls. In this part of simulation, we set the required handover dropping (HOD) rate to $0.5x10^{-3}$.

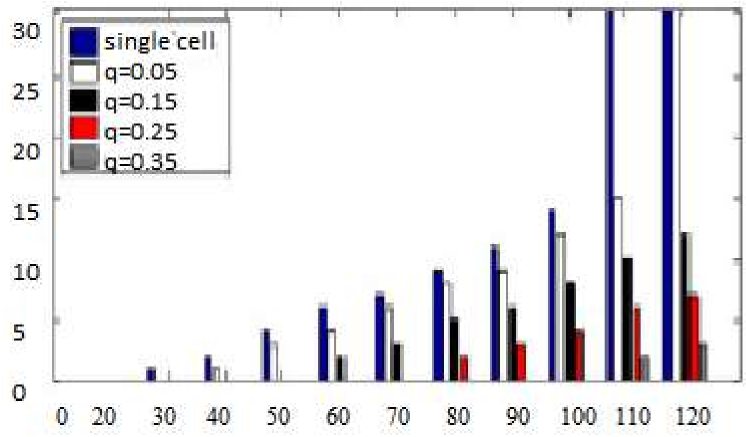


Fig 5.3:**Number of channel Reservation Vs Handover call load**

Under this constraint, each BASE STATION finds the minimum channel reservation. Single Cell case is colored as blue. In case of single hop cellular network it does not use the SSRN. We can see that without the help of adjacent cells (‘‘Single Cell Case’’ in the graph, blue), more channels need to be reserved to achieve the required handover dropping (HOD) rate.

We can see from Fig 5.3 that when handover call load is 110 single cell requires the 30 channels to be reserved to meet the required handover dropping (HOD) level. But In case we are using our proposed schemes with different accessibility we need reserve less number of channels. If the accessibility is 0.05 we need to reserve 15 channels, if it is 0.15 the reservation is down to 10 channels, 5 and 2 channels are to be reserved if the accessibility is 0.25 and 0.35 respectively.

When traffic load becomes larger, reservation does not work for the required handover dropping (HOD)rate. Fig 5.3 shows 30 reserved channels stand for this case. With the increasing access probability, the channel reservation can be greatly decreased. In the case of q = 0.35, under most of the traffic load, there is no need for channel reservation to meet the handover dropping (HOD)rate requirement till the handover call load reaches to 120.

Fig 5.4 shows the corresponding call blocking rate when the minimum reservation is applied. We can easily observe the great improvement especially when traffic load becomes heavier.

When we have a Handover call load of 165 we observe that call blocking is 8 for single cell case colored as blue in the figure. But it is only 1 and less than 1 in case of accessibility is 0.35 and 0.65 respectively(colored as green and red respectively)

We also observe that call blocking is drastically increasing for the single hop cellular network but the increment is in a much lesser pace when we are using our scheme with different values of accessibility

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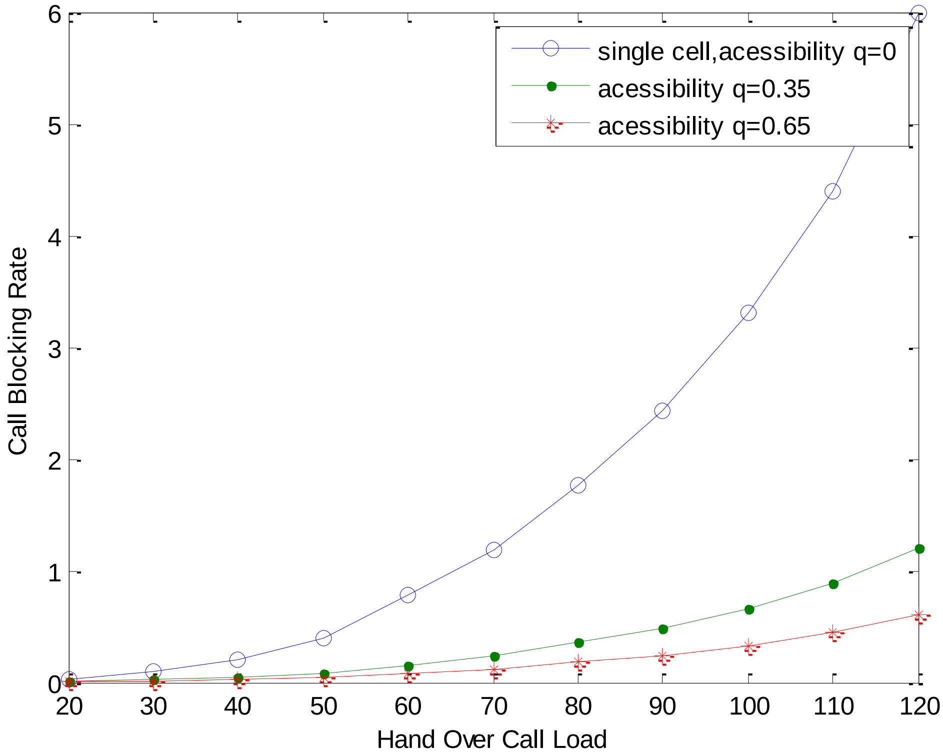

Fig 5.4 Call blocking Vs Handover call load

. Since we are using the model from [16], the 0 reservation in this simulation means that even there is no channel reserved for the handoff calls, the shared channels can still satisfy the required handover dropping (HOD)rate.

5.1.2 Simulation Set Up 2

In second scenario we have changed the reservation percentage .we have kept the reservation = 10% of the total channels.

Table 5.2 Simulation Set Up 2

Number of Channels	**30**
Number of Reserved Channels	**3**
Average Number of Initial Calls	**25**
Average Number of Handoff Calls	**20-120**
Accessibility	**0-1**
Average Call Intensity per User	**0.1**erl

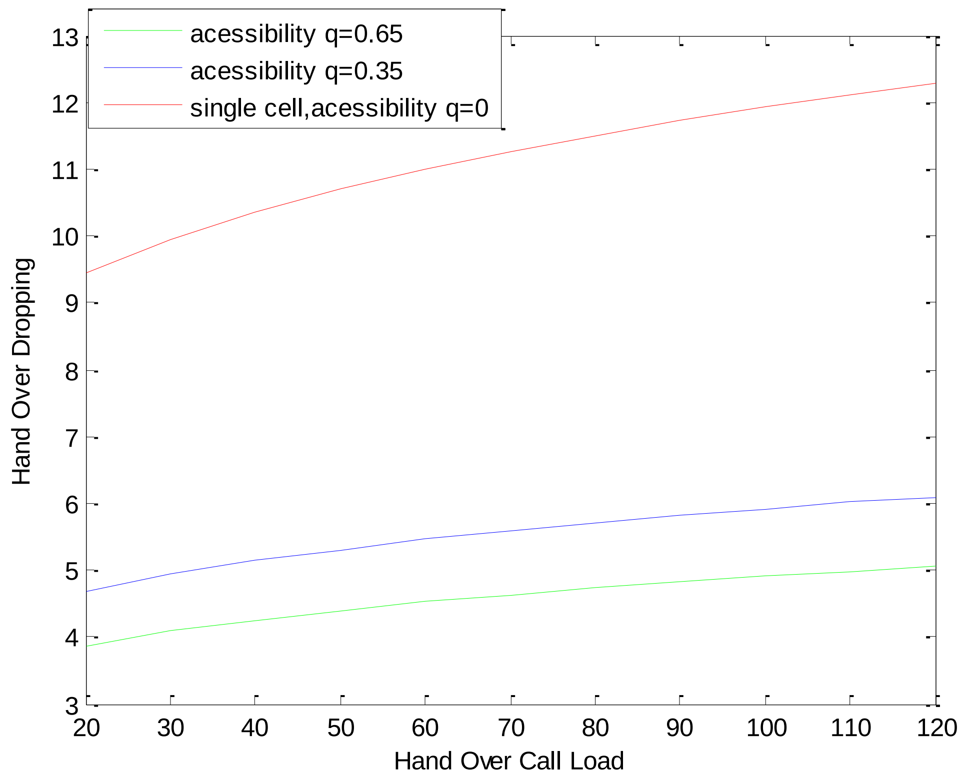

Fig 5.5 Handover Dropping Vs Handover Call Load

Fig 5.5 shows the relation between Handover call load and Handover dropping. Here we observe that the performance of Single hop cellular network has degraded compared to the first scenario where we had 20% reservation. Here we can see at call load 20 the difference between the single cell case and our proposed scheme is 4 and 5 in case q is 0.35 and 0.65 respectively. This difference as shown in Fig 5.1 was 2.

So, the reservation percentage affects the conventional system more. In proposed system if the accessibility is increased then it does not affect the dropping much.

Fig 5.6 shows Impact of accessibility on handover dropping. Even though the reservation is reduced to 10% from still this simulation shows that call dropping is down to almost 0 when the accessibility is 1.

In Fig 5.7 the numbers of reserved channels are shown (along Y axis) with different traffic loads (along X axis)

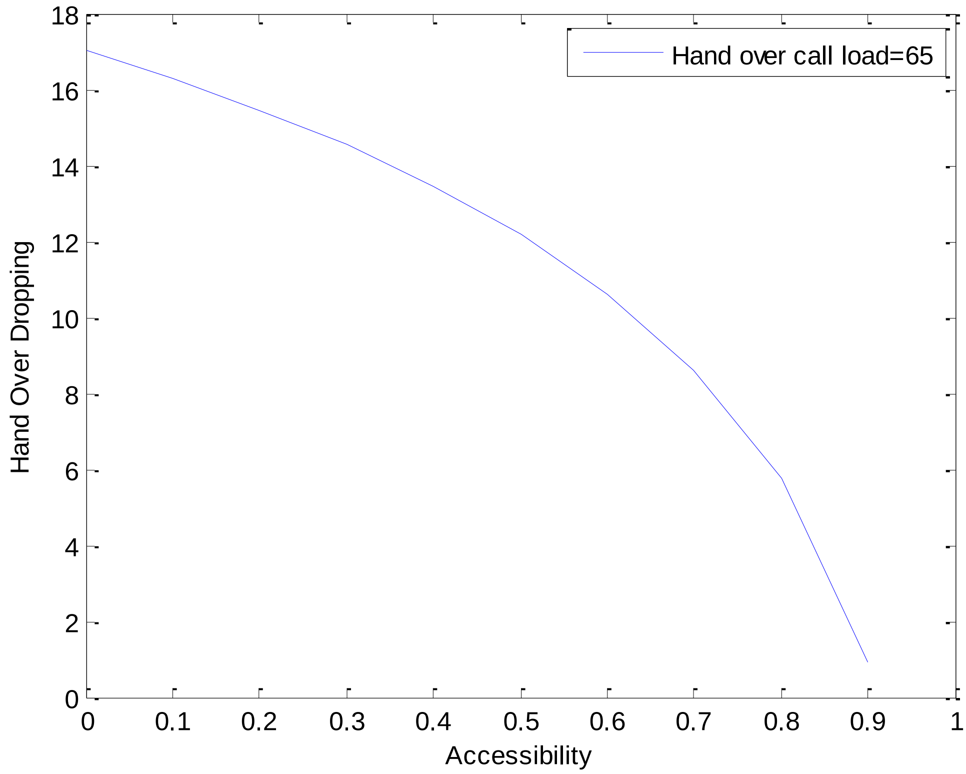

Fig 5.6 Impact of accessibility on handover dropping

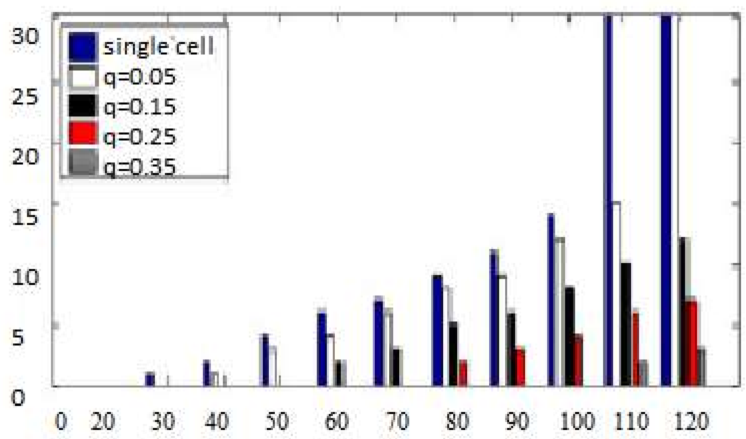

Fig 5.7 Number of channel reservation at Various Handover call Load

Here we evaluate how the channel reservation is relieved with the help of adjacent cells. Lower reservation can also greatly reduce the call blocking rate of new calls. In this part of simulation, we set the required handover dropping (HOD)rate to $0.5x10^{-3}$.

Under this constraint, each base station finds the minimum channel reservation. Single Cell case is colored as blue. In case of single hop cellular network it does not use the SSRN. We can see that without the help of adjacent cells(‘‘Single Cell Case’’ in the graph, blue), more channels need to be reserved to achieve the required handover dropping (HOD)rate. We can see from Fig 5.7 that when handover call load is 80 single cell requires the 12 channels to be reserved to meet the required handover dropping (HOD) level. But In case we are using our proposed schemes with different accessibility we need reserve less number of channels. If the accessibility is 0.05 we need to reserve 9 channels, if it is 0.15 the reservation is down to 8 channels, 2 and 0 channels are to be reserved if the accessibility is 0.25 and 0.35 respectively.

When traffic load becomes larger, reservation does not work for the required handover dropping (HOD)rate. Fig 5.7 shows 30 reserved channels stand for this case. With the increasing access probability, the channel reservation can be greatly decreased. In the case of q = 0.35, under most of the traffic load, there is no need for channel reservation to meet the handover dropping (HOD)rate requirement till the handover call load reaches to 120.

With the increasing access probability, the channel reservation can be greatly decreased. In the case of q = 0.35, under most of the traffic load, there is no need for channel reservation to meet the handover dropping (HOD) rate requirement.
Fig 5.8 shows the corresponding call blocking rate when the minimum reservation is applied. We can easily observe the great improvement especially when traffic load becomes heavier. When we have a Handover call load of 90 we observe that call blocking is 2 for single cell case colored as blue in the figure. But it is only 0.5 and less than 0.5 in case of accessibility is 0.35 and 0.65 respectively(colored as green and red respectively)We also observe that call blocking is drastically increasing for the single hop cellular network but the increment is in a much lesser pace when we are using our scheme with different values of accessibility.

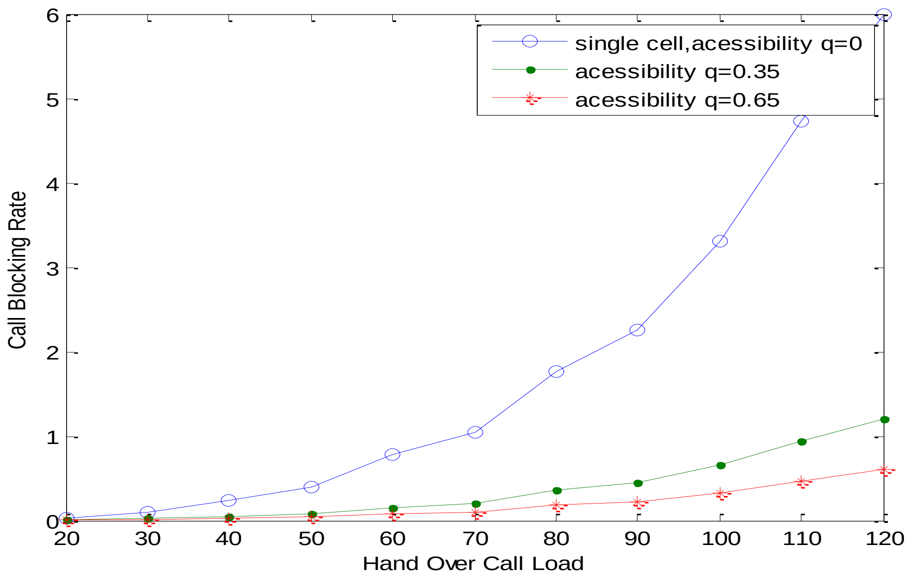

Fig 5.8 Call blocking Rate at Handover call load for Single Cell and SSRN

5.1.3 Simulation Set Up 3

In second scenario we have changed the reservation percentage .we have kept the reservation = 20%

Table 5.3 Simulation Set Up 3

Number of Channels	**10**
Number of Reserved Channels	**50**
Average Number of Initial Calls	**25**
Average Number of Handoff Calls	**120-220**
Accessibility	**0-1**
Average Call Intensity per User	**0.1**erl

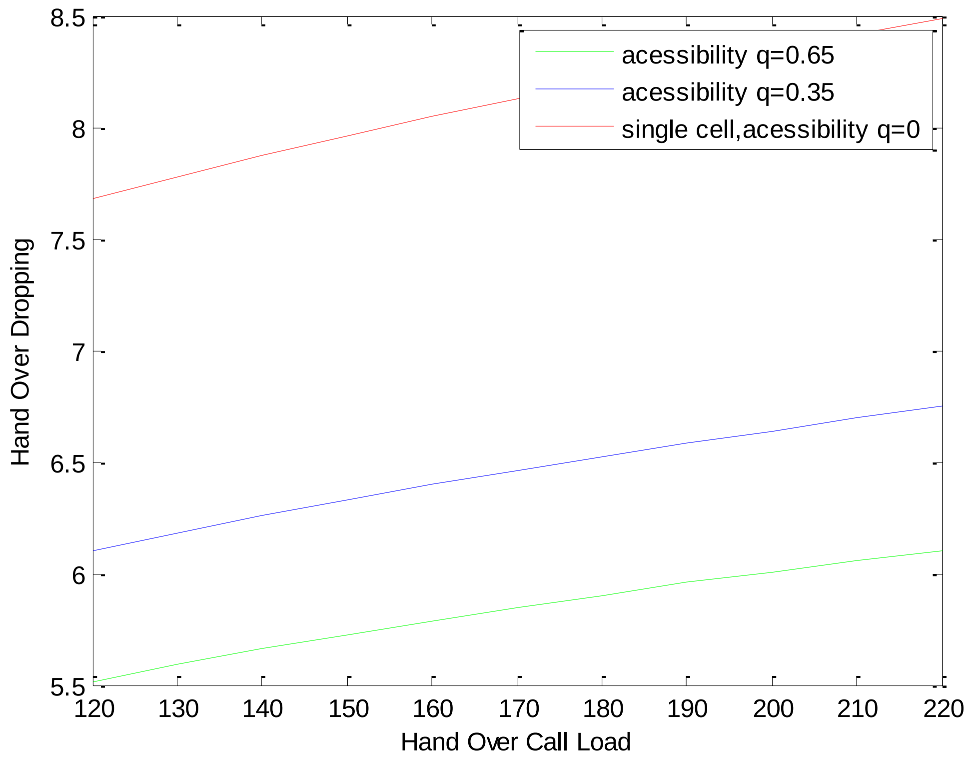

Fig 5.9 **Handover Dropping Vs Handover Call Load**

Fig 5.9 shows the overall handover dropping (HOD)rate of the center cell has been shown. It shows the relationship between traffic load and handover dropping (HOD)rate. From Fig 5.9 we can see that when traffic load increases, the handover dropping (HOD)rate increases accordingly.

Red line indicates call dropping of a single hop cellular network which does not use Small Scale Radio Network.

Blue line indicates call dropping when we use the scheme with accessibility=0.35. With the help of adjacent cells, handover dropping (HOD)rate can be reduced greatly. From Fig 5.9, we can see that even with a small access probability, such as q = 0.35, the handover dropping (HOD)rate can be improved with nearly 2.

Green line indicates call dropping when we use the scheme with accessibility=0.65.
Here call dropping is even lesser.

At Handover call load=120, Single Hop Cellular Network has a drop more than 7.5 and the scheme reduces it by 6 and 5 when using accessibility 0.35 and 0.65 respectively.
Fig 5.10 shows the relationship between handover dropping (HOD)rate and different access probabilities under a certain traffic load. Here traffic load is 75.
Call dropping is highest (more than 1.4) when q=0. This implies that when we use a single hop cellular network we have highest number of dropping.
But with increment of accessibility the dropping reduces. When we have q=0.8 the dropping is less than 0.5.
Here also we can see when the accessibility is equal to 1 then we see Handover dropping is **nearly zero**. This implies when accessibility to other cells is nearly 1 we do not need any reservation.

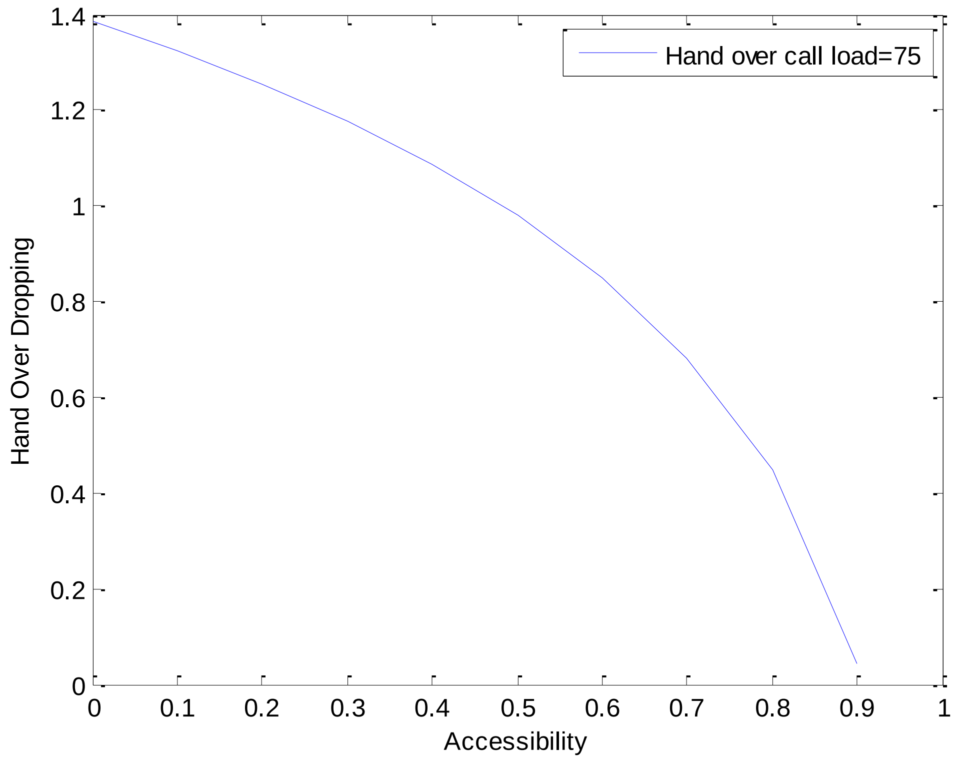

Fig 5.10 Impact of q on call dropping

In Fig 5.11 the numbers of reserved channels are shown (along Y axis) with different traffic loads (along X axis)

Here we evaluate how the channel reservation is relieved with the help of adjacent cells. Lower reservation can also greatly reduce the call blocking rate of new calls. In this part of simulation, we set the required handover dropping (HOD)rate to $0.5x10^{-3}$

Under this constraint, each BASE STATION finds the minimum channel reservation.
Single Cell case is colored as blue. In case of single hop cellular network it does not use the SSRN. We can see that without the help of adjacent cells(''Single Cell Case'' in the graph, blue), more channels need to be reserved to achieve the required handover dropping (HOD)rate.

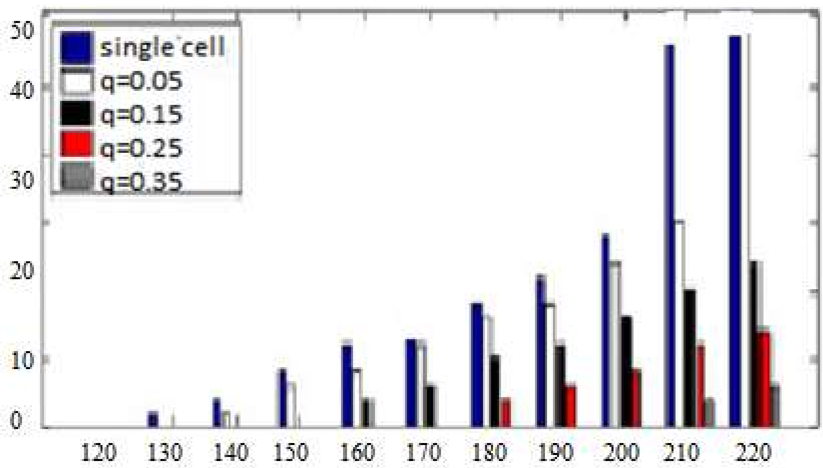

Fig 5.11 Channel Reservations at Different Call Load

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We can see from Fig 5.11 that when handover call load is 200 single cell requires the 25 channels to be reserved to meet the required handover dropping (HOD)level. But In case we are using our proposed schemes with different accessibility we need reserve less number of channels. If the accessibility is 0.05 we need to reserve 18 channels, if it is 0.15 the reservation is down to 12 channels, 6 and 0 channels are to be reserved if the accessibility is 0.25 and 0.35 respectively.

When traffic load becomes larger, reservation does not work for the required handover dropping (HOD)rate. Fig 5.11 shows 30 reserved channels stand for this case. With the increasing access probability, the channel reservation can be greatly decreased. In the case of q = 0.35, under most of the traffic load, there is no need for channel reservation to meet the handover dropping (HOD)rate requirement till the handover call load reaches to 210.

Fig 5.12shows the corresponding call blocking rate when the minimum reservation is applied. We can easily observe the great improvement especially when traffic load becomes heavier. When we have a Handover call load of 210 we observe that call blocking is 8.5 for single cell case colored as blue in the figure. But it is only 0.5 and less than 0.5 in case of accessibility is 0.35 and 0.65 respectively(colored as green and red respectively) We also observe that call blocking is drastically increasing for the single hop cellular network but the increment is in a much lesser pace when we are using our scheme with different values of accessibility.

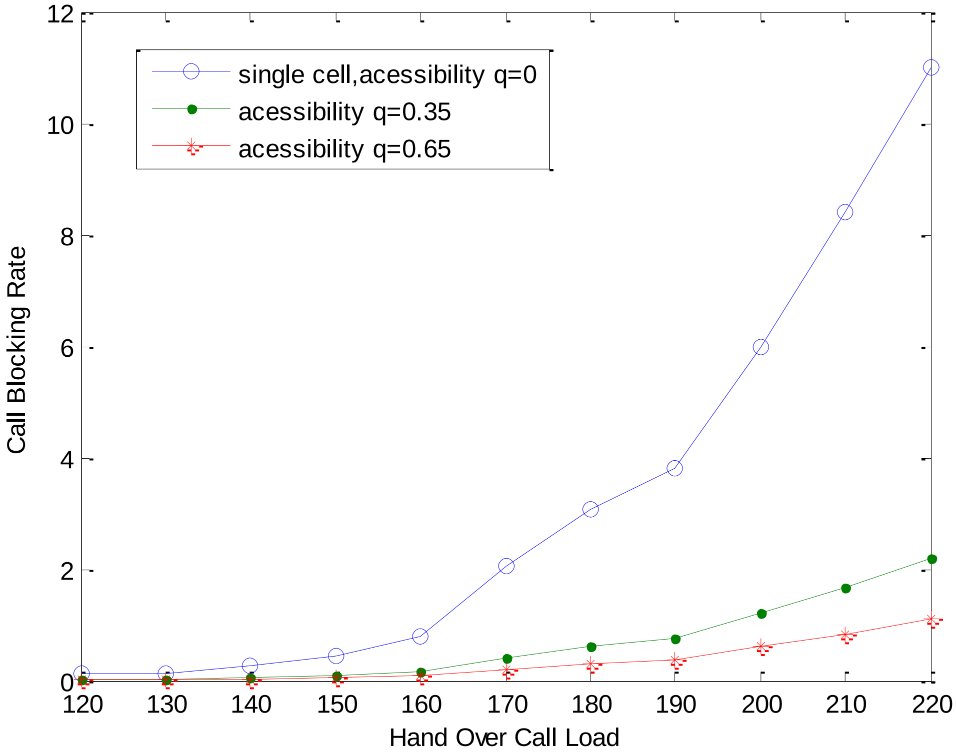

Fig 5.12 Call Blocking Rate at different Handover Call Load

5.1.4 Simulation Set Up 4

In this scenario we have changed the reservation. Here Total number channels and reserved channel are 50 and 5 respectively.

Table 5.4 Simulation Set Up 4

Number of Channels	**5**
Number of Reserved Channels	**50**
Average Number of Initial Calls	**25**
Average Number of Handoff Calls	**120-220**
Accessibility	**0-1**
Average Call Intensity per User	**0.1**erl

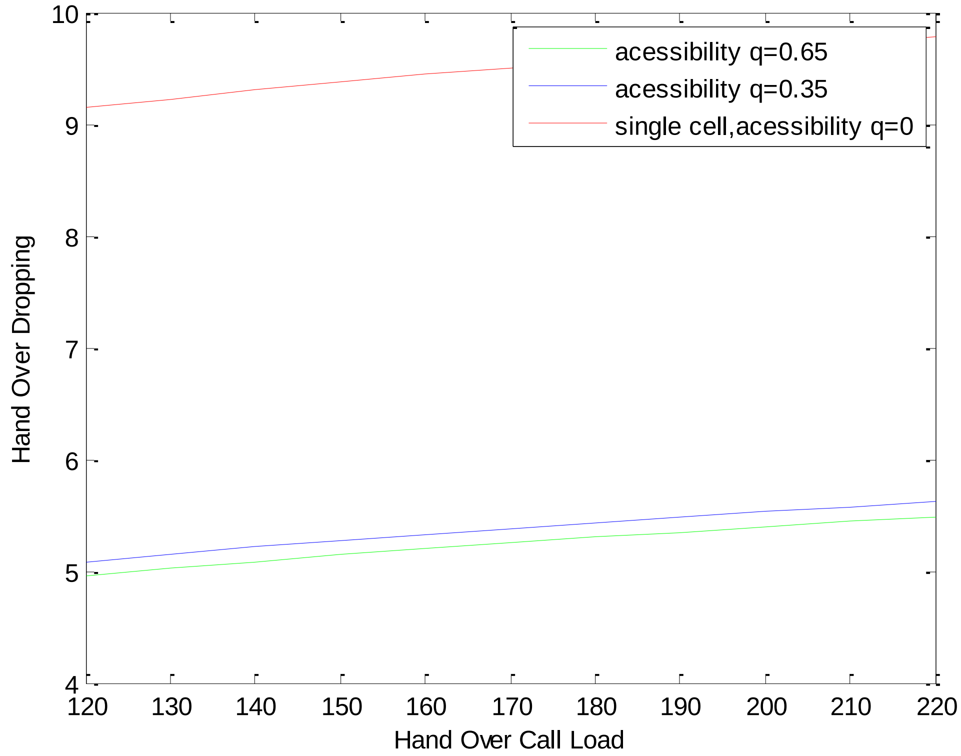

Fig 5.13 Handover Dropping Vs Handover Call Load

Here the major difference is that the deterioration in the performance of the single hop cellular network which is shown in red line. The difference with the proposed schemes here is more. At handover call load 200 the dropping for Single cell case is nearly 9 whereas for our proposed scheme it is nearly 5.

Fig 5.14 depicts the same scenario as previous simulations. The dropping is approaching near zero at accessibility 1.

This implies that there is no reservation required if the accessibility is nearly 100%.

Fig 5.15 (in the next page) depicts the scenario of reservations for different cases. The blue bar indicates reservation for single cell case. White, black, red and grey for accessibility 0.05, 0.15, 0.25 and 0.35 respectively. We can observe no channel reservation is required for the scheme with q=0.35 till the call load reaches to 220. One more important observation is that at certain level such 200 calls the reservation for single cell case has to be almost 100% i.e., all the 50 channels but for our proposed scheme this reservation is much less than that. Here it is only about 8 channels at Handover Call Load 220 where accessibility is 0.35.

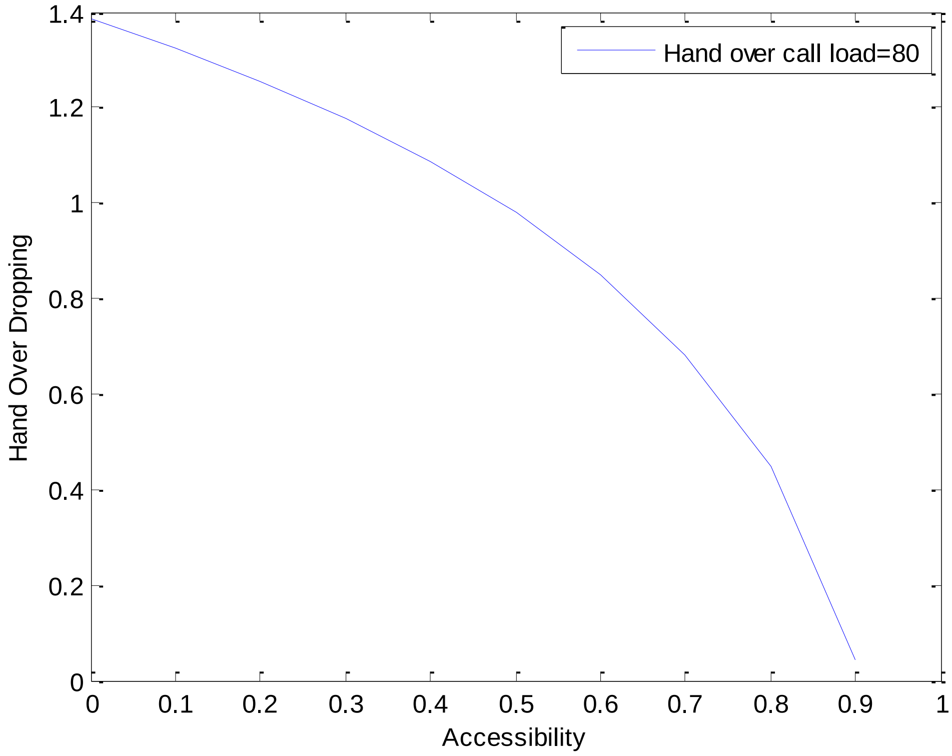

Fig 5.14 Impact of accessibility (q) on Handover Dropping

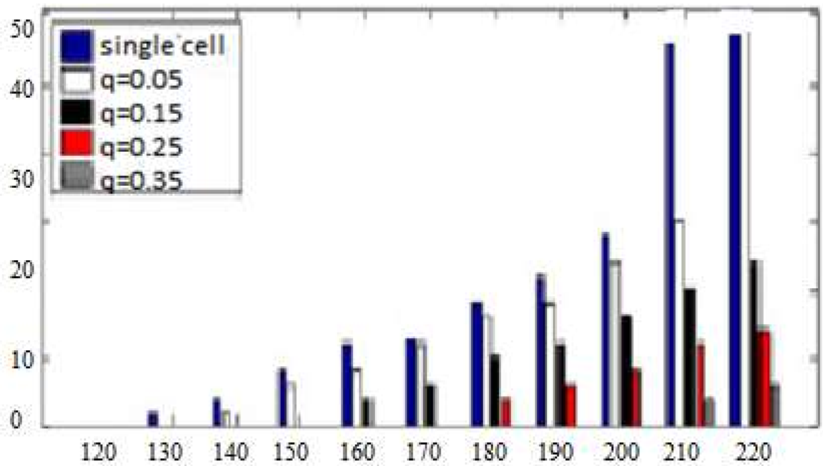

Fig 5.15 Channel Reservation at different Call loads

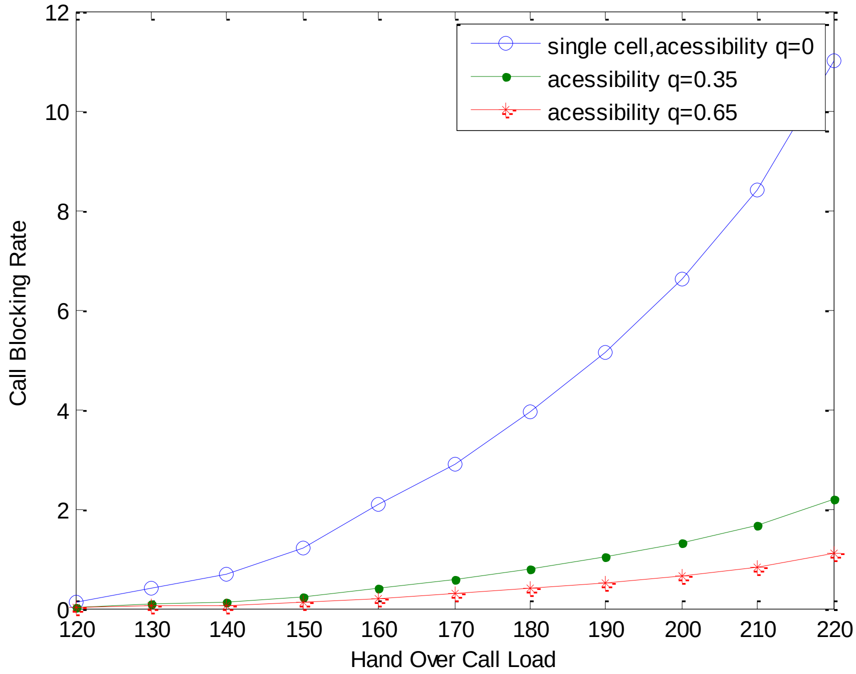

Fig 5.16 Call blocking Rate at Different Call Loads

In Fig 5.16 Blue colored graph indicates blocking for single cell case. Green color is for accessibility 0.35 and red color for accessibility 0.65.

We observe that call blocking is increasing rapidly for single cell case whereas for our proposed scheme it is not too speedy. At Handover call load 220 for single cell the blocking is nearly 12 but it is only 2 and 1 for accessibility 0.35 and 0.65 respectively for our scheme.

CHAPTER 6
Conclusion

6.1 Conclusion

Ad hoc links can offer great improvements to cellular systems in terms of handoff performance since they provide additional multi-hop connections to base stations. This project delves into how the reservation can be reduced with the existence of alternative connections to adjacent cells. Upon achieving the required handover dropping (HOD) rate, with the existence of multi-hop connections, each base station can reduce the channel reservation for handoff calls, thus reduce the blocking rate of new calls. The proposed scheme utilizing the embedded ad hoc networks to assist the multi-hop handoffs also shows novel thoughts to reduce handover dropping (HOD) rate by increasing access probability and intelligently choosing connections with lower potential handover dropping (HOD) rate.

6.2 Future Work

Load sharing among adjacent cells

With the handoff options via multi-hop connections an mobile node (MN) can achieve a much lower overall handover dropping (HOD) rate Pr(HOD) than the handover dropping (HOD)rate derived from the arrival/departure rate and reservation, P0, based on the one-hop connection. However, we should not only focus on the requirement of Pr(HOD)), but also need to maintain a certain resource to control P0. High P0 implies too much rejected traffic from current cell, which will overflow to other cells with P0, even though Pr(HOD)) can still be satisfied. This part of traffic, called ‘‘permeated traffic’’ in this project, will deteriorate other cells’ handover dropping (HOD)rates, as a chain effect, due to repeated handoff attempts. This means if one base station keeps a significantly insufficient bandwidth reservation and mostly relies on other cells’ help, it can end up deteriorating surrounding cells’ handover dropping (HOD)performance. The mathematical explanation for this situation is that the derivations of Pr (HOD)) and P0 are based on the assumption for an ergodic system. If the reservation cannot support the arriving handoff calls, this system is not ergodic anymore. Consequently, Eq. (7) is not valid any more. When one of the cells in the neighborhood has been overloaded with traffic, this problem might be inevitable and even more protuberant. Therefore, a certain threshold should be set to ensure that none of the cell is overloaded
.

Furthermore, load balancing mechanism is necessary in MCNs to utilize the whole resource more efficiently. When one cell is heavily loaded, load balancing mechanism can utilize the adjacent cells’ reservation to maintain the required handover dropping (HOD)rate
.

In this project, we build a framework for this purpose. In this framework, the traffic information in adjacent cells is exchanged and shared and the minimum reservation is calculated in a distributed fashion. More importantly, when some cell is heavily loaded, this framework provides a mechanism for base stations from other cells to take over part of the traffic so that each cell can maintain a relatively low handover dropping (HOD) rate, Pi. This framework is called ‘‘Traffic Information Exchange for base stations or Reservation Calculation Procedure’. The reservation calculation is done periodically by each base station. Between two consecutive periods of calculation, there are three phases: information collection, load balancing, and reservation calculation/information broadcasting. To elaborately deal all the above mentioned issues we need a separate project work in future.

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