Chapter 1

INTRODUCTION

The term ‘communication’ is used in the field of science and technology and it plays a significant role during sharing of information between two separate ends that are located physically apart from each other. ‘Mobile communication’ in the same way can be stated as a means of communication by the transmission and receiving of audio and data using electromagnetic waves in open space.

In mobile communication, emphasis is not only on voice but also on data. In our everyday life, we see people talking on cell phones, but at the same time mobile phones are also used to check the weather, temperature, their emails, browsing shopping sites and many other things. Since the discovery of mobile and wireless communication, basic telephones have been replaced by mobile cell phones. Now, communication or to be more precise mobile communication has become an important and integral part of human society in the present day world. This advancement in the mobile phone technology has immensely improved the way of living of modern day human beings. It will not be an exaggeration to state that life today cannot be imagined without mobile communication.

To have a quick glimpse of the journey of mobile communication, the sources can be traced in the 1940 when mobile telephone services started and was referred to as MTS i.e. mobile telephone system or sometimes the manual telephone system. Since all the calls were handled by one operator, the basics involved in the MTS systems were that they utilized frequency modulation and were assigned a single carrier frequency, which was used by the mobile unit as well as the base station. In this system, the mobile unit used a push to talk (PTT) switch to activate the transceiver. In the modern day, mobile telephone
stations are in the form of small handsets that are easily carried by a person in pockets or purses.

In 1964, Bell laboratories formed a mobile communication department after the U.S. Congress took away the satellite communications business from AT & T. The early wireless networks concentrated only on voice communication. Early, a mobile communication system in 1932 was based on amplitude modulation (AM) schemes and was maintained by the specific public organization only. As time passed by and the needs of man required more advanced technology during the World War II, the need was felt immensely and immediately for better mobile radio communication systems which resulted in the development of Frequency Modulation (FM) scheme by Edwin Armstrong in the year 1946.

Mobile communication has become a familiar term to everyone now a day’s and mobile network is gaining prime importance in the communication technology. The mobile users are demanding varieties of services along with better quality of service from the mobile network service providers. Mobile networks are advancing rapidly, and demanding research for better in our everyday lives. Since the mobile communication in the present day, world is booming it restricts the capacity of a maximum number of users supported in a wireless system. Such mobile networks can be modeled as mobile communication graphs. These are used for communication association among a few devices and nodes which are provided with wireless transceivers and receivers.

1.1 MOBILE COMMUNICATION NETWORK

The mobile communication structure has a mobile station (MS) which make use of a dissimilar radio frequency for communication to the base station. The base stations (BS) are further connected to the telephone network through mobile switching centers. The base stations function by using one channel per mobile for communication with different mobiles at the same instance. The channels used for communication in a mobile network includes a combination of two types of frequencies one for forwarding link i.e., transmitting from the cell site and the second, i.e. the reverse link for the cell site to
receive a call from the users. As it is observed that radio energy dissipates with distance so the mobile handsets must remain in proximity to the base station to maintain proper communication. The fundamental model of mobile communication networks is composed of mobile systems and radio facilities whereas the mobile radio service can work in a closed network and if there is no access to the telephone system, on the other hand the mobile telephone service allows interconnection to the telephone network. Figure 1.1 shows the basic communication structure.

The old-fashioned mobile service was designed like the television broadcasting i.e. one very powerful transmitter was located at the highest point in a specific area and which would relay the signals in a radius of fifty kilometers approximately. On the other hand, the cellular model structured the mobile telephone network in such a manner that instead of using a single powerful transmitter, a large number of low-power transmitters were installed all over the coverage area. For instance, by splitting a large metropolitan area into one hundred different areas (Cells) with low-power transmitters using twelve conversations (channels) each, the system capacity theoretically could thus be increased from twelve conversations or voice channels using one powerful transmitter to twelve hundred conversations (channels) using one hundred low-power transmitters.
Radio communication has been used extensively since old times and the society has been looking for getting flexibility in communication from that time. With the advancement of society and increase in the need for instant communication, mobiles became inevitable for every citizen, but the availability of limited frequency spectrum became a major problem for the service providers. To offer a solution to this problem, the model of cellular communication was developed. Nowadays cellular communication uses an elementary unit of the cellular system that is known as a cell. The entire place is covered by hexagonal shaped cells with a positioned base station and it communicates with the user. In order to accommodate multiple users with the limited frequency spectrum, different access codes like Time Division multiple Access (TDMA), Code Division Multiple Access (CDMA), Frequency Division Multiple Access (FDMA) and their hybrids are used. Every base station in the network is connected to the mobile switching center (MSC) and which in turn connected to the public switched telephone network (PSTN).

In a wired and wireless link, the main difference is in their type of conversation. In the wired links, one to one communication takes place without interference and in the wireless links, on the other hand, it normally provides one to many communications having limited frequency spectrum, interference level. Concurrent wireless communications need channel parting, where a channel may denote time, frequency or code.

In the mobile network, wider spectrum i.e. more bandwidth will allow for greater sharing of the spectral width to support more users. A larger population will mean a larger geographical coverage. If a single transmitter were used to cover a large geographical area, a very high power transmitter, and very high antenna would be required. With a single high power transmitter, all users will share the same set of frequencies, or radio channels. The system capacity, in terms of the maximum number of users that can be supported, offered by a single high power transmitter will hit a limit. The reasons for this limitation are that frequencies resources, i.e. radio channels are not efficiently utilized. If the same set of frequency resources were assigned to serve a smaller geographical area and then reused to serve the other small geographical area, it would be possible to extend
the system’s capacity. The efficient reuse of frequency resources helps to reduce the cost of service by reducing the number of base stations and also accommodating a number of users per base stations. However, it must be taken into consideration that the use of the same set of frequencies for serving more than one geographical area does not introduce reception interference between users in the two areas. The way of replicating identically structured and operated geographical reasons give rise to the concept of cellular communication. Figure 1.2 depicts the mobile network which consists of cells with base stations and all base stations are connected to mobile switching centers.

![Cellular Network Diagram](image)

**Figure 1.2 Mobile Communication Network**

1.1.1 The Cellular concept

The essentials of cellular concept and important functioning channels required for making a call can be summed as under:

A group consists of low-power wireless transmitters that are used in the mobile cellular network to create cells, i.e., the geographical area of a wireless communication system. A cell is referred to as an area under the ambit of a single base station within which signal reception conforms to the system specifications. A cell is assigned a range of frequencies.
and is functioned by a base station comprising a transmit-receiving system and a control unit. Since the users of the mobile cellular network are on continuous movement, they switch from one cell to another and their conversations pass on among cells in order to maintain continuous service. Frequencies which are used in one cell can be reused in another cell with some distance away. The new cells can be included to accommodate growth in an area with no service or covering cells in present zones.

The criterion is to make the shape of a cell so as to cover a specific area. If the shape of the cell is a uniform square area, then a cell has four neighboring cells at a distance $d$ and four cells at a distance $\sqrt{2}d$. When a mobile user moves across the sides of a cell, it should get signals from equidistant antennas from its neighbor cells, which is not possible in case of square cells. Thus in order to provide the user with the best signal strength ideally hexagonal cell patterns are followed while establishing cells as they provide equidistant antennas to the neighboring cell sites. Consider a cell of size $R$, $R$ is cell radius, the distance among the cell centers and each adjacent cell centers is $d = \sqrt{3}R$ as shown in figure 1.3. A hexagonal cell is the closest approximation to a circle. By using hexagonal geometry, the fewer number of cells can cover a larger geographical region.

![Figure 1.3 Honeycomb structure](image-url)
1.1.2 Active Channels

During a mobile call, four types of channels can take part in every cell as mentioned below:

- **Forward Voice Channel (FVC):** The FVC channel provides the voice communication in a forward direction from the BS to the MS.
- **Reverse Voice Channel (RVC):** The RVC channel provides the voice communication in the reverse direction from the MS to the BS.
- **Forward Control Channel (FCC):** The Control channels normally provides used for managing the activity of the call, i.e., they are used for initialization up calls and to turn these calls to available voice channels, hence these forward control channels are also called setup channels. The service required for making a call is transfer and received by these control channels. The FCC is generally used for controlling signaling purpose.
- **Reverse Control Channel (RCC):** This channel (RCC) is used to control calls in the reverse direction, i.e. from the MS to the BS.

1.1.3 Making a Call Using Mobile Cellular Network

When a mobile is unused, i.e., it is neither receiving nor sending a call, then it searches all the control channels because forward and backward control channels are used for initiating the calls from MS to BS and in the reverse direction. The mobile then keeps an eye on the particular control channels to find the one which has got the greatest signal strength. The mobile then remains tuned to this particular FCC. But it does not show any sign of slackness once it connects to the FCC with the highest signal strength, but as soon as the signal strength declines below a certain level, that is inadequate for making a call, the mobile again searches all the FCCs for the one with the highest signal strength. The control channels will always remain same for a particular country or continent. Therefore, the same set of control channels is searched by all mobiles in that particular country or continent. In case this mobile moves out of this region and enter into a different country or continent, then mobile will stop working because the control channels will be different for that new locality.
Every mobile assigned a unique mobile identification number (MIN) and this MIN is a unique number. When a user wants to make a call, he sends a call request along with the MIN of the person to whom the call has to be made is sent to the MSC on the reverse control channel. This MIN is sent to all the base stations of that area by MSC. This MIN is transmitted by the base station and received by all the mobiles within the coverage area of that base station to match it with their own MIN. An acknowledgment is sent to the base station from that mobile if the MIN matches with a particular mobile station. The MSC is then informed by the BS that the mobile is within its coverage area. The base station is instructed by the MSC to access specific unused voice channel pair. A signal to the mobile for ringing along with a message to shift to a particular channel is sent to mobile by the base station. The transmitted power of the mobile (dB) is adjusted by MSC to maintain the quality of the call.

Handoff is the process in which the call has to be shifted to other base station when the coverage area of a user changes from one base station to the other base station, i.e., shifts from one cell to another as the signal strength of the original base station may not be adequate to maintain the call in progress. In such cases, the call is transferred by MSC to one of the unused voice channels on the new base station or the control of the current voice channels is transferred to the new base station to maintain it.

1.2 DEVELOPMENT FACTORS OF A MOBILE SYSTEM

There are a number of reasons for developing a cellular mobile telephone system out of which the major ones are pointed out below:

1. Disadvantage of conventional mobile telephone system
2. Spectrum efficiency consideration
3. Technology, feasibility, affordability, and service
1.2.1 Limitations of conventional formal mobile telephone system

The limitations of a conventional mobile telephone system may be traced to be three in number (Lee C.Y., 1995) as limited service capability, poor service performance, and inefficient frequency spectrum utilization. The detailed explanation about each of them is given below.

- **Limited service capability**
  
The basic and most significant disadvantage of a conventional mobile telephone system is that in traditional communication, coverage area of each zone is normally planned to be as large as possible and in order to address this limitation the transmitted power should be as high as it is allowed by the federal specification. Due to limited bandwidth we have to share whole channel here and this saturate the services in limited number of users. Because there is no guarantee that a call will properly finished without handoff, user has to re initiate the call once again, each time he crosses his zone and move to another zone that is undesirable.

  Another drawback observed is the number of active users, which is limited to the number of channels assigned to a particular frequency zone.

- **Poor service performance**
  
The users of conventional mobile telephone system due to limited bandwidth and channels, capacity of conventional mobile system saturate early and mobile telephone system suffer from a high blocking probability during busy hours when the number of subscribers raises. Owing to this, a high capacity system for mobile telephones is required.

- **Inefficient frequency spectrum utilization**
  
The conventional system allots one channel to only one customer at a time in whole area; it limits the conventional mobile system in the context of efficient spectrum utilization in comparison to traditional system. Hence, a new cellular system that measures the frequency spectrum utilization differently proves to be the efficient system.
1.2.2 Spectrum Efficiency Consideration

The radio communication industry suffered severely from the drawbacks of the availability of radio spectrum. In fact, in setting frequency allocation, the FCC searches for systems which require minimal bandwidth but provide high usage and consumer satisfaction. Thus, an ideal mobile telephone system operates within a limited assigned frequency band and serves to an almost unlimited number of users in unlimited areas.

In order to achieve the ideal mobile telephone system the following are the three major approaches:

1. A single sideband, which divides the allocated frequency band into the maximum number of channels.

2. Cellular system, which reuses the allocated frequency band in different geographic locations, and

3. Spread spectrum or frequency-hopped, which generates many codes over a wide frequency band.

1.2.3 Technology, Feasibility, Affordability, and Service

The computer industry entered into a new era in the year 1971. Microprocessors and microcomputers were used for controlling many complicated features and functions with less power and size than was possible earlier. Apart from this, the new large-scale technology reduced the size of mobile transceivers so that they easily fitted into the standard automobile.

1.3 FREQUENCY ALLOCATION

A spectrum may be defined as an ordered range of the components of the wave. A frequency spectrum is the array of frequencies of electromagnetic waves from zero to infinity. The total spectrum of electromagnetic channels is commonly used for communication, as well as in use for radio, radar, TV and mobile phones. The radio bandwidth is as scarce resource and is an important parameter to measure performance.
In cellular wireless communication, a cell is defined as the radio coverage area covered by a base station. A single base station requires a larger power transmitter to support users within a wide coverage area. To use the radio spectrum very efficiently, unique arrangement of the cellular array is the fundamental concept of cellular wireless communication. Most of the radio spectrum, unfortunately, will remain unused most of the time. So, the frequency reuse technique enhances the system capacity. A wider spectrum will allow for greater sharing of the spectral width to support more users and increase the throughput.

The most challenging task in wireless mobile networks is the frequency (channel) allocated as it involves the significant question of how the available bandwidth will be managed. The limited frequency availability and the increasing demand for advanced services such as real-time video give rise to a special role to frequency allocation strategies. During the last few years, extensive research has been carried out towards the problem of frequency allocation in wireless networks. Channel allocation is a major problem, especially in the mobile cellular network, where many BS (base stations) sharing one or more frequencies, each control the air interference concentrically on their radio cell but have to efficiently compete with other BS for spectrum capacity to be able to fulfil quality of service contracts agreed with their respective wireless terminals. When two channels use the same frequency, (in different geographical areas) then the channels are co-channels and the signal interference between them is called co-channel interference. The available frequencies must be assigned to the cells with the minimum co-channel interference. Signal strength is degraded not only from noise but also from interference from the other co-channel cells.

The main problem which is generally faced by mobile communication in a mobile network is the assignment of frequency because frequency resources are limited and efficient utilization of channels are required for increasing capacity and minimizing interference. There are different types of frequency allocation schemes have been established to attain a good quality of service. Thus, frequency allocation can be categorized as fixed, dynamic, borrowing strategies, one of the other frequency
assignment schemes is a hybrid frequency assignment scheme which is the combination of two strategies.

- **Fixed frequency assignment**

  It defines that every cell in a mobile network is assigned a predefined collection of channels. Any cell attempt within the cell can only be served by the unused channels in that particular cell. If all the channels are occupied, the cell is blocked and the subscriber does not receive service.

- **Borrowing frequency assignment**

  A cell in a mobile cellular network is permitted to borrow frequency bands from an adjacent cell. If all the frequency assigned to it is already absorbed. The mobile switching centers (MSC) monitor such borrowing procedures and ensure that the borrowing of a frequency does not disrupt or interfere with any of the cells in progress in the donor cell.

- **Dynamic frequency assignment**

  It states that frequencies are not assigned to different cells permanently. Whenever a call is made, frequencies are assigned each time accordingly. The serving base station requests a forward channel from the mobile switching center.

  The frequency spectrum is a scarce vital resource. The term ‘Spectrum’ is mainly composed of different types of electromagnetic frequencies of various sizes. The frequency spectrums used in India are randomly limited between 9KHz and 3000 GHz and as well as used for various applications like stable communication, mobile communication, broadcasting, radio direction finding, radio position, static and mobile satellite facility, aeronautical satellite service, etc.

**1.4 MOTIVATION FOR THE RESEARCH WORK**

The motivation of the proposed work results from the fact that frequencies which are assigned to different transmitters are to be appropriately optimized. The use of radio frequencies is at the heart of the mobile communication industry, television broadcasting
as well as many government services in fields such as health services, military communication services, etc. Some common features can be traced in all these applications which lead to many different models. Initially, a set of wireless communication connections or antennas must be assigned frequencies in such a way that data transmission between two endpoints of each connection i.e. transceivers is possible. The frequency should be selected from a given set that may differ among connections. Secondly, the frequencies assigned to two connections may incur interference to one another, resulting in quality loss of the signal. The reception quality of a signal is directly affected if the frequencies are assigned incorrectly. Spectrum allocation is constrained owing to the need of restricting interference between simultaneous transmissions up to an acceptable level. For instance, if two services are geographically closer, interference will occur if they are transmitted on frequencies which are close in the radio spectrum.

Due to the rapid increase in the demand for allocation of channels or frequencies in mobile communication, at each step we need to optimize the reuse of the frequency spectrum. Base stations in the mobile communication system are allocated frequencies or channels, with the aim of minimizing interference. The optimal results obtained will have a direct impact on the geographical area for mobile communication consumed, the number of base stations in mobile networks and the number of channels used by the mobile communication network.

The frequency allocation problem is distributed in nature as the geographical distance between transmitters is increasing day by day, so the distributed algorithms are the best choice for the frequency allocation in mobile network

1.5 CONTRIBUTION

In this thesis, the problem of allocation of frequency or radio spectrum is considered to a given set of transmitters so that interference between transmitters is minimum and frequency spectrum is optimally reused by the transmitters. So our aim is to reuse frequencies between transmitters without any kind of interference between them.

Here, we took the approach of construction of independent sets for mobile cellular communication networks, both from a theoretical background and for practical
implementations. We consider the optimization problems of creating maximal independent sets for mobile network. These independent sets can solve the problem of frequency allocation without conflicts, considering the nodes of maximal independent sets as transmitters.

1.6 OVERVIEW OF THE THESIS

The thesis is organized as a set of chapters which are arranged in their order of occurrence. Chapter 1 focuses on the theoretical background of mobile cellular networks; the mobile communication system is explained with a fundamental property of cellular system structure.

In Chapter 2, various multiple access technologies are explained for the mobile cellular system. This chapter focuses on the principle of the frequency spectrum in mobile cellular networks to reuse the frequency spectrum efficiently. Relationship between the reuse ratio (q) and cluster size or reuse factor (N) for hexagonal cell geometry, as well as co-channel interference for cells have shown with cluster of different size. Different kinds of frequency allocation techniques and algorithms for the solution of frequency assignment are presented.

Chapter 3 describes a method for construction of independent sets in a mobile network with different variations. Different graphs are used with separate criteria of selection of different modules. In this chapter, Random Number Selection Algorithm for the construction of the independent set is discussed and experimental results of the algorithms are also presented.

In Chapter 4 an algorithm is developed for degree based selection in a graph and experimentally implemented. The algorithm, Random Degree Selection Algorithm (RDSA), is discussed with different alternatives and executed on different types of graph.

Chapter 5 describes the algorithm for construction of independent sets with the use of action sets. This algorithm is based on the random selection of action set. All algorithmic approaches are executed in distributed manner. Results and comparison analysis of three algorithms is considered applied on same set of manual graphs.
Chapter 6 Epilogue, this chapter includes concluding remarks and plan for future research.