Chapter 1

Introduction

1.1 Preamble:

The demand for wireless communication has consistently exceeded the capacity of available technologies. A problem unique to wireless network is the extremely hostile and random nature of radio channel and uncertainty in the demand of channels by users. Since the users may request service from any physical location while traveling over a wide range of velocities, the network switches are forced to hand over calls imperceptibly between base stations throughout the system. The radio spectrum available for wireless network is limited, and hence is constrained to operate in a fixed bandwidth to support increasing number of users and high data rate demands. As the wireless network grows, the necessary addition of base station increases the switching burden on the network switches. One of the prime issues in such network design is how to use the channels effectively for communication purpose. Another issue is interference due to massive number of users and other parameters. Unlike wired communications which benefits from isolation provided by cables, wireless users within close proximity can cause considerable interference to one another. Hence to overcome such factors, the concept of cellular wireless
mobile network was introduced where each cell is allocated a portion of the total frequency spectrum. As users move into a given cell, they are then permitted to utilize the channel allocated to that cell. The virtue of the cellular system is that different cells can use the same channel given that the cells are separated by a minimum distance according to the system propagation characteristics. For efficient utilization of the radio spectrum, frequency reuse schemes that are consistent with the objectives of increasing capacity and minimizing interferences are required. Frequency reuse is a technique of reusing frequencies and channels within a communication system to improve capacity and efficiency. By using multiple access techniques, the channels assigned to a cell are shared by mobile stations located in the cell. There are two approaches for channel allocation, viz. centralized approach [1, 2, 3, 4] in which requests for channel allocation are handled by a central controller that has access to system wide channel usage information and distributed approach [5, 6, 7, 8, 9, 10] where the base stations and/or the mobile hosts monitor the signal to noise ratio of relevant channels and exchange this information. The channel use decisions are made by each node based on its information without involving a central controller.

It can be seen that digital radio technology has tremendous impact on today's mobile computing. The three major problems of wireless communication are higher error rates, lower bandwidth and more frequent spurious disconnection. As a result of these factors, communication latency rises because of frequent retransmissions, larger time-out delays and more error-control protocol processing [11]. Based on co-channel separation the channel allocation schemes are classified as fixed, dynamic and hybrid. A channel allocation scheme decides which channel to be assigned when a call request
arrives at the base station. The choice of the channel allocation strategy has to cope up with the time and spatial variations of the traffic demand in cellular networks to minimize call blocking and efficiently use the network resources.

In Fixed Channel Allocation (FCA) scheme, each cell is allocated a predetermined set of channels. Any call attempt within the cell can only be served by the unused channels in that particular cell. The same channels are used in the cells that are located sufficient distance apart satisfying the reuse distance criterion. If a channel is used in one cell then it can not be used simultaneously in the cells that are within the reuse distance. In such schemes as soon as all the assigned channels in a cell are used up, no more traffic in that cell can be served even though there may be idle channels in the neighboring cells. Major drawback of the fixed scheme is that it cannot accommodate spatial and temporal traffic variations efficiently. Several variations of FCA exists, in one approach called the borrowing strategy, a cell is allowed to borrow channels from a neighboring cell if all of its own channels are already occupied. The network switch supervises such borrowing procedures and ensures that borrowing of a channel does not disrupt or interfere with any of the calls in progress in the donor cell. These schemes are proposed adhering to channel assignment rule in the basic fixed scheme. Current cellular mobile networks support FCA where the number of frequency carriers in each cell are fixed and does not vary according to traffic load. The allocation of frequency carrier can be changed upon the rearrangement by service provider as the allocation relies heavily on frequency planning and will not be able to adapt dynamically to the changing condition of the offered traffic.
In Dynamic Channel Allocation (DCA) scheme, traffic channels are not allocated to different cells permanently. Instead, each time a call request is made, the serving base station requests a channel from the network switch. The switch then allocates a channel to the requested cell following the procedure that takes into account likelihood of future blocking within the cell, the frequency use of the candidate channel, the reuse distance of the channel, and other cost functions. Accordingly, the switches only allocate a channel which is not presently in use in the cell or any other cell which falls beyond the minimum restricted distance of frequency reuse to avoid co-channel interference. These schemes increases the trunking capacity of the system by reducing the likelihood of blocking since all the available channels in the coverage region are accessible to all of the cells. DCA require the switch to collect real time data on channel occupancy, traffic distribution, and radio signal strength indications of all channels on a periodic basis. This increases the storage and computational load on a system but provides the advantage of increased channel utilization and decreased probability of a call rejection. The dynamic schemes perform better than the fixed schemes under low to moderate traffic intensity.

The third scheme which is called as Hybrid Channel Allocation (HCA) is a combination of fixed and dynamic schemes where the available channels are divided into fixed and dynamic channel sets. When a call arrives in a cell, it will first try to assign a channel from fixed channel set. If there is no channel available in that set, a channel from the dynamic set will be allocated. The performance of the hybrid scheme depends upon the ratio of fixed to dynamic channels. The HCA schemes have advantages of both FCA and DCA. In uniform traffic situations, a call request will be evenly distributed over the network.
Hence, the channels in fixed channel set will be used. However as the traffic intensity increases, the fixed channel set will become empty. As a result a channel from dynamic set is used even though the traffic is uniform. Therefore having dynamic channel set in uniform traffic environment will be a disadvantage in hybrid schemes. Similarly for the fixed channel set in nonuniform traffic environment is also a disadvantage especially in low traffic. Hence HCA is beneficial in some traffic patterns while becomes a bottleneck in some other traffic patterns.

1.2 Motivation:

The number of mobile users and mobile applications are increasing with the fast pace year on year. Since the spectrum is the limited resource, it is getting scarce. Next generation wireless networks are envisioned to provide multiplay services via high speed, low blocking probability, high QoS and low powered mobile computing devices. End users typically expect seamless connectivity through wireless networks, which in turn are restricted in terms of resources like bandwidth, power and error prone transmission medium. For meeting such stringent needs, development of efficient resource management schemes is the need of an hour. One of the possible ways to fulfill these requirements is to optimize the channel allocation and associated performance parameters. The Channel Allocation Problem (CAP) deals with allocation of channel to an incoming call based on the constraints and with minimal interference. It selects a channel from the available pool based on criterion which will ensure maximum utilization of the radio spectrum. Hence, well suited optimization techniques are to be used to select the best possible channel.
There are various kinds of interferences such as co-channel interference, adjacent channel interference, and co-site interferences which occur in cellular networks, where two cells uses the same channel or two cells uses channel adjacent to each other on the spectrum or when one cell is assigned two channels adjacent to each other on a frequency spectrum [12]. The system performance predominantly reduces with increase of interference as it significantly reduces the signal to noise ratio. The interference has dependencies on the topology of the real environment. It is not feasible to compute the actual level of interference because of its randomness and computational complexities. Therefore, the effect of interferences can be reasonably minimized if a process of optimization is formulated to satisfy certain hard, soft and traffic demand constraint. The electromagnetic compatibility constraints combined with traffic demand is known as hard constraint. The hard constraints are to be met in order to reduce the interference in the wireless mobile network and obtain the best possible capacity operation of the network. The three soft constraints are packing condition, resonance condition and frequency reassignment.

- **Packing Condition:** This attempts use of minimum number of channels every time a call arrives. This condition encourages the selection of channels already in use in other cells as long as the hard constraints are satisfied.

- **Resonance Condition:** It assigns the same channels to cells that belong to the same reuse scheme. The purpose of this approach is to leave as many channels as possible to be allocated to other cells belonging to other reuse schemes. Consequently, the probability of causing co-channel interference in the system is reduced.
• **Frequency Reassignment:** When a call arrives, minimum number of channel reassignment operations should be performed because excessive reallocation in a cell usually leads to increase in blocking probability.

The soft constraints help to achieve the maximum efficiency of the wireless mobile network. The optimal and best possible solution to the channel allocation problem could be designed only if there is consideration of these constraints by using robust optimization technique. For tackling such constraints, natural computing paradigms seem to be a suitable solution. These paradigms consist of simple elements working together to possibly solve the complicated problems of the real world to present an approximate solution. In general, such paradigms can be classified into three categories, viz. Epigenesis, Phylogeny and Ontogeny. The Epigenesis is concerned to a situation where an intricate structure is to be developed for which it is necessary to perform a tentative learning, e.g. Artificial Neural Network (ANN) wherein human brain is simulated as a complex system. The phylogeny group is related to Evolutionary Algorithms (EA), where competitions among agents do exist for the survival of the fittest. Algorithms of this category are Evolutionary Programming (EP), Genetic Programming (GP) and Differential Evolutionary Programming (DEP). The Ontogeny group is associated with the algorithms in which the adaptation of a special organism to its environment is used. The Particle Swarm Optimization (PSO) algorithm belongs to this type and possesses a cooperative nature in comparison with other types [13]. The advantages of such algorithms are their abilities to be utilized for various applications and most specifically the no requirement of the previous knowledge of the problem space.
Among the aforementioned paradigms, the PSO algorithm seems to be an attractive one to study since it has a simple but efficient nature. PSO is faster in finding the solutions close to the optimum and also in premature convergence compared to Genetic Algorithm (GA) [14]. PSO tries to optimize a problem through iterative method to improve a candidate solution. The PSO particles move around the search space according to mathematical formulae over the particle position and velocity. The movement of each particle is influenced by its own local best position and at the same time also guided towards the best known position found by other particles in the search space. This methodology over the iterations is expected to move the swarm towards the best solution. Such globalized channel optimization can further be taken up based on knowledge sharing among the cells of a network for call admission- handoff control using local optimization, and cost- threshold parameter to improve the performance of a cellular network.

1.3 Literature Survey:

Audhya et al. [15] presented a detailed study on the various approaches and challenges that have been taken up by different researchers to solve the problem of channel allocation considering different interference issues and better utilization of available communication channels for cellular mobile networks. The study forms the basis for the foundation of research work undertaken. Chakroborty et al. [16] had undertaken the particle swarm optimization based approach towards the solution of the dynamic channel assignment problem in mobile cellular network. Battiti et al. [17] have described a channel assignment for localized and distributed strategy wherein the fitness functions for evolution of particles has been derived. Lipo Wang
et al. [18] have used genetic algorithm where fitness of population members is evaluated for optimum channel assignment in mobile communication. The results obtained can be improved by using better optimization technique for channel allocation. Boukerche et al. [19] have proposed a Quality of Service (QoS) based dynamic channel allocation protocol for wireless and mobile networks. It states that most of the channel allocation schemes do not take the QoS provisioning into account. The study uses channel reservation for the handoff calls to improve the QoS. This scheme improves QoS at the cost of increase in the blocking probability which results in decreased efficiency due to reduced call admission. Yang et al. [20] proposed an efficient fault-tolerant channel allocation algorithm which achieves high channel utilization. In this algorithm, a cell that tries to borrow a channel does not have to wait until it receives reply message from each of its interfering neighbors. A cell can borrow a channel as long as it receives reply message from each of group of its neighbors and there is at least one common channel available allocated to that group. Thus it is claimed to be a fault tolerant. Moreover a cell can lend a channel to multiple borrowers as long as any two of them are not neighbors. When mobile hosts move from one cell to another cell, to provide uninterrupted service, the new cell should have enough channels to support the ongoing communication of the mobile hosts that moved into the cell. If channels are statically allocated, as is the case in current cellular networks, a cell may run out of channels when large number of mobile hosts moves to a cell, thus degrading the QoS. Under dynamic channel allocation, channels are allocated to cells on demand, thus increasing channel utilization and hence improving the QoS. Chen S.L. et al. [21] have developed a new network-based dynamic channel assignment scheme with flexible use of reuse
partitioning technique. Reuse partitioning is a technique to achieve higher capacity by reducing the overall reuse distance. Generally, when reuse partitioning is exploited in dynamic channel assignment, a portion of channels is assigned permanently to each partitioned region. However such assignment may not be optimum. Debabrata Sarddar et al. [22] proposed a channel allocation scheme which would effectively reduce the handoff call blocking probability. A handoff call queuing priority scheme is employed to reduce forced call termination and thereby enhance the performance of the system. Queuing makes user to wait for a longer time and hence user may drop a call and try again to get a service. Such reattempt to call increases the load on network. Vijoy Pande et al. [23] investigated the use of pricing for efficient handling of the network design and resource allocation issues. Felisa J. V. et al. [24] had undertaken a study for estimation of blocking probabilities in cellular networks with DCA. It states that estimation of blocking probabilities are hard to compute for realistic sized systems due to the structure of the state space, which imposes strong coupling constraints amongst components of the occupancy vector. Approximate tractable models have been proposed, which have product form stationary state distributions. However, for real channel assignment schemes, the product form is a poor approximation and it is necessary to simulate the actual occupancy process for estimating the blocking probabilities. Yaipairoj et al. [25] have proposed a queuing model where users are placed in either normal queue or high price priority queue. Users in high priority queue are served with higher QoS than the users placed in normal queue. This leads to unfairness and moreover queuing model may lower the QoS of the system. J. Hou et al. [26] have studied integration of call pricing with call admission control to meet QoS requirements in cellular network.
The input call arrival rate is plotted as a function of time and the pricing based network performance is studied. Chengzhi Zhao et al. [27] have presented dynamic channel assignment for large scale cellular networks using chaotic neural network wherein the large cellular network is decomposed into many subnets. Energy function is used to avoid interferences and assign required number of channels to the cell so as to improve the spectrum utilization. The blocking probability for uniform and hotspot traffic pattern is obtained for FCA and DCA. Omneya Issa et al. [28] have developed low complexity call management scheme for cellular network. The study states that the basis of QoS provisioning is the admission control of new and handoff calls. A service admission and adaption mechanism is proposed to improve the call management system.

1.4 Research Undertaken:

From the literature survey, it was learnt that many researchers have used evolutionary approach, where population members are selected on the basis of fitness. Less fit members are rejected and population evolves constantly letting members compete against each other, replacing weak members and promoting the fittest one. Mostly the FCA with minimum interference is studied whereas feasibility to DCA needs to be explored further. Most of the work is done by considering hard constraints only, neglecting soft constraints. Moreover the study is undertaken on randomly selected cell models. Such implemented techniques may have limitations with respect to real life situation. Call admission and handoff schemes plays an important role in cellular network to achieve desired QoS. The schemes are challenging because of limited, highly variable resources and mobility of users associated in such network. A tradeoff between QoS and utilization of resources is
also to be studied further. Reuse partitioning is employed in some cases to increase capacity of the network. Few of the channels are permanently allocated to each partitioned region. However the number of channels allocated may not be optimum due to uneven and time varying traffic. To reduce call dropping probability, various techniques are used at the cost of blocking probability. Optimization techniques are to be tried to obtain balance between these probabilities. The researchers attempted to increase the available capacity through cell splitting, cell sectoring and frequency reuse. The numbers of cells in large cities have already reached its maximum and reducing the size further would add more overheads than the benefits. Wireless service providers opt for fixed price owing to simplicity in billing and accounting process. Such calculations are based on static observations of the network and are not dynamically adaptive. This results in congestion during peak hours and underutilization of network during non-peak hours.

From the study, it is clear that there is lot of scope to undertake a research on channel allocation schemes, optimization techniques associated, efficient call admission hand off (CAHO) control methods and pricing based network performance improvements. With this motivation, we have undertaken a research on 'Studies and Investigations on Channel Allocation Schemes for Wireless Mobile Networks'. In this work, we have studied and investigated the state-of-the-art channel allocation schemes for wireless mobile networks and have proposed particle swarm optimization (PSO) based modified distributed dynamic channel allocation algorithm (MDDCA) for efficient channel allocation. A novel CAHO technique based on mutual exclusive paradigm for sharing of conflict free channels among the cells of the
cluster is developed. Dynamic pricing model is proposed for the performance improvement in the cellular networks.

The simulations are carried out on well known benchmark problems (HEX 1, HEX 3, KUNZ 1 and KUNZ 2). Multiple candidate solutions are provided for allocation as global optimization. To improve channel allocation further, the CAHO has been studied on HEX 1 and KUNZ 1. The channels are grouped in three sets based on three cluster model. This scheme is for local optimization to allocate channel based on information of surrounding cells so as to avoid further blocking. This helps cluster cells to know the information on channel usage and sharing among the system. Such optimization technique can help better channel utilization based on global knowledge first followed by local knowledge. To improve channel allocation, a MDDCA algorithm with adaptive reservation scheme has been proposed. It deals with both originating calls and handoff calls. The result shows an optimum balance between blocking and dropping probabilities for various traffic patterns, resulting in better QoS as well as call admission, thereby improving the performance of the network. The acquisition time for the developed algorithm is reduced as compared with existing algorithms. Further to minimize the congestion in the network and make channel allocation easier, one can stagger the traffic from peak periods to non-peak periods. A mechanism of dynamic pricing technique is proposed which helps in reducing traffic congestion during peak period and improves channel utilization. The results obtained are compared with the static pricing which indicates the significant improvement in channel allocation performance.

The research undertaken will play a vital role for real time analysis and implementation of the novel channel allocation schemes. Through this research work, optimum solution for channel allocation is obtained at a
faster rate as compared to other algorithm with lower values of call rejection ratio. This improves the efficiency of system for call admission and ultimately enhances the capacity of the system. It is found that the PSO converges very fast for CAP and hence saves the time and maximizes the efficiency of the system. As compared to research published, the time of convergence is reduced significantly. By using PSO based MDDCA with adaptive reservation and CAHO, the blocking and dropping probabilities are substantially reduced as compared with the values obtained by other algorithms. In our model, utilization of the dynamic pricing has significantly reduced the blocking probability and the congestion in the network. The developed multi-level optimization for channel allocation improves network utilization and fairness while addressing the issue of congestion control.

1.5 Thesis Organization:

The thesis work is split in eight chapters as indicated under:

**Chapter-1: Introduction**
This chapter includes introduction, objectives of the research work, problem definition, methodology used and research contributions.

**Chapter-2: Channel Allocation Schemes in Wireless Mobile Networks**
This chapter describes in detail the various channel allocation schemes like FCA, DCA and HCA along with the handoff schemes used in the wireless mobile network. It covers the channel allocation strategies, the significance, scope and limitations of various allocation schemes.
Chapter-3: Optimization for Channel Allocation in Wireless Mobile Networks
This chapter describes the hard and soft constraints associated with channel allocation problem and the need of optimization to achieve the desired goal. Various optimization techniques e.g. tabu search, simulated annealing, random walk, neighborhood search, particle swarm optimization and genetic algorithm are reviewed and discussed.

Chapter-4: PSO for Wireless Communication
This chapter describes about the need of nature inspired algorithm for optimization space. It explains the basic model and literature review of PSO for its use in wireless channel allocation. A comparative study between PSO and Genetic Algorithm (GA) for DCA based CAP optimization is also covered. An extensive survey finding has been studied and included for the Channel Allocation Problem using PSO.

Chapter-5: PSO based Channel Allocation in Wireless Mobile Networks
This chapter presents the optimization based on PSO and the results are obtained with respect to channel allocation, convergence, iterations and blocking probability for the benchmark problems in a dynamic channel allocation. The channels are further divided into three groups for sharing amongst the base station based on mutually exclusive paradigm for call admission and handoff control mechanism.

Chapter-6: Call Admission and Handoff Control in Wireless Mobile Networks
This chapter presents the call admission and handoff control in the cellular network for distributed dynamic channel allocation (DDCA). The channel reservation parameter is modified based on the volume of the traffic for type of call and threshold values set in for originating and handoff calls. This modified scheme is applied on the two
benchmark problems. The performances have been analyzed based on call blocking, call dropping, and acquisition time. The simulation results of MDDCA are compared with DDCA.

Chapter-7: Pricing based Dynamic Channel Allocation
This chapter describes the pricing based performance in the cellular network. It includes the study and analysis for the impact of dynamic pricing on traffic and congestion in cellular networks, the overall system functionalities along with significant changes in the call arrival, blocking probability, time of call variation and few other performance parameters.

Chapter-8: Conclusion
This chapter summarizes the research undertaken and the scope of future work for the channel allocation problem.