Network Design is very common problem which contributes key role in many real life applications which arose directly from everyday practice in engineering and management: determining shortest or most reliable paths in traffic or communication networks, maximal or compatible flows, or shortest tours; planning connections in traffic networks; coordinating projects; and solving supply and demand problems, electricity distribution, designing of digital circuit, designing of gas pipeline, layout planning roads and railway track, transportation and many more.

Because of vast real life application, network design has become the crucial problem in such real life applications. With the advancement of information technology our society is rapidly converting as an information society. The conversion of a society to information society means that extension of network. Each and every sector of our daily need is in the process of computerized network. Day by day it has to be extended. For developing country like India, where development is growing multidimensional, network is the primary issue. Each and every field of our daily need which is manual, has to be computerized and to materialize it, network is the key factor. If we are talking about the overload of population like the country India and China where the geographical extension is at the peak, again we need network to connect or extend these locations first physically for transportation, communication and management and then electronically in the form of computerized network,
network is required. By this discussion, the role of network is concluded in all our daily life applications and in the overall growth of the society. This is the main motivation behind this study Network Design. One fundamental problem in this area is the minimum spanning tree (MST) problem where all nodes in a graph have to be linked together in a circle-free structure in the cheapest possible way. However, there are also other problems that can be expressed as network design problems, such as various transportation and routing problems. For example shortest path problem, the famous traveling sales-man problem (TSP), one has to find a round trip (Hamiltonian cycle) through a set of cities (nodes) of minimal length[40,41]. A practical correspondent appears in the automated manufacturing of printed circuits when one wants to minimize the time required for drilling all holes by optimizing the path for moving the drill. Already this short list of problems should give a rough idea of the economical impact and therefore interest of solving such network design problems properly in general. Furthermore, network design is also important for complexity theory, an area in the common intersection of mathematics and theoretical computer science which deals with the analysis of algorithms. The term network design is involved in many contexts and there are several different aspects which deserve attention. In this study, they are regarded from a more theoretical point of view as graph theory problems, i.e. networks are modeled as graphs and optimization algorithms are applied on them. There are mainly four broad categories of network design- network topology design, network routing and flow control, network performance and network reliability. Since these all are separate category but all these categories are highly related.

In this research study, network design belongs to the category of network topology design. Further designing the topology of a large scale network can be divided into
Network Design Using Genetic Algorithm

two problems, the backbone network design and the local network design. This research work is mainly focused on large scale backbone network design which is in the form of degree constraint minimum spanning tree with other constraints required by the network. The main objective behind the network design is to find the best way to connect the locations (nodes and arcs) to minimize the cost while meeting performance criterion such as transmission delay, throughput, fault tolerance and reliability. Exploring all the constraints for such a design problem, it becomes an NP-hard problem [1]. There are many methods such as Prim [3] or Kruskal [4] which solve minimum spanning tree problem in polynomial time but adding additional constraints often make the corresponding optimization problem a hard one and one of the hardest in NP category problems. There are other methods also like Breadth First Search, Depth First Search and Branch and Bound but these entire have also their limitations. These methods can only solve small networks because the number of arcs increases, the number of possible layouts grows faster than exponentially. There are other limitations also with these methods such as degree constraint for each node, fault tolerance and reliability in the case of failure of node and other constraints as per demand of the network.

Because of these complexities, these existing methods are not computationally feasible for deserving large scale network. As a result, standard, traditional, optimization techniques are often not able to solve these problems of increased complexity with justifiable effort in an acceptable time period. Therefore, to overcome these problems, and to develop systems that solve these complex problems, researchers proposed using genetic and evolutionary algorithms. Using these nature-inspired search methods it is possible to overcome some limitations of traditional optimization methods, and to increase the number of solvable problems. Given such a
hard network optimization problem [2], it is often possible to find an efficient algorithm whose solution is approximately optimal. Among such techniques, the genetic algorithm (GA) is one of the most powerful and broadly applicable stochastic search and optimization techniques based on principles from evolution theory. Genetic Algorithm (GA) is a probabilistic search heuristic that replicates the defining features of biological evolution: reproduction with variation, selection based on fitness, and repetition. GA maintains a population of data structures, called chromosomes that encode candidate solutions to its target problem. Attached to each chromosome is its fitness, a numerical value that indicates the quality of the solution the chromosome represents. The algorithm selects chromosomes to survive or reproduce so that those with better fitness are more likely to be selected. Crossover, also called recombination, combines genetic information from two parent chromosomes. Mutation randomly modifies one parent chromosome. When the EA has generated enough offspring, they replace their parents and the process continues. As these generations succeed each other, chromosomes that represent better solutions evolve. Therefore a heuristic search method based on genetic algorithm is developed to design such network, which has minimum cost and satisfy the required constraint demanded by the system.

This thesis is located in the area of combinatorial optimization, focusing on NP hard network design problems that occur in real world where multiple local area networks are interconnected by a backbone network. Depending on the demands of such a network, the underlying problem can either be formulated as the Generalized Minimum Spanning Tree problem or the even harder Degree Constrained Minimum Spanning Tree Problem. Given a connected, undirected graph G with n nodes, a spanning tree T is a subgraph of a G that connects all of G’s nodes and contains no
cycles. When every edge \((i, j)\) is associated with a numerical costs \(c_{ij}\), a minimum spanning tree (MST) is a spanning tree of the smallest possible total edge cost

\[
C = \sum_{(i,j) \in T} c_{ij}
\]

(1)

Figure 1. A Minimum Spanning Tree of Five Networks

1.1 Overview of Thesis

The further organization of this thesis is as follows: There are seven remaining chapters:

Chapter 2. Network Design

This chapter explains that what is network design, what are the different types of network with its mathematical formulation and what are the application where network design is the backbone of the system. It also describes that what are the different types of problem related with network design with its limitation.
Chapter 3. Methodologies
In this chapter various techniques to solve network design optimization problems are presented with their limitation and literature survey with relevance of the research work has been highlighted. This chapter is the motivation of this research work.

Chapter 4. Genetic Algorithm
This chapter explains the basic of genetic algorithm.

Chapter 5. Genetic Algorithm approach to Network Design
This chapter is the backbone of this research where redefined Genetic Algorithm approach is explained to design network. This chapter contains all the methods and algorithms developed for this study. This chapter starts with the explanation of genetic algorithm and it describes that how genetic algorithm can helps to solve this network design problem. It explains the improved genetic algorithm approach with the developed fitness function and various types of genetic operators developed in this thesis. All the functions developed in this chapter are published. Following papers are published for this chapter...

1. Anand Kumar, Dr. N.N. Jani , “An algorithm to detect cycle in an undirected graph” International Journal of Computational Intelligence Research ISSN 0973-1873, (Vol 6, No 2 (2010), pp 305-310)


Chapter 6. Experimental Design and Result

This chapter explains how this experiment is carried out. The tools and data sets with the result have been presented here. This chapter is the proof of this research work. Various tables, graphs, diagrams and developed programs have been included in this chapter. Following papers are published for the experimental result.


Chapter 7. Genetic Algorithm approach to Solve Shortest Path and Traveling Salesman Problem

This chapter explains a new approach based on genetic algorithm to solve these NP-hard network design problems. To solve these problems various functions and operators are developed. These works are published also.


Chapter 8. Conclusions and Future Scope

This chapter is devoted for the discussion with conclusion and the extension of this research work.