Chapter 1

Introduction

1.1 Introduction to the Shortest Path Problem in OSPF and MPLS

The shortest path problem is concerned with finding the shortest path from a specified starting node (origin) to a specified ending node (destination) in a given network while minimizing the total cost associated with the path. The shortest path problem is a classical combinatorial optimization problem having widespread applications in a variety of settings involving routing, communications and transportation. Routing is the determination of a path that a data unit will traverse from source to destination.

In data communication and networking, networks are represented in a natural way by graphs. A network can be viewed in an obvious way as a digraph, with each packet-switching node corresponding to a vertex, and each communication link between nodes corresponding to a pair of parallel edges, each carrying data in one direction. In such a network, a routing decision is needed to transmit a packet from a source node through various links and packet switches to a destination node. This is equivalent to finding a path through the graph.

Internet is a collection of networks that are connected together via internetworking devices, i.e. routers. For an Internet, a diagraph representation is also appropriate. In this case, each router corresponds to a vertex. In an Internet, a routing decision is needed to transmit an IP datagram from a source router through various networks and routers to a destination router. Again, this is equivalent to finding a path through the graph.

One of the most complex and critical aspects of Internet design is routing. Route discovery and selection are fundamental to the operation of packet-switched networks. As a packet transits a network, routers must coordinate a path of circuits through which the packet will travel. Each router along the path should have a consistent view of how the packet is to proceed, and the selected route should be efficient.

A routing protocol is the language and grammar that routers use to exchange information needed for routing decisions. The protocol determines (1) what information needs to be shared, (2) how this information is used to determine packet routes, and (3) how this information is delivered.

Information shared by a routing protocol might include cost, bandwidth, and utilization. The routing protocol defines how these values will be obtained from the network. Often, the values for a link are manually combined to form a single composite called a "metric" or "weight". Most routing algorithms are based on variants of shortest-path algorithms, which try to determine the shortest path for a packet according to some form of least-cost criterions. Many metrics or weights can be used to assign a cost to each link, depending on which function is to be optimized.

In today's rapidly evolving networking environment, increasingly more mission-critical traffic is transported over networks and Internet. Traffic engineering targets the ability to efficiently map network traffic onto an existing network topology as to optimize the utilization of network resources. Traffic engineering is essential for Internet Service Provider (ISP).

Basically, routing can be divided into two types, i.e. hop-by-hop routing and explicit-routing. Traditional hop-by-hop routing is a distributed routing of control traffic, which builds a set of shortest path trees using shortest path algorithm. Existing routing protocols are destination prefix based, which are difficult to perform traffic engineering. Explicit-routing is a source routing of control traffic, which builds a path from source to destination. Explicit-routing requires manual provisioning or automated creation mechanisms. Operator has routing flexibility, which adapts well to traffic engineering.

Open Shortest Path First (OSPF) is the interior gateway routing protocol which uses link-state routing protocol and uses Dijkstra algorithm to find the shortest path for hop-by-hop routing in an Internet. The metrics or weights of the links, and thereby the shortest path routes, can be changed by the network operator. The quality of OSPF routing depends highly on the choice of weights.

The Multi-protocol Label Switching (MPLS) technologies [1, 2] proposed by the Internet Engineering Task Force (IETF) is to be the networking technology to deliver traffic engineering capability. MPLS supports traditional hop-by-hop routing and provides explicit-routing capability. The most significant initial application of MPLS is in traffic engineering, which gives network operators a great deal of flexibility to divert and route traffic around link failures and congestion. MPLS traffic engineering employs constraint-based routing (CBR) algorithm, in which the path for a traffic flow is the shortest path that meets the resource requirements (constraints) of the traffic flow.

1.2 Motivation of the Project

One potential technique from Artificial Intelligent (AI) community that will play a role in the evolution of the Internet routing is genetic algorithms, which borrows concepts from biology to solve complex and constraint-based problems encountered in the area of computer science. Genetic algorithms are a heuristic search method whose mechanisms are based upon simplifications of evolutionary processes based on survival of the fittest observed in nature. Most genetic algorithms operate on a population of solutions rather that a single solution.

Typically, genetic algorithms have been utilized in solving complex optimization problems. Genetic algorithms confer the following advantages:

- They evaluate several solutions simultaneously, covering a large search space.
- They work well in parallel implementation.
- They optimize parameters with very complex cost functions.
- They create a list of optimal solutions, not just a single solution.

In the context of the general optimization problem for routing, a method is needed to compare routes based on their weights to select the shortest path. Genetic methods are well suited to address the route discovery and selection problem. In shortest path problem, evaluation of the relative merits of a genetic algorithm solution will focus on the optimal solution which minimizing the space, i.e. the total weight.

The potential of genetic algorithms for solving the shortest path problem in minimizing the weight has been studied and the results are very encouraging: it can find the known optimum very rapidly with very high probability [3, 4]. These studies provide a base for constructing effective solution for more specific shortest-path based network optimization problems.

1.3 Objectives of the Project

This project proposes a heuristic search method based on genetic algorithm as a solution to the shortest path problem in routing in order to optimize the total weight. There are several primary objectives to this project. The first objective is the acquisition of knowledge – the gaining of an understanding into the use of genetic algorithm in solving the shortest path problem.

The second objective is to investigate and understand the shortest path problem in two network routing protocols, which consist of Open Shortest Path First (OSPF) and Multiprotocol Label Switching (MPLS). Here, two shortest path problem domains have been specified:

(a) OSPF hop-by-hop routing

(b) MPLS explicit-routing

The third objective is to develop a genetic algorithm solution to the above problem domains. Here, the most critical task is to develop a representation to encode a path in a network.

The fourth objective is to demonstrate the potential of using genetic algorithm to solve the shortest path problem in the above problem domains.

1.4 Goal of the Project

The goal of this project is to demonstrate the potential of using genetic algorithm to solve the shortest path problem in optimizing the weight in OSPF and MPLS. The purpose is to provide a potential alternative.

The genetic algorithm solution will achieve the following results:

(a) In OSPF hop-by–hop routing, genetic algorithm is able to find the optimum solution, which is the shortest path with the minimum weight.

(b) In MPLS explicit-routing, genetic algorithm is able to find the optimum solution, which is the shortest path that meets the resource requirements (constraints) of the traffic flow.

1.5 Significance of the Project

This project demonstrates the potential of using genetic algorithm to solve the shortest path problem in optimizing the weight in OSPF and MPLS. This solution can provide a potential alternative for such problem.

The result of this project can be viewed as an individual mutation in the population comprised of routing protocols. In the long term, as with natural evolution, the strengths of this mutation may be combined with the strengths of current practices to yield a superior hybrid protocol. The eventual result of this work, when combined with other ongoing research, will be improved reliability and performance on tomorrow's networks.

1.6 Report Organization

This report is organized in the following manner:

Chapter 2 – Literature Review: This chapter provides an overview on the background and theory of the shortest path problem in OSPF and MPLS, and genetic algorithm. Starting with the definition of the shortest path problem, this chapter then moves to the basics of OSPF and MPLS. It continues with a study of the theory of the genetic algorithm. It then discusses the related research done in using the genetic algorithm to solve the shortest path problem.

Chapter 3 – Solution Method: Genetic Algorithm Representation: This chapter presents the solution method of the genetic algorithm representation model that is proposed.

Chapter 4 – Test Problems and Results: This chapter presents an experiment to find the optimal parameter setting for the proposed genetic algorithm solution. It also covers the testing details for the genetic algorithm solution using a simulator, and the result analysis of the test problems. It then concludes the results with discussion and future research.

Chapter 5 – Conclusion: This chapter concludes the work on exploring the potential use of genetic algorithm to solve the shortest path problem in OSPF and MPLS.