EFFICIENT SHORTEST PATH ROUTING IN COMPUTER COMMUNICATION NETWORKS USING NEURAL NETWORK AND HEURISTIC ALGORITHM

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A thesis submitted to the graduate faculty of Electrical Engineering and Computer Science in partial fulfillment of the requirements for the degree of MS in Electrical Engineering.

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2011

ABSTRACT

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Computer Networks are a breakthrough in current communication technologies providing an always-on and ubiquitous connectivity to virtually millions of users with the score still mounting up. This increased usage strongly requires enhancement in network infrastructure and improvements in management to facilitate users with better quality services. As the rate of users, who are transmitting data through a network link, increases the quality of service has to be compromised if not improved. Routing, which is a major aspect of this domain, has significant impact on the effectiveness of Communication Systems. Enhanced technologies should be introduced to let the system assist problems in a better way, preventing data loss and degradation in quality.

Efficient routing algorithm should strive for the most appropriate and shortest path to route data through a network. Prior information of routers and data links, which helps to create paths, is required in almost every technique. A search algorithm, exploiting the properties of mathematical routing algorithm as well as of heuristics, can compute shortest path between given pair of routers more efficiently.

On the other hand artificial intelligence can be very helpful in this domain. Artificial Neural networks, a domain of artificial intelligence, have found their way in engineering as well as Medical Sciences. The particular adaptive ability of neural networks for dynamic situations becomes a strongest feature which renders it best suitable for dynamic systems. John Hopfield used this feature and found their

application in NP-complete optimization problems. Therefore, neural networks similar to Hopfield's can also help to enhance shortest path computational techniques in routing.

A* search algorithm and neural network are used to find shortest routes for unicast routing problems. Computer simulations are used to analyze and compare the results for different network sizes. A* search algorithm outperforms the neural network so far; however, limitations of neural networks are discussed.

I dedicate this thesis to my parents, friends, and those visionary teachers who taught me to be inventive, vigilant, to courageously lead and nobly serve the humanity at large.

ACKNOWLEDGMENTS

I wish to express my deep gratitude to my project supervisor Professor Dr. Abdul Aziz Bhatti for his continuous heart and soul support to complete the project. He is always a source of inspiration and motivation for me. His encouragement and support never faltered.

I am especially thankful to the Faculty and Staff of School of Science and Technology at the University of Management and Technology (UMT) Lahore, who have supported us immensely during this research. I am also thankful to Sir Mubasher Baig and Miss Najma Saleem for helping me in understanding the field requirements.

I am also very thankful to my entire fellow colleagues and friends who have helped me mentally as well as academically, in every hour of need.

Finally, I am passionately grateful to my parents for their everlasting moral support and encouragements.

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Introduction

1.1 Motivation and Objectives

Computer networks are the backbone of communication systems. Over the last decade, the scope of this domain has enhanced extensively, networks are getting complex and needs more attention to provide satisfactory services to the users. The expansion of computer networks is due to the growing rate of users from researchers to home users. Technologies should be improved in a way so as to ensure the availability of efficient services, avoiding short-term or long-term service problems.

Delivering data efficiently from source to destination becomes trickier with the expansion of network. Although transmission seems unproblematic if every node had a direct connection to every other node of the network, yet, it would be an impractical way. The practical way is to tackle this problem efficiently and make it less costly. In order to do so routers, internetworking devices of data networks, should operate in a way so as to make the data route through optimum path. It actually operates like a small computer and executes a special software program, routing algorithm, to determine the route.

Routing algorithms are the network layer protocols and are used to guides the data packets to route towards assigned destination through the communication links. In doing so routing requires coordination among all nodes, must be able to handle link failure, and should redirects towards new path in case of congestion. Here, the emphasis will be on the selection of routes to achieve high performance. For efficient shortest path routing computations, different algorithms were proposed and are still under research for more enhancements.

Routing techniques are categorized as centralized, distributed, and localized. As name specifies, centralized algorithms have a central node to choose for the routes, distributed algorithms distributes the information among routers to take decision and in localized algorithms each router finds its own route towards each other destination router and stores this path [28]. Dijikstra

algorithm, a localized one, and Bellman Ford algorithm, distributed one, are the main algorithms which are used by major router companies like CISCO.

Irrespective of algorithm selected, routing can be static or adaptive. For static routing link costs, delays, traffic load, link capacity etc should remain static throughout the communication. However for adaptive routing such factors may change e.g.; change in traffic load, breakage of link etc. This can result in changing of existing path to be non-extent and vice versa.

Bellman-Ford algorithm is a type of distance vector algorithm and a number or cost is assigned to the connections between nodes. Initially each node has the knowledge of its immediate neighbors only. It then exchanges information with neighbors and update its routing table and replace higher cost values with lower cost values otherwise leave them unchanged. As this information keeps on exchanging, in the end, all nodes will have routing table with minimum cost towards each destination node. The same process repeats when any link drop off.

In link-state algorithms whole network is considered as graph with links connecting nodes and this graph is used as fundamental data for each node. Information is flooded among nodes to let each one of them update their own maps and to calculate the least-cost existing path. Then it helps to construct the routing tables and it will be easy to traverse for any destination node from any source node. Dijikstra's algorithm is a part of this type of search.

Heuristic routing algorithms choose routes in heuristic manner. As heuristic refers to applying some hit and trial rules intelligently so it can encapsulate the properties of mathematical algorithms as well as some of human intelligence. It keeps on checking different routers to choose the best one with less link cost but also keeps in check whether it will lead to destination or not. It provides the optimal but may not the best solution and is capable enough to find out an alternative path if a link breaks. A* algorithm is one such algorithm which comprises the properties of Dijikstra algorithm and heuristics. It considers whole network of routers as graph with routers as nodes and connections between them as links or arcs. It is considered to be more efficient than other algorithms because of holding double properties and to be able to find route for unicast problems.

In spite of all these properties none of the algorithm is efficient enough than human brain. A digital computer can compute results efficiently and speedily but never compete with human

brain in robustness. The processing element of brain is neuron [28] and its switching speed is about million times slower than computer gates. As neurons process information in parallel manner so they can provide better results.

The use of artificial neural network is flourishing in different fields of engineering as well as of medical sciences. The basic reason behind this expansion is their properties like massive parallelism, distributed representation and computation, learning ability, adaptively, inherent information processing, fault tolerance and low energy consumption, collective analog mode- with each neuron summing up the inputs of hundreds or thou-sands of others to provide graded output [15, 18]. Anil K. Jain and Jianchang Mao compared in detail the performance of neural network and von Neumann computer in [15] and concluded that neural networks are more reliable than any other system.

John Hopfield proposed electrical components based symmetric feedback neural network in 1982 [13] and performed complete analysis to show its convergence properties. Since then Hopfield's neural network (HNN) is in use to find a way to solve NP-complete problems. Travelling salesman problem (TSP) is one among them. Hopfield and Tank successfully mapped TSP over it and show results for 10 cities. Neural networks have provided solution to many optimization problems since then. Travelling Sales Man problem, analog to digital conversion, optimum traffic flow control in routing, multihop radio routing without interference etc are among few examples.

Rauch and Winarske [22] introduced the use of neural network to find shortest path in routing and their work was based on Hopfield's neural network. Since then researchers are trying to improve this technique to avoid unstable results, which appears because of improper mapping of this routing problem over neural networks. We will discuss the complete mapping process in later sections.

1.1.1 Scope and Limitations

The extraordinary contribution of neural networks towards multi-directional fields like medical sciences, digital signal processing, communication systems, business, marketing, function approximation, time series prediction, modeling etc supports its usability in optimization problems too.

Neural networks, along with many attractive features, offer some limitations. The first of these includes the improper mapping criteria of given problem over this network. The given problem should be analyzed completely, objective function should be extracted, constrains-to achieve the required goal, should be highlighted and a link should be established between the outputs of given problem and neural networks. Summarizing it, a way has to be found to encode given optimization problem into the energy function of the neural network and then to decode the results back in required form.

The second limitation they offer is the dependence of output on the parameter values. The reason behind this constraint is the relative selection of these parameter values for cost function, and the system has to pay penalty in terms of unstable tours. These values should vary with the network size.

Different step sizes, used to update the neural network to next state, may let the system to either get trapped in one of the local minima or to jump over through global minima, which will then never be able to appear in final result. The selection of appropriate step size can also limit the results.

On the other hand, heuristic algorithm offers the limitation of network size. The greater the size of network the more time it will take to compute the shortest path towards destination. Its second limitation is the programming complexity as compared to other techniques.

Both techniques work in repetitive manner but step size of NN is very small, however, heuristic algorithms use integer value as step size. This is also one of the basic reasons of a bit slower performance of NN.

1.2 Problem Statement

Upgrading of computer networks requires improvement in routing techniques. As discussed earlier, for efficient shortest path routing computations multiple algorithms were proposed and the field is still in progress. Routing is not as simple as it seems, it is collective influence of complex collection of different algorithms-working independently but supporting each other by exchanging information. It requires, coordination among all nodes, to handle node failure, to be robust enough for being able to route packets through alternative path in case of traffic

congestion, to search for optimum or shortest available path from source to destination, and regular updating of databases for maintaining the system. In this thesis, main emphasis will be to search shortest path for unicast routing to enhance the efficiency of the computer communication networks.

For wide area data networks, dominating cost of communication link is considered to be the transmission cost of packets over that link, although initially, it was defined on whether user is availing the facility or leases it. Here Delay factor, link capacity, average flow and routing computational cost, all contribute towards the link cost between routers. So now, it is desirable, as well as a requirement for computer data networks, to use communication links efficiently. Competent routing algorithm seeks for shortest path with minimum cost. As routing techniques involve the use of graph theoretical problems-with each router depicting a node in graph and communication links as the arcs between these nodes, the cost is expressed as the lengths of connecting arcs. The longer arcs, thus represents greater cost and length is always considered to be a positive number, in our case.

So far, algorithms based on heuristic approach and neural networks are implemented separately for NP-complete optimization problems, including shortest path routing computation. Osman and Laporte [19] reported that although neural networks are supposed to act as a very powerful tool for solving prediction problem, yet they “have not been as successful when applied to optimization problems and not competitive with the best meta-heuristics from the operations research literature, when applied to combinatorial optimization problems.” For over a decade, researchers have been trying to make both techniques competitive and have experienced varying degrees of success [26]. Although many researchers have degraded the functionality of neural networks, this field has still enough potential for more enhancements. So in this thesis, a comparison between neural networks and A* search algorithm is carried out to check the performance of both techniques.

1.3 Proposed Solution

The given routing problem is initially mapped on a graph, where each node represents a router and the lines depicts the communication links between routers. For both methodologies, the problem is tackled as finding shortest path from starting source node to given destination node. As cost is depicted in terms of link length, so, shortest path will give the optimal route. No self-connection exists and zero cost is assigned to such links.

After mapping onto graph, a complete program is designed for both techniques to compute the desired results in iterative manner. Programming complexity as well as computation time is taken into consideration for comparison.

The programming complexity of both routing techniques differs to the highest degree. Heuristics offer greater programming complexity but with more accurate results. However, neural network predicts opposite results so far.

1.4 Contribution to Field

This research will assist to explore the use of neural networks and heuristic routing technique for solving NP-complete optimization problems, shortest path computation for routing in computer data networks is one such problem. None of the researchers have denied the efficiency of heuristics but show doubt about neural networks. Although heuristic algorithms have scored high in this field, yet it should be compared completely with NN and problems should be sought out.

Wilson and Pawley [29] pointed out in their research that neural network proposed by Hopfield and Tank do not give satisfactorily results. However, Behrooz Shirazi and Sue Yih [25] figured out the actual problems regarding its implementation. The energy function, which is needed to be optimized, has to get converted completely in terms of HNN. Improper mapping will definitely lead to unsatisfactorily results. The constraints should be designed properly and precisely as they will lead to stable results and let the system converge towards one of the minima, in given space of energy. However, Mehmet[3] and Park, keum[21] observed satisfactorily results. The energy functions proposed by these researchers are used for neural network implementation of SP problem.

The importance of routing in computer network communications and basic methodologies used in WANs is discussed. This field has been chosen to demonstrate the applicability of neural

networks and heuristics for combinatorial optimization problems. In order to refine the proposed research topic the literature survey of computer networks, A* search algorithm and neural network technology is carried out. The problem is designed completely implemented through computer programming to compare the simulation results of both techniques.