Advances in Environmental Biology, 6(3): 1253-1257, 2012
ISSN 1995-0756

This is a refereed journal and all articles are professionally screened and reviewed **ORIGINAL ARTICLE**

Computer Network Routing with a Fuzzy Neural Network

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ABSTRACT

The growing usage of computer networks is requiring improvements in network technologies and management techniques so users will receive high quality service. As more individuals transmit data through a computer network, the quality of service received by the users begins to degrade. A major aspect of computer networks that is vital to quality of service is data routing. A more effective method for routing data through a computer network can assist with the new problems being encountered with today's growing networks. Effective routing algorithms use various techniques to determine the most appropriate route for transmitting data. Determining the best route through a wide area network (WAN), requires the routing algorithm to obtain information concerning all of the nodes, links, and devices present on the network. The most relevant routing information involves various measures that are often obtained in an imprecise or inaccurate manner, thus suggesting that fuzzy reasoning is a natural method to employ in an improved routing scheme. The neural network is deemed as a suitable accompaniment because it maintains the ability to learn in dynamic situations. Once the neural network is initially designed, any alterations in the computer routing environment can easily be learned by this adaptive artificial intelligence method. The capability to learn and adapt is essential in today's rapidly growing and changing computer networks. These techniques, fuzzy reasoning and neural networks, when combined together provide a very effective routing algorithm for computer networks. Computer simulation is employed to prove the new fuzzy routing algorithm outperforms the Shortest Path First (SPF) algorithm in most computer network situations. The benefits increase as the computer network migrates from a stable network to a more variable one. The advantages of applying this fuzzy routing algorithm are apparent when considering the dynamic nature of modern computer networks.

Key words: Network Routing, Fuzzy Reasoning, Neural Networks, Wide Area Networks

Introduction

Computer networks are rapidly becoming a necessity in today's business organizations, leading to an increase in the number of computer networks and network users. As networks become more abundant, it becomes increasingly necessary to focus on the quality of service that is being provided to the users of the network. The responsibility of this issue lies with the network management.

Network management involves the monitoring, analysis, control, and planning of activities and resources of a computer network in order to provide the users with a certain quality of service. The idea is to ensure that the system is operating effectively and efficiently at all times, so there are no short-term or long-term service problems.

The proliferation of computer networks increases the need for improved network management techniques. As computer networks expand, they become more complex as they attempt to support a more diverse selection of applications and users. The problems associated with supporting more users are exposed when the network seeks to provide each user with an expected quality of service. Problems concerning congestion, unacceptable throughput, bottlenecks, security, equipment failure and poor response times are immediate results of growing networks that can represent an unacceptable quality of service. It has become a necessary and challenging task to provide efficient utilization by ensuring that the network remains accessible and uncrowded.

The International Organization for Standardization (ISO) has defined five areas as the key areas of network management: fault management, accounting management, configuration management, security management and performance management. Fault management is the collection of services that enables the detection, isolation and correction of abnormal operations transpiring in the managed network. The absence of fault management causes the network to become vulnerable to additional operational irregularities. A variety of

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tools is currently available to assist the network manager in fault management tasks, the majority of which automate the discovering of a fault by determining communication or lack of communication with the network devices. The remaining tasks of fault management are usually performed by the network manager. Accounting management tracks network resource utilization for each individual and each group in order for the network manager to provide the appropriate quantity of resources. It is also used to establish metrics, check quotas, determine costs, and bill users. The information gathered in accounting management can also help determine if users are abusing their privileges or transmitting data in such a way that diminishes performance. Security management controls access to information on the network (Stallings 1990). This provides protection for sensitive information that may exist in the system. Without this part of network management, there is no systematic manner to distribute, store and authorize passwords. Having the ability to maintain secure access to restricted information is necessary in most computer networks. Performance management monitors the network to ensure its accessibility so that users may utilize it efficiently. Two processes are involved in performance management: monitoring and controlling. Monitoring traces activities occurring on the network while the controlling function provides a way to adjust the network in order to improve performance. The activities that are monitored provide the network manager with measures such as capacity usage, amount of traffic, throughput levels, and response times.

Configuration management involves obtaining data from the network in order to manage the setup of the network devices. It includes the processes of network planning, resource planning and service planning. It also includes traffic management, the process of routing data correctly through a network. The process of configuration management provides an organized approach to changing and updating segments and devices on the network.

The five network management areas differ in intricacy, depending on the type of network. A computer network can be categorized into one of three categories: local area networks, metropolitan area networks, or wide area networks. The overall concept of each type is virtually the same; the difference lies within the size of the network. Local area networks (LANs) are networks that connect equipment within a single building or a group of neighboring buildings. Metropolitan area networks (MANs) are used to connect computer systems within an area the size of a city. A MAN is commonly developed by combining many LANs with a public telecommunication provider. A wide area network (WAN) connects many smaller networks, either metropolitan or local area networks. There is no specified distance that must lie between the smaller networks. A WAN connects smaller networks that are in different parts of a city, different cities, or different countries. Such large amounts of time and money are being invested into computer networks today that it has become both desirable and cost-effective to automate parts of the network management process. Applying artificial intelligence to specific areas of network management allows the network engineer to dedicate additional time and effort to the more specialized and intricate details of the system. Many forms of artificial intelligence have previously been introduced to network management; however, it appears that one of the more applicable areas, fuzzy reasoning, has been somewhat overlooked.

Computer network managers are often challenged with decision-making based on vague or partial information. Similarly, computer networks frequently perform operational adjustments based on this same vague or partial information. The imprecise nature of this information can lead to difficulties and inaccuracies when automating network management using currently applied artificial intelligence techniques. Fuzzy reasoning will allow this type of imprecise information to be dealt with in a precise and well-defined manner, providing a more flawless method of automating the network management decision making process.

Statement of the Problem:

The overall goal of network management is to provide network users with an acceptable quality of service. To reach this goal, network managers are trying to automate as many network operations tasks as possible. Many currently available network management systems are automated in order to assist managers in obtaining vital information necessary to achieve the desired quality-of-service. As a result, network managers are discovering that measurable productivity improvements can be obtained through automation of the straightforward management tasks [11].

Recent attempts at automation include integrating artificial intelligence into network management systems using neural networks, expert systems, and genetic algorithms. These methods have successfully diminished the time and effort required of the network manager by reducing the amount of interaction that is needed. One important issue that is encountered when attempting to automate segments of the network management process involves the inaccuracy of the results because of imprecise data. Many factors involved in network management cannot easily be described in a precise manner because they are either descriptors concerning the unknown future of the network, or ones that are quantified into groups having no definite boundaries. For example, when analyzing the performance of a network, we can characterize the network as being either reliable or unreliable. However, it is evident that there will be no single point that defines the cutoff between reliable and unreliable. Instead, there will be a fuzzy area between the two that describes a network as being somewhat reliable and somewhat unreliable. This type of imprecise information is very prominent in network management tasks. If methods can be developed to take into account this imprecise information, more meaningful results can be reported.

The literature currently indicates the successful application of artificial intelligence techniques to the five areas of network management. However, there is very little acknowledgment that the information required for network management is such that it cannot be accurately defined with an exact descriptor. This has caused many inaccurate assumptions when attempting to automate the network management system. Applying fuzzy reasoning to these automation processes could alleviate the problem of inaccuracy and allow for more flawless results and analyses. An issue that is burdening many computer network managers is increasing traffic. All types of networks are experiencing this problem to some degree. For example, frame relay usage is experiencing massive growth and corresponding traffic problems. Three of the major frame relay communications corporations, MCI Communications, Sprint and LDDS WorldCom have all confirmed their traffic levels are growing monthly by fifteen to twenty percent. The growth seen by these companies is analogous to the growth being experienced by all types of computer networks around the globe Increasing traffic loads will naturally lead to network delays, which will lead to other problems as well. These network delays can easily cause dropped sessions or lost data, not to mention dissatisfied users. It is impossible to stem this increasing traffic load. However, optimal routing of messages within a network can mitigate some of the difficulties of heavy traffic. Therefore, a more efficient method of routing needs to be developed to combat network delays.

Research Methodology:

This research is divided into three phases. The initial phase involves designing the simulation model to be used for obtaining data. The simulation will mimic a given computer network and its routing process. Once developed, the fuzzy algorithm will be applied to the given scenario and then simulated in order to analyze the proposed methods. The second phase consists of developing the specifics of the routing algorithm. This involves devising the fuzzy logic details as well as the details pertaining to the neural network. This phase is the focus of the study and therefore requires the most detail and explanation. Finally, the proposed method will be analyzed and compared to a current method that does not involve fuzzy reasoning. The comparison will involve the simulation model being applied to an example network situation. The complete methodology will be described in detail in chapter four.

Manipulating Fuzzy Sets:

Once the fuzzy sets have been defined, several approaches are available for manipulating those sets. The first and most common is a rule based approach. This approach was employed in the previous attempt of fuzzy reasoning applied to network routing [2]. The second approach involves using neural networks to process the information obtained from fuzzy sets. Neural networks are utilized in this study; therefore, an explanation for processing fuzzy sets with neural networks is provided in the next section. Appendix A contains a discussion of the rule based approach for the interested reader.

Neural Networks:

A neural network is an artificial intelligence technique originally designed to mimic the functionality of the human brain. It is a non-algorithmic procedure that has a strong capability of learning and adapting to changes in its operating environment. The ability to successfully modify itself indicates neural networks could be a beneficial tool in managing volatile networks. Hence, this study chose this method to process the information obtained by the fuzzy sets.

A neural network is composed of many simple and highly interconnected processors called neurodes. These are analogous to the biological neurons in the human brain. The artificial neurodes are connected by links that carry signals between one another, similar to biological neurons. The neurodes receive input stimuli that are translated into an output stimulus. A neural network consists of many neurodes connected together as in Figure 3.6. This illustrates a three layer neural network, which is the type that will be designed for this study. However, it is possible to have more than (or less than) three layers and more than (or less than) nine neurodes in a neural network. Processing begins when information (input response) enters the input layer of neurodes. Inputs entering any neurode in the neural network will follow the same basic process. This is atwo step process that uses two different mathematical expressions for evaluation. The first step utilizes a summation function to combine all input values to a neurode into a weighted input value. The second step utilizes a different mathematical expression, known as a transfer function, that describes the translation of the weighted input pattern to an output response. This two step process operates identically for all neurodes in the neural network. The summation function controls how the neurode will compute the net weighted input from the single inputs it has received. Although the summation function operates identically for all layers, summation outcomes for the input layer will be more direct than at the other layers. This is because each neurode in the input layer receives a single input value. Since the sum of a single value is equal to that original value, the net weighted inputs for these neurodes will be the original input values. Neurodes in the other two layers require some computation to obtain their net weighted inputs. This is accomplished using the following summation formula.

Conclusions:

Computer networks are becoming more abundant in today's business environments as they play a central role in maintaining and transmitting information. Many organizations have realized that ease of access to information is a critical need that can also build a competitive advantage if it is easily accessible. Networks play a central role in this concept for many reasons, with the most important being that they can help geographically dispersed organizations overcome the geographic obstacle. The growing usage of computer networks is requiring improvements in network technologies and management techniques so that users will still be provided with high quality service. A major aspect of computer networks that is vital to quality of service is data routing. As more individuals transmit data through a computer network, the quality of service received by the users begins to degrade. This indicates that more effective and adaptive measures must be developed for routing data through computer networks. The essence of this dissertation was based on developing an improved method for data routing. The primary tool applied in the routing method of this research was fuzzy reasoning. This was argued to be an appropriate technique for routing due to the imprecise measures currently used in present routing algorithms. Many of today's algorithms use various network measures, known as metrics, to establish the best path through a computer network. Few people have yet to recognize the nontrivial inaccuracies present in the measures. Increasing complexities and growth of computer networks is accelerating the significance of this notion. To combat these inaccurate metrics, fuzzy reasoning was applied as the basis of the new algorithm presented in this dissertation.

A secondary technique utilized was a neural network. The neural network was deemed suitable because it has the ability to learn. Once the neural network is designed, any alterations in the computer routing environment can easily be learned by this adaptive artificial intelligence method. The capability to learn and adapt is essential in today's rapidly growing and changing computer networks. These techniques, fuzzy reasoning and neural networks, when combined together provided a more effective routing algorithm for computer networks.

The principal objective of this dissertation was to demonstrate the advantages of applying fuzzy reasoning to routing data through a wide area network. Developing the new fuzzy routing algorithm involved many small processes, which were integrated to facilitate the modeling and testing required in the study. Simulation methods, neural network procedures, and fuzzy reasoning were all essential in achieving the research objective. A simulation model was designed following the development of the new algorithm that applied fuzzy reasoning enhanced by a neural network. The basis of the simulation was for comparing the new algorithm to a current routing algorithm based on the shortest route technique. Before the simulations could be employed, an experimental design having two factors was established. These two factors, congestion level and failure rate, were selected as primary factors in the experimental design because of their high correlation to routing level achieved. The level of congestion present in the computer network greatly affects the travel time for all types of data. Similarly, failure in the computer network can delay or completely stop the transmission of data. Each factor was divided into two levels, low and high; thus, leading to an experimental design having four sampling units. Each unit represented a different network situation under which a comparison test was performed between the two algorithms. The comparisons demonstrated that the new algorithm outperformed the shortest route algorithm in routing effectiveness under all network situations except an extremely stable one having low congestion and low failure rate. Nonparametric statistical tests were applied to establish significance at the _ = 0.10 significance level (Table 5.1). This was the expected result, and furthermore proves that the new algorithm has large potential benefits associated with it. The paucity of so-called stable networks being used today emphasizes the usefulness of this new algorithm.

Table 5.1: Significant P-values

	Low Congestion	***High Congestion***
Low Failure	Not significant	$P < 0.10$
High Failure	$P < 0.10$	$P < 0.10$

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An additional advantage of the new algorithm that was discussed but not simulated is the neural network's ability to learn. The simulation provided data to train a neural network that was trained only once. If implemented in an actual computer network, the algorithm would likely perform even better due to its learning capability. This is because the neural network would understand how to manage various modifications in the network as it grows. This is a notable feature as computer networks are not designed to be static systems, but instead are dynamic systems that are constantly changing.

The conclusions of this research are obviously limited to some extent in that a specific network structure and certain metrics were employed. However, we believe this network exhibits general characteristics that help intuitively conclude that our results can be generalized over most wide area networks. Utilizing fuzzy sets and a neural network that are defined relative to the specific computer network assists in generalizing with these results. A computer network having altered characteristics would employ fuzzy sets with different domain ranges and a different neural network. Future research involving other network configurations and metrics will also help support these generalizations.

Future Research:

The positive results encountered in this dissertation suggest that additional experiments may provide further insight into the benefits of fuzzy routing. This dissertation research studied the benefits of a single network node applying the new fuzzy routing algorithm while all other nodes applied a standard routing algorithm. Future research could employ the new algorithm at all network nodes and possibly demonstrate additional improvements to the routing process.

Another modification that could prove beneficial lies with combining the two routing algorithms that were employed in this study. It was discovered that the new algorithm did not exhibit any advantages during network situations having low failures and low congestion. This suggests that a hybrid routing scheme might improve routing efficiency. The hybrid routing algorithm would conditionally utilize the fuzzy routing scheme during chaotic instances and the shortest path scheme during more stable periods.

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