DEVELOPMENT OF AN EXPERT SYSTEM FOR MESSAGE ROUTING IN A SWITCHED NETWORK ENVIRONMENT

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ABSTRACT: The research presents an approach for routing message from source to destination in a computer network environment (Switched Network) using a Neuro-Fuzzy Expert System (NFES) model. Previous research works in message routing is indicated that routing is a very complex issue. This is because; there is problems of efficient path determination, accurate assessment of network traffic condition and imprecise and poor bandwidth management system. This work therefore employed a Neuro-Fuzzy Expert System model that combines the learning ability of artificial neural network with the intelligence exhibited by fuzzy logic to design a message routing algorithm. The NFES developed uses input data (bandwidth and delay) which are imprecise information with decision support system based on cognitive filtering in fuzzifying the routing to selects the most effective route/path with maximal bandwidth usage subject to efficient minimal path delay. The routing employed ruled based (If Then) approach for the computation of the optimal routing path. A hypothetical computer network environment was set-up with seven micro-computer systems routing window vista operating system to test the model. Twenty-four different messages were routed over the network to simulate and analyzed the algorithm developed. The result of the simulation revealed that the NFES developed was better in performance than the traditional Random and Shortest path method.

KEYWORDS: Routing, Neuro-fuzzy, Switched Network, Computer Network Environment.

1. INTRODUCTION

With the current increase in the growth of networks usage, it is very important that a network supports quality of service (QoS) for real time traffic ([Dou04]). Routing plays an important role for providing a well delivery service in a networks and the provisioning of these services has become a key issue in designing a network due to the necessity of providing multimedia in such networks. These applications are in general delay sensitive and have high bandwidth requirements. Providing QoS in these networks is challenging because the communication channel is shared among adjacent host, and network topology can change as hosts move ([BH05]).

When trying to computerize segments of network, there is one vital issue that is encountered which involves imprecision of results because of vague data. Several features that are concerned in network management cannot easily be expressed in a certain mode since they are either descriptors pertaining to the indefinite prospect of the network, or ones that are quantified into groups that include no specific margins ([Jul97]). If techniques can be developed to take into account the inaccurate information, more important results can be obtained.

An expert system needs to be built to address the issue of quality of service for routing of messages in a network. An expert system is concerned with building a system that employs human knowledge captured in a computer to solve problems that ordinarily require human expertise. A system that is well designed can imitate the reasoning processes experts use to solve specific problems and such systems can be used by non experts to improve their problem solving capabilities. Expert system is used to propagate scarce knowledge resources for improved and consistent result ([Efr95]).

Quite a number of researchers had undergone researches in different area using the application of neuro-fuzzy expert system, but few researches have been done using neuro-fuzzy expert system to route messages in a computer networks.

2. REVIEW OF RELATED WORK

Akpan ([Akp11]) developed a genetic algorithm for optimizing message routing in computer network environment, he formulated Multi-objective mathematical programming problem where Minimum cost and minimum delay on the network were obtained. He carried out an experimental study of computer network environment but there is need for a hybrid algorithm for better decision making capability and there is no comparison of the method with another method.

Also, Julia ([Jul97]) developed a Computer Network Routing with a Fuzzy Neural Network. Experimental study was carried out in a packet switched network environment where congestion, throughput, failure rate and distance were used as a metrics for comparison with OSPF. The metrics used defined with specific shapes and are limited to a specific network environment.

Arnold et al ([A+97]) make use of fuzzy reasoning method to make decisions as regards data routing. According to Arnold, there is need for an improved method that can handle imprecise information though the use of OSPF technique is good for routing. The techniques employed procedures in defining the shortest route to be the component of fuzzy system. Ruled based was also employed for fuzzy reasoning. Decision for transmission in a network was made using fuzzy reasoning. The method does not require the assistance of an expert to articulate the often complex and detailed rules necessary to determine good routes.

Adagunodo et al. ([AAO99]) presented a specification and validation of communication protocols in computer network. The protocol adopted is the alternating bit protocols with the send and wait characteristics. The techniques of specification and verification employed are numerical Petri Nets and Reach ability Analysis respectively. In the specification, users and system's requirements are reduced to primitives while the primitives are further divided up as places and transmissions. The constructs are then represented in the nets. Reach ability technique is thereafter employed to validate using the restriction of the packet being transmitted. The result of verification shows that applying the primitives yield efficient and reliable data transmission in network environment.

3. FUZZY REASONING

This research was established upon the bases of Fuzzy reasoning. Fuzzy reasoning refers to the superset of classical reasoning (Boolean logic) that has been augmented to recognize and manage imprecise information. This is accomplished through the use of fuzzy sets or fuzzy rules. A fuzzy set is one whose members either belong completely, partially, or not at all. The boundary that defines membership and non-membership in a fuzzy set is imprecise, thus allowing an object, or piece of information, to partially belong to a set ([Zad65]).

The popular vehicle for the application of fuzzy reasoning is expert system. Fuzzy expert systems make use fuzzy logic as the fundamental reasoning to evaluate a particular situation. The rules that a fuzzy system employed is in the form: If *m* is low and *n* is high then *p* is medium. However, using fuzzy reasoning, *m* is a variable defined as being completely low, not low at all, or somewhere in between those two extremes. Likewise, *n* is a variable defined as being completely high, not high at all, or somewhere in between the two extremes. Depending on the potency of membership of *m* and *n* in their respective sets, *p* will be inferred to belong, to some extent, to the set "medium" ([Jul97]). Even though fuzzy reasoning employed fuzzy sets to represent vague concepts, this is done in an extremely accurate and distinct way ([Mas93]) and this allow the results to be in reliable and rational conclusions.

4. NEURAL NETWORKS

Originally, a neural network is an artificial intelligence method intended to imitate the functionality of the human brain. It has an ability of learning and adjusting to changes in its environment. A neural network has many straightforward and extremely interrelated nodes called neurodes. Similar to biological neurons the neurodes are connected together by links that carry signals between one another. Learning and recall are two aspects in which neural network system can be make use of. The primary advantages offer by neural network is its learning ability. And this exact capability of neural network is the reason why it was chosen in the research. Possessing the capability to learn and become accustomed to its environment should allow the new routing method to be more efficient.

After the learning procedure has been concluded then the recall operation of neural networks occurs. After this, the neural network should be satisfactorily trained to produce the appropriate output for a given set of inputs. Recall is essentially the process of employing a trained network to give usable prediction.

One may integrate the concept of fuzzy logic into neural networks to enable a system deal with cognitive ambiguity in a manner more like humans. The result of this integration is called fuzzy-neural, neural fuzzy or neuro-fuzzy network ([CD00]). When two techniques of neural network and fuzzy logic are combined, each single approach limitations are eliminated while their strengths are enhanced. In so doing, the quality of service in message routing can be optimized. ([Aki02])

5. NEURO-FUZZY EXPERT SYSTEM MODELING OF MESSAGE ROUTING

An expert system was developed based on the principles of fuzzy logic and neural networks for routing of messages in switched network environment. The input parameters are bandwidth and path delay (average end – to – end delay). The architecture is made up of Knowledge Base, Neuro-fuzzy Engine and Decision Support System. The knowledge base consists of database, fuzzy logic and neural network as presented in figure 1 below.

The hypothetical wireless employed in this research is represented as a directed graph G as presented in Figure 2 where set of nodes is denoted by V representing the set of routers and the set of links of the nodes denoted by E. There is a Bandwidth denoted by ($Bandwidth\_Path_{ij}$), where $Bandwidth\_Path_{ij}$ denotes the bandwidth on the ith node and jth node. The delay is specified by ($Delay\_Path_{ij}$), where $Delay\_Path_{ij}$ is the propagation delay of transmitting a packet on link/path (i,j). Source and target nodes are denoted by 'S' and 'T' respectively.

Typical path with reference to Figure 2, (S,A), (A,E), (E,H), (S,B), (B,D), (D,F), (S,C), (A,C), (C,F), (A,B), (E,C), (D,E), and (C,D) is a path from node 'S' to 'T'.

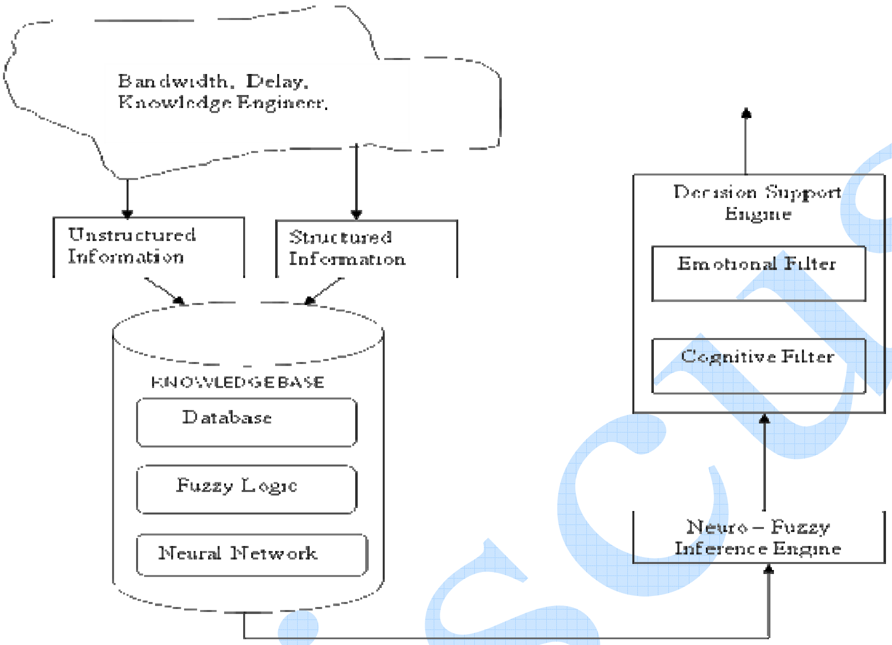

Figure 1: Architecture of Neuro-Fuzzy Expert System

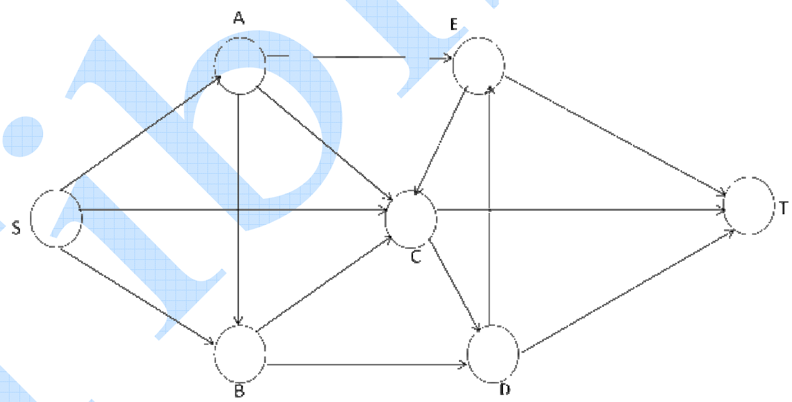

Figure 2: Hypothetical Wireless network consisting of seven nodes and fourteen links/paths

Messages to be routed are defined as follows:
Let [m_1, m_2, m_3] Є M where M is a Message to be routed
suppose

m_1 = [data (alphanumeric Characters), S_{id}, T_{id}]
m_2 = [data (Graphics), S_{id}, T_{id}]
m_3 = [data (Alphanumeric characters and Graphics), S_{id}, T_{id}]

With size m_1 = [x KB]; m_2 = [y KB]; and m_3 = [z KB]

Route is a path(s) where a message is transmitted from the source to the target and it is mathematically defined as follows:

$$Route_i = \sum_{i=1}^{n} path_i \qquad (1)$$

where i =1,…,n

6. DATABASE/INPUT MODELING OF MESSAGE ROUTING

The Database of the quantitative knowledge consists of the bandwidth and delay which are modeled as follows:
The bandwidth along a route is the addition of bandwidths of successive paths given as;

$$Total_{Bandwidth(S,T)} = \sum_{\substack{i=2 \\ j=1}}^{n,m} Bandwidth_{Path_{i,j}} \tag{2}$$

where n is the bandwidth available in a possible path(s) *i* between each node, and m is the maximum number of routes *j* possible from source (S) to target (T).
We set the condition for (bandwidth) routing as;

$$R_{M_i} = \begin{cases} 0, \text{ if } a < M_i < b, \forall \{BR_i\} \in a \vee \{BR_i\} \in b;\ a, b > 0 \\ 1, \text{ otherwise} \end{cases}$$

where BR_j is the bandwidth on each $Route_i$ and R_{M_i} is the message on a particular route.
The increment or decrement that the delay suffered is calculated by subtracting the new delay from the last value of the delay for the path.

$$Delay_{Path(S,T)} = \sum_{\substack{i=2 \\ j=1}}^{n,m} Delay_{Path_{i,j}} \mid \sum_{\substack{k=1 \\ j=1}}^{n,m} Delay_{Path_{k,j}} = \sum_{i,k,j=1}^{n,m} Delay_{Path_{i-k,j}} \tag{3}$$

where *i*-*k* = difference in time from path *i* to path *k*.
The conditions for routing of delay can be written as;

$$Delay_{R_{i,j}} = \begin{cases} 0, \text{ if } Delay_{R_{i,m}} > Delay_{R_{j,m}} \\ 1, \text{ otherwise} \end{cases}$$

where condition is 0, there will not be any routing but 1 otherwise.

7. FUZZY LOGIC MODELING

Fuzzification of the inputs parameters are carried out as follows: For a fuzzy subset 'Route'; based on the Quality of Service (QoS) defined by the membership function '$R_{(S,T)}$' as follows:

$$Route_{(S,T)} = \begin{cases} 0, \text{ if } Delay_{Path(S,T)} > h \\ Delay_{Path(S,T)} / h, \text{ if } 1 < Delay_{Path(S,T)} =< h \\ 1, \text{ if } Delay_{Path(S,T)} <= 1 \end{cases}$$

where $Delay_{Path(S,T)}$ represents the delay acquired on each route $Route_{(S,T)}$ and the maximum delay for routing is h for a particular message size, certainty of routing is at least 1 for a particular Route $_{(S,T)}$

$$Route_{(S,F)} = \begin{cases} 0, \text{ if } Total_{Bandwidth(S,T)} < m \\ Total_{Bandwidth(S,T)} / B_{(M)}, \text{ if } m <= Total_{Bandwidth(S,T)} < B_{(M)} \\ 1, \text{ if } Total_{Bandwidth(S,T)} >= B_{(M)} \end{cases}$$

where m is the message size and $Total_{Bandwidth(S,T)}$ is the bandwidth on a particular route/path $Route_{(S,T)}$, $B_{(M)}$ is the maximum bandwidth that can be acquired on a particular route $Route_{(S,T)}$, the membership functions of the input parameters (bandwidth and Delay are; Minimum, Average and Maximum while Route (QoS) is High, Average and Low.
The fuzzy inference engine extracts and evaluates rules from the rule base and produces fuzzy outputs. The fuzzy inference engine presented in ([Akp11]) is studied and modified for the design of this message routing as in Figure 3 below:

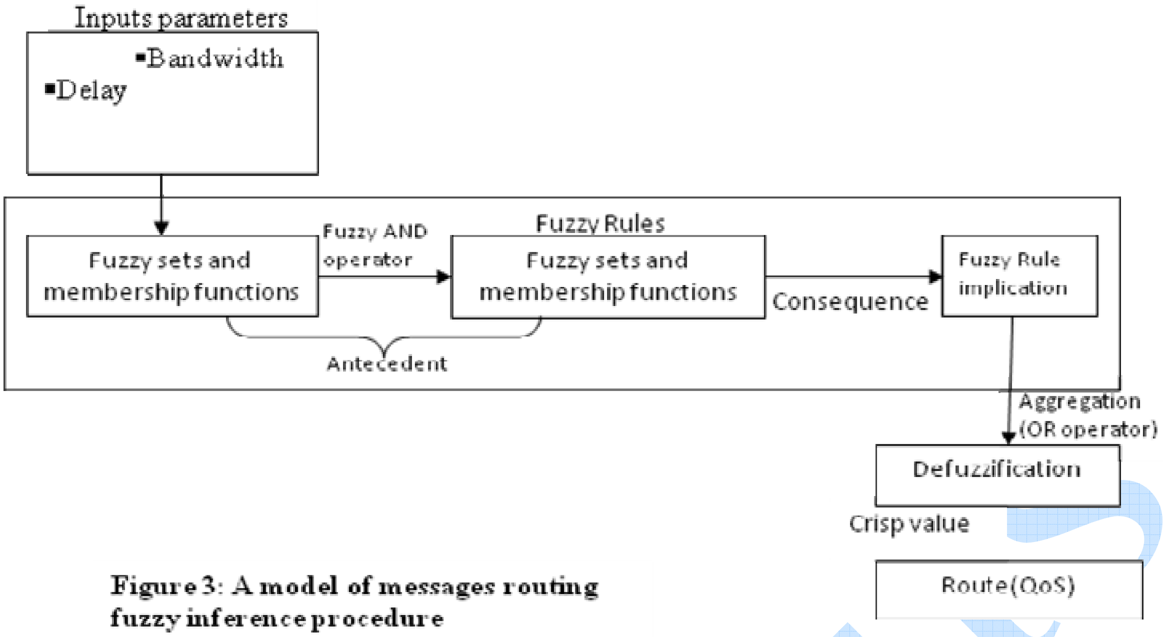

Figure 3: A model of messages routing fuzzy inference procedure

An "IF THEN" Ruled based is then computed for the premise and applied to the conclusion part to determine the optimal routing path, for example;

A = If 'DY' is Min and 'BW' is Max then 'R'

B = If 'DY' is Max or 'BW' is Max then not 'R'

where DY = delay; BW = bandwidth; and R = Route.
The 'min' composition rules which is based on the principle of fuzzy logic operator 'and' is adopted. If there are rules 'R_k', k =, 2…n, then the output signals of the rules 'R_k' is represented by the set;

$\{0(R_1)$, then $0(R_k),\ldots 0(R_n)\}$. (4)

The aggregated output signal is computed by;

min $\{0(R_1)$, then $0(R_k),\ldots 0(R_n)\}$. (5)

It is noted that $0(R_k) <= 1.0$; k=1,2…n,
Defuzzification involves conversion of the linguistic variables to numerical or crisp values; this work adopts the centroid defuzzification method described in [Bod09]. This is given as follows:

$$Z = \frac{\sum_{i=1}^{n} \propto_{i} y_{i}}{\sum_{i=1}^{n} \propto_{i}} \quad (6)$$

where z is the crisp value and can be used for decision making, αi is the fuzzy implication (firing strength) of the ith rule μ(α) is the degree of membership of the ith route value, yi is the consequent of each rule.

8. NEURAL NETWORK MODELING OF MESSAGE ROUTING

Simulation techniques will be designed first before neural network will have to be trained. The training method of Julia 1997 was adopted and modified. The training procedure will be as follows:

a. Eight input nodes, one bias node and one output node that represents the delay at the destination was the design of neural network. By applying the common rules of thumb (i.e. number of input nodes and number of output nodes divided by 2), the appropriate number of hidden nodes was determined. In figure 4 below the input and output nodes are defined.
b. Two facts were constant all through the process; the network topology and the source node of interest. A simulation model was built to represent hypothetical network environment.
c. In the course of the training, a great number of simulations were run to build up a sufficient training set. Each simulation was made of routing a message from a source node to the probable departing links using a data report which was made of: target node, message size, bandwidth of packets roaming on that route and the type of delay present on that link.
d. Going over the simulation and varying the values of this four data, database of the resulting transmission delay along each path leaving the source nodes was generated and that of operating characteristics.
e. The input segment of the training set for the network are these operating characteristics where the delay and bandwidth broadcast using that path served as an output portion of the training set.

f. To determine the best path to the destination, this database was made available on each node on the network.
g. The record regarding each possible outgoing path to travel from source to the next node was made use by the simulation to determine which route to take in the course of transmission. The testing set was generated by evaluating the new method with random method and shortest distance method.

Six input was served into the neural network from the information that each specific path has (that is bandwidth and delay), which was changed into six fuzzy membership grades, one for each of the fuzzy sets. In addition to this, message size and destination of the message was the two additional inputs into the neural network. In Figure 4 below the neural network design is illustrated.

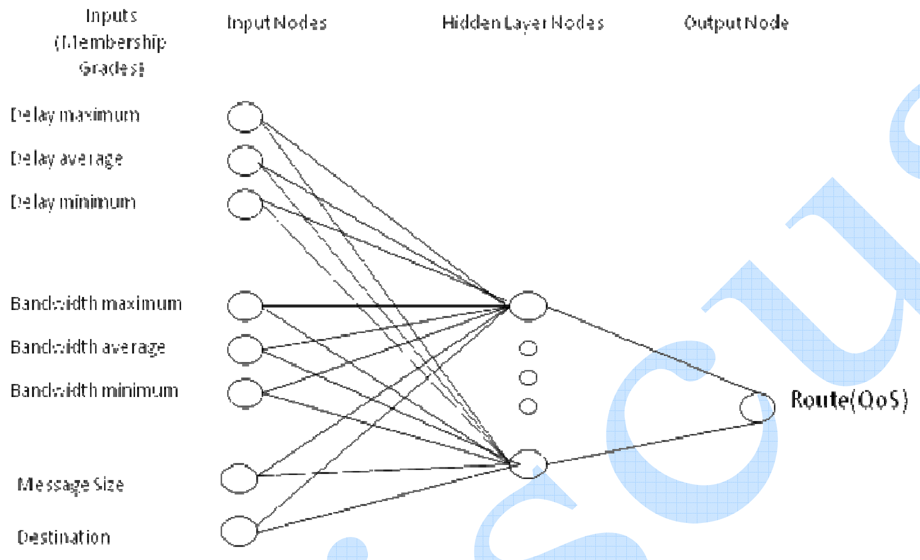

Figure 4: Architecture of Neural Network of message routing

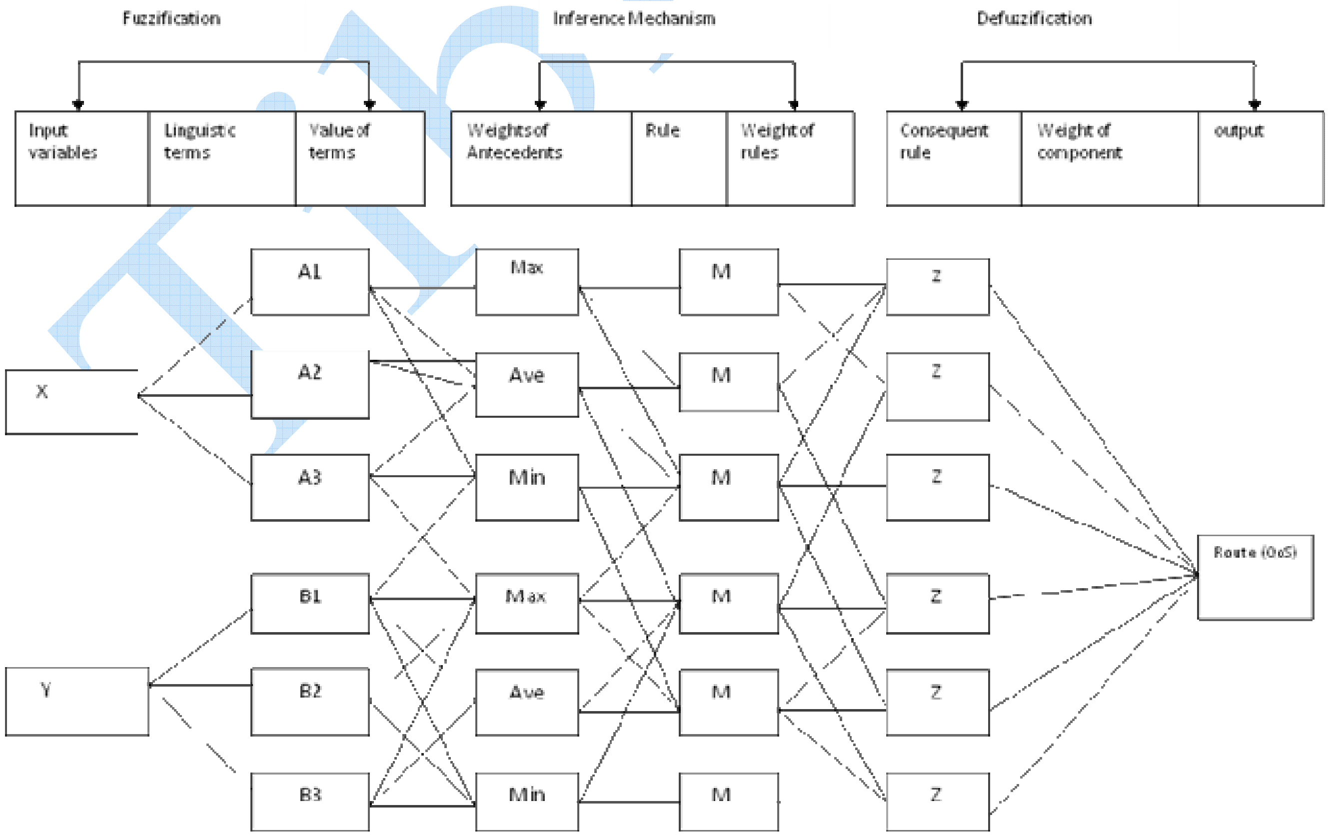

Figure 5: Architecture of Neuro – Fuzzy component of message routing (where M = multiply)

9. NEURO-FUZZY MODELING OF MESSAGE ROUTING

Neuro-Fuzzy inference engine which is concerned with carrying out the relevant and inductions on both the qualitative and quantitative knowledge is based on fuzzy inference system that matches some input values with some fuzzy reasoning model (a collection of If – then rules) to perform the message routing. It is always good to represent a learning algorithm using architecture. The final output is the weighted average of each rule's firing strength [TS83].
Figure 5 depicts the following

i. The neuro fuzzy inference is a five layered architecture. The first, second and fourth layers is made up of adaptive nodes while the third and fifth layer is made up of fixed nodes.
ii. The architecture implements the Mamdani's inference mechanism. It handles rules of the form

Rule^1: if (x_i is A^1_i) AND…AND
(X^m is A^1_m) then (y_i is B^1)
… (7)
Rule^n: if (x_i is A^n_i) AND…AND
(X_m is A^n_m) then (y^n is B^n)

iii. Where x_i = 1 = 1, 2, …, m are inputs, A_i = 1, 2, …, m are fuzzy sets of the inputs variables and B_i = 1, 2, …, m are fuzzy sets of outputs variables within the fuzzy regions specified by the rule.
iv. There are three inputs to the system; the rule may therefore assume the form:

IF (X is A_i) AND (y is B_i) THEN (Z is C_i) (8)

For example: IF (Bandwidth is High) AND (Delay is Low) THEN (QoS is High)
The layers of neuro-fuzzy architecture presented in Figure 5 are described below:

i. Layer 1: this node represents the input such into the system such as bandwidth and end – to – end delay. For example, the two inputs X and Z may be maximum delay, average delay and maximum delay respectively. The outputs of layer 1 are the fuzzy membership grade of fuzzy inputs which are represented in layer 2.
ii. Layer 2: this node represents the fuzzy membership grades of the inputs. This is the degree to which a given input satisfies the linguistic label associated with it. μA_i (x) and μB_i (x) can adopt any membership function. In this work triangular membership function adopted is given as follows:

$$\mu A_i (x) = (x - b) / (a - b) \tag{9}$$

where a, b1 and b2 are the parameters of the membership function governing the triangular shaped functions accordingly such that $b \le x \le a$.
iii. Layer 3: the nodes in this layer are called the rule nodes, they are labeled M, indicating that they function as simple multipliers to compute the rule antecedent part. Each node computes the firing level of the associated rule. The output of ith neuron is, suppose

$$\alpha_1 = \mu A_i (x) * \mu B_i (x) = \mu A_i (x) \wedge \mu B_i (x)$$
$$\alpha_1 = \text{Min} \{\mu A_i (x), \mu B_i (x)\} \tag{10}$$

where i = 1, 2, …..n
For example, suppose:

$$\mu A_i (x) = 0.18, \text{ and } \mu B_i(x) = 0.35$$
$$\alpha_1 = \mu A_i (x) \wedge \mu B_i (x) = 0.18 \wedge 0.35 = 0.18 \tag{11}$$

iv. Layer 4: Defuzzification begins at layer 4, here the output of

$$Z_{i+1} = Z_i (F_i) \tag{12}$$

where $F_i = (SiX + R_iY)$ and (S_i, R_i) is the consequent parameter set
v. Layer 5: The sum of signals are computed at this layer by summing up weights derived at layer 4 and dividing the result by the sum of the weights obtained at layer 3. This layer completes the defuzzification stage by outputting the consequent parameters

The final stage of the defuzzification module is computed as:

$$\text{Output}_i = \sum M_i Z_i P_i = \frac{\Sigma M_i Z_i P_i}{\Sigma M_i Z_i} \tag{13}$$

where M_i is the membership grades function, Z_i is the consequent of each rule, P_i is the firing strength of the ith rule and Output_i is the crisp value that can be use for decision making.
Implementation of the System in Window Vista Ultimate 32bit operating system as the platform, the back-end comprises of the database characteristic for routing decisions using MySQL, while JAVA programming language serves as the front-end engine.

10. RESULTS DISCUSSION OF MESSAGE ROUTING USING NEURO-FUZZY REASONING IN THE NETWORK ENVIRONMENT

In the experiments, three types of messages (m_1, m_2, m_3, as stated in chapter three) were sent across the network. m_1 and m_2 contains five different types of messages with different sizes while m_3 contains four with different sizes. These messages were sent as training data sets across the network with bandwidth on each path and delay acquired on each route are stored in the database. The total number of training data sets gotten from delay are 196, Neuro-fuzzy reasoning (using both bandwidth and delay for routing), 759 and for Linguistic conditioned table, 759.

11. PERFORMANCE EVALUATION OF NEURO-FUZZY, RANDOM AND SHORTEST PATH METHOD

This study compared the new method with shortest route algorithm and random method. Shortest route is expected to generate the best routing path under steady and predictable situations when taking into consideration only the distance from source to the destination node. The reason being that only on one measure, usually distance was shortest route designed to optimize the path of travel. Messages were sent randomly across the network in random method. To determine which path that will be most successful, many factors are very crucial. This implies that another system with extra network characteristics will be more efficient. Neuro-Fuzzy method was employed using both bandwidth and delay as a measure to obtain best route to the destination.

In the experiment 10 different messages (testing data sets) with different sizes were sent across the network using these three methods. The results are presented in Appendix. From the result Neuro-fuzzy method outperformed other two methods in its efficiency (QoS). The graph is presented below.

ID	Msg size(kb)	Fuzzy Path(sec)	Random Path(sec)	Shortest Path(sec)
1	30	1.03	3.51	1.80
2	35	0.85	1.19	3.23
3	73	2.50	8.84	5.41
4	96	3.09	11.04	7.34
5	169	5.63	20.29	13.55
6	204	6.91	25.37	16.84
7	387	13.02	46.74	32.39
8	444	14. 3	52.88	36.41
9	533	18.11	67.49	45.27
10	1103	36.87	135.09	92.36

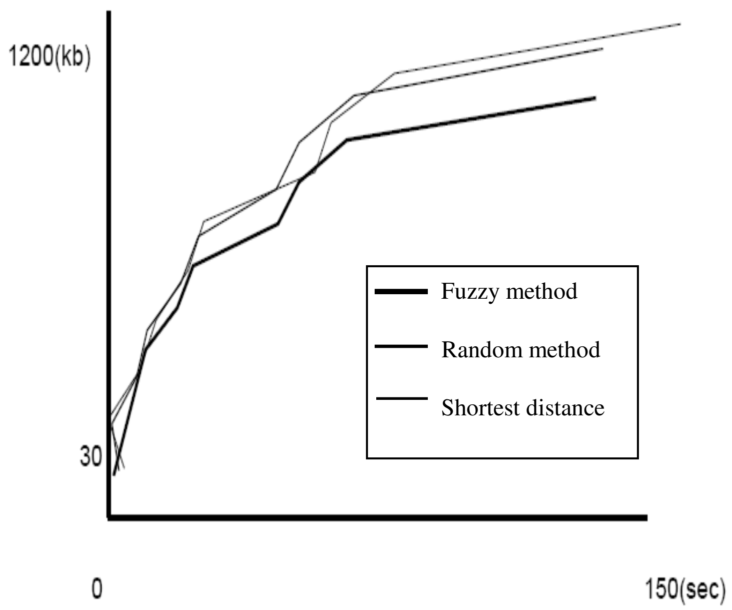

Figure 6: Graphical Representation of the evaluation of Neuro-Fuzzy, Random and Shortest path

12. DECISION SUPPORT SYSTEM

A Decision Support System that is based on cognitive filtering was employed in using the fuzzy routing to objectively determine the course of action to be taken depending on the level of quality of service.

a. High quality of service (QoS): means that the routing can best take place using a particular link that has these characteristics.
b. Average Qos: means that data can still be routed along a specific path exhibiting these characteristics.
c. Low Qos: means that routing through this path may not be the best.

13. CONCLUSION

For the users to still be provided with high quality of service then the enhancement in the network technologies that the growing usage of computer network requires has to be met. Message routing (data routing) is the main aspect of computer networks that is important to quality of service. The quality of service received by the users begins to reduce as more individual transmit data through a network. This implies that more efficient and adaptive measures have to be developed for routing of data through the networks. An enhancement method for message routing was the purpose of developing this study.

Fuzzy reasoning was the major tool applied in the routing method of this research. Fuzzy reasoning is a suitable method for establishing the best path through a computer network by the use of computer measures known as metrics and for routing due to the inexact measures currently used in present routing algorithms and it also help to establish the best path through a computer network by the use of network measures called metric.

Neural network is another method utilized because of its ability to learn. Any alterations in the computer routing environment can effortlessly be learned by this adaptive artificial intelligence method, once the neural network is designed. The integration of fuzzy logic and neural network provides a more efficient routing algorithm for computer network.

The development of this new algorithm that makes use of fuzzy reasoning enhanced by neural network simulation was modeled. The reason been to compare the new algorithm with the current routing algorithm based on shortest route and random technique. Two factors were established based on the experimental design before the simulations could be in use. These two factors, bandwidth and delay, were selected as primary factors in the experimental design because of their high association to routing level achieved. The delay in the computer network can greatly affect the transmission of data as well as the level of bandwidth present in the computer network can also affects the travel time for all types of data.

The evaluation demonstrated that fuzzy method outperformed random method and shortest path method in routing effectiveness in a switched network environment.

14. RECOMMENDATIONS

It is therefore recommended that this method's efficiency be improved upon by combining it with another method i.e., genetic algorithm for its optimization purpose.

Also the method can be further improved by carrying out the case study of a real live computer network environment.

There is also a need to increase the network metrics such as failure rate, computer memory, message traffic and congestion.

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