Performance Evaluation of Fuzzy Routing Algorithms for a New Fuzzy Mixed Metric Approach

***Shuchita Upadhayay, **Mini Sharma**
Dept. of Computer Science and Applications
Kurukshetra University Kurukshetra

Abstract- Optimizing routing decisions has been an important subject in research of communication networks. The present paper is introducing a new fuzzy mixed metric approach, which takes routing decisions based on fuzzy costs in parallel to crisp cost of other metrics. The present paper evaluates the new fuzzy approach for its performance. The paper first describes the new fuzzy approach and the fuzzy routing algorithms developed for the approach and then the performance is evaluated both in empirical and analytical terms to show its advantages over the previous fuzzy approaches and traditional link-state routing approach. The paper analyzes the performance for different cases to show the efficacy of load on delay. The present paper bargains with three such cases.

Therefore, to achieve the above objectives the performance evaluation is done using a sample distributed network, to analyze it comprehensively.

Keywords: Fuzzy logic, mixed metric, packet-switched networks, fuzzy routing algorithms, performance evaluation.

1. Introduction

With the passage of time, various routing algorithms were introduced to achieve improved routing decisions. However, achieving optimized routing decisions is still a vital field of research in communication networks. A variety of routing techniques were introduced starting from shortest path routing to link-state routing to achieve better routing decisions over one another [04]. However, all the techniques were trade on the crisp values of metrics. Tan and Sacks [05] in 2001 introduced a fuzzy mixed metric approach, to achieve improved routing decisions over crisp values of delay metric. Tan and Sacks [05] approach got reinforcement from fuzzy theory, interposed by Zadeh (1965) [10]. Fuzzy set theory, completely non-statistical in nature was introduced to eradicate the sharp boundaries which divide the members of the class from non-members. Simplicity of fuzzy theory has prompted many researchers to use it in their work, like Aboelela and Douligeris [6, 7] has used it for developing a fuzzy inference system for Qos B-ISDN and introducing fuzzy link cost for routing in multimetric networks. Cohen, Korach and others [03] are generating a fuzzy based path ordering algorithms for imperfect Qos information. Chemouil, Khalfet and Lebourges [13] are introducing a fuzzy control approach for adaptive routing and Chanas [16] is making use of fuzzy sets of solving classical operational research problems. All these works are justifying the usefulness of fuzzy set theory in the field of communication networks.

In the present paper a new fuzzy approach is discussed and in parallel to the approach performance evaluation is done. The main objective of the paper will be to evaluate its performance both empirically and analytically. A sample packet switched network will remain as the basis to evaluate the performance of the approach. The results will be analyzed through line graphs for better understanding. The approach is tested for diverse conditions or cases, to analyze the results thoroughly.

The present paper is organized as follows. Section 2 views the new fuzzy approach and the corresponding routing algorithms. Section 3 provides an overview of the fuzzy routing algorithms. Section 4 deals with the objective of the paper i.e. the performance evaluation of the approach. Section 5 concludes the paper and outlines the future work.

2. Overview of the New Fuzzy Approach

The proposed approach introduces a fuzzy mixed metric formed from delay and load. Load's variability prompts us to realize it as a part of mixed metric. Therefore, allows to realize its effect on delay. The formation of mixed metric demands the construction of fuzzy sets and membership function corresponding to input and output linguistic variables and a rule matrix which will define a rule base upon which the decision will be based.

For input linguistic variables three fuzzy sets, Low, Average and High are defined and for output linguistic variables five fuzzy sets are defined i.e. Minimum, Low, Average, High and Maximum. Fuzzy sets are defined as a set consisting of vague boundaries [10]. On the other hand, a parallel membership function is a function, which yields a degree of strength to each value belongs to a fuzzy set. The grade of membership is given between [0, 1]. However, a rule base originates from a rule matrix formed of the two linguistic variables. Here, as both the inputs have three linguistic terms correspondingly. So, a 3 by 3 rule matrix is prepared and represented by figure1.

After defining fuzzy rules and membership functions, fuzzy inferencing is performed to reach the conclusion. After obtaining the prerequisite degree of strengths for each node of sample network an shown in fig.4 in section-4, these values are stuffed into a new format of link-state packet as shown in fig.2.

New format for link state packets will consequently give rise to a more precise and coherent routing table. Figure3. shows such a sample of routing table.

The actual approach entails the comparison of degree of strengths for the Minimum output linguistic variable if and only if at least one entry for Minimum linguistic variable is non-zero. Otherwise, the next output linguistic variable is considered for decision making and so on. The logic behind the procedure is that "as suggested by literature that both delay and load are considered best with Minimum values, so output mixed metric is also considered best with Minimum values. The more closer the degree of strength to 1 for Minimum linguistic variable, the better it is considered over others.

DELAY \ LOAD	Low	Average	High
Low	FR1	FR2	FR3
Average	FR4	FR5	FR6
High	FR7	FR8	FR9

Figure.1The Fuzzy Rule Matrix

N1					
Seq.					
Age					
Neigh.	Mixed Metric				
	Min.	Low	Avg.	High	Max
N2	0.24	0.48	0.24	0.0	0.0
N5	0.37	0.74	0.37	0.0	0.0
N3	0.0	0.25	0.50	0.25	0.0

Figure2.New Structure proposed for link-state packet

The next step is to reveal the best path or preference order of paths or a set of alternate paths for load balancing for transmission of packets. Therefore, the whole procedure could be

Source – N1

Destination	BN	Ds	AN	Ds		
N1	-	-	-	-	-	-
N2	N5	0.37	N2	0.24		
N3	N5	0.37	N2	0.24	N3	0.0
N4	N5	0.37				
N5	N5	0.37				

BN – Best Node to route traffic
AN – Alternate Node
Figure3. Routing Table for node N1 containing degree of strengths corresponding to 'low' linguistic term

implemented with the help of two algorithms 1) algorithm to compute the fuzzy mixed metric and 2) formulation to compute the best path or finding the preference order and alternate paths, using the concept of TE for load balancing. The next section discusses both algorithms.

3. The Fuzzy Routing Algorithms

3.1 *Algorithm to compute the output linguistic variable and assembling the routing table.*

(a). Computation of Fuzzy Mixed Metric

Let MF is a system denoting the membership function and X is any value from the universal set of linguistic variables

Step-1 Put X into the MF system.
Step-2 Check the area in which X is lying i.e.

i) *If* perfectly lying in **Low** area
Then compute the degree of strength and assign to linguistic term low.

ii) *If* in the area **Low & Average**
Then compute the degree of strength and assign to both fuzzy sets.

iii) *If* exactly in **Average** area
Then assign the computed degree of strength to the fuzzy set **Average** only.

iv) *If* in area **Average & High**
Then compute the degree of strength and assign the same to both fuzzy sets.

v) *If* exactly in **High** area
Then compute and assign the degree of strength to fuzzy set **High** only.

Step-3 Install these degree of strengths with in

the rule base.
Step-4 Compute the score of each rule using AND/MIN operation.
Step-5 Apply SUM composition to achieve the final degree of strength for linguistic terms defined for the output linguistic variable.
Step-6 Stop.

(b). The Logic of Assembling the Routing Table

Step-1 For any node N in the network perform the following:-
Search the Min linguistic term for non-zero entries.
If all entries are equal to zero
Then search the next term for non-zero entries.
Else put the corresponding entries in the routing table.
Step-2 Repeat step-1 until a set of non-zero entries are found
Step-3 Stop

3.2 Proposed Routing Algorithm

(a). Computation of Best Path

RT[S, D] is a 2D, N X N matrix representing a routing table. Where S, may be any source node 1 to N and D may be destination node 1 to N. DEST is a variable containing the final destination node. TEMP and NODE are one dimensional array to store the non-zero entries of routing table and the corresponding node position. NS is a one dimensional array to store the previously traversed nodes. I, J, K are the temporary variables.

```
Step-1 For any source node S from 1 to N, select the best
neighbor.
Step-2 Initialization, I=0, K=0
Step-3 NS[K]=S
       K=K+1
Step-4 Repeat step-5 for D=1, N
Step-5 If RT [S, D] ≠ ∞
       Then J= J+1
            TEMP[J] = RT [S, D]
            NODE[J] = D
Step-6 Repeat step-7 for 1 = 1, J
Step-7 If TEMP[I] < TEMP[I+1]
       {
            X = TEMP[I]
       TEMP[I] = TEMP[I+1]
          TEMP[I+1] = X
            Y = NODE[I]
       NODE[I] = NODE [I+1]
          NODE[I+1] = Y
       }
* Sorts the list to give the preference order of nodes and
their corresponding degree of strengths
Step-8 I = 1
Step-9 For K = 0, K-1, repeat step-10
Step-10 If NODE[I] = NS[K]
       {
            I = I+1
            go to step-9
       }
Step-11 If NODE[I] = DEST
       Then STOP
        Else S = NODE[I]
Step-12 Repeat steps 1 to 11 until destination is found
i.e. DEST
```

Computation of preference order within the paths and finding the alternate paths will follow the same logic.

4. Performance Evaluation

The present paper evaluates the performance of the new fuzzy routing algorithm with the help of an example network. Therefore, the performance has been realized, here, by considering a simple five node distributed packet switched network (N,E), Where N is the set of nodes i.e. N = {N1, N2, N3, N4, N5} and E is the set of links i.e. E = {ℓ1, e2, …e8}.

Consider N1 be the source and N4 as destination. N2, N5 and N3 are the neighbors to N1. The delays on the three links from node N1 to its neighbors are computed traditionally (using round-trip time) and the load would be considered at an instant of time t on that particular node. However, the upper bounds for delay and load with in a network are computed using the following equations:-

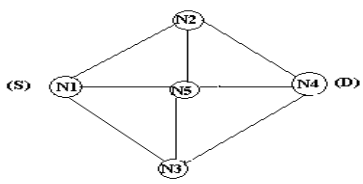


Fig. 4 Illustrative Network

High = (max_Load) / (link_capacity) ….(1)

High = maximum buffering capacity of the router ….(2)

For illustration, let the link capacity of each link e is 5pac/sec, and the maximum buffering capacity at each node is 40packet. Therefore, the upper bound for delay is computed as follows:-

Max. Delay D = 40/5 = 8s

Using equation (1) and the upper bound for load will be the maximum buffering capacity.

Let the *delay values *for node N1 are*

N1-N2 = d1 = 3s
N1-N5 = d2 = 2.5s
N1-N3 = d3 = 7s

(*Delay here is computed traditionally)

For node N2
N2-N1 = 3s
N2-N5 = 2s
N2-N4 = 4s

For node N3
N3-N1 = 7s
N3-N5 = 3.5s
N3-N4 = 4.5s

For node N4
N4-N2 = 4s
N4-N5 = 5s
N4-N3 = 4.5s

For node N5
N5-N1 = 2.5s
N5-N2 = 2s
N5-N3 = 3.5s
N5-N4 = 5s

and load at time t, N1 = 35 packets, the load queued for the neighbors of N1 as follows:-
N2 → 15 packets
N5 → 8 packets
N3 → 12 packets

Similarly, for N2 = 25 packets, load queried for its neighboring nodes are:-
N1 → 8 packets
N5 → 7 packets
N4 → 5 packets

For N3 = 30packets, load queried for its neighbouring nodes are:-
N1 → 10 packets
N5 → 5 packets
N4 → 15 packets

For N4 = 15packets, load queried for its neighbouring nodes are:-
N2 → 5 packets
N5 → 6 packets
N3 → 4 packets

For N5 = 20packets, load queried for its neighbouring nodes are:-
N1 → 6 packets
N2 → 3 packets
N3 → 6 packets
N4 → 5 packets

Therefore, from membership functions for both delay and load, the degree of strengths are computed as follows:-

The corresponding membership functions for delay and load are:-

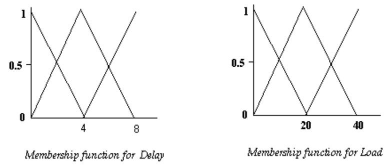


Figure 5

These degrees of strengths are computed on the basis of its crisp value lying in a particular region and therefore, for each node, combinations are formed of delays (on their neighboring nodes) and the load queried for that particular node. Therefore, a set of combinations has been formed for each node and the corresponding degree of strength for each combination is given below:-

For node N1
Opmm1 = C1 = dsd1 + dsl1
Opmm2 = C2 = dsd2 + dsl2
Opmm3 = C3 = dsd3 + dsl3

For node N2
Opmm1 = C1 = dsd1 + dsl1
Opmm2 = C2 = dsd2 + dsl2
Opmm3 = C3 = dsd3 + dsl3

For node N3
Opmm1 = C1 = dsd1 + dsl1
Opmm2 = C2 = dsd2 + dsl2
Opmm3 = C3 = dsd3 + dsl3

For node N4
Opmm1 = C1 = dsd1 + dsl1
Opmm2 = C2 = dsd2 + dsl2
Opmm3 = C3 = dsd3 + dsl3

For node N5
Opmm1 = C1 = dsd1 + dsl1
Opmm2 = C2 = dsd2 + dsl2
Opmm3 = C3 = dsd3 + dsl3
Opmm4 = C4 = dsd4 + dsl4

For node N1, N2, N3, N4 and N5 the degree of strength of the output linguistic variables are:-

	Min	Low	Avg	High	Max
C1:	0.24	0.48	0.24	0.0	0.0
C2:	0.37	0.74	0.37	0.0	0.0
C3:	0.0	0.22	0.50	0.25	0.0

For node N2

	Min	Low	Avg	High	Max
C1:	0.25	0.50	0.25	0.0	0.0
C2:	0.35	0.70	0.35	0.0	0.0
C3:	0.0	0.26	0.26	0.0	0.0

For node N3

	Min	Low	Avg	High	Max
C1:	0.0	0.25	0.50	0.25	0.0
C2:	0.12	0.24	0.12	0.0	0.0
C3:	0.0	0.13	0.26	0.13	0.0

For node N4

	Min	Low	Avg	High	Max
C1:	0.0	0.26	0.26	0.0	0.0
C2:	0.0	0.13	0.26	0.13	0.0
C3:	0.0	0.20	0.40	0.20	0.0

For node N5

	Min	Low	Avg	High	Max
C1:	0.30	0.60	0.30	0.0	0.0
C2:	0.15	0.30	0.15	0.0	0.0
C3:	0.12	0.24	0.12	0.0	0.0
C4	0.0	0.25	0.50	0.25	0.0

The degree of strengths corresponding to linguistic terms of the output linguistic variable are puffed into the link-state packet to give rise to a new format of link-state packets as shown in fig. 2. New format of link state packets will consequently give rise to a more precise and coherent routing table as shown in fig 3. Hence, yielding more accurate and improved routing decisions.

Accuracy of the routing decisions can be checked from figure 6. Analyzing fig. 6(a) it can be seen that in 6(a.1) the Min line graph entails the highest degree of strength for node N5. In parallel to 6(a.1), 6(a.2) is showing the routing decision based on both the metrics i.e. fuzzy mixed metric and delay metric. The accuracy of the decision could be measured from the point that both the approaches are pointing to the same node as the next best node to route the traffic. Figure 6(b), 6(c), 6(d) are advocating the result drawn by 6(a). However, 6(e) is showing N1 as the best node according to fuzzy mixed metric instead of N2.

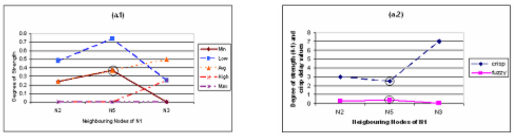


Figure6(a).

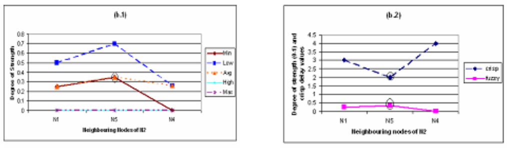


Figure6(b).

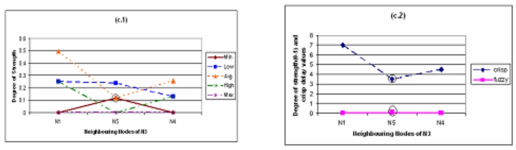


Figure6(c)

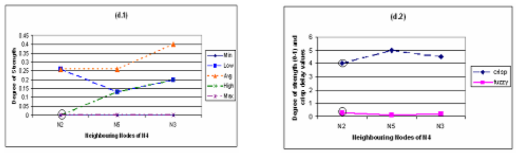


Figure6(d).

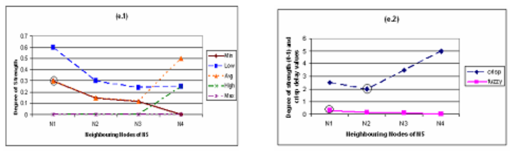


Figure6(e).

Figure6 Shows the accuracy of the new approach and a comparison based on routing decisions using both the metrics.

In 6(e), according to fuzzy mixed metric N1 would be the next best node to route the traffic. However, its counter part delay metric suggest N2 as the next best node customary. This is happening so, in this case, as the load is playing the vital role here, instead of delay. This case would be discussed later in this section. The preciseness of fuzzy cost can be analyzed over the crisp delay values with the help of the following figure in taking the optimized routing decisions.

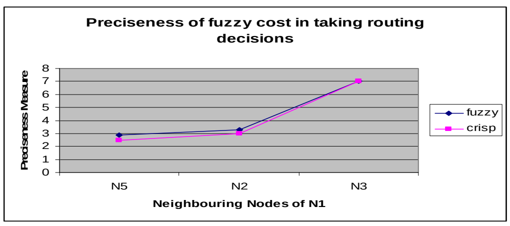


Figure7. Preciseness of Fuzzy cost over crisp delay in taking routing decisions

The performance is illustrated here, in terms of efficacy of load on delay in achieving improved routing decisions. Therefore, three such cases are taken in consideration below.

Case-I. *Analyzing the effect of High and Low Load conditions on delay*

It has been analyzed, empirically that two types of routing decisions are taken under two parallel load conditions i.e. load [low-avg] and load[avg-high].

Generally, the routing decisions under these two load conditions would be taken as:-

Case-I.1 If load [low-avg] then the *RD[MM] will be the same as **RD[DM].
*RD[MM] - Routing decision based on Mixed Metric
**RD[DM] - Routing decision based on Delay Metric

A sub case of case-I.1 will be, when all the load values are in range [low-avg], then of all the load values, the value tending more closer to Min plus the delay value not closer to Min. would be considered as the best combination to route. The case analyzes the effect of load on delay with the help of following diagram:-

Figure 8.suggests N5 as the next routing node, however, the delay at this node is more as compared to node N2, therefore, according to delay metric, N2 should be considered as the next best routing node.

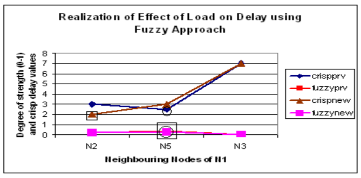


Figure8.

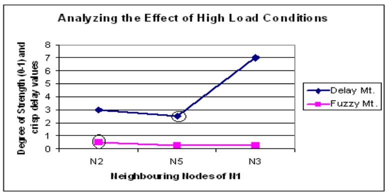
○ - Encircled points corresponds to the previous case where fuzzy cost is high for the lowest delay

□ - Squared points corresponds to the new fuzzy costs and crisp delays, here, fuzzy cost is suggesting N5 as the next best node instead of N2

But, as the load assigned at N5 is approximately half of the load assigned to node N2. Therefore, the effect of load on delay can be seen transparently. The difference in taking routing decision in the later case and the present case, therefore can be analyzed from the above graphs.

Case-I.2 If load [avg-high] then the RD[MM] will not be same as RD[DM], load values in this range are tending to high load conditions and are severely affecting the delay, therefore, even if the delay metric value is least from the rest of values, the corresponding node will not be considered as the best node to route.

The diagram clearly shows that if routing decision is based on delay metric then N5 will be the next best node, however, if based on fuzzy metric, N2 will be the next best node. This is because as N5 consists of a heavy load besides a low delay.



○ - Representing the next best node to route the traffic

Figure.9

Analyzing several such cases it is concluded generally, that the routing decision will be always with those combinations whose both bits are tending to minimum i.e. fuzzy approach will always find the best combination in every sense. As from the above case example, the approach has found C1 as the best combination with delay 3s and load 10 packets, however, there could be another choice of combination i.e. C3 with load only 5 packets and delay 7s, as the load at this node is more closer to 'minimum' as compared to other node load. But at the same time the delay is tending to a 'High' value, however in the previous combinations both delay and load were tending to 'Minimum' range value. Therefore, a perfect combination is extracted from all the available choices, using the new fuzzy approach.

A proportional relationship is derived to show the effect of low and high load conditions on routing decisions.

Effect of Low Load Conditions

$$\rho(L) \;\; \alpha \;\; (load, delay) \qquad \ldots(i)$$

$$\sigma\,(load, delay) \;\alpha\; MM(l,d) \;\alpha\; RD(MM) \qquad \ldots(ii)$$

As discussed above, in sub case of case-I.1, the basis of routing decision has changed in contrast to the traditional method of achieving routing decisions.

Here, ρ(L) in equation (i) is representing the load values tending towards 'Minimum' fuzzy set, σ (load, delay) is representing the efficacy of load on delay. Equ.(i) is representing a directly proportional relationship between the two. As under various circumstances, the minimum or low load values are directly affecting the delay values. It is known that efficacy of load on delay could be measured with the help of fuzzy mixed metric. Therefore, the routing decisions taken on the basis of fuzzy mixed metric will be affected directly. This gives rise to the proportional relation between the three parameters σ (load, delay) i.e. effectiveness of load on delay, MM(l,d) fuzzy mixed metric formed from load and delay and RD(MM) is the routing decision based on the mixed metric as shown in equ. (ii).

Effect of High Load Conditions

$$\delta(L) \;\; \alpha \;\; (load, delay) \qquad \ldots(i)$$

σ (load, delay) α MM(l,d) α RD(MM) …(ii)

As discussed above, in sub case of case-I.2, the nodes with high load conditions in combination with lower delay values would not be considered as the best possible node to route the traffic, therefore, again directly affecting the way routing decision were taken as shown in fig.9. δ (L) is representing the load values tending towards high load fuzzy set.

Case-II Analyzes the case where a set of alternate paths is supported by the approach. For this, the following case values are considered.

Let at node N1 the delay values to its neighboring nodes are:-

(d1'') N1-N2 = 1s
(d2'') N1-N5 = 3s
(d3'') N1-N3 = 5s

And the total load at N1 is 20, which is distributed to its neighboring nodes in the following way:-

(e1'') → N2 = 5 packets
(e2'') → N5 = 15 packets
(e3'') → N3 = 5 packets

Therefore, the new set of combinations in the form of degree of strengths is formed for node N1 as follows:-

For node N1

Opmm1'' = C1 = dsd1'' + dsl1''
Opmm2'' = C2 = dsd2'' + dsl2''
Opmm3'' = C3 = dsd3'' + dsl3''

Hence, for C1 the degree of strength (ds) for output fuzzy sets is:-

	Min	Low	Avg	High	Max
C1:	0.0	0.25	0.50	0.25	0.0

Similarly, for C2 and C3 the corresponding degrees of strengths are:-

C2:	0.0	0.25	0.50	0.25	0.0
C3:	0.0	0.25	0.50	0.0	0.0

Now, from the above computations it can be seen that C1, C2 and C3, all can be considered equally best, to route the traffic. In such cases, the concept of traffic engineering (TE) can be used to exploit the full advantage of the fuzzy approach i.e. to route the traffic on all the three paths at the same time. However, the traditional approach only allows to route traffic on one best path. The concept can be made more clear by analyzing it through graphs given below:-

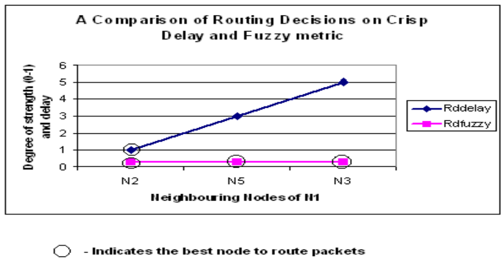


Figure10.

The above graph is showing clearly that if routing decision is taken based on crisp delay, there will be only one best node to route the traffic while at the same time if the fuzzy mixed metric is considered for taking the routing decision, will provide all the three nodes as the best node to route the traffic in spite of the different delay values, therefore, showing the effect of load on delay. This allows to implement the concept of traffic engineering which allows to route the traffic on all the three route simultaneously.

Case-III Setting of routes according to priority of traffic, here, is considered as the third most important case as satisfying the Qos parameter **.

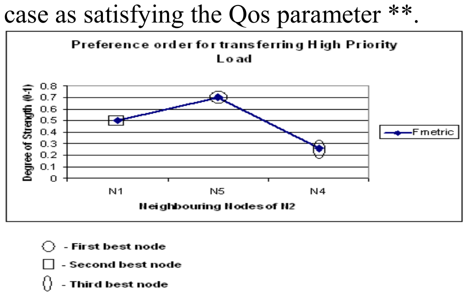


Figure11.

Consider the line graph of node N2, clearly gives the first best node, second best node and third best node in case we have priority assigned data. Therefore, the high priority data could be shifted to node 5 then a lower priority on node N1 and the least priority data on node N4. Hence, a preference order for priority assigned traffic would be revealed.

Hence, the approach provides an efficient way to evaluate the effect of load on delay under assorted situations. It also establishes a unique pattern to analyze the fuzzy figures. Therefore, the approach defined here, quite so analyzes the effect of variability of load.

These are some of the empirical results on the performance of new fuzzy mixed metric approach. Analytically, the following points are revealed in favor of the new approach. The algorithms described in section 3 eradicated the problem existing in previously proposed techniques. Such as, it eliminates the impression of the global state of the distributed networks mentioned in [QOSR], by allowing filling real numbers ranging 0-1 i.e. degree of strengths for the corresponding fuzzy metric instead of approximate numeric values. The algorithm also handles the Qos factors for delay in a more meticulous manner by providing *path constrained path optimization routing.*

5. Conclusion and Future Work

The present paper is evaluating the new fuzzy mixed metric approach in different aspects to analyze its performance over the traditional approach. The paper is presenting many new aspects for taking routing decisions. It has been analyzed that the preciseness of fuzzy metric is more than the delay metric in taking routing decisions. Also there are a variety of ways to interpret the routing decisions in spite of just getting one best node to route the traffic. A preference order can be designed for priority traffic as described in case-III. Also, there can be a scenario in which we could exploit all the routes at the same time besides there are different values of delay and load. The most important fact that is realized is the effect of load on delay, as the approach is selecting the best node whose delay is high as compared to its neighboring nodes only because the corresponding load is lower on that node as compared to its neighboring nodes. Therefore, various results are drawn with one approach.

Future works reveals the correctness of the approach by simulating it.

References

[1] Anindya Basu, Jon G. Riecke (2001), "Stability Issues in OSPF Routing", *SIGCOMM '01, San Diego, California, USA August 27-31.*

[2] Antoine B. Bagula (2006), "Hybrid Routing in Next Generation IP Networks", *Elsevier Computer Communications Vol 29, Issue 7, pp 879-892.*

[3] A. Cohen, E. Korach, M. Last and R. Ohayon, (2003) "Fuzzy based Paths Ordering Algorithm in Networks with Imperfect Qos Information", *10th International Conference on Telecommunications ICT 2003, Vol. 2, 23 Feb-1 March, pp 1373-1380.*

[4] Andrew S. Tanenbaum, "Computer Networks", Third Edition, *Prentice-Hall India, September, 2001.*

[5] Chiang Kang Tan, Lionel Sacks (2001), "The Use of Fuzzy Metric in OSPF Network", *http://www.ee.ucl.ac.uk/~/sacks/projects/pastproj/ck_tan.pdf.August 3.*

[6] Emad Aboelela and Christos Douligeris (1998), "Fuzzy Inference System for Qos-B-ISDN" , *IEEE 1998 Canadian Conference on Electrical and Computer Engineering. (CCECE'98/CCGEI'98). Waterloo, Ontario, Canada, May 24-28.*

[7] Emad Aboelela and Christos Douligeris (1997), "Routing in Multimetric Networks Using a Fuzzy Link Cost", *Second IEEE Symposium on Computers and Communication, 1-3 July, pp 397-401*

[8] James F. Brule (1985), "Fuzzy Systems-ss A tutorial ", Ortec Engineering Inc., *http://www.orteh engr.com/fuzzy/tutor.txt*

[9] Junaid A. Khan, Hussein Alnuweiri (2003)", A Traffic Engineered Routing Algorithm Based on Fuzzy Logic", *IEEE Pacific Rim Conference on Communications, Computers and Signal Processing (PACRIM'03).* 1:PP 454-457.

[10] L.A. Zadeh (1965), "Fuzzy Sets", *Information and Control, Vol.8.*

[11] Mini Sharma and Dr. Shuchita Upadhayay (2006), "Fuzzy Evaluation of Routing Metries", *in the 8th annual Conference of ISITA ,March 18-20.*

[12] Mischa Schwartz and Thomas E. Stem (1980) ", Routing Techniques used in Computer Communication Networks", *IEEE Transactions on Communications, Vol. COM-28, No.4.*

[13] P. Chemouil, J. Khalfet and M. Lebourges (1995), "A Fuzzy Control Approach for Adaptive Routing", *IEEE Commmunications Magazine, 33(7), pp 70-76, July.*

[14] Shigang Chen, Klara Nahrstedt (1998), " An Overview of Quality of Service Routing for the Next Generation High-Speed Networks: problems and Solutions" , *IEEE Networks http://www.cise.ufl.edu/~sgchen/papers/OoSRoutingSurvey99.pdf*

[15] Steven D. Kaehler (1998), "Fuzzy Logic-AnIntroduction Part 1 – 6", *http://www.seattlerobotics.org/encoder/mar98/fuz/fl_part1.html*

[16] S. Chanas (1993) , " Fuzzy sets for Intelligent Systems: Fuzzy sets in Few Classical Operational Research Problems, *Morgan Kaufmann, San Mateo, California.*

Authors

Mini Sharma received her MCA (Master's of Computer Applications) degree from Guru Jambeshwar University, India in 2003, received her NET (National Education Test for teaching) certification in 2005. Has a teaching experience of around 2 years in Kurukshetra University .Presented one research paper in a national conference ISITA and published one paper in International Journal of Computer and Network Sciences(IJCNS). Is pursuing PhD under the guidance of Dr. Shuchita Upadhayay senior Professor in department of Computer science, Kurukshetra University. She has presented and published a number of papers research papers in National and International Conferences.

Dr. Shuchita Upadhyaya is a Senior Reader in the Department of Computer Science and Applications, Kurukshetra University, Kurukshetra, India. She has a teaching experience of 20 years. Her fields of interest are Computer Networks & Data Communication and Graphics and has been teaching these subjects to post graduate classes for the past 20 years. Her research area is routing in Computer Networks and has published a number of papers in international journals. At present six scholars are pursuing their research work under her guidance.